Independent State of Samoa
Ministry of Foreign Affairs and Trade
Ministry of Finance
Ministry of Natural Resources and Environment
Secretariat of the Pacific Regional Environment Programme

Independent State of Samoa Project for Capacity Building on Climate Resilience in the Pacific

Final Report (Training Program on Climate Change) Appendix (relevant materials)

January 2023

Japan International Cooperation Agency (JICA)

Pacific Consultants Co., Ltd.
Japan Weather Association
Oriental Consultants Global Co., Ltd.

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List of Appendixes (relative materials)

<Executive course>

<Open learning course>

Executive course

Exective course: List of training materials (Climate science)

Section		Name of material			Type	Length
Module 1	**Demonstrate knowledge of climate science and impact of climate change**					
	Lecture slide	1.1 Basics of climate change		part1	PPT	39 min.
		1.1 Basics of climate change		part2	PPT	31 min.
		1.2 Observed climate change (global)			PPT	39 min.
		1.3 Observed climate changes (regional)			PPT	33 min.
		1.4 Impact of Climate change on the Pacific region			PPT	-
	Reference materials	UON-SPREP short course (UNITAR accredited)				
			Course 1, Meteorology and the South Pacific	Reference material for 1.1	PDF	-
			Course 2, Past and Present Climate of the South Pacific	Reference material for 1.2, 1.3, 1.4	PDF	-
		Pacific Climate Change Science Program (PCCSP)				
			Current and future climate of the Cook Island	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Fiji Island	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Federated States of Micronesia	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Kiribati	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Marshall-Islands	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Nauru	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Niue	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Pacific-region	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Palau	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the PNG	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Samoa	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Solomon-Islands	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Timor-Leste	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Tonga	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Tuvalu	Reference material for 1.3, 1.4	PPT	-
			Current and future climate of the Vanuatu	Reference material for 1.3, 1.4	PPT	-
			Climate in the Pacific: A regional summary of new science and management tools	Reference material for 1.4	PDF	-
		IPCC				
			IPCC Fifth Assessment Report - Working Group I (English)	Introduction video on IPCC Fifth Assessment Report (AR5)	PDF	-
			IPCC_WG1AR5_SPM	IPCC Fifth Assessment Report (AR5), https://www.ipcc.ch/assessment-report/ar5/	PDF	-
			IPCC_SROCC_SPM	Special Report on the Ocean and Cryosphere in a Changing Climate, https://www.ipcc.ch/srocc/	PDF	-
			IPCC_SR15_SPM	SPECIAL REPORT Global Warming of 1.5 ºC, https://www.ipcc.ch/sr15/	PDF	-
			IPCC_SRCCL_SPM	SPECIAL REPORT Climate Change and Land, https://www.ipcc.ch/srccl/	PDF	-
		WMO				
			THE GLOBAL CLIMATE IN 2015–2019	Global Climate in 2015-2019: Climate change accelerates, https://public.wmo.int/en/media/press-release/global-climate-2015-2019-climate-change-accelerates	PDF	-
		UK-MetOffice				
			https://www.metoffice.gov.uk/weather/climate-change/causes-of-climate-change		-	-
		PACC Videos on Adaptation				
			2 PACC Fiji Vital Food		MP4	11 min.
			3 PACC Vanuatu P3D Model		MP4	5 min.
Module 2	**Projections of climate change**					
	Lecture slide	2.1 Projected climate change (global)			PPT	35 min.
		2.2 Projected climate change (regional)			PPT	44 min.
	Reference materials	UON-SPREP short course (UNITAR accredited)				
			Course 3, Adapting to the impacts of climate variability and change in the South Pacific	Reference material for 2.1, 2.2	PDF	-

Exective course: List of training materials (Access to Climate finance, Part 1)

Section		Name of material			Type	Length
Module 1	**Demonstrate knowledge of climate science and impact of climate change**					
	Lecture slide	1.1 Basics of climate finance			PPT	20 min.
		1.2.1 Strategies, policies and guidelines of GCF			PPT	30 min.
		1.2.2 Project Preparation Facility (PPF)			PPT	20 min.
		1.2.3 Concept notes:			PPT	25 min.
		1.2.4 Full project proposal and simplified approval process (SAP)			PPT	30 min.
		1.3 Strategies, policies and guidelines and supporting programs of Multilateral climate fund: Adaptation Fund (AF)			PPT	20 min.
	Reference materials	Reference materials for Module 1.1				
			Introduction to Climate Finance	Reference material for 1.1	PDF	-
			Global Landscape of Climate Finance 2019		PDF	-
			Climate finance in the Pacific: An overview of flows to the region's Small Island Developing States		PDF	-
			Status of the GCF portfolio: approved projects and fulfilment of conditions		PDF	-
		Reference materials for Module 1.2 : GCF				
			Project Preparation Facility Guidelines		PDF	-
			Readiness and Preparatory Support Programme Guidebook		PDF	-
			GCF handbook: Decisions, policies and frameworks (updated May 2020)		PDF	-
			Simplified Approval Process (SAP) funding proposal preparation guidelines		PDF	-
			Concept Note template		doc	-
			GCF Concept Note User's Guide		PDF	-
			Funding Proposal template		doc	-
			Annex 1: No objection letter template		doc	-
			Annex 2a: Example project level logframe		doc	-
		Reference materials for Module 1.3 : AF				
			Medium-Term Strategy 2018-2022		PDF	-
			OPERATIONAL POLICIES AND GUIDELINES FOR PARTIES TO ACCESS RESOURCES FROM THE ADAPTATION FUND		PDF	-
			Adaptation Fund Project/Programme Review Criteria		PDF	-
Module 2	**Projections of climate change**					
	Lecture slide	2.1 Centrality of the climate rationale			PPT	30 min.
		2.2 Adaptation options			PPT	30 min.
		2.3 Project/programme objectives			PPT	30 min.
		2.4 Public participation			PPT	25 min.
	Reference materials	Reference materials for Module 2				
			ENHANCING THE CLIMATE RATIONALE FOR GCF PROPOSALS		PDF	-
			Climate Resilient Infrastructure OECD Environment Policy Paper No. 14		PDF	-
			Economic Analysis of Climate-Proofing Investment Projects.		PDF	-
			Analyzing Climate Change Adaptation Options Using Multi-Criteria Analysis		PDF	-
			Mitigation and adaptation performance measurement frameworks		PDF	-
			Reference material for logical framework published by ADB		PDF	-
			Public Participation Guide: Tools to Inform the Public	https://www.epa.gov/international-cooperation/public-participation-guide-tools-inform-public	PDF	-
			Public Participation Guide: Tools to Generate and Obtain Public Input	https://www.epa.gov/international-cooperation/public-participation-guide-tools-generate-and-obtain-public-input	PDF	-
			Public Participation Guide: Tools for Consensus Building and Agreement Seeking	https://www.epa.gov/international-cooperation/public-participation-guide-tools-consensus-building-and-agreement-seeking	PDF	-
			International Association for Public Participation (IAPP)	https://www.iap2.org/mpage/Home	PDF	-
Module 3	**Exercise material**					
		3_PPT Introduction of the Exercise			PPT	-
		gcf_logframe_template			doc	-
		GCF document, Mitigation and adaptation performance measurement frameworks			PDF	-

Exective course: List of training materials (Access to Climate finance, Part 2)

Section		Name of material			Type	Length
Module 1	**Principles of gender, social inclusion, safeguards of GCF**					
	Lecture slide	1.1 Climate change impact on gender in Pacific Islands Countries (PICs)			PPT	15 min.
		1.2 Policies and relevant documents on gender equality and social inclusion			PPT	30 min.
		1.3 Environmental and social safeguards			PPT	35 min.
	Reference materials	Reference materials for Module 1.1				
			Capstone Project Research Report. Gendered Impacts of Weather and Climate: Evidence from Asia, Pacific and Africa		PDF	-
			AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability	https://www.ipcc.ch/report/ar5/wg2/	PDF	-
			Post-Disaster Needs Assessment Government of Fiji May 2016		PDF	-
		Reference materials for Module 1.2				
			GCF Gender Equality and Social Inclusion Policy and Action Plan 2018-2020		PDF	-
			Gender Analysis/Assessment and Gender and Social Inclusion Action Plan Template		PDF	-
			Mainstreaming Gender in Green Climate Fund Projects		PDF	-
		Reference materials for Module 1.3 : AF				
			UNEP (2020) Environmental and Social Sustainability Framework		PDF	-
			ADB (2009) Safeguard Policy Statement.		PDF	-
			World Bank (2017) Environmental and Social Framework		PDF	-
			Green Climate Fund (u/d) Environment and Social Safeguards	https://www.greenclimate.fund/projects/safeguards/ess	PDF	-
			Adaptation Fund (2013) Environmental and Social Policy		PDF	-
			Global Environment Facility (2019) Guidelines on GEF’s Policy on Environmental and Social		PDF	-
Module 2	**Key aspects to address gender, social inclusion and environmental safeguard in PICs**					
	Lecture slide	2.1 Gender and social inclusion			PPT	30 min.
		2.2 Environmental safeguard			PPT	30 min.
Module 3	**Exercise material**					
		3_PPT Introduction of the Exercise			PPT	-
		gcf_logframe_template			doc	-
		GCF document, Mitigation and adaptation performance measurement frameworks			PDF	-

Exective course: List of training materials (DRR sector)

Section	Name of materiala	Type	Length
Introduction	Welcome remarks from PCCC Manager	Movie file	3 min.
	Sample-day-to-day schedule	PDF	-
	Live lecture agenda	PDF	-
	Live consulatation agenda	PDF	-
Module 1	**Understanding the vulnerability of structures**		
Module 1.1	Climate and non-climate impacts		
	1. Key concepts to assess climate risk and impacts	Movie file	5 min.
	2. Observed and projected climate change and its impact	Movie file	18 min.
	3. Non-climate hazards	Movie file	10 min.
	Lecture slides and notes	PDF	-
Module 1.2	Basic knowledge of vulnerability assessment of structures-Buildings		
	Review of impacts of climate change in building	Movie file	5 min.
	Lecture slides and notes	PDF	-
	Basic knowledge of vulnerability assessment of structures-Coastal protection structures		
	1. Outline of coastal disaster	Movie file	10 min.
	2. Hazards to coastal protection structure and its projected change	Movie file	18 min.
	3. Focal points to assess vulnerability of coastal protection structure	Movie file	20 min.
	4. Summary	Movie file	2 min.
	Lecture slides and notes	PDF	-
Module 2	**CCA and DRR activities focusing on structural approaches**		
Module 2.1	Buildings		
	1. Overview of risk-informed land use planning	Movie file	18 min.
	2. Designing climate-resilient buildings in the Pacific_part1 (a) Updating of building codes)	Movie file	13 min.
	2. Designing climate-resilient buildings in the Pacific_part2, b) Other manuals and guidelines (1)	Movie file	16 min.
	2. Designing climate-resilient buildings in the Pacific_part3, b) Other manuals and guidelines (2)	Movie file	8 min.
	2. Designing climate-resilient buildings in the Pacific_part4, c) Capacity building needs, d) Green building concept	Movie file	9 min.
	Lecture slides and notes	PDF	-
Module 2.2	Coastal protection structure		
	Coastal protection structure_part1 (1. Types of coastal protection structure, 2. Impacts to coastal protection structure)	Movie file	17 min.
	Coastal protection structure_part2 (3. Adaptation options for coastal protection structure, 4. Examples and challenges in the Pacific region, 5. Summary)	Movie file	17 min.
	Lecture slides and notes	PDF	-
Module 3	**Problem and Objective trees and Logical framework**		
Module 3.1	Project objective		
	Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
	Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	12 min.
	Lecture slides and notes	PDF	-
Module 3.2	Exercise		
	Reference: Mitigation - adaptation performance measures	PDF	-
	Template for exercise_logframe template	Word file	-

Exective course: List of training materials (Ecosystem sector)

Section		Name of materiala		Type	Length
Introduction		Welcome remarks from PCCC Manager		Movie file	3 min.
		Backgound of the course		PDF	-
		Sample-day-to-day schedule		PDF	-
Module 1	**Climate and non-climate impacts on ecosystem**				
	Module 1.1	Climate and non-climate impacts on ecosystem			
			Key concepts to assess climate risk and impacts	Movie file	3 min.
			Observed and projected climate change and its impact	Movie file	15 min.
			Non-climate threats	Movie file	2 min.
			Lecture slides and notes	PDF	-
	Module 1.2	Basic knowledge of the vulnerability assessment of ecosystem			
			Ecossytem and Socio-Economic Resilience Analysis and Mapping (ESRAM)	Movie file	15 min.
			Lecture slides and notes	PDF	-
Module 2	**Ecosystem-based adaptation and mitigation**				
	Module 2.1	Terrestrial and freshwater ecosystems			
			Ecosystem-based Adaptation and Ecosystem-based Mitigation in the context of Terrestrial and freshwater ecosystems	Movie file	2 min.
			Ecosystem-based adaptation and mitigation options for terrestrial and freshwater ecosystems, Option 1: Forest (Adaptation & Mitigation)	Movie file	20 min.
			Ecosystem-based adaptation and mitigation options for terrestrial and freshwater ecosystems, Option 2: Watershed & reservoir (Adaptation)	Movie file	9 min.
			Lecture slides and notes	PDF	-
	Module 2.2	Marine and coastal ecosystems			
			EbA in the context of Coastal and Marine ecosystems (part1)	Movie file	17 min.
			EbA in the context of Coastal and Marine ecosystems (part2)	Movie file	13 min.
			Coastal and Marine ecosystems, Option1, Option2	Movie file	17 min.
			Coastal and Marine ecosystems, Option3	Movie file	23 min.
			Lecture slides and notes	PDF	-
	Module 2.3	EbA Implementation: Cross-cutting Issues and Approaches			
			EbA Implementation: Cross-cutting Issues and Approaches	Movie file	19 min.
			Lecture slides and notes	PDF	-
Module 3	**Problem and Objective trees and Logical framework**				
	Module 3.1	Project objective			
			Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	10 min.
			Lecture slides and notes	PDF	-
	Module 3.2	Exercise			
			Introduction of exercise session	Movie file	11 min.
			Example of Logical Framework	Movie file	16 min.
			Lecture slides and notes	PDF	-
			Template for exercise_logframe template	PDF	-
			Reference: Mitigation - adaptation performance measures	Word file	-

Exective course: List of training materials (Food sector)

Section			Name of materiala	Type	Length
Introduction		Welcome remarks from PCCC Manager		Movie file	3 min.
		Bacground of the course		html	
		Sample-day-to-day schedule		Word file	-
Module 1	**Understanding of climate change risks and vulnerabilities of food production systems**				
	Module 1.1	Climate and non-climate impacts on food production systems			
			Lecture (part 1: IPCC risk-based conceptual framework to assess climate risk and impacts, Observed and projected climate change and its impact)	Movie file	30 min.
			Lecture (part 2: Observed and projected climate change and its impact, Non-climate hazards to food production systems)	Movie file	23 min.
			Lecture slides and notes	PDF	-
	Module 1.2	GHG emissions from food production systems			
			Lecture (part 1: Potential GHG emissions from food production systems, GHG emissions from Food Production systems in the Pacific)	Movie file	18 min.
			Lecture (part 2: Climate Change Mitigation Policies on Food Production in the Pacific)	Movie file	8 min.
			Lecture slides and notes	PDF	-
Module 2	**Climate mitigation and adaptation options for food production systems**				
	Module 2.1	The nexus of climate change, gender and agriculture and key international decisions under the			
			FAO Video – Climate change, agriculture and food security	URL	2 min.
			Intergovernmental Panel on Climate Change – Special Report on Land, Chapter 5.1 – Food Security	URL	-
			FAO Video – What is the Koronivia Joint Work on Agriculture?	URL	3 min.
			FAO Video – Koronivia Joint Work on Agriculture Explained	URL	2 min.
			FAO Video – The Koronivia Joint Work on Agriculture Process Explained	URL	3 min.
			FAO Video – Why does the Koronivia Joint Work on Agriculture matter?	URL	3 min.
			FAO Video – Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land 2019	URL	2 min.
			Full text Decision 4/CP.23 – Koronivia Joint Work on Agriculture	URL	-
			FAO Video – Addressing Gender in Climate Change Policies for Agriculture	URL	5 min.
			Full text of Decision 3/CP.25 Lima Work Programme on Gender and its Enhanced Gender Action Plan	URL	-
	Module 2.2	Adaptation and mitigation options of agriculture			
			Live lecture slides (Climate variability, Community based vulnerability analysis, CSA and case studies, Co-benefits)	PDF	-
			Lecture (Improvement of facilities for cultivation, storage and primary processing)	Movie file	19 min.
			Lecture slides and notes		
	Module 2.3	Adaptation options of coastal fisheries			
			Live lecture slides (adaptation concepts in Pacific coastal fisheries)		
			Live lecture slides (experiences in coastal fisheries adaptation - Samoa case study)		
	Module 2.4	Climate information services			
			Lecture (part 1: Concept of CIS and cases in the region)	Movie file	18 min.
			Lecture (part 2: Concept of CIS and cases in the region)	Movie file	19 min.
			Lecture slides and notes (Concept of CIS and cases in the region)	PDF	-
			Lecture (part 1: Case study in Vanuatu)	Movie file	11 min.
			Lecture (part 2: Case study in Vanuatu)	Movie file	18 min.
			Lecture (part 3: Case study in Vanuatu)	Movie file	22 min.
			Lecture slides and notes (Case study in Vanuatu)	PDF	-
Module 3	**Problem and Objective trees and Logical framework**				
	Module 3.1	Project objective			
			Lecture (part 1: 1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Lecture (part2: 4. Logical framework, 5. Summary)	Movie file	10 min.
			Lecture slides and notes	PDF	-
	Module 3.2	Exercise			
			Lecture (part 1: Introduction of exercise session)	Movie file	14 min.
			Lecture (part2: Example of Logical Framework)	Movie file	16 min.
			Lecture slides	PDF	-
			Template for exercise_problem and objective trees	PPT	-
			Template for exercise_logframe template	Word	-
			Reference: Mitigation - adaptation performance measures, GCF	PDF	-
			Reference: Photos of the group exercise during the previous training	PDF	-

Exective course: List of training materials (Tourism sector)

Section		Name of materiala	Type	Length
Introduction		Welcome remarks from PCCC Manager	Movie file	3 min.
		Bacground of the course	html	
		Sample-day-to-day schedule	Word file	-
		How to use the auto-translation function on YouTube	PDF	
Module 1	**Understanding of risks of climate change impacts on tourism sector**			
	Module 1.1	Risks of climate change impacts on tourism		
		Introduction to climate change in the Pacific and IPCC risk-based conceptual framework	Movie file	17 min.
		Observed and projected climate change in the Pacific	Movie file	18 min.
		Projected climate changes in the Pacific - Emission Scenarios, Temperature, Precipitation	Movie file	13 min.
		Projected climate changes in the Pacific - Sea level, ocean, tropical cyclone	Movie file	11 min.
		Climate change Impact on Tourism	Movie file	7 min.
		Lecture slides and notes	PDF	-
	Module 1.2	Basic knowledge of business implication of climate change		
		Basic knowledge of business implication of climate change Part 1	Movie file	21 min.
		Basic knowledge of business implication of climate change Part 2	Movie file	17 min.
		Lecture slides and notes	PDF	-
	Module 1.3	GHG emissions from the tourism sector		
		GHG emissions from the tourism sector	Movie file	11 min.
		Lecture slides and notes	PDF	-
Module 2	**Opportunities of the tourism to respond to climate change**			
	Module 2.1	Possible options for tourism sector to respond to climate change		
		2.1.1 Ecosystems-based approaches: coast, ocean, lake, forest and mountain		
		Ecosystem-based Adaptation (EbA) with a focus on coastal and marine ecosystems, and opportunities to strengthen socioeconomic resilience by mainstreaming ecosystem-based adaptation in the tourism sector	Movie file	21 min.
		Ecosystem-based Adaptation (EbA) with a focus on terrestrial ecosystems	Movie file	14min.
		Ecosystem-based approaches: Coast, Ocean, Lakes, Forest and Mountains - Cases from the Pacific	Movie file	14 min.
		Lecture slides and notes: Coastal and marine	PDF	-
		Lecture slides and notes: Terrestrial	PDF	-
		Lecture slides and notes: Case study	PDF	-
		2.1.2 Resilient and low-carbon infrastructures, facilities and Information management		
		Update on global and regional efforts including Pacific Sustainable Tourism Policy Framework (PSTPF)	Movie file	15 min.
		Opportunities for tourism responses in resilience building and GHG emissions from the aspect of built environment and transport	Movie file	15 min.
		Climate information service	Movie file	14 min.
		Six Senses Fiji- Case study	Movie file	16 min.
		Lecture slides and notes: Low carbon infrastructure and facilities	PDF	-
		Lecture slides and notes: Information service	PDF	-
		Lecture slides and notes: Case study	PDF	-
		2.1.3 Business risk management and recovery		
		Climate-related risks in relation to business activities with examples of a hotel and tourism service	Movie file	19 min.
		Steps to identify and assess climate-related risks; inclusion of outputs of climate-related risk analysis into business strategies and plans; effective structure for managing climate-related risks; and climate-related risks and COVID-19 recovery	Movie file	17 min.
		Lecture slides and notes	PDF	-
	Module 2.2	Enhancing mainstreaming climate change in the national tourism strategy and plan		
		Alignment of National Tourism Policies, Plans & Strategies with tourism climate change frameworks including National Adaptation Plans (NAPs), Joint National Adaptation Plans (JNAPs) & National Determined Contributions (NDC)	Movie file	22 min.
		Lecture slides and notes	PDF	-
Module 3	**Problem and Objective trees and Logical framework**			
	Module 3.1	Project objective		
		Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
		Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	12 min.
		Lecture slides and notes	PDF	-
	Module 3.2	Exercise		
		Introduction of exercise session	Movie file	14 min.
		Example of Logical Framework	Movie file	16 min.
		Lecture slides and notes	PDF	-
		Exercise template checklist logframe	Word file	
		Exercise template checklist trees	PPT	
		Reference 1_Mitigation and adaptation performance measurement frameworks_GCF	PDF	
		Reference 2_Photos of the group exercise during the previous training	PDF	-

Exective course: List of training materials (Water sector)

Section		Name of materiala		Type	Length
Introduction		Welcome remarks from PCCC Manager		Movie file	2 min.
		Bacground of the course		html	
		Sample-day-to-day schedule		Word file	-
Module 1	**Understanding of climate change risks and vulnerabilities of rural water access**				
			Introduction to climate change in the Pacific and IPCC risk-based conceptual framework	Movie file	17 min.
			Observed and projected climate change in the Pacific	Movie file	20 min.
			Projected climate changes for near- to long-terms	Movie file	23 min.
			Climate change impact on water resources	Movie file	8 min.
			on-climatic drivers	Movie file	7 min.
			Lecture slides and notes	PDF	-
Module 2	**Adaptation and mitigation options with innovative approaches**				
	Module 2.1	Technical solutions for safe water access from water source to households			
		How to identify and manage water resource? tools, surveys and data			
			Part 1	Movie file	19 min.
			Part 2	Movie file	23 min.
			Part 3	Movie file	15 min.
			Part 4	Movie file	15 min.
		What innovative technologies, devices and tools are available to deliver and monitor safe water for households?		Movie file	23 min.
		How renewable energy can be used to reduce use of fossil fuels? What innovative devices and solutions are available to encourage water and energy saving?		Movie file	9 min.
		Case in the Pacific: Ecological Purification Systems (EPS) in Fiji		Movie file	25 min.
		Lecture slides and notes: How to identify, develop and manage water resource? Tools, surveys and data		PDF	-
		Lecture slides and notes: Technical solutions for safe water access from water source to households		PDF	-
		Lecture slides and notes: Renewable Energy Energy Saving		PDF	-
		Lecture slides and notes: Renewable Energy Energy Saving_supplement material		PDF	-
		Lecture slides and notes: EPS project in Fiji		PDF	-
	Module 2.2	Community-based management for rural safe water access: Case study in Samoa			
		Ownership arrangement		Movie file	8 min.
		Operation and maintenance of water supply systems		Movie file	9 min.
		Social and gender inclusion		Movie file	7 min.
		Disaster preparedness and post-disaster response		Movie file	6 min.
		From short to mid-term plan and management		Movie file	6 min.
		Lecture slides and notes		PDF	-
	Module 2.3	Projects in the Pacific			
		Enhancing the Climate Resilience of vulnerable island communities in Federated States of Micronesia (Adaptation Fund)		Movie file	25 min.
		Managing Coastal Aquifers in Selected Pacific SIDS (Global Environment Facility)		Movie file	24 min.
		South Tarawa Water Supply Project in Kiribati (Green Climate Fund)		Movie file	18 min.
		Addressing Climate Vulnerability in the Water Sector (ACWA) in the Marshall Islands		Movie file	12 min.
		Lecture slides and notes: Adaptation fund project in FSM		PDF	-
		Lecture slides and notes: Managing Coastal Aquifers in Selected Pacific SIDS		PDF	-
		Lecture slides and notes: Kiribati South Tarawa Water Supply Project		PDF	-
		Lecture slides and notes: RMI ACWA Project		PDF	-
Module 3	**Project formulation and management**				
	Module 3.1	**Problem and Objective trees and Logical Framework**			
		3.1.1 Project objective			
			Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	10 min.
			Lecture slides and notes	PDF	-
		3.1.2 Group exercise 1 on project logical framework			
			Part1: Introduction of group exercise 1	Movie file	14 min.
			Part2: Example of Logical Framework	Movie file	16 min.
			Lecture slides and notes	PDF	-
			Exercise Logframe template points to be considered	Word file	
			Exercise Trees template ponts to be considered	PPT	
			Check list for self-review of exercise outputsFile	PDF	
	Module 3.2	**Project management, schedule and budget**			
		3.2.1 Fundamentals of project management, schedule and budget planning			
			Part1: Project cycle	Movie file	13 min.
			Part2: Work Breakdown Structure and project schedule	Movie file	16 min.
			Part3: Cost planning, Quality management and risk management and risk response	Movie file	13 min.
			Key items of project budget	Movie file	23 min.
			Lecture slides and notes: Fundamentals of project planning	PDF	-
			Lecture slides and notes: Key Items of Project Budget	PDF	-
		3.2.2 Group exercise 2 on project schedule and budget			
			Introduction of group exercise 2	Movie file	11 min.
			Lecture slides and notes: Group Exercise 2 on project schedule and budget	PDF	-
			Exercise templates for Group Work 2 (water)	Excel	

Exective course: List of training materials (Access to Climate finance, Part 3 and Part 4)

Section		Name of materiala	Type	Length
Introduction		Welcome remarks from PCCC Manager	Movie file	2 min.
		Bacground of the course	html	
		Sample-day-to-day schedule	Word file	-
Part 3	**Project planning, budgeting and scheduling**			
	Part 3.1	Facilitation for project planning		
		Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
		Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	10 min.
		Lecture slides and notes	PDF	-
		Draft Project Formulation Handbook	PDF	-
	Part 3.2	Project schedule and budget		
		Project schedule	Movie file	16 min.
		Project budget	Movie file	18 min.
		Lecture slides and notes	PDF	-
	Part 3.3	Group exercise 1 on project schedule and budget		
		Introduction of group exercise 1	Movie file	11 min.
		Lecture slides and notes: Group Exercise 1 on project schedule and budget	PDF	-
		Exercise templates for Group works	Excel	
Part 4	**Project execution, monitoring and evaluation**			
	Part 4.1	Project management		
		Project life cycle, main components of execution and management, managent of constraints	Movie file	12 min.
		Quality management, risk management and risk response	Movie file	9 min.
		Lecture slides and notes	PDF	-
	Part 4.2	Monitoring and Evaluation (M&E): from basic to practice		
		Key terminologies in M&E		
		Key terminologies used in M&E, and their application and examples	Movie file	19 min.
		Developing an M&E plan for a climate proposal		
		Tips to make a good M&E plan and how to developing a monitoring plan	Movie file	19 min.
		Key elements of and evaluation plan and M&E requirements, reporting and learning	Movie file	8 min.
		Lecture slides and notes	PDF	-
		Additiona reading materials: Regional initiative to measure climate resilience		
	Part 4.3	Group exercise 2 on M&E		
		Introduction of group exercise 2	Movie file	4 min.
		Lecture slides and notes: Group Exercise 2 on M&E	PDF	-
		Exercise templates for Group work 2	Word file	

Exective course: List of training materials (Health sector)

Section		Name of materials		Type	Length
Introduction		Welcome remarks from PCCC Manager		Movie file	2 min.
		Bacground of the course		html	
		Sample-day-to-day schedule		Word file	-
		Video recording of the orientation session		Movie file	2 min.
		Video recording of the talanoa session with Sir Collion Tukuitonga		Movie file	52 min.
Module 1	**Understanding of risks of climate change impacts on human health and health services, and GHG emission from health services**				
	Module 1.1	Risk of climate change impacts			
			Introduction to climate change in the Pacific and IPCC risk-based conceptual framework	Movie file	18 min.
			Observed and projected climate changes in the Pacific	Movie file	51 min.
			Climate change impact on health, and non-climatic factors	Movie file	13 min.
			Lecture slides and notes	PDF	-
		Cases of climate change impacts on human health and health services in the Pacific		Movie file	10 min.
			Lecture slides and notes	PDF	-
	Module 1.2	Vulnerability and adaptation assessment			
		Vulnerability and adaptation assessment of health care facilities in the context of climate change			
			Vulnerability and adaptation assessment guidelines	Movie file	5 min.
			Comprehensive steps in conducting and adaptation assessment	Movie file	3 min.
			Checklist to assess vulnerabilities in health care facilities in the contexts of climate change	Movie file	13 min.
			Checklist for assessing vulnerabilities to Flood	Movie file	9 min.
			Lecture slides and notes	PDF	-
		Cases of vulnerability and adaptation assessment in the Pacific		Movie file	8 min.
			Lecture slides and notes	PDF	-
		Climate risk assessment of health facilities in Samoa		Movie file	13 min.
			Lecture slides and notes	PDF	-
	Module 1.3	GHG emissions from health services			
		Health service activities, Scope of greenhouse gas emission, Carbon footprint of health, and Opportunities to reduce health care carbon emission		Movie file	25 min.
			Lecture slides and notes	PDF	-
Module 2	**Climate adaptation and mitigation options of health systems**				
	Module 2.1	Health workforce: surveillance, assessment, risk communication and planning			
		Surveillance for outbreak prediction and response			
			Part 1	Movie file	13 min.
			Part 2	Movie file	25 min.
			Lecture slides and notes	PDF	-
		Forecasting outbreaks			
			Part 1	Movie file	13 min.
			Part 2	Movie file	12 min.
			Part 3	Movie file	20 min.
			Lecture slides and notes	PDF	-
		The WHO-Spatio-temporal EWARS			
			Part 1	Movie file	70 min.
			Part 2	Movie file	66 min.
			Lecture slides and notes	PDF	-
		The WHO-Spatio-temporal EAWRS Framework: Risk Mapping			
			Part 1	Movie file	38 min.
			Part 2	Movie file	26 min.
			Lecture slides and notes	PDF	-
	Module 2.2	Facilities and Infrastructures			
		Building, energy and water			
			Health systems building blocks and service activities	Movie file	10 min.
			Goals of climate resilience and environmental sustainability: energy use; infrastructure, technology and products; and water and waste	Movie file	25 min.
			Lecture slides and notes	PDF	-
		Cases in the Pacific: Assessment and improvement of health facilities in Fiji		Movie file	21 min.
			Lecture slides and notes	PDF	-
	Module 2.3	Policies and regulations			
		Overview of the United Nations Framework Convention on Climate Change, Paris Agreement, Nationally Determined Contribution and National Adaptation Plan		Movie file	26 min.
			Lecture slides and notes	PDF	-
		Quality Criteria for Health National Adaptation Plan		Movie file	41 min.
			Lecture slides and notes	PDF	-
Module 3	**Project planning**				
	Module 3.1	**Logical framework development**			
		3.1.1 Project objective			
			Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	10 min.
			Lecture slides and notes	PDF	-
		3.1.2 Fundamentals of project planning			
			Project cycle, scope and Work Breakdown Structure	Movie file	21 min.
			Project schedule, Cost planning, Quality management and Risk management	Movie file	24 min.
			Lecture slides and notes	PDF	-
		3.1.3 Basic of M&E			
			Key terminologies used in M&E, and their application and examples	Movie file	19 min.
	Module 3.2	**Group exercise on project logical framework**			
		Introduction of group exercise		Movie file	11 min.
		Lecture slides and notes		PDF	-
		Exercise Logframe template points to be considered		Word file	
		Exercise Trees template ponts to be considered		PPT	
		Check list for self-review of exercise outputsFile		PDF	

Open-learning course

Open learning course : List of training materials (DRR sector)

Section		Name of materiala		Type	Length
Module 1	**Understanding the vulnerability of structures**				
	Module 1.1	Climate and non-climate impacts on structures			
			IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific	Movie file	14 min.
			Observed and projected climate change in the pacific	Movie file	18 min.
			Observed and projected climate change in the pacific	Movie file	26 min.
			Climate change impact on structure	Movie file	1 min.
			Lecture slides and notes	PDF	-
	Module 1.2	Basic knowledge of vulnerability assessment of structures-Buildings			
			Review of impacts of climate change in building	Movie file	5 min.
			Lecture slides and notes	PDF	-
		Basic knowledge of vulnerability assessment of structures-Coastal protection structures			
			1. Outline of coastal disaster	Movie file	10 min.
			2. Hazards to coastal protection structure and its projected change	Movie file	18 min.
			3. Focal points to assess vulnerability of coastal protection structure	Movie file	20 min.
			4. Summary	Movie file	2 min.
			Lecture slides and notes	PDF	-
Module 2	**CCA and DRR activities focusing on structural approaches**				
	Module 2.1	Buildings			
			1. Overview of risk-informed land use planning	Movie file	18 min.
			2. Designing climate-resilient buildings in the Pacific_part1 (a) Updating of building codes)	Movie file	13 min.
			2. Designing climate-resilient buildings in the Pacific_part2, b) Other manuals and guidelines (1)	Movie file	16 min.
			2. Designing climate-resilient buildings in the Pacific_part3, b) Other manuals and guidelines (2)	Movie file	8 min.
			2. Designing climate-resilient buildings in the Pacific_part4, c) Capacity building needs, d) Green building concept	Movie file	9 min.
			Lecture slides and notes	PDF	-
	Module 2.2	Coastal protection structure			
			Coastal protection structure_part1 (1. Types of coastal protection structure, 2. Impacts to coastal protection structure)	Movie file	17 min.
			Coastal protection structure_part2 (3. Adaptation options for coastal protection structure, 4. Examples and challenges in the Pacific region, 5. Summary)	Movie file	17 min.
			Lecture slides and notes	PDF	-
Module 3	**Problem and Objective trees and Logical framework**				
	Module 3.1	Theory of change			
			Theory of change	Movie file	13 min.
			Lecture slides and notes	PDF	-
	Module 3.2	Project objectives			
			Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	12 min.
			Lecture slides and notes	PDF	-
	Module 3.3	Exercise			
		Reference: Mitigation - adaptation performance measures		PDF	-
		Template for exercise_logframe template		Word file	-

CBCRP-PCCC Virtual Training Course

"Climate Change Adaptation and Disaster Risk Reduction through structural approaches"

Government of Samoa, SPREP, and JICA

1. Understanding of risks of climate change impacts on structures

- IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific

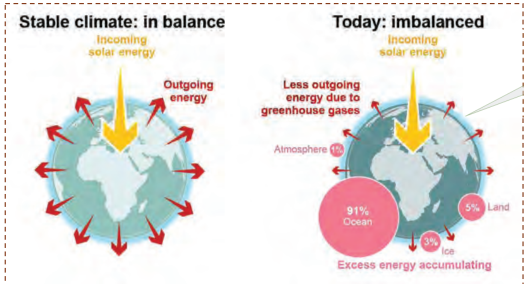
Mr Koji Kuroiwa (Engineering)
JICA Short-term Expert
Overseas Business section, Business Management Department
Japan Weather Association

CONTENTS

Introduction to climate change in the Pacific - I

Climate change and the Earth's energy budget

- Earth's climate is largely determined by the Earth's energy budget, i.e., the balance of incoming and outgoing energy.
- Since at least the1970s, less energy is flowing out than is flowing in, which leads to excess energy being absorbed by the ocean, land, ice and atmosphere, with the **ocean absorbing 91%**.



*Some of the solar energy is trapped by greenhouse gases such as CO_2, CH_4, and N_2O ; **Greenhouse effect.***

Source: IPCC[1]

Narrative Part

1. Roughly, global warming is the main driver of climate change, causing other various changes like heavier rains and more intense storms. In other words, climate change can be described as "global warming and its consequences".
2. Earth's average temperature is determined by the balance between incoming energy from the sun and the outgoing energy emitted back into space. The left panel shows how our planet receives vast amounts of energy every day in the form of sunlight. About a third of the sunlight is reflected back to space, and the rest is absorbed by the ocean, land, ice, and atmosphere. Normally, these incoming and outgoing energies are in balance, the earth's climate is stable, and the temperature remains constant.
3. In recent years, human activities have unbalanced these energy flows. The right panel shows that outgoing energy is less than incoming because part of the solar energy is trapped increasingly by some gasses in the atmosphere and warm the Earth; they are carbon dioxide, methane, and nitrous oxide - the greenhouse effect process and the cause of global warming.
4. Since the 1970s, the excess energy has warmed the ocean and land and melted ice sheets and glaciers. The ocean absorbs as much as 91% of the excess energy, which leads to long-term sea level rise.

Glossary

➢ **Greenhouse gas (GHG)**

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF6),

1. Introduction to climate change in the Pacific and IPCC risk-based conceptual framework

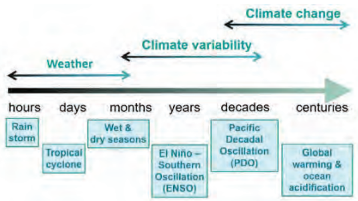
Introduction to climate change in the Pacific - III

5

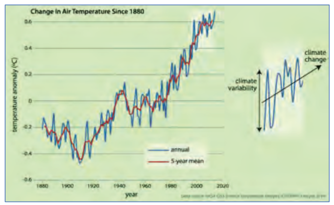
Weather and climate time-scales

- The difference between weather and climate is a matter of time-scale. Climate is sometimes understood as the "average weather" over a long period of time. Climate variability looks at changes that occur within smaller timeframes, such as months, years and decades, and climate change considers changes that occur over a longer period of time, typically over decades or longer.

Illustration of weather/climate time-scales (left) and climate variability/change (right)



Source: PACCSAP



Source: UCAR SciEd

Narrative Part

1. Weather, climate variability and climate change operate on different time scales. Different periods (hours/days/years/centuries) of weather, climate variability, and climate changes are shown on the left panel, including rainstorms that last a couple of hours and tropical cyclones for several days.
2. Weather is highly variable. Climate can be defined as the "average weather" over a long period. The classical period used for describing a climate is "30 years". While weather is variable, climate also shows variability due to internal and external factors.
3. The right panel shows the change in the surface temperature over the past century and suggests the difference between climate and climate variability. Climate variability occurs over months, years, and decades and are defined by climate patterns such as El-Niño Southern Oscillation (ENSO). Other than ENSO, Pacific Decadal Oscillation (PDO) and Interdecadal Pacific Oscillation (IPO) affect the regional climate over much longer terms on decadal scales.
4. The last category, "climate change", occurs over decades and centuries and even much longer time scale. A typical example is global warming.

Glossary

➢ **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

➢ **Pacific Decadal Oscillation (PDO)**

The pattern and time series of the first empirical orthogonal function of sea surface temperature over the North Pacific north of 20° N. The PDO broadened to cover the whole Pacific Basin is known as the Inter-decadal Pacific Oscillation. The PDO and IPO exhibit similar temporal evolution.

➢ **Inter-decadal Pacific Oscillation (IPO)**

A large-scale, long period oscillation that influences climate variability over the Pacific

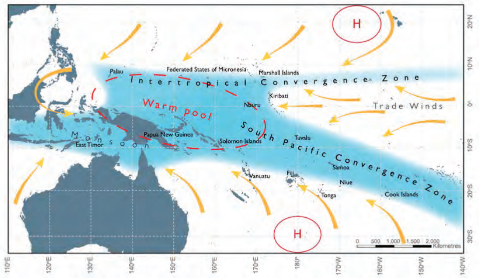
hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Introduction to climate change in the Pacific - II

Large-scale climate features in the W-Pacific

- The South Pacific Convergence Zone (SPCZ), the West Pacific Monsoon (WPM) and the Intertropical Convergence Zone (ITCZ) affect the regional pattern and seasonal cycle in rainfall, winds, tropical cyclone tracks and many other climate aspects of the western tropical Pacific.

Map showing the mean positions of SPCZ, ITCZ and WPM between Nov & Apr



Country	Main features and influences
Cook Islands	SPCZ, sub-tropical highs, trade winds, tropical cyclones, topography
Timor-Leste	WPM, topography
Federated States of Micronesia	ITCZ, WPM, trade winds
Fiji	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Kiribati	ITCZ, SPCZ, trade winds
Marshall Islands	ITCZ, WPM (in some years), tropical cyclones
Nauru	ITCZ, SPCZ, trade winds
Niue	SPCZ, trade winds, sub-tropical highs, tropical cyclones
Palau	WPM, ITCZ, trade winds
Papua New Guinea	WPM, ITCZ, topography
Samoa	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Solomon Islands	SPCZ, WPM, tropical cyclones, topography
Tonga	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Tuvalu	WPM, SPCZ, trade winds, sub-tropical highs, tropical cyclones
Vanuatu	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography

Source: PACCSAP

Narrative Part

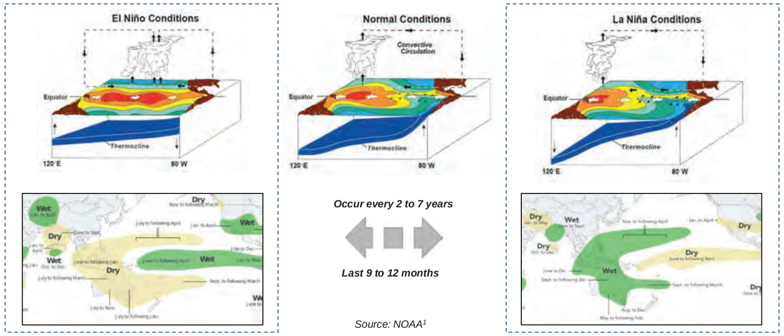
1. The Pacific Ocean covers almost a third of the Earth's surface. It plays an essential role in shaping the climate of the Pacific and the entire globe. The climate of the Pacific is characterized by large-scale climate features and different-sized land masses, which leads to regional variations in climate. At the same time, the El Niño-Southern Oscillation is the source of year-to-year climate variations.
2. The left map shows the average positions of the main features of the regional climate between November and April. The yellow arrows show surface winds; the blue shading represents the bands of rainfall or convergence; the dashed area shows the Pacific Warm Pool, which holds the warmest seawaters in the world. The two rounds stamped by H are high pressures. All these features affect the regional patterns and seasonal cycle of rainfall, winds, tropical cyclone tracks, ocean currents, and many other aspects of the environment of the Pacific.
3. The three extensive bands of large-scale wind convergence are closely associated with rainfall. They are the Intertropical Convergence Zone (ITCZ), the South Pacific Convergence Zone (SPCZ), and the West Pacific Monsoon (WPM).
4. The SPCZ significantly impacts most South Pacific countries, extending from near the Solomon Islands to the east of the Cook Islands. The SPCZ is strongest in the Southern Hemisphere wet season. It stretches across the Pacific just north of the equator and is strongest in the Northern Hemisphere wet season. West Pacific Monsoon is driven by large differences in temperature between the land and the ocean. It moves north to mainland Asia during the Northern Hemisphere summer and south to Australia in the Southern Hemisphere summer. The Monsoon's seasonal arrival usually switches from very dry to very wet conditions.
5. Other aspects of the climate, such as sub-tropical highs, trade winds and tropical cyclones, also impact countries in the Pacific.
6. On larger elevated islands, topography can have a significant effect, so the climate of the key location may not be the same several kilometres away. For example, in Fiji, rainfall is higher in Suva, which is exposed to the southeast trade winds, than in Nadi, which lies on what is predominantly the lee side of the same island. Notable differences in climate also occur within countries that are spread over a

Basin. The IPO operates at a multi-decadal scale, with phases lasting around 20 to 30 years. During the positive phase of the IPO, precipitation is generally higher than normal northeast of the South Pacific Convergence Zone and lower than normal southwest of the SPCZ. Mean sea level pressures are higher than normal to the west of the dateline and lower than normal to the east of the dateline. Due to these pressure differences, there is a southerly flow anomaly during the positive phase of the IPO.

Introduction to climate change in the Pacific - IV

El Niño-Southern Oscillation (ENSO)

- ENSO is a key driver of climate variability in the Pacific, causing short-term changes in climate, including **precipitation patterns** in particular.



Source: NOAA[1]

Narrative Part

1. Climate change is a decades-long event and fluctuates in shorter timescales of months to years, which we call climate variability. Various climate features drive the climate of the Pacific.
2. El Niño-Southern Oscillation (ENSO) is a predominant climate variability for the Pacific and significantly affects regional as well as global climate conditions. ENSO refers to the recurrence of two opposite climate episodes, El Niño and La Niña. Southern Oscillation is the term for atmospheric pressure changes between the east and west tropical Pacific, which accompanies El Niño and La Niña, like a seesaw. As a result, ENSO has distinct impacts on precipitation over most Pacific Island countries.
3. The middle panel shows normal ocean and atmospheric conditions over the Pacific. Typically, trade winds take warm water to the west to create Warm Pool in the western equatorial Pacific. As a result, more clouds are formed where the ocean is warm, and more rainfall is brought.
4. When El Niño occurs, which is shown on the left panel, trade winds weaken, and warm water is pushed back toward the east. Meanwhile, South Pacific Convergence Zone (SPCZ) migrates towards the equator. Typically, it results in wetter conditions in the central and eastern equatorial Pacific and drier conditions in the north of the equator and south-west Pacific.
5. In a La Nina (right panel), trade winds strengthen reversely and take the warm water further to the west. It causes opposite changes to El Nino. ITCZ and SPCZ tend to move away from the equator, drier near the equator, while wetter in the north and southwest Pacific.
6. ENSO events occur every 2 to 7 years and last 9 to 12 months. Typically, El Niño occurs more frequently than La Niña, but, in any case, their frequency is quite irregular.

large area, such as the northern and southern Cook Islands.

7. The right table summarizes the main features and influences on the climate in each country. For example, the Cook Islands are typically influenced by SPCZ, sub-tropical highs, trade winds, tropical cyclones and topography. But when we look at other countries in the west of the region, such as Papua New Guinea, they are typically influenced more by the West Pacific monsoon and the ITCZ. The table also shows that topography is a significant factor in impacting the climate of the mountainous islands.

Glossary

➢ **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

➢ **Inter-tropical Convergence Zone (ITCZ)**

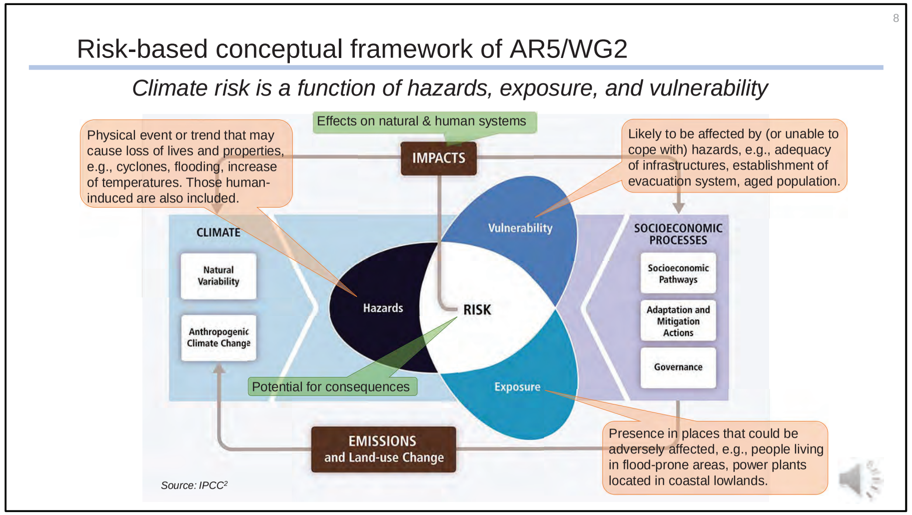
The Inter-Tropical Convergence Zone is an equatorial zonal belt of low pressure, strong convection and heavy precipitation near the equator where the northeast trade winds meet the southeast trade winds. This band moves seasonally.

➢ **South Pacific Convergence Zone (SPCZ)**

A band of low-level convergence, cloudiness and precipitation ranging from the west Pacific warm pool south-eastwards towards French Polynesia, which is one of the most significant features of subtropical Southern Hemisphere climate. It shares some characteristics with the ITCZ, but is more extratropical in nature, especially east of the Dateline.

➢ **Monsoon**

A monsoon is a tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.



Narrative Part

1. Risk-based conceptual framework is a basic scheme for climate risk assessment, which IPCC Working Group-2 (WGII) adopted in its 5th Assessment Report (AR5). Its fundamental philosophy is that risk management is the key to reducing climate change impacts. This concept underlies the discussion of adaptation and mitigation options in a series of PCCC training courses.
2. Various factors determine the rise and fall of Risk. The essence of the AR5's concept is to focus on three main factors of human and natural systems, i.e., Hazards, Vulnerability and Exposure.
3. Risk emerges from the overlap of Hazards, Vulnerability, and Exposure. There are two approaches to reducing Risk; one is to control Hazards, which can be done through changes in emissions, including anthropogenic sources, and the other is to manage Vulnerability and Exposure. It should be noted that vulnerability and Exposure develop from many different socio-economic processes, and therefore, a wide range of measures to reduce Vulnerability and Exposure can be taken, such as through socio-economic pathways, adaptation and mitigation, and social governance.
4. For the reduction of Risk to Structures, it is vital to identify the significant components of Hazards, Vulnerability, and Exposure related to this sector. Some examples are indicated in balloons in the chart: Hazards to Structures include "cyclones", "flooding", "increase of temperatures"; Vulnerability includes: "adequacy of infrastructures", "establishment of evacuation system", and "aged population"; Exposure includes "people living in flood-prone areas" and "power plants located in coastal lowlands.
5. Vulnerability and Exposure in the Structures have both direct and indirect pathways. Consideration of different factors for Vulnerability and Exposure will provide valuable basics for this training course discussion.

Glossary (Definitions at AR5)

➢ **Hazard**

The potential occurrence of a natural or human-induced physical event or trend or

physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term *hazard* usually refers to climate-related physical events or trends or their physical impacts.

➢ **Exposure**

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

➢ **Vulnerability**

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

➢ **Impacts**

Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

➢ **Risk**

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

9

2. Observed and projected climate changes in the Pacific

9

10

Observed Climate Change

10

Observed Climate Change – *Temperature I*

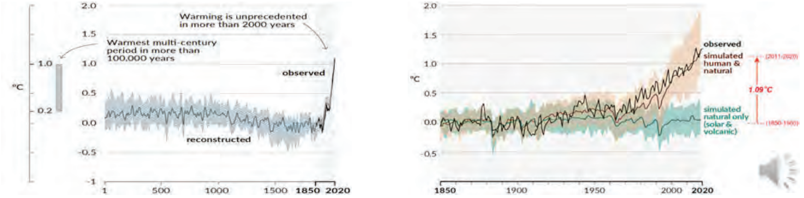
Global surface temperature (GST)

- GST has increased faster since 1970 than in any other 50-year period over at least the **last 2000 years**. *(IPCC[4])*
- It was **1.09°C higher** in 2011-2020 than 1850-1900 with larger increases over land (**1.59°C**) than over the ocean (**0.88°C**). *(IPCC[5])*

Changes in global surface temperature (GST) relative to 1850-1900

(a) Change in GST (decadal average) as reconstructed (1-2000) and observed (1850-2020)

(b) Change in GST as observed and simulated (both 1850-2020)



Source: IPCC[6]

Narrative Part

1. In the bottom right panel, the black line shows the record of observations by instruments. Temperatures gradually increased from around 1900 after the industrial revolution and have grown much faster since 1970.
2. The brown line is the model simulations that considered the human drivers such as emission of GHGs and natural drivers such as solar and volcanic activities. The green line also shows the simulation of the temperatures but considers only natural effects. The brown lines coincide with observations and well adjust to reality.
3. The left panel shows the temperature change over the past 2,000 years. For the period before the observation started, temperatures were reconstructed from natural archives, such as tree ring data and sea sediments. A dashed line depicts the latest 70-year change in the right panel. The nearly vertical change shows how drastic the recent temperatures increase was. This panel's left is the estimated warmest temperatures over the past more than 100,000 years. It further endorses that the current warming is a historical incident.
4. These findings and the change of GHGs concentrations shown in the previous slide collectively endorse that global warming is attributed to anthropogenic greenhouse effect.

Observed Climate Change – *Temperature II*

Regional surface temperatures

- Warming trends are clearly evident in the small islands, such as those in the Pacific, particularly over the latter half of the 20th century. *(IPCC[7])*
- Significant positive trends ranging from 0.15°C/10yr (1953–2010) to 0.18°C/10yr (1961–2011) are noted in the tropical Western Pacific. *(IPCC[8])*

Recent changes in temperature in the Western Pacific Islands

(a) Trends in annual mean temperature over 1951–2015

(b) Regional mean temperature anomalies relative to the 1971–2000 climatology

(c) Regional amount of warm/cold nights, hot/cool days anomalies relative to the 1971–2000 climatology

Source: McGree et al. 2019

Narrative Part

1. Along with the global mean surface temperatures, warming trends are clear at the Pacific Island countries. In the Southwest Pacific, 2020 was the second or third warmest year, depending on the data sets. The warmest year on record was observed in Southern French Polynesia and Tonga. The warming trends in the region have been examined and endorsed by a couple of climate studies, which suggest increases of roughly 0.15° C to 0.18° C per decade.
2. The left panel shows the results of McGree's study from 1951 to 2015 based on the data from 57 stations. Although regional differences exist, most locations indicate warming trends in annual mean temperatures from 0.06 to 0.30, resulting in a regional average of 0.14. In addition, increases in average temperature were found in all seasons throughout the study period.
3. The middle panel was also given from the McGree's, representing the time change of regional average temperature. A warming trend is clear, particularly during the latter half of the 20th century.
4. The study also revealed significant trends in extreme temperatures in the region. The right panel shows the rates of warm nights and cold nights and hot days and cool days, which were derived from daily maximum and minimum temperatures using a percentile analysis. In addition, it shows the increasing trend of hot days and warm nights, which are grey and blue colors, and the decreasing trend of cool days and cold nights, orange and red.
5. Overall, a widespread increase in mean temperature, fewer cool extremes and more warm extremes are represented from 1951-2015.

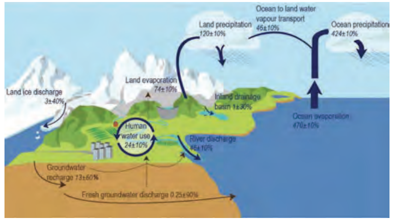
Global Water Cycle; water stores and fluxes

- Global water cycle is the continuous, naturally occurring movement of water through the climate system from its liquid, solid and gaseous forms among reservoirs of the ocean, atmosphere, cryosphere and land.
- While **saline ocean water accounts for 97%** of all water on Earth, **terrestrial freshwater represents less than 2%** and saline groundwater & lakes 1-2%.

Water stores (units in thousands of km^3)

⇦ ***Total water on Earth; 1,380,000,000 km3)***

Water fluxes (units in thousands of km^3 per year)



Source: IPCC[11]

Narrative Part

1. This slide shows an overview of the global water cycle in the climate system, including water stores or reservoirs on the left, and water fluxes or movement on the right. The water cycle is a complex system but is very important because it let us know how water reaches us.
2. What are water stores in the water cycle? The major stores of water are the ocean, ice caps, land including underground, and the atmosphere. Among these, the ocean is the primary reservoir storing 97% of all water on Earth, mostly as salt water. Liquid freshwater on land forms surface water such as lakes and rivers, soil moisture and groundwater stores, together accounting for less than 2% of global water.
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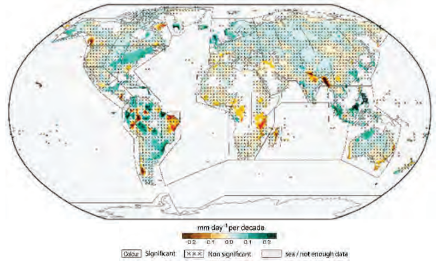
4. Focusing freshwater, ice sheets, glaciers and snowpack account for approximately 96% of all freshwater resources, with less than 4% of freshwater considered easily accessible and available for human society's water resource needs.
5. Meantime, some water moves quickly from one place to another. It is illustrated in the right panel, where the continuous movement of water within the Earth and atmosphere is shown as water fluxes. Water fluxes consist of three major processes, that is "evaporation" where water changes phase from liquid to gas or vapor with solar energy, and "condensation" where water vapor cools and joins together into drops of water and clouds, and "precipitation" where water falls from clouds as rain and snow.
6. The largest component of the global water cycle operates over the ocean, where 85% of evaporation and 77% of precipitation occurs at the ocean-atmosphere interface. Meantime, regional evaporation is rather complex to measure, as it depends on a myriad of localized conditions, including wind speed, humidity, and

Observed Climate Change – *Precipitation*

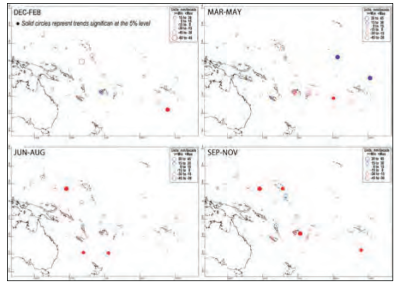
Trends on global and regional scales

- Trends vary spatially and seasonally over Small Island regions in the Pacific. Rainfall has decreased in parts of the Pacific islands poleward of 20° latitude in both hemispheres. However, **trends are not significant** across the globe, including the Pacific. *(IPCC[9])*

Trends of annual precipitation
(1961-2015; CRU TS 4.04)



Trends of quarterly precipitation (mm/decade) at PICs
(1951-2015; positive (blue) and negative (red))



Sources: IPCC[10] (left), McGree et al. 2019 (right)

Narrative Part

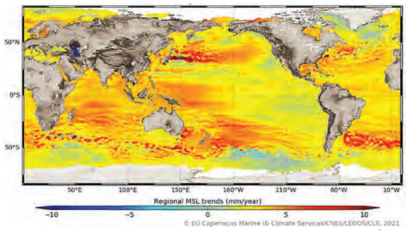
1. Precipitation is a major atmospheric variable, together with temperature. However, compared with temperature, it is much more difficult to find significant changes in precipitation. The left panel shows global trends of annual precipitation over the 55 years from 1961 to 2015. The widespread of x-marks indicates the regions where trends are not significant. A comparison between this chart and that of temperature two slides before demonstrates the difference.
2. The main reasons for the less significance in the precipitation trend analyses are the sparsity and less quality of data, particularly in developing countries, and the large natural variabilities that precipitation has.
3. Nevertheless, some significant increases in land areas are shown in this chart, such as North and South America, Eurasia and northwestern Australia, while decreases are apparent across tropical western and equatorial Africa and southern Asia.
4. Significant trends are not noticeable in the western Pacific region like the global views. Pacific is one of the most data-sparse areas of the world, while interannual and decadal variabilities drive long-term trends in rainfall, as we discussed previously.
5. Four panels on the righthand side depict the findings of regional precipitation trends from the same study in the previous slide. Results are shown in quarterly periods. In the study region, statistically significant annual precipitation trends were only found in the southern subtropics and southwest French Polynesia, both of which are negative. These were associated with negative trends in June to August and from December to February. Significant negative trends were also present from September to November in the north ITCZ and north PNG subregions.
6. Unlike the changes in temperature, which are dominated by background global warming, rainfall patterns in the Pacific are strongly influenced by natural climate variability. Such a regional characteristic makes it difficult to detect rainfall trends.

Observed Climate Change – *Sea Level Rise I*

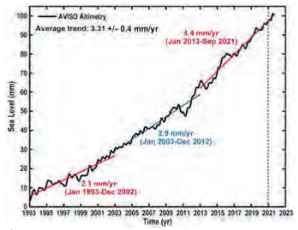
Global mean sea level (GMSL)

- GMSL rose faster in the 20th century than in any prior century over the last three millennia, with a 0.20 m rise over 1901-2018.
- GMSL rise has accelerated since the late 1960s, with an average rate of 2.3 mm/yr over 1971-2018, increasing to 3.7 mm/yr over 2006-2018. *(IPCC[12])*

Regional sea level trend for Jan-1993 to Dec-2020



GMSL evolution for Jan-1993 to Sep-2021



Source: AVISO altimetry

Narrative Part

1. Global mean sea level changes primarily result from ocean warming, leading to the thermal expansion of seawater and land ice melting and adding water to the ocean. As a result, the sea level is continually rising, and it has been found to be accelerating. This has gathered the increasing attention of world scientists.
2. Recent measurements by satellite altimeters revealed that the global mean sea level rise was 2.1 mm per year between 1993 and 2002, 2.9 between 2003 and 12, and 4.4 between 2013 and 21, as shown in the right panel. This rapid step-up was primarily due to the accelerated ice mass loss from glaciers and ice sheets.
3. The regional sea level trends in the left panel demonstrate a considerable variation between the basins. Much of the spatial variation results from natural climate variabilities—such as El Niño and the Pacific Decadal Oscillation—over time scales from months, about a year, to several decades. These climate variations shift surface winds, ocean currents, temperature, and salinity, affecting sea levels. Also accountable are Earth's geological changes, such as changes in Earth's gravity and vertical land motion.
4. The chart shows such variations also in the Pacific. The western tropical Pacific Ocean intensified sea-level rise during the 1990s and 2000s. Ten-year trends exceeded 20 mm yr-1, while sea level trends were negative on the North American west coast.

Glossary

➢ **Altimeter**

Satellites carrying radar altimeters record the surface topography along the satellite's ground track. They precisely measure a satellite's height above water, land or ice by timing the interval between the transmission and reception of very short radar pulses. This is the only technology that can measure, systematically and globally, changes in the height of the ocean – and is therefore essential for monitoring sea-level rise. (ESA)

temperature.

7. Discharge of rivers, groundwater, and land ice, as well as water use by human, are also important components of water fluxes. In terms of drinking water and irrigation, recharge and discharge of groundwater is a major contributor in the water fluxes together with precipitation.

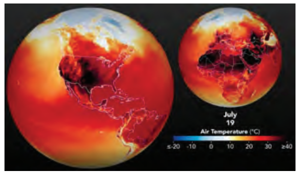
Recent topics in climate observation - (global)

✓ Four key climate change indicators – **GHG** concentrations, **sea level rise**, **ocean heat** and ***ocean acidification*** – set **new records in 2021**. *(WMO)*

✓ **Over 40°C** was observed in parts of Portugal, Spain, France, US, and UK, which breached the 40°C for the first time. *(WMO)*

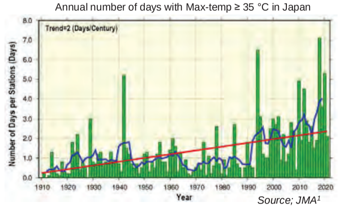
✓ The frequency of heatwaves **has also been increasing in Japan**. The annual average of the number of days of 35°C or higher for 1992-2021 has been **3.3 times the average** for 1910-1939. *(JMA)*

Daily maximum surface temperature on 19 July 2022



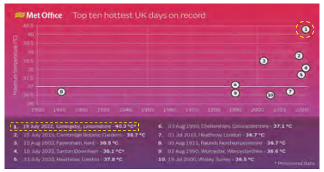
Source; NASA

Annual number of days with Max-temp ≥ 35 °C in Japan



Source; JMA[1]

Top ten hottest UK days on record



Source; Met Office

Narrative Part

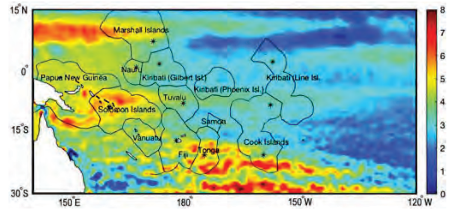
1. Recently, the world climate monitoring system has been observing exceptional weather conditions across the globe. Some of the cases are unprecedented and highly suggestive of accelerating climate change. For example, in 2021, four key climate change indicators set new records. In addition to the record-breaking GHG concentration as well as the accelerating global mean sea level, as shown in the previous slides, scientists have revealed that ocean heat made a record high exceeding the 2020 value and that the ocean surface acidity was at its highest "for at least 26,000 years".
2. In 2022, the world had the third warmest July, with prolonged and intense heat waves affecting the US and parts of Europe and Asia. The top right panel displays a snapshot of the global surface temperatures in July. Nearly 40° C temperatures stand out in the US, Asia and Europe. Despite the weak La Niña, which has a cooling influence, northern hemisphere land masses saw well-above-average temperatures, almost predominantly. Temperatures measuring over 40° C were observed in parts of Portugal, Spain, France, and the UK, which breached 40 degrees for the first time. The World Health Organization witnessed more than 1,700 deaths in Spain and Portugal alone.
3. The top ten hottest days on record in the UK after 1900 are plotted on the bottom right panel. It shows nine out of 10 hottest days have been recorded since 1990, including the 40.3° C on 19 July this year.
4. The Japan Meteorological Agency has also noticed a similar trend over the past hundred years, as shown in the left panel. The number of days of 35° C or higher for 1992-2021, the latest 30-year statistical period, has been 3.3 times the average for 1910-1939, the first statistical period of the Agency. This same trend in the two countries clearly endorses the temperature findings in IPCC AR6.

Observed Climate Change – *Sea Level Rise II*

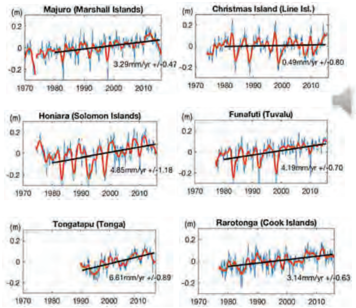
Regional sea level rise

■ Across the globe, sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific over the period 1993–2018. *(IPCC[13])*

Rates of sea level rise from satellite altimetry for 1993-2017 (mm/yr)



Monthly and yearly running average of relative sea level measured at tide gauges for 1977-2017



Source: Aucan, J. 2018

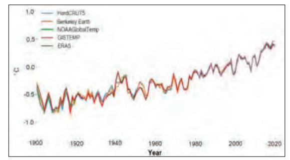
Narrative Part

1. Mean sea level can fluctuate over a long period, even for decades. It should be noted that sea level is defined in two different ways: “absolute sea level”, which refers to the sea level as measured from the center of the earth, and “relative sea level”, which refers to the sea level relative to the coastal area of interest. Absolute sea levels have been monitored by satellite altimetry since 1993, while relative sea levels are by tide-gauges which started in the 1960s in the Pacific.
2. Regarding the sea levels in the Pacific, it’s worth noting that satellite altimeters found sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific from 1993 to 2018, among all basins. This slide presents a recent study which demonstrates this typical trend. The left panel shows calculated rates of the regional sea level rise from 1993 to 2017. During this period, results show a rise in sea level of 3-6 mm/year for the Pacific islands, with notable differences between islands. Some islands in the Western Pacific, such as the Solomon Islands, Papua New Guinea, and the Marshall Islands, have experienced a higher rate of sea level rise (up to 6 mm/year), while other islands further east, such as Samoa and Kiribati are much lower. This difference in sea level rise is attributed to large-scale trends in trade winds.
3. Changes of the relative sea level at some selected stations are shown in the panels on the right. Data measured at tide-gauges combines the measurements of satellite altimeters. All show a rise in relative sea level over the past 30 to 40 years and the varied rates between islands. They also demonstrate inter-annual variability, which is attributed mostly to El-Niño Southern Oscillation.

Recent topics in climate observation - (regional)

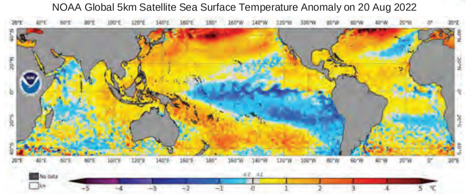
- ✓ In the South-West Pacific region, **2020 was the second or third warmest year** on record.
- ✓ 2020 was **a relatively wet** year over PNG, Solomon Islands, Vanuatu, Fiji, Tonga and Samoa, while many equatorial regions close to IDL were **dry**.
- ✓ PICs were affected straight by the **La Niña** events in 2020-21 and 2021-22. *(On 16 Aug., BoM suggested a 70% chance of a 3rd consecutive La Niña year forming.)*

Area average temperature anomalies from the 1981–2010



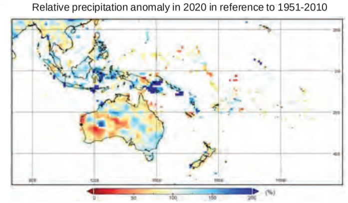
Source; WMO

NOAA Global 5km Satellite Sea Surface Temperature Anomaly on 20 Aug 2022



Source; NOAA

Relative precipitation anomaly in 2020 in reference to 1951-2010



Source; GPCC

Narrative Part

1. The 2020 climate report for the Southwest Pacific issued by WMO emphasized that the significant and growing impacts of extreme hydro-meteorological phenomena and tropical cyclones, plus new multi-dimensional threats, pose increasing challenges to communities in the region. Regarding regional averaged temperatures, 2020 was the second or third warmest year on record. The top right panel shows a consistent increase in the regional average temperature has been demonstrated over the past century.
2. In 2020, the Great Barrier Reef suffered a major marine heatwave. In February, sea surface temperatures over the region were 1.2° C above the 1961-1990 average, making it the hottest month on record. Such high temperatures affected the entire GBR, and widespread coral bleaching was reported.
3. The bottom right panel gives an overall regional rainfall condition in 2020. Under the 2020-21 La Nina and the 2021-22 La Nina, relatively wet conditions continued over the region from PNG and Solomon Islands to Fiji and Samoa from 2020 through early 2022, while lower-than-normal rainfall continued in the equatorial region. During these years, Australia suffered frequent floodings, including the 2022 eastern Australia floods, one of the nation's worst recorded flood disasters.
4. The Bureau of Meteorology stated on 16 August that a third consecutive La Niña is likely from late 2022. The latest monitoring of sea surface temperatures (SSTs) shown in the bottom left represents below-average SSTs extending from the eastern to central tropical Pacific and suggests the possible occurrence of La Nina soon.

Projected Climate Change

experiments involving multiple international modeling teams worldwide.

- CMIP has led to a better understanding of past, present and future climate change and variability in a multi-model framework.
- CMIP defines common experiment protocols, forcings and output.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

➢ **Representative Concentration Pathways (RCPs)**

Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. (Moss et al., 2010). For further description of future scenarios, see Box 1.1 of AR5/WG1.

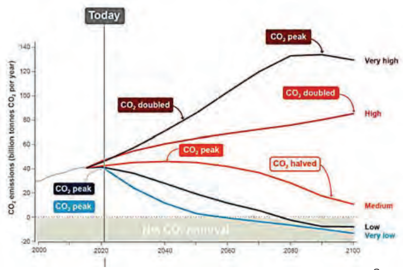
20

Projected Climate Change – *GHGs*

Greenhouse gases (emission scenario)

■ AR6 considers a set of **five new illustrative emissions scenarios** (Shared Socio-economic Pathways; SSPs). Coupled Model Intercomparison Project Phase 6 (CMIP6) was conducted using these scenarios, and its outcomes served as the main bases of AR6.

New scenarios (SSPs) of annual anthropogenic emission of CO_2 over 2015–2100 (AR6)



➢ SSP5-8.5
Very high; Close to RCP*8.5 of AR5. Worst case scenario with no additional climate policy.

➢ SSP3-7.0
High; Between RCP8.5 and RCP6.0. Realistic worst-case with continuing CO_2 emission. Would result in serious consequences.

➢ SSP2-4.5
Medium; Close to RCP4.5 and later RCP6.0. More consistent with government polices but CO_2 emission remain above zero.

➢ SSP1-2.6
Low; Close to RCP2.6. CO_2 emission to plateau and decline after 2025. Temperatures to stay well below 2°C.

➢ SSP1-1.9
Very low; No equivalent RCP. Efforts to remove CO_2 needed. Will meet the Paris goal of limiting global warming to 1.5°C.

Source: IPCC[14]

- *Representative Concentration Pathways (**RCPs**) are GHG emission scenarios used in AR5.*

Narrative Part

1. AR6 adopted five new scenarios for GHGs emissions called SSP scenarios instead of 4 RCP scenarios in AR5. The new scenarios represent five different socio-economic pathways. World climate scientists performed simulations of climate change based on these scenarios in the Coupled Model Intercomparison Project--Phase 6 (CMIP6), which formed the basis of AR6. The chart below shows SSP scenarios for CO2. IPCC produced SSP scenarios also for other Green House Gases.
   - SSP/585, the Very high emission scenario, is close to RCP8.5. It assumes no measures will be taken to reduce CO2 emissions. CO2 emissions soar up and double from current levels by 2050.
   - SSP/370, the High scenario, was newly introduced. CO2 emissions double from current levels by 2100.
   - SSP/245, the Medium scenario, is an update to RCP4.5. It assumes that climate protection measures are taken. CO2 emissions remain around current levels until the middle of the century.
   - SSP/126, the low scenario, is a remake of the RCP2.6. CO2 emissions decline to net zero around 2080 and goes into net negative emission.
   - SSP/119, the very low scenario, assumes CO2 emissions declines to net zero around 2050 and then net negative.
2. Roughly, Very high scenario is pessimistic as CO2 emissions are unregulated. And Low and Very low scenarios are optimistic as they require drastic measures to reduce CO2 emissions. The recently released AR6/WG3 report suggests that limiting warming to around 1.5° C requires global greenhouse gas emissions to peak before 2025 at the latest and be reduced by 43% by 2030. The next few years are critical.

Glossary

➢ **Coupled Model Intercomparison Project (CMIP)**

CMIP is a project of the World Climate Research Programme (WCRP)'s Working Group of Coupled Modelling (WGCM). Since 1995, CMIP has coordinated climate model cement emissions, land-use change emissions, ocean and land CO2 sinks, and the resulting atmospheric CO2 growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that that is estimated to limit global surface temperature to a given level above a reference period, taking into account global surface temperature contributions of other GHGs and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of equity, costs or efficiency.

➢ **Gigatons of Carbon Dioxide (GtCO2)**
GtCO2 refers to gigaton of carbon dioxide (a gigaton is equal to 1 billion metric tons). GTCO2 (or GtC) is used as the reference unit for the global carbon cycle (Gigaton of carbon = 1 GtC = 1015 grams of carbon. This corresponds to 3.667 GtCO2).

➢ **Carbon cycle**
The term used to describe the flow of carbon (in various forms, e.g., as carbon dioxide (CO2), carbon in biomass, and carbon dissolved in the ocean as carbonate and bicarbonate) through the atmosphere, hydrosphere, terrestrial and marine biosphere and lithosphere.

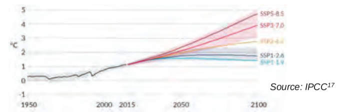
➢ **Cumulative emissions**
The total amount of emissions released over a specified period of time.

Projected Climate Change – *Temperature I*

Global surface temperature (GST)

- GST will continue to **increase until at least the mid-century** under all emissions scenarios. *(IPCC[15])*
- It was reaffirmed that there is a **near-linear relationship** between cumulative anthropogenic CO_2 emissions and the global warming they cause. *(IPCC[16])*

GST change relative to 1850-1900



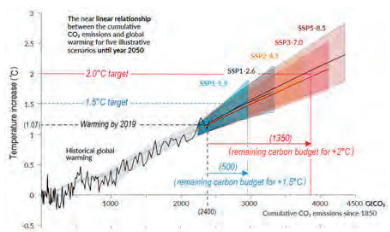
Source: IPCC[17]

Changes in GST under the 5 emissions scenarios

Scenario	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
SSP1-1.9	1.5	1.6	1.4
SSP1-2.6	1.5	1.7	1.8
SSP2-4.5	1.5	2.0	2.7
SSP3-7.0	1.5	2.1	3.6
SSP5-8.5	1.6	2.4	4.4

Source: IPCC[18]

GST increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Source: IPCC[19]

Narrative Part

1. This slide shows one of the main outcomes of CMIP6 projections - global surface temperatures. The top left panel shows the projected change of temperatures under all five scenarios. There is a slow turning point during the mid-century, where the trend becomes relatively flat or even starts to decline for Low and Very-low scenarios while continuing to grow for medium and higher scenarios. The difference can be seen more precisely in the table below.
2. The best estimates of the near-term temperatures are 1.5 degrees or higher for all scenarios. It provides new estimates of the chances of crossing the global warming level of 1.5° C in the following decades. The table also shows the significant difference between Very-low and Very-high scenarios in the long term; it is about 3 degrees.
3. More importantly, hot temperatures include heat waves and growing average temperatures. Such extreme events have highly serious impacts and are projected to occur far more frequently in the near future.
4. The right panel shows the near-linear relationship between temperature increase and cumulative CO2 emission until 2050. This diagram shows that the historical cumulative CO2 emissions from 1850 to 2019 were 2400 GtCO2, resulting in global warming of 1.07 degrees. If the emissions continue, Earth will also continue to warm in the same way.
5. This diagram suggests that if we hope to limit the warming to 1.5 degrees, the remaining carbon budget will be about 500 GtCO2. Similarly, for 2.0 degrees, it will be about 1350 GtCO2. So, it gives us an estimate of the allowable amount of additional CO2 emissions for limiting global warming to any target level. In this regard, we should note that the global emissions of GHGs in 2018 were more than 50 GtCO2 in total.

Glossary

➢ **Carbon budget**
This term refers to three concepts in the literature: (1) an assessment of carbon cycle sources and sinks on a global level, through the synthesis of evidence for fossil fuel and

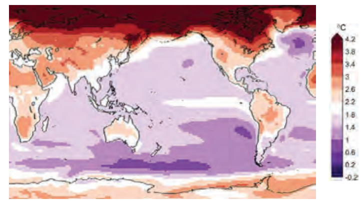
future periods and emissions scenarios or warming levels. A description of the datasets, temporal and spatial scales and dimensions of analysis, as well as the representation of robustness and uncertainty (Cross-chapter Box Atlas.1) are introduced in Atlas.1.

Projected Climate Change – *Temperature II*

Regional surface temperature (RST)

- It is very likely that the significant recent warming trends observed in the small islands **will continue in the 21st century**, which will likely further increase heat stress in these regions. *(IPCC[20])*

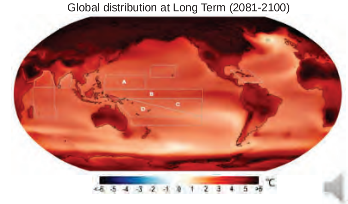
The multi model average projection of 2°C global warming with a color scale centered on +2°C.



Source: RCCAP

Projected changes (°C) relative to 1850-1900 under SSP3-7.0

Global distribution at Long Term (2081-2100)



Global and sub-regional means (°C) at 3 terms

*(**A**: NW-Tropics, **B**: Equatorial Pacific, **C**: Northeast SPCZ, **D**: Southwest SPCZ)*

Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	0.7	1.3	2.6
(B) Equatorial Pacific	0.8	1.4	2.8
(C) NE-SPCZ	0.7	1.2	2.4
(D) SW-SPCZ	0.7	1.2	2.4
GLOBAL	**1.5**	**2.1**	**3.6**

Source: IPCC[21]

Narrative Part

1. The projected warming over the Pacific Island region is relatively moderate compared with the global-average warming for all emissions scenarios. This is linked to the fact that the oceans are warming at a lower rate than land areas, and this clear trend in the observation part is noted.
2. The top right chart shows the increase of regional temperatures at the end of the 21st century under the high emission scenario. It indicates that warming is clear and almost universal. Looking at the western Pacific, changes are relatively uniform over the region; all are around 2 to 3 degrees.
3. Those of areal means of the four sub-regions; NW Tropics, Equatorial Pacific, NE SPCZ and SW SPCZ; were calculated for each of three terms with AR6-Interactive Atlas, where sub-regions are determined based on the average positions of the ITCZ and SPCZ. The results are listed in the table below. Sure enough, changes are roughly comparable from region to region. If anything, warming is slightly larger in the Equatorial Pacific. Anyhow, the smaller-than-global-average trend in the region is evident. The magnitudes of warming are roughly 50% of the global mean for the near term and 70% for the long term.
4. The left panel depicts the regional temperatures at a 2° C global warming. Changes are shown in a finer and specific color scale centered on plus 2° C. Red indicates the areas hotter than the global average, and purple is cooler than the average. It clearly shows that warming is less than the average across the entire ocean, and it is largely uniform over the western Pacific.

Glossary

➢ **IPCC WGI Interactive Atlas**

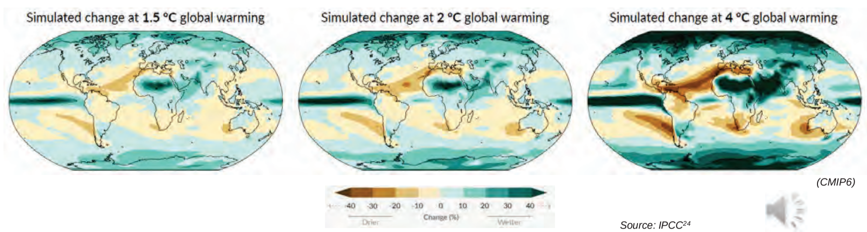
The Interactive Atlas regional information supports the assessment done in the AR6-WGI chapters, the Technical Summary (TS) and the Summary for Policymakers (SPM), allowing for flexible temporal and spatial analyses of trends and changes in key atmospheric and oceanic variables, extreme indices and climatic impact-drivers (CIDs), as obtained from several global and regional observational and model simulated datasets used in the report. These analyses are available for a range of historical and

Projected Climate Change – *Precipitation I*

Global precipitation

- **Precipitation is projected to increase** over high latitudes, the **equatorial Pacific** and parts of the monsoon regions but decrease over parts of the subtropics and limited areas in the tropics under Medium, High, and Very-high scenarios. *(IPCC[22])*
- It is very likely that **heavy precipitation events will intensify and become more frequent** in most regions with additional global warming, including the **western tropical Pacific.** *(IPCC[23])*

Annual mean precipitation change (%) relative to 1850-1900



Source: IPCC[24]

Narrative Part

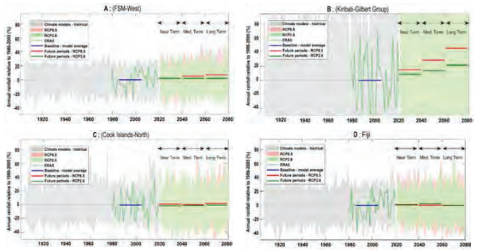
1. Precipitation has a unique characteristic as it represents opposite changing trends over time and space. Roughly, its contrast will become more significant between dry regions and wet regions and between the dry season and rainy seasons. A warmer climate will intensify very wet and dry weather, with implications for increasing flooding or drought.
2. The three maps on this slide show projected changes in annual mean precipitation for a global warming of 1.5 degrees on the left, 2 degrees in the middle, and 4 degrees on the right. The projection of global precipitation is roughly a half-and-half mixture of positive and negative trends. This is the crucial difference with the projection of temperatures. Precipitation will increase over high latitudes, the equatorial Pacific and parts of the monsoon regions but decrease over parts of the dry subtropical regions and in limited areas of the tropics. Models generally agree that precipitation, when it once occurs, will become more intense. Unlike average annual precipitation, almost the entire world is expected to see an increase in extreme precipitation along with global warming. Also, it's worth noting that rainfall variability related to the El Nino-Southern Oscillation (ENSO) is projected to be amplified by the second half of the 21st century under the Medium and higher scenarios.

Projected Climate Change – *Precipitation II*

Regional precipitation

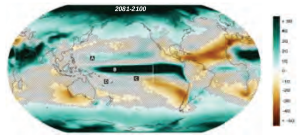
- ENSO will remain the dominant mode of interannual variability, and its influence will strengthen. It is very likely that **ENSO rainfall variability** will increase significantly over the 21st century.
- **Higher evapotranspiration** under a warming climate either amplifies or partially offsets, respectively, the effect of decreases or increases in rainfall. *(IPCC[25])*

Annual mean precipitation change (%) in sub-regions relative to 1850-1900



Source: RCCAP; CMIP5

Annual mean precipitation change (%) relative to 1850-1900 under SSP3-7.0



Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	2.2	3.7	6.2
(B) Equatorial Pacific	10.2	16.1	33.8
(C) NE-SPCZ	4.3	6.0	8.1
(D) SW-SPCZ	1.3	2.1	1.9
GLOBAL	–	–	4.7

Source: IPCC[26]

Narrative Part

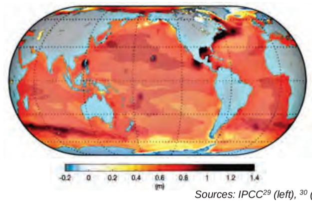
1. In the western tropical Pacific, increases in annual mean rainfall will stand out near the SPCZ and ITCZ.
2. However, as suggested earlier, it is rather challenging to find clear trends in the projection of precipitation changes in contrast to temperature. While the models used by scientists generally agree on how different parts of the Earth will warm, there is much less agreement about where and how precipitation will change. Such difficulties are even more on smaller scales.
3. This is mainly because of the complexity of the water cycle that we saw in the earlier slide. In addition, the scarcity of data, as well as the year-to-year variability of precipitation, is also highly challenging. These hurdles significantly increase uncertainty in model simulations.
4. Still, there were some findings in SMIP5 and 6. The right map is the projection with SMIP6. The models' average shows significant increases in precipitation in the equatorial Pacific, as suggested earlier. Yet, we note again that much of the Pacific region is hatched in the map, meaning the model agreement is low over a wide range.
5. Areal means of the projection were sought for the four sub-regions with the Interactive Atlas, the same as for temperatures in the earlier slide. The results are listed in the table below. Notable increases are shown in the Equatorial Pacific, while other sub-regions are rather flat.
6. Four panels on the left are time-series charts of multi-model means from RCCAP by SMIP5. Each represents the respective subregions. They show the same trend as SMIP6 but are relatively underestimated. In either case, we should note that those projections are just the mid-points of different results from different models with significant uncertainties.

Projected Climate Change – *Sea level I*

Global mean sea level (GMSL)

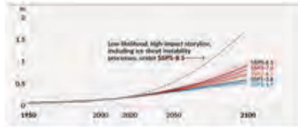
- GMSL will continue to rise over the 21st century; **0.63-1.01 m at 2100** under SSP5-8.5. *(IPCC[27])*
- In the longer term, **sea level is committed to rise for centuries to millennia** due to continuing deep ocean warming and ice sheet melt and will remain elevated for thousands of years. *(IPCC[28])*

Projected sea level changes at 2100 under SSP3-7.0



Projected GMSL changes relative to the 1900 level

Dashed lines show changes that could occur only in case of high-impact ice-sheet processes.



(17th-83rd percentile ranges)

Sources: IPCC[29] (left), [30] (right)

(AR6)

Narrative Part

1. Projections of sea level rise under five scenarios are given in the two panels in the middle and on the right. The left shows that sea level rise will reach nearly 1 meter at 2100 and then approach 2 meters at 2150 under Very-high scenario. The vertical graph on the right shows further projections for 2300 under Very-low and Very-high scenarios. Sea levels rise will be 0.5 to 3 meters for Very-Low scenario and 2 to 7 meters for Very-high scenario.
2. Interesting to note in these charts is another storyline indicated by the broken lines. Although it is not included in the projections under five scenarios but suggests that, in case the ice-sheets become highly unstable, in Antarctica in particular, sea level rise could present quite a different storyline. It is shown by the dashed curve here; along this line, sea level rise could be 2 meters at 2100 and 5 meters at 2150. Further, at 2300, the sea level could rise by 15 meters or more.
3. Another point is that even if global temperatures peak by the end of this century, it will continue for centuries or even millennia to come, as the oceans, glaciers and ice sheets take time to reach an equilibrium state (or steady state, in other words). We are only at the starting line of the long-lasting sea level rise to come.
4. The global map on the left shows a snapshot of the rising regional sea levels under the high-emission scenario. Although it shows some regional trends, sea level rise should be recognized as a universal trend across the globe.

Projected Climate Change – *Sea level II*

Regional sea levels

- Relative sea-level rise (RSLR) is very likely to continue in the tropical Pacific, where regional-mean RSLR will be **0.4–1.0m** for 2081–2100 (relative to 1995–2014) under the high-emission scenario.
- Even a **5-10 cm** additional SLR will **double flooding frequency** in much of the tropical Pacific.

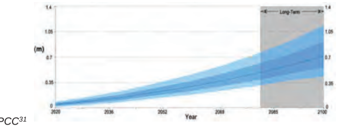
CMIP6-SLR projection relative to 1995–2014 under SSP3-7.0 for Near-, Mid-, and Long-Terms

Projection of SLR for 2081-2100

Sub-regional projections of median RSLR (m) for three terms

	N-Term (2021-2040)	M-Term (2041-2060)	L-Term (2081-2100)
NW-Tropics	0.1 [0.0-0.2]	0.2 [0.1-0.4]	0.7 [0.4-1.0]
EQ-Pacific	0.1 [0.0-0.2]	0.2 [0.1-0.3]	0.6 [0.4-0.9]
NE-SPCZ	0.1 [0.0-0.2]	0.2 [0.1-0.3]	0.6 [0.4-0.9]
SW-SPCZ	0.1 [0.0-0.2]	0.2 [0.1-0.4]	0.6 [0.4-0.9]

Time-series projection of the sub-regional mean for the Equatorial Pacific



Source: IPCC[31]

Narrative Part

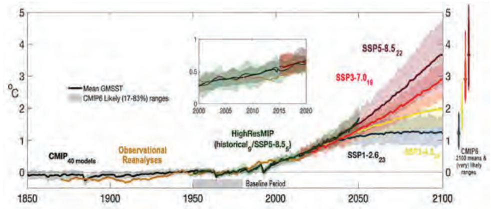
1. In consideration of the sea level change on a global scale in the previous slide, we should narrow the focus on the Pacific region. Again, AR6's Interactive Atlas was used to see the results of CMIP6 for the sub-regions under the high-emission scenario. As shown in the top table's multi-model averages for three terms and the time-series projection in the bottom chart, you can see that regional sea-levels will be 0.4-1.0m higher than in 1995-2014 in the long term. Also, together with the projected unique pattern in the long-term on the left, it is clear that differences between the regions are minimal—about 0.1m for the near-term and 0.6m for the long-term.
2. Interestingly, the magnitude of regional sea-level rise projections by models has gradually increased over the past decade, along with global projections. For example, sea-level rise in the western tropical Pacific was projected to be 0.26 to 0.82 m by 2100 under the very high emission scenario in the PCCSP report in 2011. Further, we should note that extreme sea-level events are projected to be more intense and frequent. For example, AR6 estimated that even a small amount of sea-level rise, say 5 to 10cm, could increase the frequency of flooding in the tropical Pacific as early as 2030.

Projected Climate Change – *Sea surface temperature (SST)*

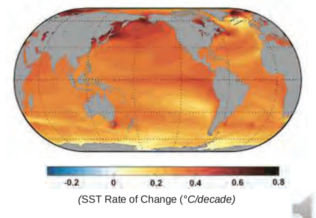
Global mean SST

- Past GHG emissions since 1750 have committed the global ocean to future warming. Over the rest of the 21st century, likely ocean warming ranges from **2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5)** the 1971–2018 change. *(IPCC[32])*

Global mean (SST); modern history and model projections to 2100



SSP5-8.5 CMIP Change Rate (2005-2100)



Source: IPCC[33]

Narrative Part

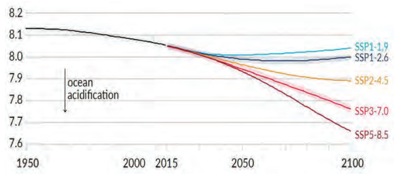
1. The global ocean has warmed since 1970 and has taken up more than 90% of the excess heat in the climate system, as we have learned in the earlier slide. Regionally, tropical oceans, including the western Pacific, have been warming faster than other regions since 1950.
2. As shown in the left panel, this ocean warming trend is consistent through the 21st century, except for the very-low emission scenario. The right panel shows the SST changes with time. Under the Very-high scenario, ocean warming could range from 4 to 8 times the 1971-2018 temperatures.
3. Notably, the warming of the ocean is irreversible on centennial to millennial time scales. It is also worth noting that the warming will lead to extreme heat conditions across the basins. Marine heatwaves will become more frequent, and the largest increases will be found in the tropical ocean, especially over the western Pacific.

Projected Climate Change – *Acidification*

Acidification

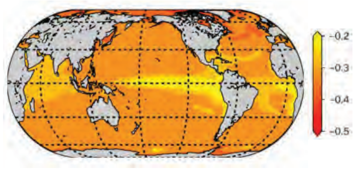
- Upper ocean stratification, ocean acidification and ocean deoxygenation **will continue to increase in the 21st century**, at rates dependent on future emissions. *(IPCC[34])*

Change in global ocean surface pH based on CMIP6 model simulations



Source: IPCC[35]

Change in ocean surface pH for 2081-2100 relative to 1986-2005 under RCP8.5



Source: JMA[2]

Narrative Part

1. Sea water is becoming more acidic across the entire ocean. Along with sea surface temperatures, this acidification trend will continue all through this century under medium or higher emission scenarios. Please take a look at the left panel. Under the Very-high scenario, the ocean pH will reach around 7.7 or less at the end of the century, which is about 0.4 units lower than the present value. Globally, acidification will be faster over the Equatorial Pacific, as shown in the right panel.

Projected Climate Change – *Tropical Cyclone (TC) I*

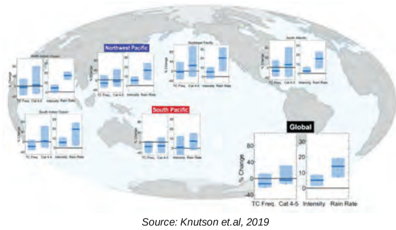
TC projection on the global scale for a 2°C global warming *(AR6)*

- Average peak TC wind speeds
- Proportion of category 4-5 TCs
- Average & Max rain rates associated with TCs
- Peak wind speeds of the most intense TCs

→ **Increase** *(all high confidence)*

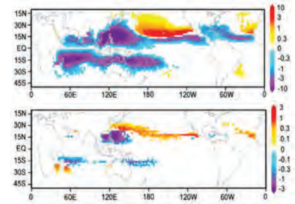
- ▫ Frequency of all TCs → **Decrease or unchanged** *(medium confidence)*

Regional TC projections for a 2 °C global warming



Source: Knutson et.al, 2019

Projected frequency of TCs of all categories (top) and category 4-5 (bottom) for a 4 °C warming.



Source: Yoshida et al, 2017

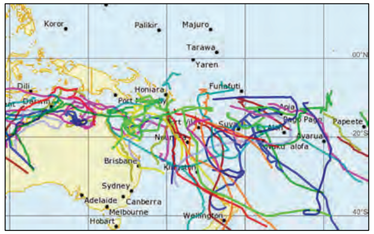
Narrative Part

1. This slide presents the results of two recent studies on tropical cyclones. One is shown in the left map by Knutson et al., indicating the future status under 2 degrees warming, and the other is the two panels on the right by Yoshida et al., showing the projected TC frequencies of all categories on the top and 4-5 categories in the bottom.
2. Regarding tropical cyclones, confidence is low in identifying their long-term trends, such as frequency or intensity, due to changes in the technology used to collect best-track data. In addition, for projection, the simulation capabilities of global models are still challenging. However, recent studies, including those in this slide, suggested several essential features.
3. In summary, mainly from the Knutson's and AR6, average peak TC wind speeds and the proportion of Category 4-5 TCs will very likely increase globally with warming. However, over the western North Pacific, the frequency of Category 4-5 TCs will likely increase in limited regions. This trend in the western North Pacific is suggested in the bottom panel of Yoshida's. Also, average TC rain rates will likely increase with warming, and, finally, the frequency of TCs overall categories will decrease or remain unchanged.
4. Although degrees of some changes are different between the basins, tendencies are less similar for all seven basins, including NW and SW Pacific.

Projected Climate Change – *Tropical Cyclone (TC) II*

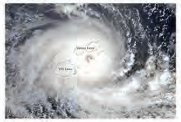
TC projections on the regional scale for S-Pacific *(by RCCAP based on Knutson's)*

- Average TC intensity will increase; *(mid to high confidence)*
- Frequency of category 4-5 TCs will change; *(low confidence)*
- TC rainfall rates will increase; *(mid to high confidence)*
- Sea level rise will increase TC-related storm surge events; *(high confidence)*
- ▫ Frequency of all TCs will decrease; *(high confidence)*



✓ ***All TC tracks during the six seasons from 2012/13 to 2017/18***

TC Winston hit Fiji, Feb. 2016



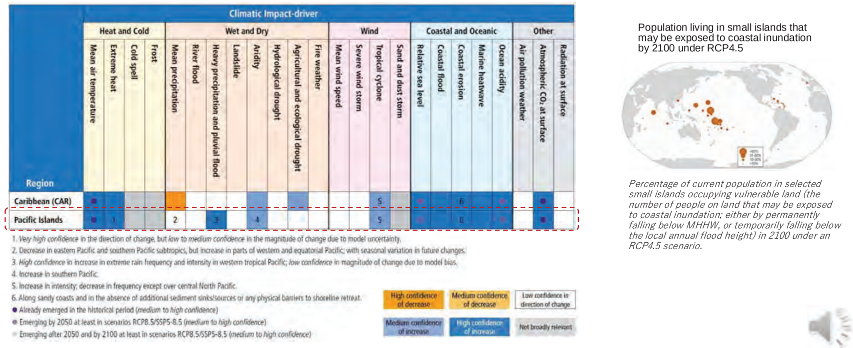
Source: Southern Hemisphere Tropical Cyclone Data Portal

Narrative Part

1. Compared with the assessment of TC projections on a global scale, it is much more difficult to discuss it for a specific basin, including the South Pacific. It is partly because of the limited ability of climate models to simulate various climate features and variabilities that influence tropical cyclones, such as ENSO and the SPCZ activity.
2. This slide summarizes the regional assessment by RCCAP for the South Pacific. Assessment is made based on Knutson's and therefore has a lot of commonalities with the global assessment in the previous slide.
3. Points to be underlined are; 1) a clear view that TC frequency will decrease, and 2) an increase of TC-related storm surge is emphasized. Sea level rise will lead to a higher impact of storm surges. It needs to be considered with the projection of more intense TC rainfalls because it could cause the combined effect of storm surge and river flooding in coastal areas.

Overall assessment of climatic impact-driver (CID) in SIDS

Summary of confidence in direction of projected change in climatic impact-drivers (CIDs) in the small islands.



Source: IPCC[36] (left), [37] (right)

Narrative Part

1. In AR6, WGI has introduced the term "climatic impact-drivers". A climatic impact-driver or CID refers to a long-term condition or an extreme event that directly affects society or ecosystems.
2. The table on this slide shows the regional assessment of CIDs change in the small islands of the Pacific and the Caribbean for mid-century under RCP4.5, the medium scenario. They are most relevant to small islands and will lead to "hazards" in the five primary domains, i.e., (1) "Heat and Cold", (2) "Wet and Dry", (3) "Wind", (4) "Coastal and Oceanic", and (5) "Other".
3. The table assesses each CID by representing the confidence in its projected change and thereby suggests the level of confidence which is determined by the existence of robust evidence and model agreement. So, it will help identify the drivers of greater significance to the region. The level of confidence is indicated by the orange colour for decrease, blue for increase, white for no significant trend, and grey for not applicable.
4. Regarding "Heat and Cold", "Mean air temperature", and "Extreme heat" are identified as "High confidence of increase". It suggests significant recent warming trends will continue in the 21st century with an increase in intensity and frequency of temperature extremes, particularly in the Pacific. So, a considerable increase in heat stress will be inevitable.
5. There are many white squares found in "Wet and Dry". It is mainly because of the complexity of the global water cycle, scarcity of regional datasets, and complex climate variability of the regions. Nonetheless, high confidence is solely given to the increase of "Heavy precipitation and pluvial flood" in the Pacific. It reflects the increase in frequency and intensity of extreme rainfall events in the western tropical Pacific in the 21st century, even for the Low emission scenario. Meanwhile, the increase in "Aridity" is classified with medium confidence for the southern Pacific.
6. For Wind, again, many are in white due to the scarcity of data. Regarding "Tropical cyclones", the Pacific region will generally face fewer but more intense storms, as we saw in the previous slides. However, we should note that there is a large variance between regions.

7. Regarding the "Coastal and Oceanic", it is notable that all the drivers are categorized as "High confidence of increase", including acidification, heatwave, sea level, coastal flood and erosion, and sea level rise. In particular, the effect of sea-level rise is considered to continue to be a major threat to small islands and atolls, as it exacerbates the impacts, coupled with storm surges and swells. Projections indicate that shoreline retreat will occur over most of the Pacific and Caribbean small islands throughout the 21st century.
8. The chart on the right illustrates the impact of coastal inundation on small islands. It represents the potential effect of the percentage of the population that may be exposed to coastal inundation. It considers not only environmental but also political and socioeconomic factors and demonstrates the vulnerability of an island to sea level rise. As shown here, it is noteworthy that the islands in the Pacific are far more vulnerable than those of other regions, including the Caribbean.

Glossary

➢ **Climatic impact-driver (CID)**

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral or a mixture of each across interacting system elements and regions. See also Risk, Hazard and Impacts (consequences, outcomes).

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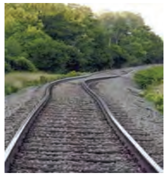
Climate change impacts in the Pacific; *Temperature*

- Increased incidence of heat stress on structures, including public buildings and roads.
- Accelerated corrosion and carbonization of concrete due to more frequent extreme high temperatures.
- Increased risk of fire, particularly wildfires, that could damage structures.



Railway deformation

Concrete cracking
(photo; K.Sakata)

Narrative Part

1. Warming of climate is the core of climate change. Increased temperatures will most seriously affect living things on Earth, including human beings. However, we cannot set aside its impact on structures.
2. Temperature is an essential driver for the deterioration of concrete. For example, chloride-induced corrosion is significantly affected by surface temperatures. Exposure to extremely high temperatures will lead to the deterioration of concrete through carbonization.
3. High temperatures often distort steel structures, including railroads. We should also consider that higher temperatures, such as heat waves, are one of the main causes of fires, including wildfires or forest fires in particular, together with dryness and strong winds.

Glossary

➢ **Corrosion of concrete**

Chloride-induced corrosion is considered one of the most severe causes of concrete deterioration. According to an investigation of the influence of temperature on the deterioration process of chloride-induced corrosion in reinforced concrete, the rates of diffusion of substances and corrosion of steel bars rise with temperature increases (Otsuki et al.)

➢ **Carbonization**

Carbonation of concrete is a process by which carbon dioxide from the air penetrates into the concrete through pores and reacts with calcium hydroxide to form calcium carbonates. A study showed that the effects of temperature on carbonation depth, strain, and compressive strength were significant and led to concrete deterioration. (Liu et al.)

➢ **Risk of wildfires**

There is strengthened evidence that climate change increases the frequency and/or severity of fire weather worldwide due to a combination of high temperatures, low humidity, low rainfall and often high winds – in many regions around the world. (WMO)

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3. Climate Change Impact on Structures

Climate change impacts in the Pacific; *Sea level and Waves*

35

- More severe impact to coastal communities by the combination of the long-term sea-level rise, the natural variability in sea level, and extreme sea-level (ESL) events caused by storms and waves.
- Increased risk of coastal inundation and associated storm surge/extreme sea levels damaging land-based infrastructure such as coastal buildings, roads, ports, power stations, communication facilities and sites of cultural significance. *(PCCSP)*
- Increase of annual flood damages by 2–3 orders of magnitude by 2100 due to more intense and frequent ESL events together with trends in coastal development, in the absence of adaptation. *(SROCC)*

Swell/wind-waves, Kiribati, Mar 2015
(photo: Niuslady)

King tide, RMI, Jan 2015
(photo; RMI Govt.)

Swell, Fiji, May 2011
(photo; SPC)

Narrative Part

1. Pacific Island Countries will face a wide range of challenges associated with sea-level rise and ocean waves, without exception. High mean water levels and the possibility of more frequent extreme water level events will threaten infrastructures, groundwater reservoirs, harbor operations, wastewater systems, sandy beaches, coral reef ecosystems, and other social and economic concerns.
2. Low islands such as atolls are especially vulnerable due to their limited elevation above the current sea level. As for high islands, impacts to their low-lying portions will be much the same as those experienced on low islands. Beaches, dunes, coastal wetlands, and their associated species will face similar pressures to those on low islands. For example, sea-level rise is a particular threat to mangroves, as human infrastructure and steep volcanic topography are likely to restrict landward migration.
3. Under these circumstances of increasing exposure and vulnerability of coastal communities, SROCC estimated that annual coastal flood damages are projected to increase by 2–3 orders of magnitude by 2100 compared to today if more ambitious adaptation efforts are not made.

Climate change impacts in the Pacific; *Precipitation*

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- Increased incidence of river floods (including flush floods), landslides, flood-related loss and damage, and disturbance to local and national infrastructure (transport, energy, water, telecommunication), economies and livelihoods.
- Increased risk of stormwater exceeding design specifications for urban and rural drainage systems.

Vanuatu, Mar 2015
(photo; dailypost.vu)

Solomon Is, Apr 2014
(photo; AFP/Carlos Aruafu)

Fiji, Mar 2012
(photo; imaginesouthpacific.com)

PNG, Jan 2018
(photo; RNZ)

Narrative Part

1. An increase in average rainfall and more frequent extreme rainfall events will increase the risk of flooding along rivers and streams. Even moderate amounts of rainfall can cause severe damage, particularly in places where urban flooding is increasing.
2. In Pacific Island Countries, flooding arising from the overflow of rivers and streams has caused significant damage to urban communities. The high elevation of volcanic islands such as Fiji, Samoa, Solomon Islands and Vanuatu is also associated with heavy rains due to the topographic effect. In addition, most rivers and streams in these islands are relatively short and steep, so water levels are likely to rise quickly. So, frequent occurrence of flash flood will become more serious as it takes place so quickly that people are not watchful.
3. Floods are likely to cause major damage to infrastructure, especially to roads, bridges, and water supply pipes exposed to floodwater and flood-borne debris. Damage to roads and bridges will lead to a massive disruption to transportation and even the closure of airports. Those cases of extensive river flooding in Fiji, Solomon Islands and Vanuatu, which are shown in the photos below, caused wide-ranging damage to the social economies of each country.
4. The increasing risk of flooding may require even careful review of the design specification of the drainage systems of the Pacific island countries.

Glossary

➢ **Flash flood**

Flash floods are sudden and short, with a time frame of less than six hours between the observable causative event and the flood itself, which tends to have a high peak discharge. Flash floods have enough power to change the course of rivers, bury houses in mud, and sweep away or destroy whatever stands in their path. (WMO)

Climate change impacts in the Pacific; *Tropical Cyclone*

- Increased loss and damage to coastal, inland and urban infrastructure, including public and private buildings, bridges, roads, power generation and transmission infrastructure, communication facilities, airports and seaports, due to more intense wind and rain associated with TCs.
- Strengthened multi-hazard impact on coastal infrastructures, beaches, mangroves, sea grasses and coral reefs due to more severe coastal inundation with the combined effect of heavy rain, storm surge and wind waves.

TC Harold, Vanuatu, Apr 2020 *(photo; Ryry Titus)*

TC Gita, Tonga, Feb 2018 *(photo; UN Women)*

TC Winston, Fiji, Feb 2016 *(photo; ADB)*

TC Pam, Vanuatu, Mar 2015 *(photo; Vanuatu NDMO)*

TY Hayan, Palau, Nov 2013 *(photo; OCHA)*

Narrative Part

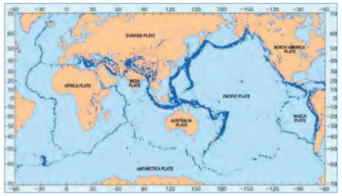
1. Tropical cyclones are the most significant extreme events in much of the Pacific. As most countries are small islands scattered over the tropical ocean, tropical cyclones can affect one country after another without being weakened by continent areas and high mountains. Tropical cyclones include different hazards that can cause significant impacts on our socioeconomies, such as storm surges, flooding, extreme winds, tornadoes and lighting. They can cause extensive damage to communities, infrastructure, and agriculture and cause injury and loss of life.
2. During the past decade, Pacific islands were affected by intense tropical cyclones of record-breaking intensities, including Typhoon Hayan, Soudelor and Tropical Cyclone Pam, Winston, and Yasa. Some of the cases of tropical cyclone disasters shown in those photos are arranged at the bottom. It is not clear at this time, but it could be a sign of the increase in TC intensities.
3. Among the various hazards of tropical cyclones, storm surges are devastating, particularly for coastal areas. While large islands such as Fiji are likely to be damaged by an intensive wind-driven surge over the large shallow waters around them, small islands are affected mainly by wind waves. Furthermore, from the projected increase in rain rate, we need to consider that flooding will play a more significant role in TC-induced disasters. In other words, TC will enhance its multi-hazard nature, including the combined effect of storm surges and river flooding in coastal areas.
4. Recently, increasing attention has been given to large swells, which originate from distant storms such as tropical cyclones and extratropical cyclones. Swells propagate hundreds or even thousands of kilometers, and produce hazardous surf over the island coasts. You may recall that Tuvalu and Kiribati were seriously affected by the swells from distant TC Pam in 2015. Large swells also impact Palau, Micronesia, and the Marshall Islands from extra-tropical cyclones in the North. In some cases, eastern Micronesia and the Marshal Islands can be impacted by large southerly swells caused by extratropical cyclones off New Zealand. Such an impact of large swells is often enormous when the events are concurrent with King Tides during a certain time of the year

4. Non-climate factors

Geological factors: *Earthquake*

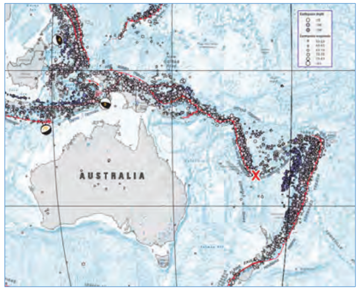
- Most earthquakes occur on the boundary of the major tectonic plates, which collide with huge force (plate tectonics). In the South Pacific, earthquakes are caused by the cross-interactions between the Pacific Plate and the Australian Plate.

Seismicity of the Earth (1975-1994) and tectonic plates.



source Chronological Scientific Table, Japan

Seismicity of SW Pacific for 1900-2018. Red "X" is the epicenter of the M7.7 earthquake on 11 Feb 2021. *(USGS)*



Narrative Part

1. A typical example of a natural factor is those induced geologically, such as earthquakes. The occurrence of earthquakes is related closely to plate tectonics, a geological theory describing the large-scale motion of Earth's outer shell, which is divided into large slabs of solid rock called "tectonic plates".
2. An earthquake is caused by a sudden slip on a fault between the tectonic plates. The left panel shows the different tectonic plates covering the Earth, and that seismicity is active along the borders between those plates.
3. The right panel depicts the seismic belt in the Pacific, which is part of the circum-Pacific seismic belt called the Pacific Ring of Fire. Most of the earthquakes in the South Pacific occur along this seismic belt due mainly to the interactions of the Pacific Plate and the Australia Plate. The 7.7-magnitude quake that struck Loyalty Islands on 11 February 2021 was located on this seismic belt in the vicinity of New Caledonia. Its epicenter is marked by Red X in the chart.

Glossary

➢ **Circum-Pacific seismic belt**

The world's most significant earthquake belt is found along the rim of the Pacific Ocean, where about 81 percent of our planet's largest earthquakes occur. The belt exists along the boundaries of tectonic plates, where plates of mostly oceanic crust are sinking (or subducting) beneath another plate. Slips between plates and ruptures within plates cause earthquakes in these subduction zones.

➢ **Tectonic plates**

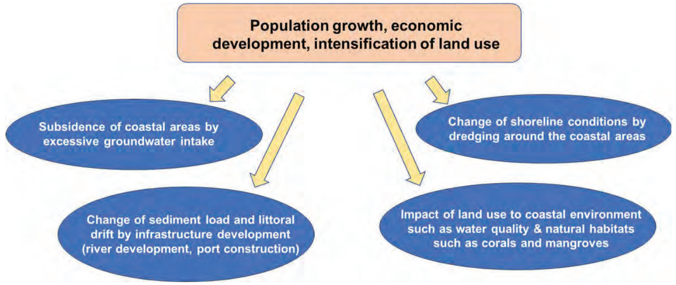
The tectonic plates are the large, thin, relatively rigid plates that move relative to one another on the Earth's outer surface.

➢ **Fault**

A fault is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.

Human factors

- While coastal structures are subject to climate hazards such as sea level rise and cyclones, they are also affected by socioeconomic activities through population growth, and intense land uses, etc. They are identified as human-induced (i.e., non-climatic) factors (or anthropogenic drivers).



Source: JICA Climate-FIT (Adaptation) 2011 edition

Narrative Part

1. This section is devoted to non-climate factors that affect structures but are out of relation to climate change. A clear recognition of such non-climate factors, as opposed to climate-related ones, is necessary to make adaptation programs more concentrated.
2. In general, there are two types of non-climate factors. One is those induced by human activities, and the others are natural hazards. This slide deals with human-induced hazards related to coastal structures.
3. Many of the human-induced factors are found in coastal areas as socio-economic activities in coastal areas are growing in the Pacific Island Countries. They increase coastal populations, boost the countries' economies, and facilitate land use.
4. Population growth, economic development, and intensification of land use will facilitate the development and settlement in coastal areas, and such increases in human activities are likely to pose impacts and issues on coastal areas. For example:
   - Subsidence in coastal areas occurs due to excessive groundwater intake.
   - Shoreline conditions are changed by dredging around the coastal areas.
   - Characteristics of sediment load and littoral drift are changed by infrastructure development, including port construction.
   - Coastal environment, such as water quality and natural habitats like corals and mangroves, are affected by Land use change.

wind waves that affect just the surface of the ocean, tsunamis propagate (move) through the entire depth of the ocean, from the surface to the floor. They move at great speeds and have tremendous energy. Large tsunamis can move across entire oceans. The speed of a tsunami depends on the depth of the water it is traveling through. The deeper the water, the faster the tsunami. In the deep ocean, tsunamis can move as fast as a jet plane, over 800 km/h, and can cross entire oceans in less than a day. Pacific Island Countries (PICs) should therefor be attentive also to distant tsunamis from other tsunamigenic regions, the west coast of South America (WSA) for example. (NOAA)

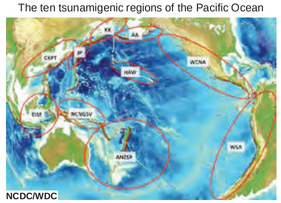
➢ **Subduction**

Subduction is the process of the oceanic plates colliding with and descending beneath the continental plates. (USGS)

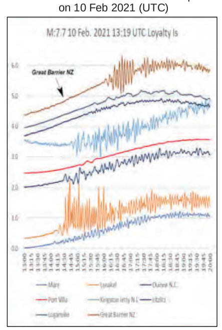
Geological factors; *Tsunami*

■ Tsunamis of the Pacific Ocean are also closely related to plate tectonics or the "Pacific Ring of Fire" (PRF). The PRF comprises regions of active volcanoes and large subduction earthquakes that are major tsunami sources.

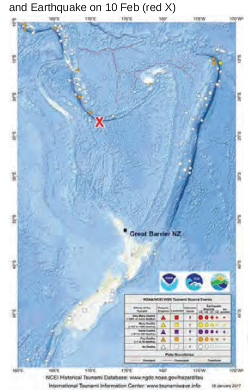
The ten tsunamigenic regions of the Pacific Ocean



Tsunamis records of the M7.7 earthquake on 10 Feb 2021 (UTC)



Historical Tsunamis (805-2017) in the SW Pacific and Earthquake on 10 Feb (red X)



Narrative Part

1. A tsunami is mostly caused by large earthquakes that occur underwater at tectonic plate boundaries. Therefore, it is very common for tsunamis to occur in the Pacific Ring of Fire, where about 80 percent of tsunamis occur due to tectonic activities. The left panel depicts the 10 tsunamigenic regions defined by the US National Climatic Data Center (NCDC), including the two regions covering the West to South Pacific. Surrounded by those tsunamigenic regions, Pacific Island Countries are highly vulnerable to the effects of tsunamis, which occur locally, regionally, and distantly.
2. Unlike ocean waves which are generated by winds and move at a speed of up to 50 to 60 km/h, Tsunamis can move as fast as a jet plane, 800 km/h or even faster over deep waters, and can cross entire oceans in less than a day.
3. The middle panel shows the records of tide stations which detected tsunamis generated by the Loyalty Islands earthquake. The chart suggests that the tsunamis reached all the tide stations within 3 hours. For example, Great Barrier NZ, located about 1500 km from the epicenter, detected the first tsunami at around 16:00 of the day, about 2 hours and 40 minutes from the earthquake. It means that the tsunami reached the station at an average speed of 560 km/h.

Glossary

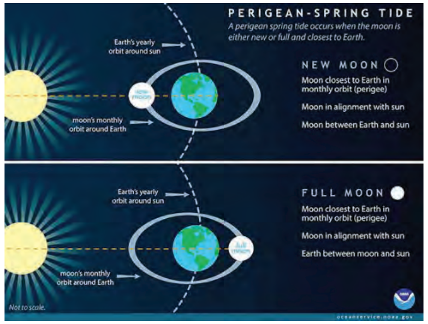
➢ **Tsunamis**

By far, the most destructive tsunamis are generated from large, shallow earthquakes with an epicenter or fault line near or on the ocean floor. These usually occur in regions of the earth characterized by tectonic subduction along tectonic plate boundaries. The high seismicity of such regions is caused by the collision of tectonic plates. When these plates move past each other, they cause large earthquakes, which tilt, offset, or displace large areas of the ocean floor from a few kilometers to as much as a 1,000 km or more. The sudden vertical displacements over such large areas, disturb the ocean's surface, displace water, and generate destructive tsunami waves. (UNESCO/IOC)

Once generated, tsunamis radiate outward in all directions from their source. Unlike

Geological factors; *King Tide*

■ A King Tide is a non-scientific term used to describe the astronomical highest high-tide and lowest low-tide events of the year. King Tides are regular and predictable events reoccurring multiple times a year. They are unrelated to climate change.



Schematic illustration of the relationship between the occurrence of King Tides and the relative positions of the moon and the sun.

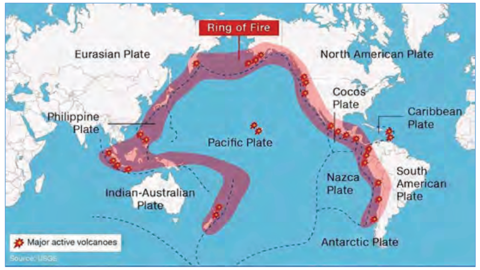
- ✓ *The moon is at its closest point to the Earth in its monthly orbit, and the gravitational pull is stronger.*
- ✓ *When the sun, the moon and the Earth are in alignment, it means that the sun and moon's individual gravitational pulls work together, producing the highest high tides of the year, or the King Tides.* (NOAA[4])

Narrative Part

1. King Tide is another type of natural factor and is often mixed up with climate change.
2. It is the highest high tides of the year and a unique coastal hazard. King Tides are astronomical; therefore, the timing of these extreme water level events can be anticipated using tidal predictions. However, they cause coastal flooding and inundation in low-lying areas and have devastating consequences for coastal inhabitants.
3. King Tides occur during a perigean spring tide at the time of the new and full Moon. In other words, a new or full moon must co-occur when the Moon is closest to Earth in its elliptical orbit. So, a King Tide can be reworded as an extreme spring tide, which is more academic wording.
4. The impacts of King Tide are particularly serious when combined with severe weather or high wave events. It is a common misunderstanding that King Tides result from human-induced climate change. They are not the byproducts of climate change but are windows for us to see what the future of sea level rise from global climate change might look like along our coastlines.

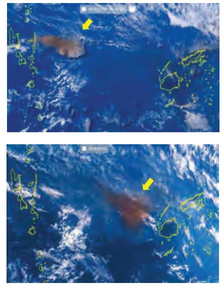
Geological factors; *Volcanic eruption*

■ Most of the active volcanoes on Earth are also located underwater, along the Pacific Ring of Fire (PRF), made up of more than 450 volcanoes. In the South Pacific, the 'island-arc' nations of PNG, Solomon Islands, Vanuatu, Tonga, New Zealand, and, to a lesser extent, Fiji are the most volcanically vulnerable countries.



Source: USGS

Volcanic ash from Manaro Volcano of Vanuatu affecting Fiji (27 Jul 2018)



Source: JMA[3]

Narrative Part

1. A volcanic eruption is a geologic hazard on which molten rock, gases, ash, and other materials are released. As with earthquakes, volcanic eruptions break out due to interactions of adjacent tectonic plates. Many volcanoes in the Ring of Fire were created through subduction. Furthermore, most of the planet's subduction zones happen to be located in the Pacific Ring of Fire. Two panels on the right show the volcanic ash cloud approaching Fiji, which was released from the Manaro Volcano of Vanuatu at its eruption in 2018. The eruption forced many islanders to be displaced with heavy ashfalls and landslides. Volcanic ash also caused serious trouble to aviation. A large-scale eruption could disrupt international air traffic across a vast range over an extended period.

Glossary

➢ **Subduction**

Subduction is the process of the oceanic plates colliding with and descending beneath the continental plates. (USGS)

CBCRP-PCCC Training Course
“Climate Change Adaptation and Disaster Risk Reduction through structural approaches”

Government of Samoa, SPREP and JICA

1. Understanding of vulnerability of structures
1.2 Basic knowledge of vulnerability assessment of structures - Buidlings -

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Pacific Region Infrastructure Facility (PRIF)
Email: jromero@theprif.org

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   - [3]: WGI AR6; SPM-9 (A.2.1)
   - [4]: WGI AR6; SPM-9 (A.2.2)
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   - [15]: WGI AR6; SPM-17 B.1
   - [16]: WGI AR6; SPM-36 D.1.1
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   - [19]: WGI AR6; Figure SPM.10
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   - [30]: WGI AR6; Figure SPM.8 d)-middle, e)-right
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Review of impacts of climate change in buildings

2

Impacts of a **changing** climate in buildings

TEMPERATURE	RAINFALL INTENSITY AND FREQUENCY (Drought)	SEA SURFACE TEMPERATURE SEA-LEVEL RISE OCEAN ACIDIFICATION	TROPICAL CYCLONE INTENSITY AND FREQUENCY
• Increased thermal discomfort and risk of heat stress • Increased energy demand for cooling • "Heat island" effect in urban areas • Risk of cracking of some building elements (roofing, cladding, windows)	• Increased flooding • Buildings maybe contaminated with increased flooding • Foundations could be compromised • Degradation and failure of pipes	• Intensify coastal erosion • Increased risk of flooding and water damage • Cause contamination from sewage, soil and mud • Foundations could be compromised • Increase salt spray which compromises durability of building materials	• Increased stress on building loadings and materials leading to structural failure and loss of roofing • Cause damage to other properties due to flying debris • Increased rain and moisture penetration of buildings causing internal damage

These impacts are based on projected changes in the following key climate hazard indicators:

- Annual mean air temperature (and by association sea surface temperature)
- Extreme daily maximum and minimum temperatures
- Annual mean rainfall
- Wet and dry season mean rainfall
- Frequency of drought
- Frequency of heavy rainfall
- Frequency of tropical cyclones
- Annual mean sea level
- Aragonite saturation state.

3

CBCRP-PCCC Training Course
“Climate Change Adaptation and Disaster Risk Reduction through structural approaches”

Government of Samoa, SPREP and JICA

1. Understanding of vulnerability of structures
1.2 Basic knowledge of vulnerability assessment of structures - Coastal Protection Structure -

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CONTENTS

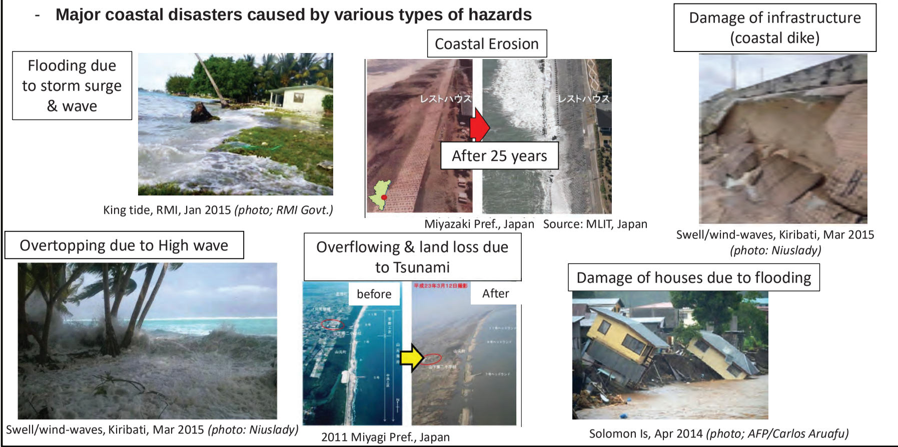
1. Outline of coastal disaster
2. Hazard to coastal protection structure & projected change
3. Focal points to assess vulnerability of coastal protection structure

2

1. Outline of coastal disaster

1.1. Coastal disaster

- **Major coastal disasters caused by various types of hazards**

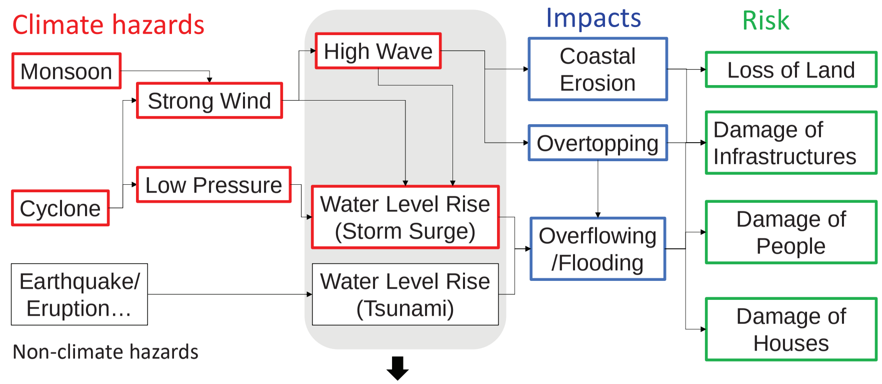


Introduction – coastal disaster
Major coastal disasters caused by various types of hazards such as wave, storm surge and tsunami and so on.

- Flooding due to storm surge and high waves
- Overtopping due to high wave
- Coastal erosion (land loss)
- Overflowing & land loss due to Tsunami
- Damage of infrastructure
- Damage of houses due to flooding

1.2. Relationship of coastal disaster

- **This flowchart indicates the relationship between coastal disasters and those factors**



Design force for coastal protection structure

The relationship of coastal disaster
- This flowchart indicates the relationship between coastal disasters and those factors
- Monsoon and cyclone cause strong wind and low pressure
- Waves are generated by strong wind caused by monsoon or cyclone and so on.
- Storm surge (extreme water level rise) comes from low pressure, strong wind and wave.
- When high wave arrives to sandy coasts, coastal erosion may occur.
- When high wave with storm surge arrives at coasts and sea level exceeds the land elevation, overtopping and overflowing may occur, resulting in flooding.
- Coastal erosion directly leads to loss of land, probably cause damage of infrastructures.
- Overtopping/ overflowing/ flooding lead to damage of coastal dike, houses and people.

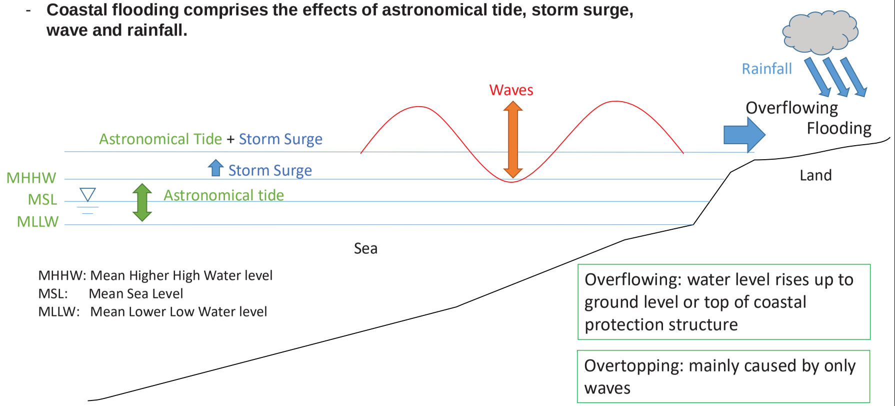
On the other hand,
- As all you may know, tsunami is quite different from storm surge, although the 2 phenomena are similar : that is extreme water level rise.
- The sources of tsunami are earthquake, eruption and landslide and so on . That is geological hazard, not climate hazard although they cause the similar damage at coasts.

Classification of 3 categories
1. hazards: Climate hazards: cyclone, strong wind, high wave, storm surge etc. colored in red instead of Non climate hazards: tsunami
2. impacts to coastal area: coastal erosion, overtopping/ overflowing and flooding
3. Disaster Risk : loss of land, damage of infrastructures, people and houses.

We need coastal protection to prevent such coastal disaster. The main design forces are high wave and water level rise (storm surge) as well as tsunami (non-climate hazard)

1.3. Overflowing/ Flooding/ Overtopping

- **Coastal flooding comprises the effects of astronomical tide, storm surge, wave and rainfall.**

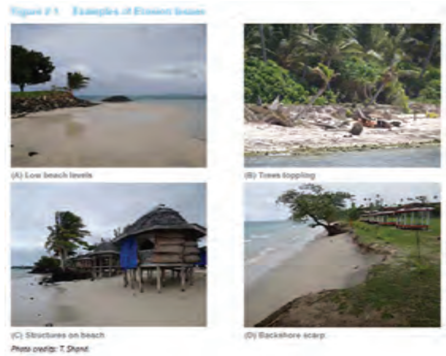


Coastal flooding comprises the effects of astronomical tide, storm surge, wave and rainfall.

- As you know, sea level always change from low water level to high water level: astronomical tide has some ranges of water levels.
- Cyclone causes storm surge and high waves
- If crest of wave exceeds the ground level of lands or the elevation of coastal structure, overtopping occurs.
- If sea level including astronomical tide and storm surge exceeds the elevation of land or coastal structure, overflowing occurs, resulting in coastal flooding.
- Of course, rainfall may cause coastal flooding when heavy rain occurs with high tide.
- That is the mechanism of coastal flooding.

1.4. Coastal erosion

- Coastal erosion: the landward movement of the coastal edge.
- On unconsolidated coastlines, the shoreline position
  - ➢ fluctuates in the short term as a result of storms and calm periods
  - ➢ over longer periods, recede or accrete as a function of sediment supply and demand.
- Estuarine shorelines are highly dependent on water level, with the shoreline position typically a function of water level with exposure to wave energy a secondary control
- In order to solve an erosion issue, local coastal processes and the drivers of erosion must be fully comprehended. Otherwise, the solution may not prove to be successful or may have unintended consequences.

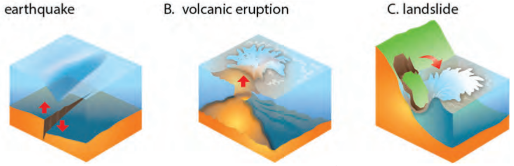


Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Coastal erosion is the landward movement of the coastal edge.
- Erosion occurs on all coastal types, including unconsolidated beaches, soft estuarine shorelines, and a harder cliffed coastline.
- The mechanism of coastal erosion and the rate of erosion will vary.
- On unconsolidated coastlines, the shoreline position fluctuates in the short term as a result of storms and calm periods and,
  over longer periods, can recede or accrete as a function of sediment supply and demand.
- Estuarine shorelines are highly dependent on water level, with the shoreline position typically a function of water level with exposure to wave energy a secondary control.
- In order to solve an erosion issue, local coastal processes and the drivers of erosion must be fully comprehended. Otherwise, the solution may not prove to be successful or may have unintended consequences.

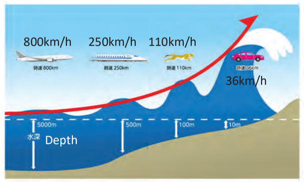
1.5. Tsunami (non-climate hazard)

- A tsunami is a series of waves caused by earthquakes, undersea volcanic eruptions or landslides



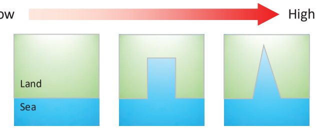
Source: University of Hawaii website, https://manoa.hawaii.edu/exploringourfluidearth/physical/coastal-interactions/tsunamis

As a tsunami hits shallower water, the wave height increases with the velocity slowing.



(Source: https://www.data.jma.go.jp/svd/eqev/data/tsunami/generation.html)

The tsunami height is increased with the shape of coast.

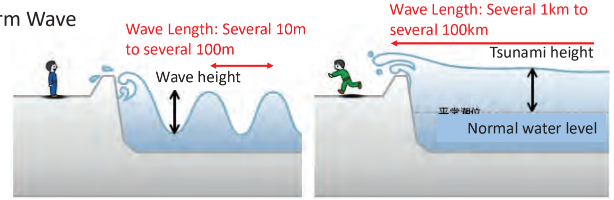


Source: JICA survey team

- According to NOAA, a tsunami is defined a series of waves caused by earthquakes, undersea volcanic eruptions or landslides: geological hazard.
- The sources of tsunami is illustrated in this figure. The most typical source is earthquake and the 2nd is volcanic eruption and the last is landslide.
- the 2018 Sulawesi tsunami was to be mainly caused by landslide.
- As a tsunami hits shallower water, the wave height increases with the velocity slowing.
- The tsunami height is increased with the shape of coast.

1.5.1. Tsunami vs Storm wave

- **Storm wave is different from tsunami in terms of the cause, wave length and wave period.**



Source: Cabinet Office, Japan

	Causes	Wave Length	Wave Period
Storm Wave	Wind	Several 10m to several 100m	Several seconds to several 10s
Tsunami	Earthquakes, undersea volcanic eruptions or landslides	Several 1km to several 100km	Several min to several 10 min

- Storm wave is different from tsunami in terms of the cause, wave length and wave period.
- The cause of storm wave is wind, while tsunami is from geological movement.
- The wave length of storm wave due to tropical cyclone and so on, is several 10m to several 100m,
- While tsunami wave length is about several km to 100km.
- Wave periods are also quite different each other. The wave period of storm wave is several seconds to several 10s (less than 30s), while the wave period of tsunami is several minutes.
- Wave force acting coastal protection structure is also different.
- So storm wave is quite different from tsunami.

9

2. Hazards to coastal protection structure & its projected change

10

2.1. Types of hazards of coastal protection structure

- **The hazard in coastal area causes several types of forces acting on coastal protection structure.**
- **Coastal protection structure should be designed so as to prevent coastal disasters by such forces.**
- **Major hazards for design of coastal protection structure are divided into 2 categories: climate hazards and non-climate hazards (other factors).**

Categories	Force for design of coastal protection structure		Climate Change Effect
Climate hazard	Water Level (sea level)	**Mean sea level**	**Sea Level Rise**
		Astronomical tide	----
		Storm surge	**Intensity of tropical cyclone**
	Wave	**Wave height/period**	**Intensity of tropical cyclone**
		Wave force	**Intensity of tropical cyclone**
		Wave run-up/overtopping	**Intensity of tropical cyclone**
Non-climate hazard (Other factors)	Tsunami	Tsunami height/ Tsunami wave force	----
	Current	Induced by wave, tide, wind, river discharge	----
	Ground/ soil	Soil pressure	----
	Earthquake	Seismic force	----
	Collison force	Collison from debris, ships etc.	----

* Wind is a minor factor for design of coastal protection structure, although wind is one of climate hazards.

- The hazard in coastal area causes several types of forces acting on coastal protection structure.
- Coastal protection structure should be designed so as to prevent coastal disasters by such forces.
- It is important to understand what is design forces for coastal protection structure because design forces are quite variable based on local condition there.
- The design force will be affected by climate change reflecting the local conditions.
- Major hazards for design of coastal protection structure are divided into 2 categories: climate hazards and non-climate hazards (other factors).
- The 1st primary design force is water level including mean sea level, tide and storm surge. The climate change effect of mean sea level is sea level rise.
  Intensity of tropical cyclone affects design condition of storm surge.
- The other primary design force is wave: design wave height and wave period is necessary for design of coastal structure to calculate wave force acting on the structure as well as estimation of wave run-up & overtopping.
- Design force should cover several forces related to non-climate hazards such as tsunami, earthquake, current, ground and collision force.
- The main factors of design force are explained in detail later.

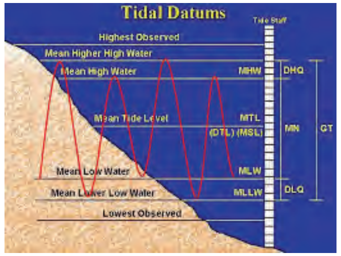
2.2. Design force: Water Level (Sea level)/ Tide

◆ **Astronomical Tide**

- **Astronomical tide should be evaluated by a series of observed data (i.e. tide station)**
- **Hourly data for 1 year is necessary for analysis of astronomical tide although 19 years data is necessary for exact estimation of astronomical tide.**

◆ **Design Water Level (High Tide)**

- **Design water level should be determined considering local conditions**
- **30 years or more observed data is necessary although more data (i.e. 50 – 100 years) leads to more accurate estimation.**
- **The candidates are following**
- **Historical highest tide**
- **MHHW + historical highest storm surge**
- **MHHW + estimated highest storm surge***



Samples of observed tide data
https://tidesandcurrents.noaa.gov/datum_options.html

*Particular return period of storm surge can be applied

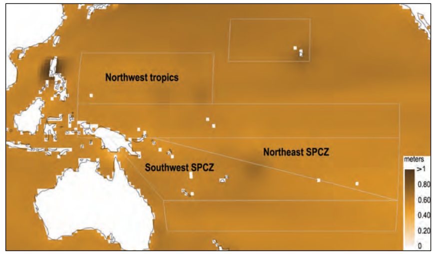
- Astronomical tide should be evaluated by a series of observed data (i.e. tide station)
- Hourly data for 1 year is necessary for analysis of astronomical tide although 19 years data is necessary for exact estimation of astronomical tide.
- We can estimate astronomical tide by using harmonic analysis.
- After that, we have to determine the design water level for coastal protection structure considering local conditions.
- 30 years or more observed data is necessary although more data (i.e. 50 – 100 years) leads to more accurate estimation.
- The candidates of design water level are following
- Historical highest tide
- MHHW + historical highest storm surge
- MHHW + estimated highest storm surge*
- *Particular return period of storm surge can be applied such as 50 years or 100 years.

2.2.1. Climate change effect: Sea level rise

- **Modelling, presented within the AR5 of IPCC (2014), shows projects global SLR values by 2100 to range from 0.27 m to 1 m, depending on the emission scenario adopted.**

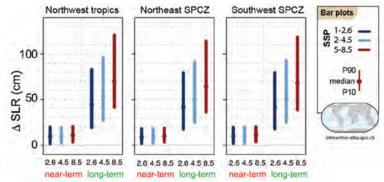
- **Relative sea-level rise is very likely to continue in the oceans in the small island states, where regional-mean RSLR projections vary widely, from 0.4m–0.6m (SSP1-2.6) to 0.7m–1.63m (SSP5-8.5) for 2081–2100 relative to 1995–2014. (AR6)**

SLR projections for 2080–2100 relative to 1995–2014 under SSP3-7.0



(from IPCC Interactive Atlas)

Mean changes in annual SLR in the near-term (2021–2040) and long-term (2081–2100) for 3 scenarios relative to 1995-2014. Bar plots indicate median (dots) and 10th to 90th percentile range (bars) across each model ensemble.



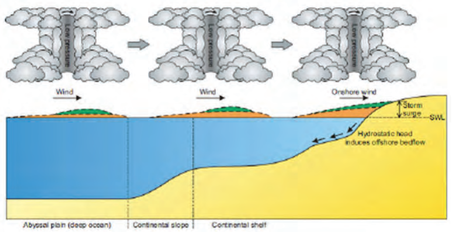
- As mentioned in the section 1.1, sea level rise has been observed and future sea level rise seems to occur.
- Modelling, presented within the AR5 of IPCC (2014), shows projects global SLR values by 2100 to range from 0.27 m to 1 m, depending on the emission scenario adopted.
- Relative sea-level rise is very likely to continue in the oceans in the small island states, where regional-mean RSLR projections vary widely, from 0.4m–0.6m (SSP1-2.6) to 0.7m–1.63m (SSP5-8.5) for 2081–2100 relative to 1995–2014. (AR6)

- Based on recent rates of SLR, those within the Pacific could be higher than this global average projection.
- Within the Pacific, projections of SLR also vary, with Figure 5-7 showing sea level projections for the ''A1B'' scenario (based on IPCC AR4 modelling) for 2081-2100 to vary by up to 10 cm.

2.2.2. Design force: Storm Surge

- **Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore**
- **These effects elevate the water level above the predicted astronomical tide.**
- **Cyclones are particularly effective at generating storm surge due to their very low central pressure and high winds**
- **However, their small size means that the cyclone must pass very close to the observation point for the surge to be significant. Additionally, storm surge is amplified in shallow coastal waters and within embayments, implying that islands surrounded by relatively deep water are less vulnerable to large surge heights.**

Figure 8: Processes Contributing to Storm Surge



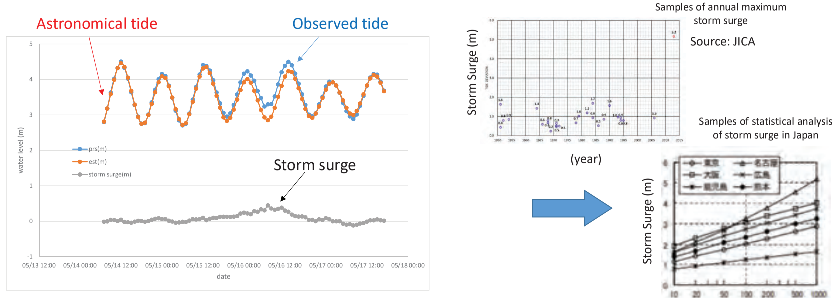
Source: Adapted from Shand et al. (2010).

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore, which elevates the water level above the predicted tide.
- The combined elevation of the predicted tide, climatic cycles and storm surge is known as storm tide. Cyclones are particularly effective at generating storm surge due to their very low central pressure and high winds;
- However, their small size means that the cyclone must pass very close to the observation point for the surge to be significant. Additionally, storm surge is amplified in shallow coastal waters and within embayments, implying that islands surrounded by relatively deep water are less vulnerable to large surge heights.

2.2.2. Design force: Storm Surge (Cont.)

- **Storm surge data should be estimated by subtracting astronomical tide from observed tide data.**
- **Observation data should be used for estimation of probable storm surge if enough observation data are available (ex. more than 30-50 years).**
- **Annual maximum or extreme storm surge is extracted from all observed tide data.**
- **Statistical analysis can estimate the values of several return periods.**

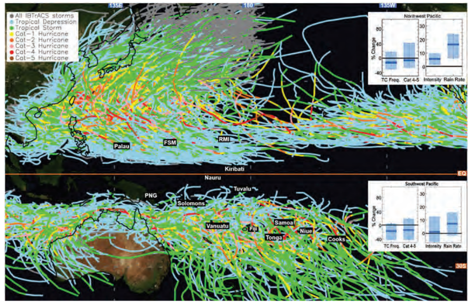


Samples of observed tide, astronomical tide and storm surge (deviation) in Myanmar.
Source: JICA

- Storm surge data should be estimated by subtracting astronomical tide from observed tide data.
- Orange: astronomical tide, blue: observation tide, gray: the difference between the 2 data is storm surge deviation.
- As for design of coastal structure, target return period of storm surge in design water level is from 30 to 100 years according to target safety level.
- Observation data should be used for estimation of probable storm surge if enough observation data are available (ex. more than 30-50 years).
- Annual maximum or extreme storm surge is extracted from all observed tide data.
- Statistical analysis can estimate the values of several return periods (such as 50 years and 100 years).

2.2.3. Climate change effect: Intensification of tropical cyclone

- **While the TC frequency will decrease, the average intensity of TCs, the proportion of Category 4 and 5 TCs and the associated average precipitation rates are projected to increase for a 2ºC global temperature rise above any baseline period (medium confidence). Such trends are clearer in N-Pacific. (Knutson et al.)**



The map is from IBTrACS's tracks for 1947-2008 in NW- and SW Pacific basins. It covers all the storms of different intensities ranging from tropical depressions to Category 1 to 5 tropical cyclones.

Inserted diagrams are from TC projections for a 2ºC warming (Knutson et al. 2020) of "TC frequency", "Category 4-5 TC frequency", "TC intensity", and "TC near-storm rain rate".

Source: Knutson et al. 2020

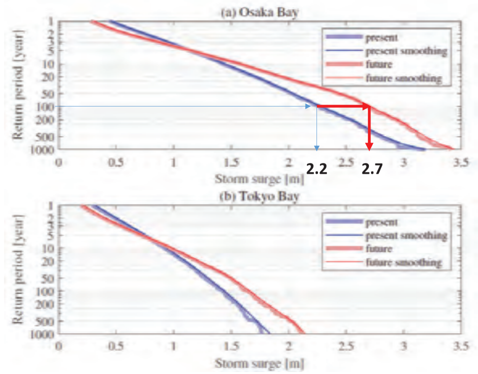
Tropical cyclone

✓ The average intensity of tropical cyclones, the proportion of Category 4 and 5 tropical cyclones and the associated average precipitation rates are projected to increase for a 2ºC global temperature rise above any baseline period (medium confidence). (SROCC)

✓ Rising mean sea levels will contribute to higher extreme sea levels associated with tropical cyclones (very high confidence). Coastal hazards will be exacerbated by an increase in the average intensity, magnitude of storm surge and precipitation rates of tropical cyclones. There are greater increases projected under RCP8.5 than under RCP2.6 from around mid-century to 2100 (medium confidence). There is low confidence in changes in the future frequency of tropical cyclones at the global scale. (SROCC)

2.2.4. Climate change effect: Future change of storm surge

- Future change of tropical cyclone impacts on storm surge
  - ➢ Frequency -> less frequent
  - ➢ Intensity -> increased
- The return periods in future climate condition would be shorter.
- The particular return period of values (e.g. 100 year storm surge) would be larger from 2.2m to 2.7m.



Source: Mori et al. (2018): Future changes in extreme storm surges based on mega ensemble projection using 60 km resolution atmospheric global circulation model, Coastal Engineering

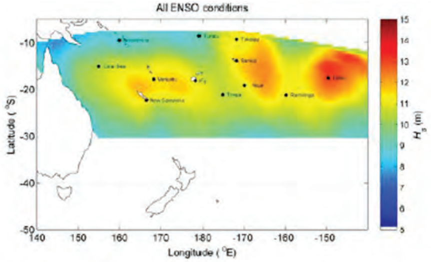
- As mentioned above, a particular return period of storm surge is necessary for design of coastal protection structure.
- Future change of tropical cyclone is estimated less frequent and increase of intensity.
- Here is an example of changes of return period of storm surge in Japan considering climate change effect.
- This figure shows the extreme value distribution of regional projections of storm surge heights in Osaka Bay and Tokyo Bay in Japan, respectively.
- The top two historical, highest storm surges in Osaka Bay were occurred with TC Nancy in 1961 and TC Jebi in 2018, which storm surge height was 2.5 m and 2.8 m.
- Although it is difficult to estimate future return periods of extreme storm surge, the future climate condition shows shorter intervals between extreme surge events.
- The particular return period of values (e.g. 100 year storm surge) would be larger from 2.2m to 2.7m in Osaka Bay.

2.3. Design force: Wave

- As winds blow over a water surface, energy is transferred into the water column to form waves. There are typically four sources of waves in the Pacific:

i. Waves generated locally within lagoons.
ii. Wind sea waves associated with local trade winds.
iii. Swell waves generated by large extratropical storms in the 40°-50° belt of the southern and northern Pacific Ocean.
iv. Tropical cyclone and storm-induced waves are generated locally.

Significant wave height associated with 50-year annual recurrence interval tropical cyclones



Notes: °S = degrees south; H_s = significant wave height; m = metre; °E = degree east.
Source: Stephens, S.A. and D.L. Ramsay. 2014. Extreme Cyclone Wave Climate in the Southwest Pacific Ocean: Influence of the El Niño Southern Oscillation and Projected Climate Change. Global and Planetary Change, 123, pp. 13-26.

Source: Guidance for coastal protection works in Pacific island counties, PRIF

As winds blow over a water surface, energy is transferred into the water column to form waves. There are typically four sources of waves in the Pacific:

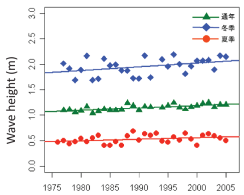
i. Waves generated locally within lagoons. These waves will typically be "'fetch-limited" or limited in height by the distance that wind can blow over. In larger lagoons (e.g., Tarawa, Kiribati), these waves may be over 1 m high with periods of 3 to 5 s, but are typically less than 0.5 m with periods of 1-3 s.
ii. Wind sea waves associated with local trade winds. Waves are typically less than 2 m with less than 10 s periods. These waves affect all Pacific islands between +30° and -30°.
iii. Swell waves generated by large extratropical storms in the 40° -50° belt of the southern and northern Pacific Ocean. These waves typically affect all Pacific island coasts facing them, with waves up to 5 m or more and long periods between 13 and 20 s (Kruger et al., 2011). Swell may propagate through the entire Pacific, however, with swells from the southern area reaching Hawaii in the north and swells generated in the north of the Pacific reaching Tonga in the south.
iv. Tropical cyclone and storm-induced waves are generated locally. These waves are generally responsible for the largest waves and can be combined with significant storm surge.

An example of the significant wave height (m) associated with 50-year ARI tropical cyclones in the southwest Pacific is shown in this figure.

The actual wave height reaching a particular coastline is highly affected by local bathymetry and presence of offshore fringing reefs, which cause breaking and refraction of incoming wave energy. Local nearshore wave modelling is typically required to resolve nearshore wave processes.

2.3. Design force: Wave (Cont.)

- Long terms of observed wave data is necessary for designing the structure (i.e. design wave).
- Japan has observed waves over 30 years in 78 wave stations.
- Target return period of design wave for construction of coastal structures is from about 30 to 100 years according to target safety level as well as storm surge.
- Same as storm surge, statistical analysis can estimate the values of several return periods.

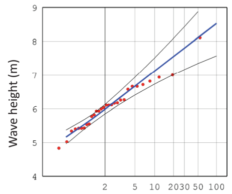


Samples of historical wave data

Source: JMA

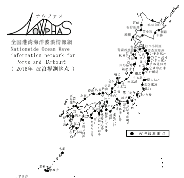
Using historical data

Statistical analysis: fitting several extreme value distributions



Samples of statistical analysis of wave

Source: JMA



78 wave stations around Japan's coast

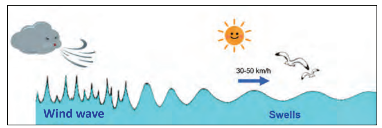
Source: MLIT

- Design wave is necessary for design of coastal protection structure.
- Long terms of observed wave data is necessary for designing the structure (i.e. design wave).
- Japan has observed waves over 30 years in 78 wave stations.
- Target return period of design wave for construction of coastal structures is from about 30 to 100 years according to target safety level as well as storm surge.
- Same as storm surge, statistical analysis can estimate the values of several return periods by using a series of annual maximum wave heights.

2.3. Design force: Wave (Cont.)

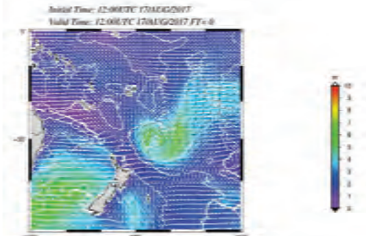
- Wind waves are developing or matured waves under the direct action of winds. They are remarkably irregular and have skewed and short-crested profiles.
- Swell refers to waves that propagate free from wind action. They travel long distance (hundreds or thousands kilometers), gradually decaying by dispersion, viscosity, etc. They look like monotone sinusoidal waves and have smoothed surface and long-crested profiles.

Schematic image of generation of wind seas and swells



Source: Japan Meteorological Agency

Propagation of swells in S-Pacific (2017)



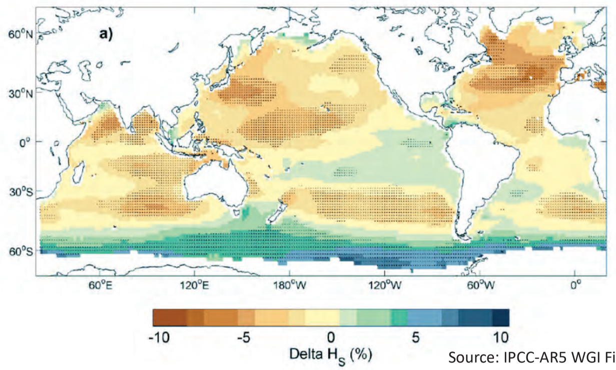
Source: Japan Meteorological Agency

- Wind waves are developing or matured waves under the direct action of winds. They are remarkably irregular and have skewed and short-crested profiles.
- Swell refers to waves that propagate free from wind action. They travel long distance (hundreds or thousands kilometers), gradually decaying by dispersion, viscosity, etc. They look like monotone sinusoidal waves and have smoothed surface and long-crested profiles.

2.3.1. Climate change effect: Future change of waves

- **Changes in ocean wave conditions are determined by changes in the major wind systems, especially in the main areas affected by tropical and extra-tropical storms**

A few % of significant wave height (Hs) will increase in some area of the pacific islands.



Source: IPCC-AR5 WGI Figure 13.26

- Changes in ocean wave conditions are determined by changes in the major wind systems, especially in the main areas affected by tropical and extra-tropical storms.
- The figure shows the ensemble projected changes of annual mean SWH under an A2 scenario.
- The largest change is projected to be in the Southern Ocean, where mean SWHs at the end of the 21st century are approximately 5 to 10% higher than the present-day mean.
- A few % of significant wave height (Hs) will increase in some area of the pacific islands.
- However, there is low confidence in projections of future storm conditions and hence in projections of ocean waves. Nevertheless, there has been continued progress in translating climate model outputs into wind–wave projections.

2.4. Non-climate hazard (Other factors)

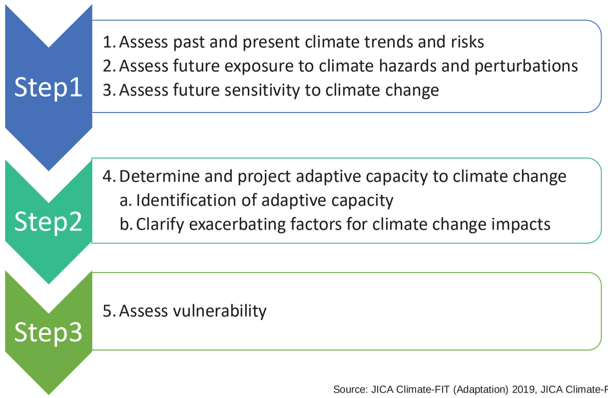
- **Tsunami:** design tsunami height should be determined as tsunami of several 10 years to several 100 years return periods, considering maximum tsunami recorded in the past or simulated by numerical simulation.
- **Current:** design for coastal structure includes currents induced by wave, tide, wind and river discharge.
- **Ground/ soil:** soil condition for structure design should be determined by the results of borehole survey and laboratory test. Soil pressure should be acquired by the formula based on the characteristics of soil, structure and seismic force.
- **Earthquake:** design of coastal structure should ensure the required seismic performance, considering the function, structure, importance and ground elevation of the facility.
- **Collison form debris:** collision force against structure is considered when action from debris and ships is assumed.

- **Tsunami:** design tsunami height should be determined as tsunami of several 10 years to several 100 years return periods, considering maximum tsunami recorded in the past or simulated by numerical simulation.
- **Current:** design for coastal structure includes currents induced by wave, tide, wind and river discharge.
- **Ground/ soil:** soil condition for structure design should be determined by the results of borehole survey and laboratory test. Soil pressure should be acquired by the formula based on the characteristics of soil, structure and seismic force.
- **Earthquake:** design of coastal structure should ensure the required seismic performance, considering the function, structure, importance and ground elevation of the facility.
- **Collison form debris:** collision force against structure is considered when action from debris and ships is assumed.

3. Focal points to assess vulnerability of coastal protection structure

3.1. Vulnerability assessment of coastal protection structure

- **The overview of vulnerability assessment of coastal protection structure is shown in the this flowchart.**



Source: JICA Climate-FIT (Adaptation) 2019, JICA Climate-FIT (Adaptation) 2011 edition

The overview of vulnerability assessment of coastal protection structure is shown in the this flowchart.

1. Assess past and present climate trends and risks
2. Assess future exposure to climate hazards and perturbations
3. Assess future sensitivity to climate change
4. Determine and project adaptive capacity to climate change
   a. Identification of adaptive capacity
   b. Clarify exacerbating factors for climate change impacts
5. Assess vulnerability

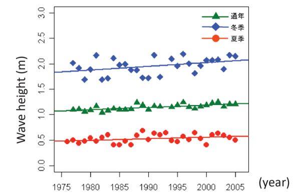
3.1.1. Vulnerability assessment – Step 1

Step 1

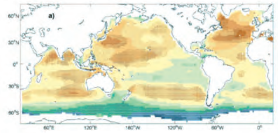
1. **Assess past and present climate trends and risks**
   - **tide level, wave, storm surge and high wave, in and around the target coastal area**

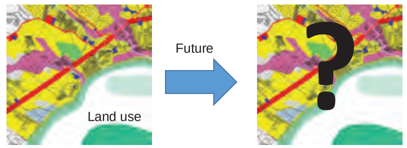
2. **Assess future exposure to climate hazards and perturbations**
   a. **Study future weather conditions**

   b. **Study other factors related to socio-economic changes**



example of historical wave data
Source: JMA


example: Future wave change
Source: IPCC



Source: JICA

Step 1
1. Assess past and present climate trends and risks
   - Collect past marine weather records such as tide level, wave, storm surge and high wave, in and around the target coastal area, from marine weather stations and regulatory agencies.

2. Assess future exposure to climate hazards and perturbations

a. Study future weather conditions
   - Review the national policies related to climate change, and discuss and confirm with counterpart organization the applied climate change scenarios and analysis models, and target year for adaptation measures. Estimate marine and meteorological weather aspects for the target year based on the analysis results on climate change.

b. Study other factors related to socio-economic changes
   - Study change factors for land use in the target area, which affect the inundation, coastal erosion, storm surge and high wave damage, sediment load and littoral drift, such as population change and industrial development, through review of the national and regional development plan and land use regulations.

3.1.1. Vulnerability assessment – Step 1

Step 1

3. **Assess future sensitivity to climate change**
   a. **Study past damage**
      - **the records on inundation, coastal erosion, storm surge and high wave damage**

   b. **Study present condition of facilities and measures**
      - **Condition of facilities:**
      - **Operating / functioning conditions of facilities:**

Example: past damage


Solomon Is, Apr 2014 *(photo; AFP/Carlos Aruafu)*

Figure 3-2 Example of a Rigid Vertical Seawall


Photo credits: J. Carley

Example: coastal revetment
Source: Guidance for coastal protection works in Pacific island counties, PRIF


Example: operational facilities
Source: JICA Survey Team

Step 1

3. Assess future sensitivity to climate change

a. Study past damage
   - Study the records on inundation, coastal erosion, storm surge and high wave damage such as observed record, aerial photo, and topographic surveys, through collection and hearing investigation among stakeholders such as the related agency and inhabitants, as well as through websites on meteorology. Organize the areas vulnerable to inundation, coastal erosion, storm surge, and high wave damage in the target coastal area.

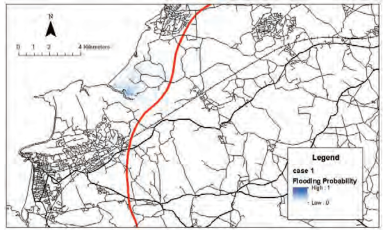
b. Study present condition of facilities and measures
   - Condition of facilities:
     - Assess the present condition of facilities based on the design condition, bearing capacity, and maintenance condition, through inventory survey and review of documents such as reports and drawings for coastal structures in the target coastal area.
   - Operating / functioning conditions of facilities:
     - Assess the operational condition of the facilities such as flood gate and drainage pumping station, through investigation on operation and management records of facilities, as well as through interviews among stakeholders.

3.1.1. Vulnerability assessment – Step 1

Step 1

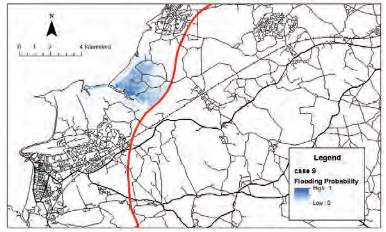
3. Assess future sensitivity to climate change (Cont.)

c. Assess future sensitivity to climate change



Example: coastal flooding with **present** climate condition

Source: D. Tsujio



Example: coastal flooding with **future** climate condition

Source: JICA Climate-FIT (Adaptation) 2019, JICA Climate-FIT (Adaptation) 2011 edition

3. Assess future sensitivity to climate change

c. Assess future sensitivity to climate change

- Study the submarine and coastal topographical features, coastal characteristics such as wave, flow, and longshore sediment transport, and coastal vegetation of the target coastal areas. Then, assess the future sensitivity of coastal area to inundation, coastal erosion, and storm surge and high wave damage, based on the relationship between past disasters and oceanographic and meteorological conditions, future climate and marine condition, and condition of facilities, with consideration on future socio-economical change factors.

3.1.2. Vulnerability assessment – Step 2

Step 2

4. Determine and project adaptive capacity to climate change

a. Identification of adaptive capacity

- **Community based disaster management and crisis management**

⬇

- **Disaster resilience capability of regulatory agency**

⬇

- **Existence and ability of research and development**

Step 2

4. Determine and project adaptive capacity to climate change

a. Identification of adaptive capacity

- Community based disaster management and crisis management
  - Assess the responsiveness against storm surge and high wave occurrence:
    - Situations of non-structural measures such as hazard maps, warning system, and evacuation drills, which are related to the responsiveness of the local government and inhabitants.
    - Maintenance conditions of roads and shelters, which can facilitate evacuation during disaster.

- Disaster resilience capability of regulatory agency
  - Assess condition of budget and program of activity for disaster recovery of regulatory agencies.

- Existence and ability of research and development
  - Assess condition of research and development for coastal protection.

3.1.2. Vulnerability assessment – Step 2

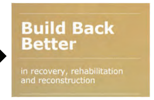
Step 2

4. **Determine and project adaptive capacity to climate change**
   a. **Identification of adaptive capacity (Cont.)**
      - **Compensation for storm surge and high wave damage**

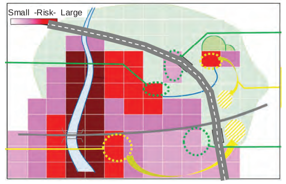
   b. **Clarify exacerbating factors for climate change impacts**
      - **Land use and land use regulations**

   c. **Clarify the land use and related regulatory policies which affect the inundation, coastal erosion, and storm surge and high wave damages.**

Example: build back better



Solomon Is, Apr 2014 *(photo; AFP/Carlos Aruafu)*



Example: land use regulations

Source: Guidelines for disaster risk reduction town development based on water-related disaster risk, MLIT, Japan, translated by author

Step 2

a. Identification of adaptive capacity
   - Compensation for storm surge and high wave damage
   - Assess the post-disaster restoration capability:
     - Situations of available insurance or mutual aid system for storm surge and high wave damage.

b. Clarify exacerbating factors for climate change impacts
   - Land use and land use regulations

c. Clarify the land use and related regulatory policies which affect the inundation, coastal erosion, and storm surge and high wave damages.

3.1.3. Vulnerability assessment – Step 3

Step 3

5. **Assess vulnerability**
   - **Assess vulnerability to climate change in the target area by overlapping the factors assessed in Steps 1 and 2. If vulnerability differs within the target area, its spatial distribution shall be studied.**

Items	Low ← Vulnerability → High	
Future sensitivity to climate change	Small	Large
Community based disaster management and crisis management	Excellent	Poor
Disaster resilience capability of regulatory agency	Excellent	Poor
Existence and ability of research and development	Exist/ Excellent	None/Poor
Compensation for storm surge and high wave damage	Sufficient	Poor
Land use and land use regulation	Planned	Unplanned

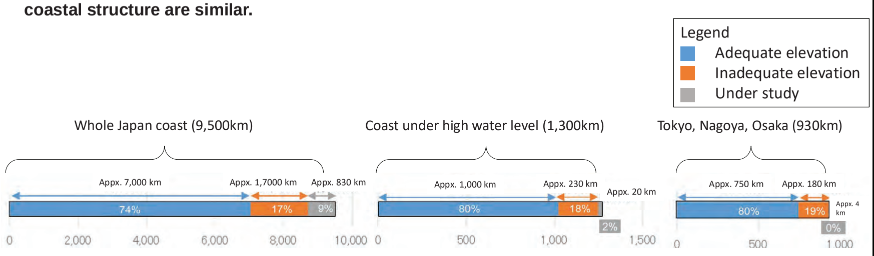
Source: JICA Climate-FIT (Adaptation) 2019, JICA Climate-FIT (Adaptation) 2011 edition

5. Assess vulnerability
   - Assess vulnerability to climate change in the target area by overlapping the factors assessed in Steps 1 and 2. If vulnerability differs within the target area, its spatial distribution shall be studied.

1. Future sensitivity to climate change
2. Community based disaster management and crisis management
3. Disaster resilience capability of regulatory agency
4. Existence and ability of research and development
5. Compensation for storm surge and high wave damage
6. Land use and land use regulation

3.2.1. Location (example in Japan)

- **The location/ ground elevation where coastal protection facilities are installed is critical for vulnerability assessment because huge inundation damage may occur after breaching.**
- **The length of coastal dike which ensure the enough elevation of coastal dike along Japan coast where needed is about 70 %.**
- **The vulnerability of coastal structure under high water level and in front of mega city (Tokyo, Nagoya and Osaka) is more severe than those of other areas even if the percentages of adequate elevation of coastal structure are similar.**



(Source: Review committee for coastal protection based on climate change, MLIT, Japan, translated by author)

- The location/ ground elevation where coastal protection facilities are installed is critical for vulnerability assessment because huge inundation damage may occur after breaching.
- Here is an example of the length of coastal dike which ensure the enough elevation of coastal dike along Japan coast where needed.
- The cover ratio is about 70 % for whole Japan coast.
- The cover ratio at coast under high water level is about 80 % and the cover ratio in front of mega cities (Tokyo, Nagoya and Osaka) is about 80 % too.
- The vulnerability of coastal structure under high water level and in front of mega city (Tokyo, Nagoya and Osaka) is more severe than those of other areas even if the percentages of adequate elevation of coastal structure are similar.

3.2. Focal points to vulnerability assessment

Category	Definition
Vulnerability	The propensity or predisposition to adverse effects (undesirable effects). Vulnerability encompassed various concepts and factors such as susceptibility and sensitivity to hazards and lack of capacity to cope and adapt.

Category		Item
Infrastructure development	Location/ Elevation	Percentage of coastal protection facilities installed in areas at high risk of disaster
	Monitoring & Maintenance	Deterioration and repair frequency of coastal protection facilities and related facilities
	Design condition	Application of design conditions for coastal structures (e.g. breakwaters and levees) predicting wave heights and tidal deviations
	Related facilities	Road/ port/ airport in coastal area e.g. road environment (Strength to rainfall and high temperature damage)

Source: JICA Climate-FIT (Adaptation) 2019, JICA Climate-FIT (Adaptation) 2011 edition

- Vulnerability :The propensity or predisposition to adverse effects (undesirable effects).
- Vulnerability encompassed various concepts and factors such as susceptibility and sensitivity to hazards and lack of capacity to cope and adapt.

1. Location/ Elevation: Percentage of coastal protection facilities installed in areas at high risk of disaster
2. Monitoring & Maintenance: Deterioration and repair frequency of coastal protection facilities and related facilities
3. Design condition: Application of design conditions for coastal structures (e.g. breakwaters and levees) future change of predicting wave heights and storm surge deviations
4. Related facilities: Road/ port/ airport in coastal area. e.g. road environment (Strength to rainfall and high temperature damage)

3.2.2. Monitoring and Maintenance

- **Once a structure is constructed, it should be subject to ongoing monitoring and maintenance to ensure that the structure remains in good condition over its design life.**

- **Seawall monitoring can typically be divided between:**
  - **condition monitoring to assess the condition of the structure**
  - **performance monitoring, focusing on the assessment of the principal function of the structure**

Figure 3-2 Example of a Rigid Vertical Seawall

Photo credits: J. Carley

Example: coastal revetment

Example: damage of coastal protection structure

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Once a structure is constructed, it should be subject to ongoing monitoring and maintenance to ensure that the structure remains in good condition over its design life. If adequately maintained, structures can often significantly exceed their intended design life. Conversely, structures which are not maintained may fail prior to their intended design life.

- Seawall monitoring can typically be divided between:
  - condition monitoring to assess the condition of the structure, including:
    - ➢ superficial inspections multiple times a year and reporting of defects, changes, or unusual features of the seawall, such as cracks, displaced elements, or scour;
    - ➢ special inspections carried out following specific events, such as extreme events, floods, storms, or when other inspection indicates a cause for major concern;
  - performance monitoring, focusing on the assessment of the principal function of the structure, such as:
    - ➢ limiting overtopping to tolerable levels; and
    - ➢ protecting the land and structures behind the seawall.

3.2.2. Monitoring and Maintenance (cont.)

- **Monitoring of the structure would typically be undertaken after large wave and high sea level conditions, or reports should be collated of such conditions. Results of monitoring may be to:**

  i. take no action/continue monitoring when no problems are identified or issues are minor
  ii. rehabilitate all or part of the structure, where steps are taken to correct a problem before the structure functionality is significantly degraded
  iii. repair all or part of the structure after damage has occurred and structural functionality is significantly reduced.
  iv. Upgrade or retrofit the structure to achieve a higher functionality or to withstand modified design conditions.

Figure 6-12 Examples of seawall repair

Applying grout to degrading sandbags in South Tarawa (left); repair a collapsed seawall by placing tribar units in Majuro, Marshall Islands (right)

Source: R. Craven, 2014 (left photo).

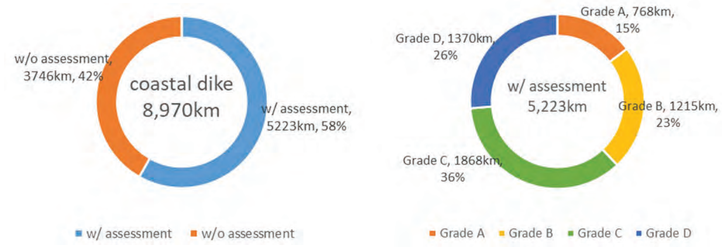
Source: Guidance for coastal protection works in Pacific island counties, PRIF

Monitoring of the structure would typically be undertaken after large wave and high sea level conditions, or reports should be collated of such conditions. Results of monitoring may be to:

1. take no action/continue monitoring when no problems are identified or issues are minor
2. rehabilitate all or part of the structure, where steps are taken to correct a problem before the structure functionality is significantly degraded (e.g., grouting holes in a seawall before fine particles of materials are lost from behind the wall)
3. repair all or part of the structure after damage has occurred and structural functionality is significantly reduced (i.e., after a seawall failure).
4. Upgrade or retrofit the structure to achieve a higher functionality or to withstand modified design conditions (e.g., as the climate changes or new information is available to define design conditions).

3.2.2. Maintenance (example in Japan)

- **Deterioration and repair frequency of coastal protection structure affect the vulnerability of the structure.**
- **Assessment for condition of coastal structure is regularly implemented based on the assessment manual in order to preventively manage coastal structure in Japan.**
- **About 60 % of the coastal dike along Japan's coast have been assessed and 15 % of coastal dike (Grade A) needs somehow countermeasures.**



(Source: Review committee for coastal protection based on climate change, MLIT, Japan, translated by author)

- Deterioration and repair frequency of coastal protection structure affect the vulnerability of the structure.
- Assessment for health of coastal structure is regularly implemented based on the assessment manual in order to preventively manage coastal structure in Japan.
- About 60 % of the coastal dike along Japan's coast have been assessed and 15 % of coastal dike (Grade A) needs somehow countermeasures.
- It is critical to regularly assess the health of coastal protection structure and understand their conditions as well as formulation of maintenance and monitoring strategy.

3.2.3. Design condition

- **Design conditions for coastal protection structures comprise water level/ tide, wave, tsunami, current/ earthquake etc.**
- **Some critical forces could be affected by climate change; such as sea level rise, wave etc.**
- **Design condition for coastal protection structure should consider the climate change effect such as sea level rise, predicting wave (height, period and direction) and predicted storm surge.**
- **The vulnerability of coastal protection structure would be less if design conditions with climate change effect are applied.**

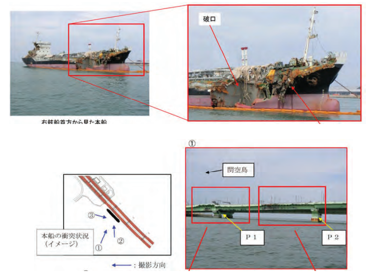
Categories	Design force for coastal protection structure		Climate Change Effect
Climate hazard	Water Level (sea level)	**Mean sea level**	**Sea Level Rise**
		Astronomical tide	----
		Storm surge	**Intensity of tropical cyclone**
	Wave	**Wave height/period**	**Intensity of tropical cyclone**
		Wave force	**Intensity of tropical cyclone**
		Wave run-up/overtopping	**Intensity of tropical cyclone**

- Design conditions for coastal protection structures comprise water level/ tide, wave, tsunami, current/ earthquake etc.
- Some critical forces could be affected by climate change; such as sea level rise, wave etc. as mentioned above.
- Design condition for coastal protection structure should consider the climate change effect such as sea level rise, predicting wave (height, period and direction) and predicted storm surge.
- The vulnerability of coastal protection structure would be less if design conditions with climate change effect are applied.

3.2.4. Related facilities

- **Coast has critical relationship between various other related facilities such as road, port, airport in coastal area.**
- **The vulnerability assessment should also consider these conditions based on the characteristics of related facilities (e.g. road environment: strength to rainfall and high temperature damage)**
- **Example in Japan: The access bridge to Kansai airport was damaged by collision of large ship that was uncontrolled by strong wind due to Typhoon No.21 in 2018.**

Source: Japan Transport Safety Board



Source: Japan Transport Safety Board

- Coast has critical relationship between various other related facilities such as road, port, airport in coastal area.
- The vulnerability assessment should also consider these conditions based on the characteristics of related facilities (e.g. road environment: strength to rainfall and high temperature damage)
- Example in Japan: The access bridge to Kansai airport was damaged by collision of large ship that was uncontrolled by strong wind due to Typhoon No.21 in 2018.
- We can not use the bridge for a while, which resulted in huge economic loss by closure of the airport.

Summary of this presentation

1. **Introduction- outline of coastal disaster**
   - **Coastal disaster including coastal flooding, storm surge, wave & swell, coastal erosion as well as non-climate hazard are outlined.**
   - **It is important to recognize types of coastal disasters and these causes, especially related to climate change effect.**
2. **Hazards of coastal protection structure and its projected change**
   - **Design forces for coastal protection structure: tide/ storm surge/ waves/ other factors are explained.**
   - **The difference in the two categories: 1) climate hazards, 2) non-climate hazards are critical.**
   - **Sea level rise, intensification of tropical cyclone, future change of storm surge as well as wave are explained.**
3. **Focal points to assess vulnerability of coastal protection structure**
   - **The methodology of vulnerability assessment for coastal protection structure is explained step by step.**
   - **Focal points to vulnerability assessment are also explained like location/ management/ design condition and related facilities.**

References

Guidance for coastal protection works in Pacific island counties, https://www.theprif.org/document/regional/coastal-protection/guidance-coastal-protection-works-pacific-island-countries

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CBCRP-PCCC Training Course
"Climate Change Adaptation and Disaster Risk Reduction through land use management and structural approach"

Government of Samoa, SPREP and JICA

2. CCA and DRR focusing on structural approaches
2.1 Buildings

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Pacific Region Infrastructure Facility (PRIF)
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CONTENTS

1. Overview of risk-informed land use planning
2. Designing climate-resilient buildings in the Pacific
   a) Updating of building codes, other manuals and guidelines
   b) Capacity building needs
   c) Green building concept

1. Overview of risk-informed land use planning

3

How can we adapt our habitat to the impacts of climate change?

- **Traditional land use planning approach**

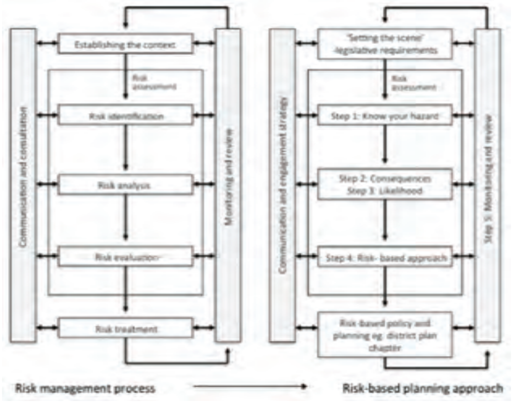
Land use planning helps determine how communities will grow and how they will adjust to change. It is a rational and judicious approach of allocating available land resources to different uses and functions balancing the needs of various stakeholders consistent with overall development goals.

- **Risk-informed land use planning approach**

Combines land use planning and natural hazard risk reduction by overlaying risks and vulnerability exposure prior to allocation of available land resources. Risk-informed planning highlights the role of land use plans to control or prevent development in extreme risk areas, and to mitigate risk in existing developments.

4

Relationship of risk-based planning to risk management process



Source: Innovative land use planning for natural hazard risk reduction: A consequence-driven approach from New Zealand (https://www.sciencedirect.com/science/article/pii/S221242091630070X)

5

Estimated human and economic costs of some recent floods in PICs

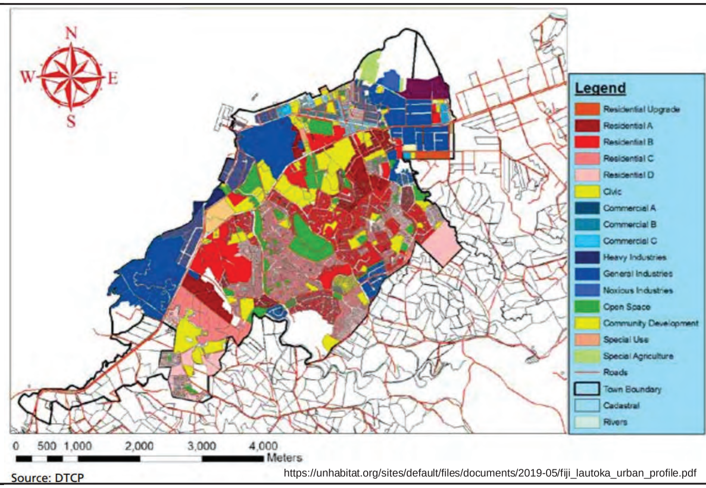
Flood	Death Toll	Damage and Loss	% GDP	Source
Northern Fiji, *Jan. 2003*	16	F$105 million[a]	Data not available	NDMO 2003; Yeo 2011
Central Fiji, *Apr. 2004*	12	F$13 million (Navua only)	Data not available	Holland 2008; Yeo 2011
Western Fiji, *Jan. 2009*	7	F$440 million (government and private losses)[b]	~7%	Holland 2009; Ambroz 2009; Yeo 2011
Western Fiji, *Jan. 2012*	8	F$41 million (government only)	Data not available	"Fiji Live," May 8, 2012, "March floods cost govt $90 million"; Kuleshov et al. 2014
Western Fiji, *Mar. 2012*	12	F$90 million (government only)	Data not available	Fiji Live," May 8, 2018, "March floods cost govt $90 million"; Fiji Times, April 7, 2012, "Loss and grief".
Apia, Samoa, *Dec. 2012*[c]	5	SAT 465 million	~25%	GoS 2013
Honiara and Guadalcanal, Solomon Islands, *Apr. 2014*	24	SI$787 million	9.2%	GoSI 2014; MHA 2014

6

Floodplain before (left) and after (right) the April 2014 flood, Koa Hill, Honiara

7

Lautoka City Scheme Plan



https://unhabitat.org/sites/default/files/documents/2019-05/fiji_lautoka_urban_profile.pdf

8

4

To consider the impacts of climate change,

PROJECT 1 CLIMATE CHANGE AND DISASTER MANAGEMENT — Prepare a disaster management plan for Lautoka.

PROJECT 2 CLIMATE CHANGE AND DISASTER MANAGEMENT — Revise development controls for all new developments and subdivisions so that they consider flood mitigation and climate change adaptation measures.

PROJECT 3 CLIMATE CHANGE AND DISASTER MANAGEMENT — Community-level awareness raising and capacity building for the disaster management plan.

Records of the flood water level in the industrial area of Lautoka City
© SCOPE

https://unhabitat.org/sites/default/files/documents/2019-05/fiji_lautoka_urban_profile.pdf

9

How to practice risk-informed land use planning?

- Review and update legislation, policies, and zoning plans relating to urban land use in PICs to ensure flood risk and other natural hazards are considered as integral part of urban development planning
- Risk information needs to be provided to planners in a fit-for-purpose format
- Consider densification of safe areas to increase supply of residential areas to persuade people to relocate from high-hazard sites before a disaster occurs
- Encourage resilient buildings
  - Review and update building codes
  - Improve human resources to increase capacity to check compliance with controls
  - Prepare locally tailored guidelines for hazard-resilient housing, including for low-income groups
  - Recognize that it may not be practical to relocate communities away from high-risk areas but the priority is to always to “ build back better”

(Adopted from: World Bank, 2017. *Urban Flood Risk Management in the Pacific: Tracking Progress and Setting Priorities.*)

10

5

State of national urban policy development in the Pacific (https://unhabitat.org/national-urban-policy-pacific-region-report)

Country	Urban-Related Policies on the National Level
Papua New Guinea	▪ Urban Profiles for Port Moresby, and on the national level ▪ National Informal Settlements Upgrading Strategy (2016, to be endorsed) ▪ National Urbanisation Policy 2010 to 2030
Samoa	▪ Planning and Urban Management Act (2004) ▪ Samoa National Urban Policy (2013) ▪ Apia Spatial Plan (2014) ▪ City Development Strategy (Draft 2015) ▪ Apia Waterfront Plan 2016 ▪ Urban Design Standards 2018 ▪ National Infrastructure Strategic Plan (2011)
Fiji	▪ Urban Policy Action Plan (2004-2006) ▪ Urban Profiles were developed for the Cities of Suva, Nadi and Lautoka, national level ▪ National Housing Policy (2011) ▪ Urban NAP (as part of the National Adaptation Plan)
Solomon Islands	▪ Urban Profiles: national level, Honiara, Gizo, Tulagi, Kirakira and Auki ▪ National Urban Policy (2016-2035)
Kiribati	▪ Kiribati Development Plan ▪ National Urban Policy (final draft)

11

State of national urban policy development in the Pacific (https://unhabitat.org/national-urban-policy-pacific-region-report)

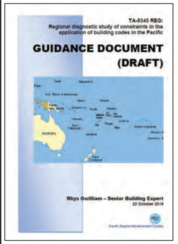
Tuvalu	▪ National Strategy for Sustainable Development (NSSD) – Te Kakeega III (TKIII) 2005 – 2015 ▪ National Population Policy 2010-2015 ▪ Urban profiles: Vaitupu and Funafuti
Vanuatu	▪ Priorities and Action Agenda, 2006 – 2015 ▪ National Population Policy 2011 – 2020 ▪ 2012 Land Use Planning and Zoning Policy ▪ Urban profiles: Port Vila, Luganville, Lenakel
Tonga	▪ Tonga Strategic Development Framework (TSDF) 2015-2025 ▪ Urban Planning and Management System ▪ National Spatial Planning and Management Act (2012)

12

2. Designing climate-resilient buildings in the Pacific

13

Regional diagnostics on building codes and standards



Recommends a tiered approach
1. National Building Code
2. Home Building Manual
3. Shelter/Traditional Construction Handbook in local language

Status of building codes in PICs

	Cooks	FSM	Fiji	Kiribati	Nauru	Niue	Palau	Marshall	Samoa	Solomons	Tonga	Tuvalu	Vanuatu
NBC exists	✓	×	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓
NBC legislated	✓	×	✓	✓	×	✓	×	✓	✓	×	✓	×	✓
NBC recently updated	✓	×	×	×	×	✓	×	✓	✓	×	✓	×	×

Assistance to update building codes
- ADB/WB supporting Tuvalu
- DFAT supporting Solomon Islands
- ADB will support Vanuatu
- PRIF/MFAT will support Kiribati
- WB supported updating of Fiji Home Building Manual

14

Old NBC vs Updated NBC (Samoa)

NBC-1992		NBC-2017
A General Provisions		**A** Core Provisions
B Structure		**B** Stability
Dwellings & Outbuildings	*Public Buildings & Group Dwellings*	
DC Fire Resistance	**NC** Fire Resistance	**C** Fire Protection
DD Access & Egress	**ND** Access & Egress	**D** Access
		E Hazardous Substances
DE Electricity	**NE** Services & Equipment	**G** Site Servicing & Waste
DF Health & Amenity	**NF** Health & Amenity	**F** Interior
		H Climate Change & Adaptation
		J Natural Disaster Resilience
DG Ancillary Provisions	**NG** Ancillary Provisions	**K** Minor Structures & Major Infrastructure
	NH Special Use Buildings	

- National Building Code 2017
  - Intended to be used by building design professional
  - Covers all types of buildings, with some exclusions
  - Performance based outcomes through achieving with deemed to satisfy solutions or a performance solution
  - Frequent references to external standards to achieve intended outcomes
  - Highly technical & requires up-to-date knowledge

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Building group categories

Building Group	Description
1	BUILDINGS, FACILITIES or Major Infrastructure whose function serves a large area or large number of people in Samoa
2	BUILDINGS and FACILITIES that are essential to post-DISASTER recovery or the primary function is storage or handling of HAZARDOUS SUBSTANCES BUILDINGS with activities that affect large groups of people in a village
3	BUILDINGS which may house groups of people, vulnerable populations, or fulfil a role of importance to the community or village
4	BUILDINGS which accommodate a low number of people, or with a low replacement cost
5	Samoan **Fale** and **Single Unit Residential**

- Communal Residential Building (greater than 350 m^2)
- Multiple Unit Residential Building (with more than 4 UNITS)
- Assembly Building (greater than 150 m^2)
- Tourist Accommodation (a BUILDING with 1-8 guest rooms)
- Aged-Care Building for disabled and/or the elderly (250 m^2 or less)
- Office/ Commercial (greater than 350 m^2)
- Mixed Use Building (greater than 350 m^2)
- Industrial / Storage Building (greater than 350 m^2)
- Heritage Building

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Application of building group and building type

Refer to each section for specific requirements

		Building Group 1	2	3	4	5	Residential – Multiple Unit	Residential – Single Unit	Aged-Care, Health-Care	Commercial, Office, Industrial	Retail	Mixed Use	Schools	Major Infrastructure	Minor, Temporary Structures	Other Non-Residential
B1 Structure																
B1. A	Loads	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B1. B	Foundations + Waterproofing	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B1. C	Building Lifespan	•	•	•					•	•				•		
B1. D	External Concrete Panel	•	•	•			•		•	•	•	•	•	•		•
B1. E	Lightweight Construction	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B2 Sitework																
B2. A	Construction Safety	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B2. B	Slope Stability, Erosion and Sedimentation	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B2. C	Groundwater and Saturated Soil	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B2. D	Stormwater Management	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B2. E	Roof Drainage System	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B3 Unstable Buildings and Demolition																
B3. A	Unstable Buildings	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B3. B	Termites	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B3. C	Demolition	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B4 Building Materials																
B4. A	Durability Standards for Building Materials	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B5 Glazing and Windows – Structure and Safety																
B5. A	Materials and Structural Integrity	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B5. B	Human Impact Safety	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
B5. C	Glazing for Fall Protection	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

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B1.C Building lifespan

.3 All BUILDINGS in BUILDING GROUPS 1 and 2, and **Assembly/Office/Commercial/Mixed Use** BUILDINGS in BUILDING GROUP 3 must demonstrate DURABILITY, efficient use of BUILDING MATERIALS, and reduction of the CARBON FOOTPRINT by the preparation and implementation of one of the following Building Life Cycle Evaluation system, or an approved equivalent:

- Athena Impact Estimator (IE) - an on-line assessment tool that provides ratings for fossil fuel consumption, GLOBAL WARMING POTENTIAL, acidification potential, eutrophication potential, ozone depletion and smog potential for foundations, walls, beams,columns, floors and roofs
  http://www.athenasmi.org/our-software-data/impact-estimator/
- eTool CD - a web-based Life Cycle Assessment using the IMPACT database
  http://etoolglobal.com/wp-content/uploads/2016/03/eTool-LCA-Training-Certificate.pdf
- Green Guide Calculator by BRE Global which is available to BREEAM and CSH Assessors
  https://www.bre.co.uk/greenguide/calculator/page.jsp?id=2071
- BEES Building for Environmental and Economic Sustainability life cycle assessment
  https://www.nist.gov/services-resources/software/bees

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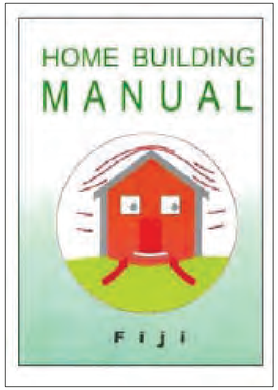
Home Building Manual

- Associated with 1990s National Building Code, but should still be relevant, after review
- Applies to houses only, up to 2 storeys, using conventional construction
- Aimed at professionals & contractors looking for deemed to satisfy structural engineering solutions (mostly), without expense of extensively using an engineer



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Limitations and scope of Home Building Manual

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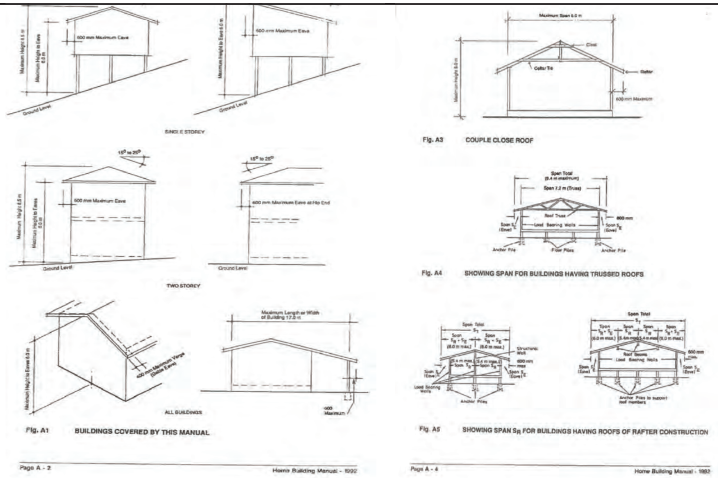
Home Building Manual



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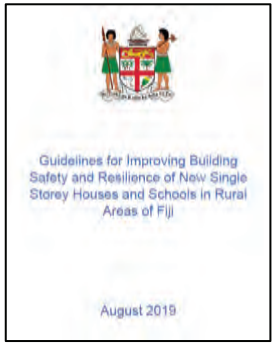
Other guidelines - Fiji

- Application of revised NBC to new single storey residential housing
- Based on a document developed in Dominica in 2017, following severe hurricanes there that heavily impact the general housing stock
- Content:
  - 1. Introduction
  - 2. Process for Obtaining a Building Permit
  - 3. Risks to Buildings
  - 4. Building design to Address Risk
  - 5. Construction Methods
  - 6. Good Practice
  - 7. Indicative Costings
  - 8. External Agencies and the National Building Code
  - 9. Suggestions for Leniency of Inclusion of Section H [Climate Change & Adaptation]
  - 10. Next Steps



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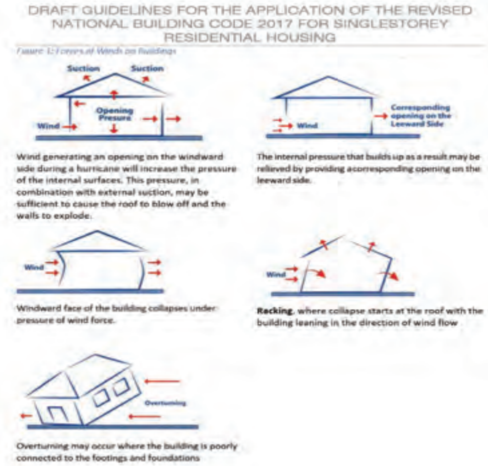
Risks to building considered in the Guidelines



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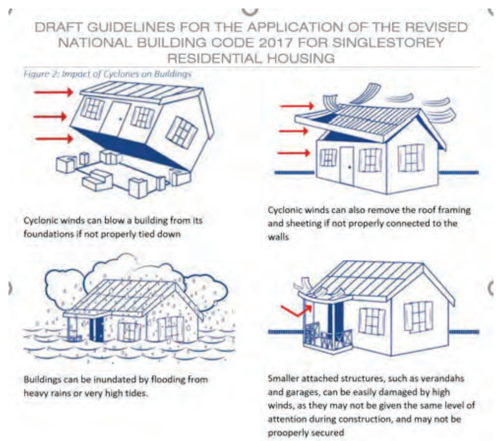
Risks to building considered in the Guidelines



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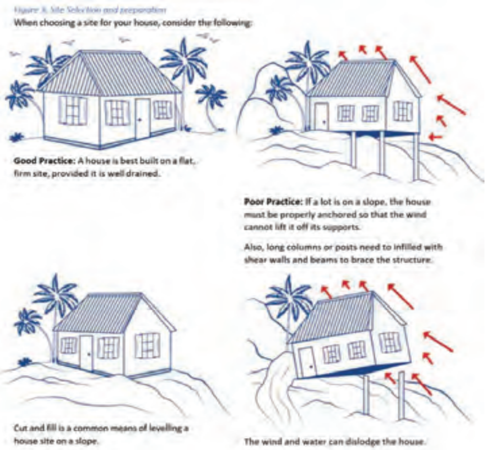
Building design to address risks



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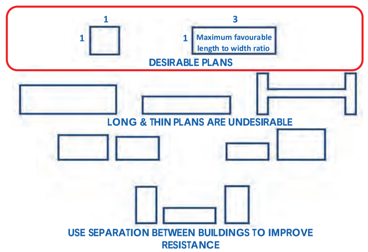
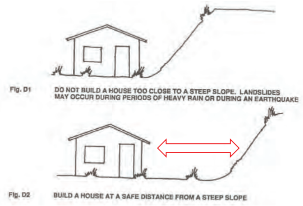
Building design to address risks



Building shape



Choosing building site

https://mitt.gov.fj/wp-content/uploads/2019/12/MITT-Guideline-single-store-houses-schools-11-12-2019.pdf

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Building design to address risks

Types of foundation

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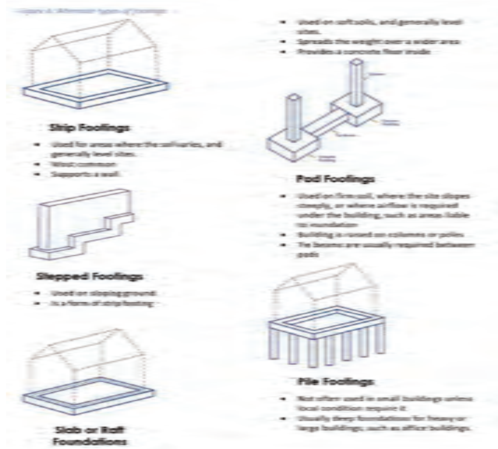

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Building design to address risks

Types of roof

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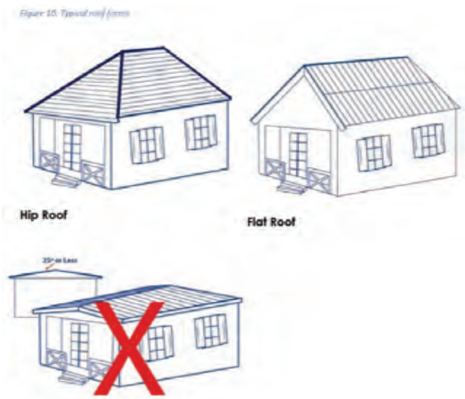

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Construction methods

https://mitt.gov.fj/wp-content/uploads/2019/12/MITT-Guideline-single-store-houses-schools-11-12-2019.pdf

- Concrete
  - Basic mix components
  - Reinforcement: start bars, jointing by splicing, bending, edge distance
- Footings & Foundations
- Floors
  - Concrete
  - Timber framed
- Walls
  - Concrete block & reinforcement
  - Timber framed; basic framing sizes; lintels & bracing; cyclone strapping

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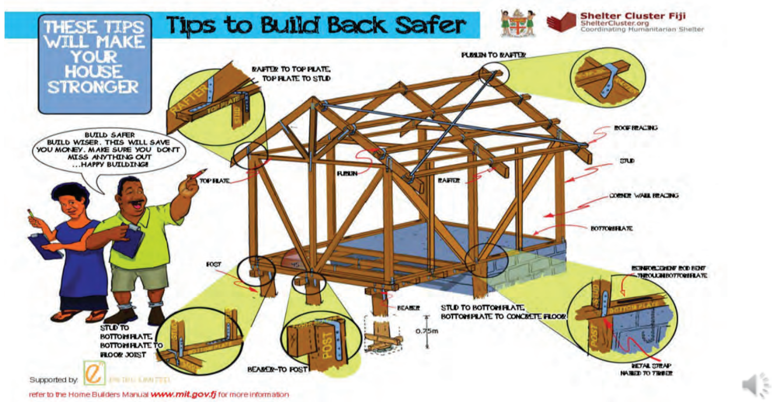
Emergency shelter reconstruction & basic construction techniques



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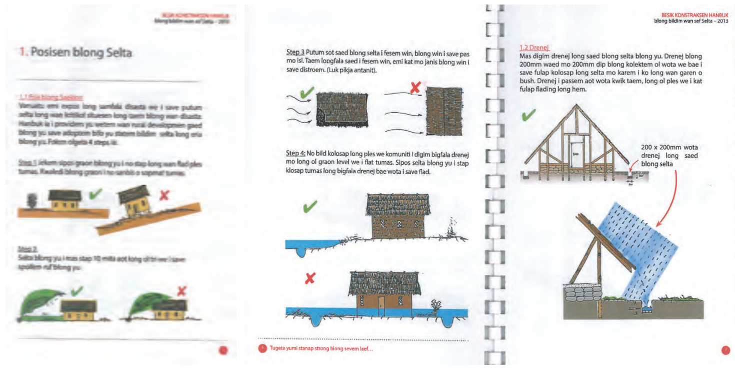
Vanuatu Besik Konstraksen Hanbuk 2015



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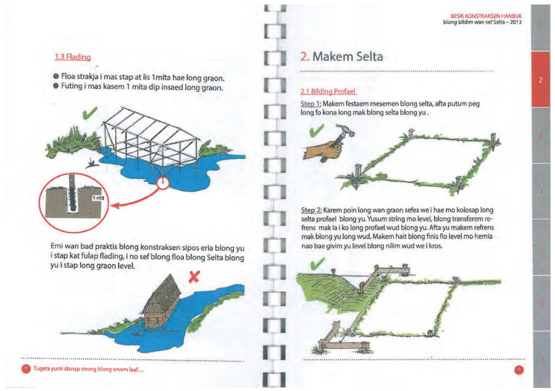
Vanuatu Besik Konstraksen Hanbuk 2015



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Other handbooks relevant to Pacific case

https://www.unisdr.org/files/10329_GoodBuildingHandbookPhilippines.pdf

Example of bad location. This house is located on a river bed, close to running water, where it is very vulnerable to flooding. Not only the house, but also its contents are vulnerable to destruction due to heavy rains. Houses should not be built in such obviously vulnerable locations, or if they are, they should be designed to resist the hazards of their location.

A good roofing example of column steel reinforcement bent over roof truss to tie house structure to the roof structure. This is an essential detail in areas subject to earthquake and to winds, to keep the roof on the house when a natural hazard strikes the structure. Such exposed steel should be painted with rust-proof paint to minimize corrosion.

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Typical steps in acquiring building permit

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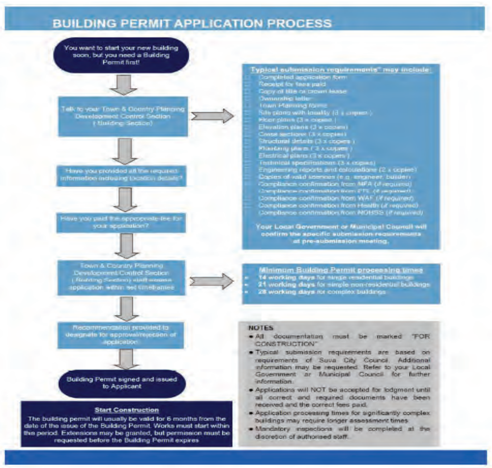

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Enhancing capacity

- Capacity development and training programs targeting building professionals, builders, compliance inspectors and regulators to be developed and delivered in conjunction with the roll out of the new or updated NBCs and updated guidelines.
- Material support to be provided to construction industry professional organizations (CIPOs) that exist in some of the PICs (eg Fiji, Solomon Islands, Samoa). Material support could include the establishment of a small secretariat to administer the CIPO and/or the provision of office space. In PIC's where CIPO's do not exist the PIC central control body responsible for administering and managing the NBC should encourage the local construction industry to establish one. This could be achieved by the provision of incentives such as material support for a secretariat.
- CIPOs to be mandated to assist with the regulatory process, including technical assessment of building applications, planning approvals, building inspections and licensing.

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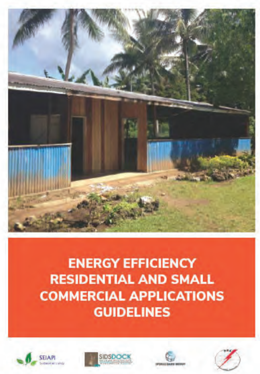
Green buildings

Some ways to make a building green (https://www.worldgbc.org/how-can-we-make-our-buildings-green)

- Taking an intelligent approach to energy
- Safeguarding water resources
- Minimizing waste and maximizing reuse
- Promoting health and well-being
- Keeping our environment green
- Creating resilient and flexible structures
- Connecting communities and people
- Considering all stages of building's life-cycle



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Pacific Risk Information System, http://pcrafi.spc.int/

Guidelines for Improving Building Safety and Resilience of New Single Storey Houses and Schools in Rural Areas of Fiji 2019, https://mitt.gov.fj/wp-content/uploads/2019/12/MITT-Guideline-single-store-houses-schools-11-12-2019.pdf

National Urban Pacific Region Report 2020, https://unhabitat.org/national-urban-policy-pacific-region-report

HANDBOOK ON Good Building Design and Construction In the Philippines, https://www.unisdr.org/files/10329_GoodBuildingHandbookPhilippines.pdf

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CBCRP-PCCC Training Course
“Climate Change Adaptation and Disaster Risk Reduction through structural approaches”

Government of Samoa, SPREP and JICA

2. CCA and DRR activities focusing on structural approaches
2.2 Coastal protection structure

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JICA Short term Expert
Global Company, Pacific Consultants, Co., Ltd.
daiki.tsujio@os.pacific.co.jp

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CONTENTS

1. Types of coastal protection structure
2. Impacts to coastal protection structure
3. Adaptation options for coastal protection structure
4. Examples and challenges in the Pacific region

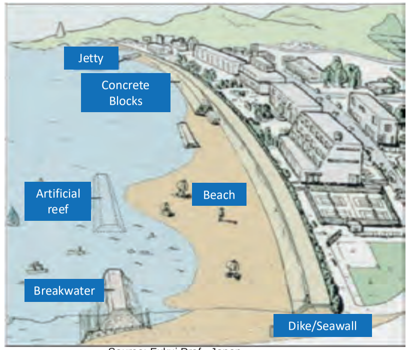
2

1. Types of coastal protection structure

1.1. Types of coastal structure

- **Various types of coastal protection structures should be applied for appropriate countermeasures of the target coast, based on their characteristics and functions.**

1. Rigid structure
   - ➢ Dike
   - ➢ Seawall
   - ➢ Revetment
   - ➢ Concrete blocks
2. Semi-rigid structure
   - ➢ Rock revetment
   - ➢ Geotextile
3. Dynamic shoreline protection
   - ➢ Mobile rock
   - ➢ Beach nourishment
4. Offshore structure
   - ➢ Breakwater
   - ➢ Artificial reef
5. Non-structural measure
6. Ecosystem-based Approaches



Source: Fukui Pref., Japan
https://www.pref.fukui.lg.jp/doc/sabo/kaigansisetuyakuwari.html

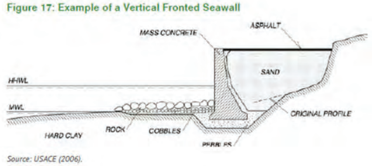
Various types of coastal protection structures should be applied for appropriate countermeasures of the target coast, based on their characteristics and functions.

1. Rigid structure includes:
   - ➢ Dike
   - ➢ Seawall
   - ➢ Revetment
   - ➢ Concrete blocks
2. Semi-rigid structure represents:
   - ➢ Rock revetment
   - ➢ Geotextile
3. Dynamic shoreline protection such as
   - ➢ Mobile rock
   - ➢ Beach nourishment
4. Offshore structure:
   - ➢ Breakwater
   - ➢ Artificial reef
5. Non-structural measure (drill/ Town Planning/ Relocation/Formulation of Hazard Map/ Early warning system)
6. Ecosystem-based Approaches

1.2. Rigid structures

- Vertical sloping, or stepped, and are traditionally constructed of mass concrete or reinforced concrete, grouted rock or blocks, timber or steel sheet piling, or timber posts.
- Needs a well-founded toe, preferably on hard substrate or deeply piled to avoid scour and undermining.
- The structures must be robust due to the high wave loading and;
- to be either massive structures or better suited to low-to-medium wave environments where wave loading is moderate.
- Runup and overtopping is similarly high
- Backshore protection is often required to limit damage by wave overtopping.

Figure 17: Example of a Vertical Fronted Seawall



Source: USACE (2006).

Figure 3-2 Example of a Rigid Vertical Seawall

Photo credits: J. Carley

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Rigid structures protect the land by resisting coastal processes.
- They may be vertical (Figure 3-2), sloping, or stepped, and are traditionally constructed of mass concrete or reinforced concrete, grouted rock or blocks, timber or steel sheet piling, or timber posts.
- They require a well-founded toe, preferably on hard substrate or deeply piled to avoid scour and undermining.
- Additional toe protection, using a semi-rigid structure, may be required to prevent scour and undermining.
- The structures must be robust due to the high wave loading and, therefore, they tend to be either massive structures or better suited to low-to-medium wave environments where wave loading is moderate.
- Runup and overtopping is similarly high, as rigid structures do not effectively dissipate wave energy.
- Backshore protection is often required to limit damage by wave overtopping.

1.3. Semi-rigid structures

- Able to move under wave loading, allowing some energy to be dissipated and for the structure to settle as the seabed or backshore changes form due to erosion or settlement.
- Better suited to higher wave environments and to dynamic environments such as sandy beaches compared to rigid structures.
- Generally sloped revetments and, therefore, use more space than rigid structures.
- Due to the flexibility of the outer layer, a filter layer is required to contain the fine land material behind.

Photo 1: Semi-rigid geotextile container (Maccaferri NZ Ltd.)

Photo 2: Rock revetments (Shand) in Kiribati

Examples:
- rock revetments
- concrete armor unit revetments
- articulated blocks and blanket structures
- cut and stacked blocks
- sand-filled geotextile bags held under gravity

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Semi-rigid structures are able to move under wave loading, allowing some energy to be dissipated and for the structure to settle as the seabed or backshore changes form due to erosion or settlement.
- Semi-rigid structures are, therefore, often better suited to higher wave environments and to dynamic environments such as sandy beaches compared to rigid structures.
- Semi-rigid structures are generally sloped revetments and, therefore, use more space than rigid structures .

- Examples of semirigid structures include:
- rock revetments
- concrete armor unit revetments
- articulated blocks and blanket structures
- cut and stacked blocks
- sand-filled geotextile bags held under gravity.

- Due to the flexibility of the outer layer, a filter layer is required to contain the fine land material behind. This filter may be smaller aggregate or a geotextile fabric, and it essentially forms the barrier between land and sea, with the armour providing protection to the filter from wave attack.

1.4. Dynamic shoreline protection

- **Respond to incoming waves, altering in shape to effectively absorb energy without compromising the integrity of the structure.**
- **Coastal protection, using dynamic materials must include sufficient material to protect against wave attack and gradual material loss over time.**
- **Rock and gravels are generally less mobile than sands and require less ongoing maintenance and replenishment.**

Figure 3-4 A stacked coral block wall in Kiribati collapses, forming a "Dynamically Stable Revetment"(left) and sand replenishment at Manase, Samoa (right)

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Dynamic structures respond to incoming waves, altering in shape to effectively absorb energy without compromising the integrity of the structure.

- Examples of dynamic protection include:
- reshaping revetments, whereby rocks are mobile under wave attack and form a more stable profile; and
- beach nourishment, the artificial addition of sand or gravel to the coast to improve the capacity of a beach to act as a buffer against storm erosion, coastal recession or tidal inundation to protect the land behind.

- Dynamic materials may continue to be moved over time, with some losses from the system expected.
- Coastal protection, using dynamic materials, therefore must include sufficient material to protect against wave attack and gradual material loss over time.
- Rock and gravels are generally less mobile than sands and require less ongoing maintenance and replenishment.
- Control structures, such as groynes and offshore structures, also are used to limit material loss from the system.

1.5. Offshore structures

- **Protect the shoreline by reducing the wave energy arriving at the shore and rotating incoming wave crests.**
- **On a sandy coast, this can reduce longshore drift gradients and encourage sand deposition in the lee of the structure.**
- **Offshore structures may be emergent, partially-emergent, or submerged.**
- **Constructed from rock, pre-cast concrete armor units, or geosynthetic containers (GSC) and must be stable under wave attack while also reducing transmitted wave energy to a desirable level.**

Figure 3-5 Salients Created in the Lee of Offshore Breakwaters at Manase Beach, Samoa

Source: Quilter, 2015.

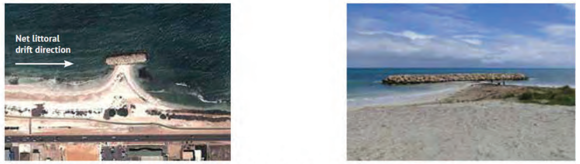


Photo 5 and Photo 6: Beach Tombolo created in lee of an offshore breakwater in Geraldton, Western Australia *(Credit: Shand)*

Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Offshore structures protect the shoreline by reducing the wave energy arriving at the shore and rotating incoming wave crests.
- On a sandy coast, this can reduce longshore drift gradients and encourage sand deposition in the lee of the structure.
- Offshore structures may be emergent, partially-emergent, or submerged.
- Submerged and semi-submerged structures act by breaking or refracting the waves rather than absorbing or reflecting them to dissipate energy.
- While less visually intrusive, they are less effective than emergent structures, particularly during high water level and wave conditions that can result in beach erosion.
- Structures may be constructed from rock, pre-cast concrete armor units, or geosynthetic containers (GSC) and must be stable under wave attack while also reducing transmitted wave energy to a desirable level.

1.6. Non-structural measures

- Various non-structural measures should be considered for enhancement of local residents' disaster prevention in the target area.
- The possible non-structural measures in target coast are following.

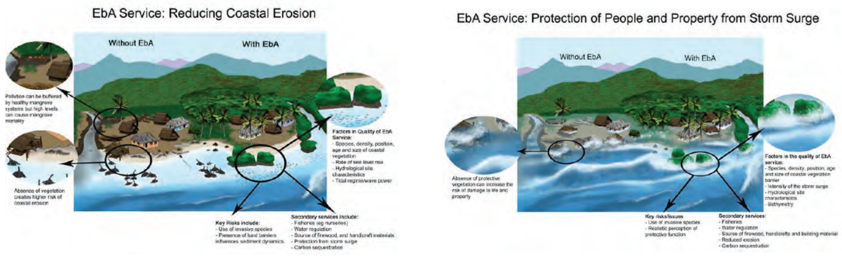
➢Town Planning/ Relocation
➢Formulation of Hazard Map of Coastal Disaster (workshop, field survey)
➢Shelter and evacuation route
➢Education
➢Early warning system
➢Disaster drill

- Various non-structural measures should be considered for enhancement of local residents' disaster prevention in the target area.
- The possible non-structural measures in target coast are following.

➢Town Planning/ Relocation
➢Formulation of Hazard Map of Coastal Disaster (workshop, field survey)
➢Shelter and evacuation route
➢Education
➢Early warning system
➢Disaster drill

1.7. Ecosystem-based Approaches (EbA)

- **Ecosystem-based approaches (EbA) aim to protect the shoreline from wave-induced erosion by maintaining healthy ecosystems.**
- **Although economic analyses of ecological approaches often identify high benefit-cost ratios compared to coastal protection structures, this is generally a function of low implementation costs with modest improvements in the protection provided.**



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Ecosystem-based approaches (EbA) aim to protect the shoreline from wave-induced erosion by maintaining healthy ecosystems.

- This may include the following:
- establishment of offshore vegetation, such as mangroves, to dissipate wave energy before it reaches the shoreline and traps fine sediment, while maintaining habitats for juvenile fish and marine species;
- establishment of backshore vegetation to reduce wave run-up extent and damage potential, trap windblown sand, and improve ecological connectivity between land and sea; and
- improvement of coral reef health to ensure coral production is maintained.

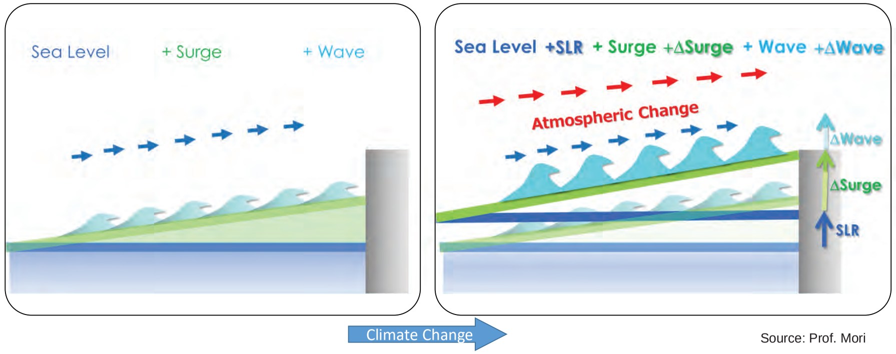
- The use of EbA for coastal protection and as a method to offset the impacts of climate are described extensively in the literature (e.g., World Bank, 2010; Hills et al., 2011), including techniques to combine EbA with conventional protection structures (DECCW, 2009).

- Although economic analyses of ecological approaches often identify high benefit-cost ratios compared to coastal protection structures, this is generally a function of low implementation costs with modest improvements in the protection provided.

2. Impacts to coastal protection structure

2.1. Overview: Impact to coastal protection structure

- **The major impacts to coastal protection structure are sea level rise (SLR), increase of storm surge and wave due to intensification of tropical cyclones.**
- **These effects leads to instability of the structure, insufficient elevation to prevent inundation.**



Source: Prof. Mori

- The major design forces for coastal protection structure are Mean sea level, Storm surge and Wave, which act coastal protection structure directly.
- We have to consider the climate change effects of those forces.
- The left figure shows the current design conditions of coastal structure.
- The major impacts of climate change to coastal protection structure are sea level rise (SLR), increase of storm surge and wave due to intensification of tropical cyclones.
- The future design condition considering these effects is shown in the right figure.

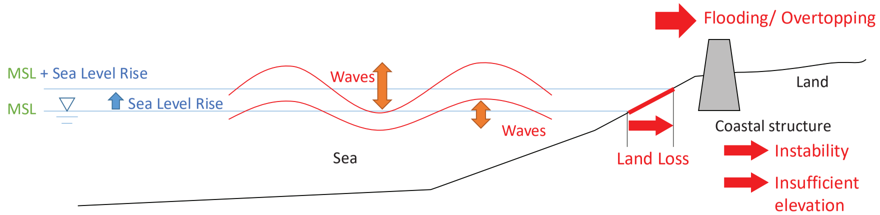
- Higher sea level (SLR + increase of storm surge) and higher wave height cause instability of coastal structure.
- Higher sea level and higher wave height also cause insufficient elevation of coastal structure.

- Therefore, it is very important to consider these effects to prevent coastal flooding with future climate condition.

2.2. Impact of Sea Level Rise

Source: JICA Climate-FIT (Adaptation) 2011 edition

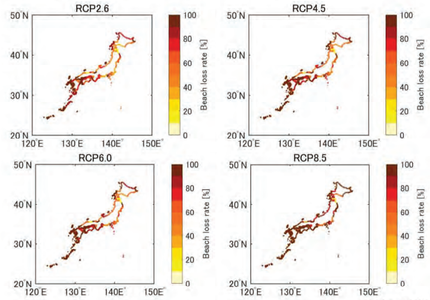
- **Sea Level Rise (SLR)**
  - **i. Coastlines will recede due to rising sea levels, and as a result, some land would be lost.**
  - **ii. Some areas will become flooded during high tide, and inundation on coastal areas will be prolonged.**
  - **iii. Incidence of wave overtopping breakwaters and sea walls will increase.**
  - **iv. Wave force will intensify in association with increase in water depth, even in the same sea wave condition.**
  - **v. Sea level rise will increase buoyancy of buried pipes and manholes, and cause ground uplift. Risk of liquefaction of ground will also increase.**



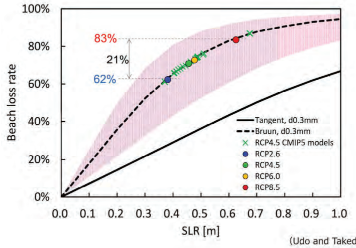
- SLR
1. Coastlines will recede due to rising sea levels, and as a result, some land would be lost.
2. Some areas will become flooded during high tide, and inundation on coastal areas will be prolonged.
3. Incidence of wave overtopping breakwaters and sea walls will increase.
4. Wave force will intensify in association with increase in water depth, even in the same sea wave condition. This may lead to exceedance of the design capacities of structures, and will cause displacement and damage to revetments, wave dissipating blocks, parapets, etc. The effects on coastal erosion would also intensify.
5. Sea level rise will increase buoyancy of buried pipes and manholes, and cause ground uplift. Risk of liquefaction of ground will also increase.

2.2. Impact of Sea Level Rise (Cont.)

- **Sea Level Rise (SLR) directly causes beach loss (or set back of coastline).**
- **An example of a research result reported that the beach loss rates in Japan coast vary from 62% to 83% with different emission scenarios.**



(Udo and Takeda, 2017)



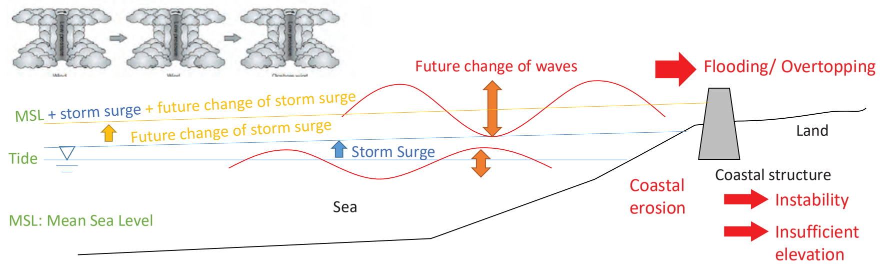
(Udo and Takeda, 2017)

- Sea Level Rise (SLR) directly causes beach loss (or set back of coastline).
- Here is an example of a research result in Japan coast.
- The report clarified the beach loss rates with different 4 emission scenarios along Japan coast.
- According to the report, the beach loss rates in Japan coast vary from 62% to 83% with different emission scenarios.

2.3. Impact of Increase/ Intensification of Cyclones

Source: JICA Climate-FIT (Adaptation) 2011 edition

- **Intensification of Cyclones**
  1. **Damage from storm surge and high wave will increase and intensify, and it will worsen coastal erosion in association with sea level rise.**
  2. **Flooding in the coastal land area will increase.**
  3. **Sea waves larger than design conditions might hit the coastal area, and consequently, hasten deterioration of coastal protection structures.**

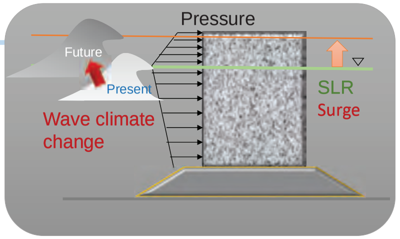


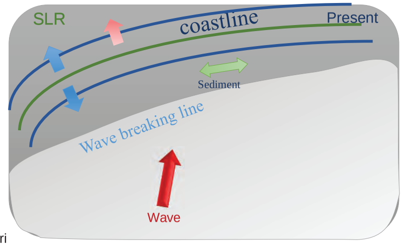
- Intensification of Cyclones leads to increase of storm surge as well as increase of wave height, which cause severer damage in coastal area.
- Sea level including MSL, future storm surge and future higher wave height will act on coastal structure.
  1. Damage from storm surge and high wave will increase and intensify, it will worsen coastal erosion in association with sea level rise.
  2. Flooding in the coastal land area will increase.
  3. Sea waves larger than design conditions might hit the coastal area, and consequently, hasten deterioration of coastal protection structures.

These effects might cause instability of coastal structure and insufficient elevation to prevent coastal flooding.

2.4. Impact to coastal protection

- **Static change**
  - **Sea level rise**
- **Dynamic change**
  - **Storm surge**
  - **Storm wave**
- **Extreme condition**
  - **Coastal protection structure**
- **Daily condition**
  - **Coastline change**
  - **Coastal environment**





Source: Prof. Mori

When we think the impact to coastal protection structure, we have to understand the characteristics of climate change effects and impacts.

Static change

Sea level rise is static change. SLR steadily increase and firmly act on coastal protection structure.

Dynamic change which is caused by extreme event like tropical cyclone and extreme low atmospheric pressure. That is rare event and the action does not last for a long time.

Storm surge:

Storm Wave:

Extreme condition: mainly affects coastal protection structure

Coastal protection structure

When we design coastal protection structure, we have to consider the extreme condition so as to ensure the stability of the structure against such extreme conditions.

Increase of wave height and water level rise directly lead to enlargement of wave pressure which cause instability of coastal protection structure

Daily condition affects

Coastline change

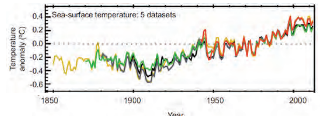
Coastal environment

SLR affects coastline change

change of daily wave action (not extreme wave) will affect the characteristics of sediment transportation.

2.5. Impact of temperature, precipitation, currents

- **Sea Temperature Rise**
  - **Sea temperature rise would cause widespread coral bleaching and fish kills**

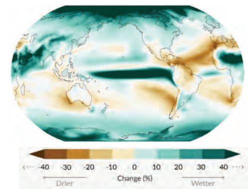


Sea –surface temperature change
Source: IPCC AR5 WG1

- **Increase/ Intensification of Precipitation**

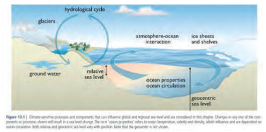

Vanuatu, Mar 2015 *(photo; dailypost.vu)*


PNG, Jan 2018 *(photo; RNZ)*



Future change of precipitation
Source: IPCC Interactive Atlas

- **Change of Ocean Currents**
  Mechanism of change of ocean currents



Source: IPCC AR5 WG1

- Sea Temperature Rise
  - Sea temperature rise would cause widespread coral bleaching and fish kills, which lead to reduction of its preventive functional capacity against coastal erosion and environmental deterioration in coastal areas

- Increase/ Intensification of Precipitation
  - Sediment loads will increase in association with increased river discharge. However, sediment supply to sandy shore will not increase, since sedimentation in the river will be deposited and dredged before reaching sandy shore.

- Change of Ocean Currents
  - Characteristics of littoral drift will be changed, and sandy beaches will be affected.

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3. Adaptation options for coastal protection structure

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3.1. Major Adaptation Measures in Coastal Protection Structure

Major Factor	Impact	Adaptation Measures (■: Hard measure, □: Soft measure)
Beach & Land protection	● Deterioration of protective function due to retreat of shoreline in front of coastal protection facility ● Changes / deterioration of landscapes with sandy beaches ● Decrease in value as a tourism resource, such as impact on leisure (decrease in beaches)	□ Creation of comprehensive sediment management plan ■ Implementation of measures based on the comprehensive sediment management plan ■ Implementation of beach nourishment and erosion countermeasures □ Development of new technology for coastal erosion countermeasures, etc. □ Optimizing land use by seizing the opportunity to set back protection lines and transfer / consolidate urban functions
Coastal protection structures	● Sliding, overturning, and collapsing of the coastal dike ● Damage to covering and superstructure ● Damage to levee & breach due to scouring, overtopping & overflowing ● Deterioration of protective function due to retreat of shoreline	□ Monitoring of sea conditions □ Regular review of external design force based on the latest prediction results □ Facility soundness evaluation □ Understanding the impact on coastal protection facilities when excess external force acts ■ Development of resilient coastal dike □ Examination of the concept of optimal renewal in consideration of life cycle cost ■ Implementation of beach nourishment and erosion countermeasures

Source: Impact and direction of adaptation of climate change in coastal areas, MLIT, Japan, 2015.

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3.1. Major Adaptation Measures in Coastal Protection Structure

Major Factor	Impact	Adaptation Measures (■: Hard measure, □: Soft measure)
Hinterland	● Increase in inundation damage due to overtopping and overflowing ● Increase in inundation damage due to inflow of seawater	□ Understanding the protective function of coastal protection facilities □ Examination of the concept of optimal renewal in consideration of life cycle cost ■ Strategic development of coastal conservation facilities based on areas with high risk of damage and renewal time □ Monitoring of sea conditions ■ Ensuring drainage function in collaboration with related organizations ■ Measures to prevent backflow at high tide □ Support for preparing hazard maps by municipalities □ Analysis and provision of information that contributes to evacuation decisions □ Promotion of evacuation plan formulation and training (including ensuring consistency with operation rules) □ Optimizing land use by seizing the opportunity to set back protection lines and transfer / consolidate urban functions

Source: Impact and direction of adaptation of climate change in coastal areas, MLIT, Japan, 2015.

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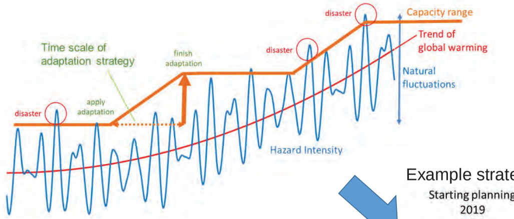
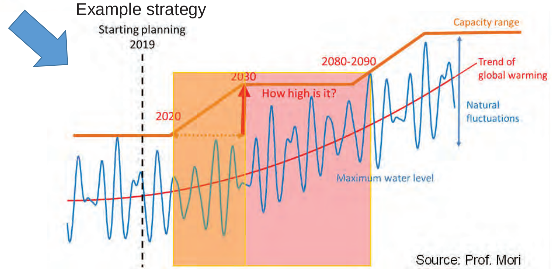
3.2. Development/ Improvement of Coastal Structure



1. **WHAT: rise or stabilization?**
2. **WHEN: Implementation before occurrence of disaster**
3. **HOW MUCH: Natural fluctuations or trend of global warming?**



To develop and improve coastal structure,
- **Time scale of global warming effect**
- **Width of natural fluctuations**
- **Time scale of adaptation strategy**
- **Cost effectiveness**

Source: Prof. Mori

- It is a critical countermeasure for climate change adaptation in coastal area to develop and improve coastal protection structure.
- In development & improvement of these structure, there are 3 key questions.

1. WHAT should we implement: rising the height of structure or increase of stability of the structure?
2. WHEN should we implement: Implementation before occurrence of disaster. Nobody knows when disaster happen.
3. HOW MUCH should we consider the climate change effect?; observation data may include both Natural fluctuations and trend of global warming.
   so we have to distinguish these effects in observation data.

To develop and improve coastal structure, the important factors are
- Time scale of global warming effect
- Width of natural fluctuations
- Time scale of adaptation strategy
- Cost effectiveness

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3.3. Adaptive coastal management

- **In future measures against beach erosion, adaptive coastal management with an emphasis on prediction should be implemented instead of taking measures after the erosion damage has become serious as in the past.**
- **Practice adaptive beach management, and promote the development of monitoring methods**

Adaptive management

Prediction Process
- **Setting of monitoring details**
- **Development of monitoring system**
- **Setting of monitoring method**
- **Implementation of monitoring**
- **Storing monitoring data**
- **Evaluation of beach function in sustainability and inundation prevention**
- **Evaluation of environment and activity in coast**

Adaptive Process
- **Setting of required function**
- **Setting of management index**
- **Amendment of master plan**
- **Planning of countermeasures**
- **Implementation of countermeasures**
- **Evaluation of mechanism of coastal erosion**

Source: Review committee for coastal protection based on climate change, MLIT, Japan

- In future measures against beach erosion, adaptive coastal management with an emphasis on prediction should be implemented instead of taking measures after the erosion damage has become serious as in the past.
- It is very important to practice adaptive beach management, and promote the development of monitoring methods.
- Adaptive coastal management has 2 process: prediction process and adaptive process which interactively cooperate each other.

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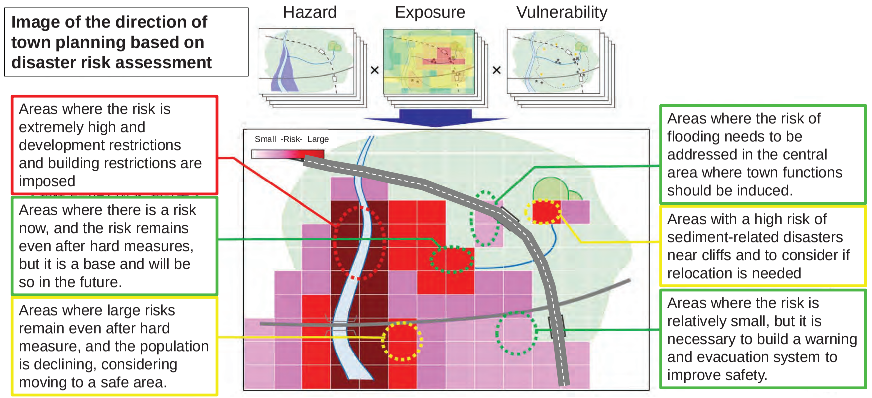
3.4. Direction of town planning based on disaster risk reduction



Source: Guidelines for disaster risk reduction town development based on water-related disaster risk, MLIT, Japan

- Based on the evaluated risks, in principle, we must avoid the risk of water disasters as much as possible in each region. We have to determine the direction of town development considering the necessity of town structure such as the location of important facilities for town functions.
-
- There might be some areas where town functions are concentrated and is necessary for town functions even if the risks remain after implementation of disaster prevention and mitigation measures.
- It is also possible to position such area as town development promotion area with risk avoidance by taking evacuation measures, etc.

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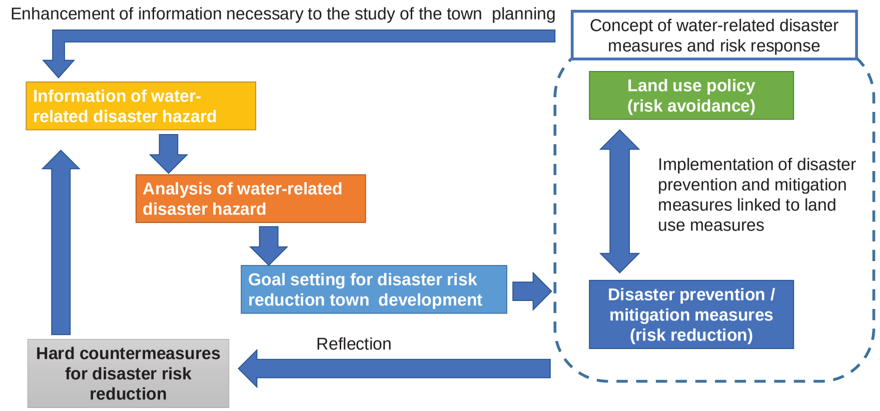
3.4. Cooperation of town planning and disaster risk reduction



Source: Guidelines for disaster risk reduction town development based on water-related disaster risk, MLIT, Japan

- Various approaches can be considered when considering community development from the perspective of disaster risk reduction, but first it is necessary to organize hazard information and enhance the multi-stage hazard information that is necessary for studying community development.
- Based on those water-related hazard information, the risks in the area are analyzed and evaluated and the direction of town development is considered.
- If it is necessary to recognize and accept the risk of water-related disasters and then proceed with town development due to the necessity of town structure and town functions, it is necessary to implement disaster prevention and mitigation measures in combination. At that time, if new hazard information is needed, it is necessary to further enhance the information.

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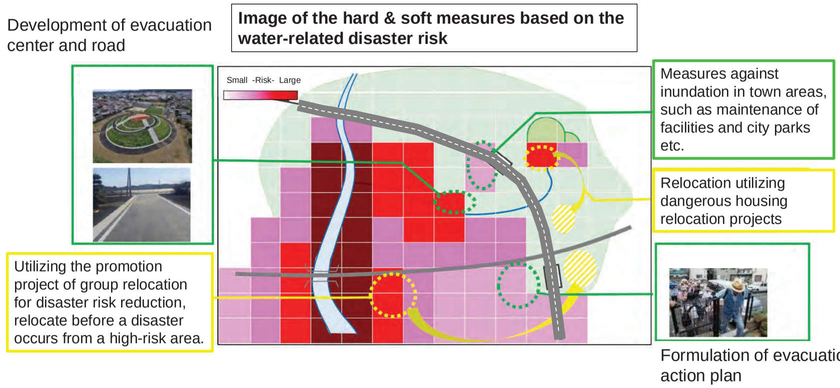
3.4. Disaster risk reduction with town planning



Source: Guidelines for disaster risk reduction town development based on water-related disaster risk, MLIT, Japan

- If community development is promoted in areas where water disaster risk exists, it is necessary to work on disaster prevention and mitigation measures according to the content of the risk.
- If we have areas where the disaster risk is high and is judged that it is not appropriate to proceed with community development, these areas should be relocated to a safer area.
- At that time, careful consensus building with the residents of the area to be relocated is required.

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4. Examples and challenges in the Pacific region

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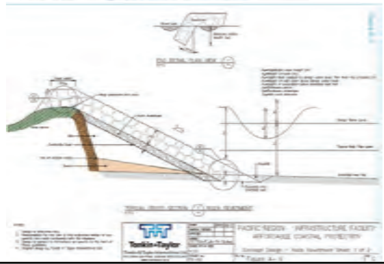
4.1. Rock Revetment

- Rock revetments are conventional land protection structures.
- A geotextile filter fabric placed on a formed backshore slope
- The high porosity provide a form of wave energy dissipation, reducing the reflected wave and wave overtopping.

Climate change adaptation

- Future sea level rise may result in higher water levels and higher waves reaching the structure.
  - ➢ An additional layer of larger rock
  - ➢ Raising the crest of the structure or installing or upgrading a crown wall.

Rock revetment at South Tarawa, Kiribati



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Rock revetments are conventional land protection structures that have been used extensively throughout the Pacific.
- A rock revetment is formed using a geotextile filter fabric placed on a formed backshore slope, overlain by a cushioning layer of small rock, and protected from wave energy by suitably large rock armor.
- The high porosity provided by the voids between the rock, together with the slope, provide a form of wave energy dissipation, reducing the reflected wave and wave overtopping.

Climate change adaptation

- Future sea level rise may result in higher water levels at the structure and higher waves reaching the structure.
  - ➢ Undersized rock can be upgraded by placing an additional layer of larger rock over the undersize rock.
  - ➢ Increased overtopping can be reduced by raising the crest of the structure, using either additional geotextile and rock armor or by installing or upgrading a crown wall.

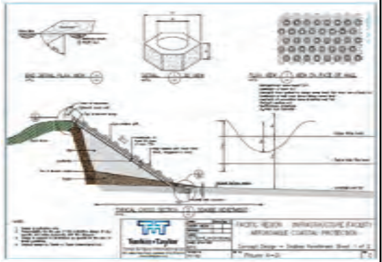
4.2. Seabee Revetment

- Seabees are pattern-placed, hexagonal, interlocking units.
- Once interlocked, the units act as a blanket with a high structural integrity
- Stability is dictated by layer thickness
- Runup can be reduced by using a “paired upstand” design, whereby every third unit is elevated.
- The toe and ends of such blanket walls also require consideration as scour of the toe

Climate change adaptation

- Future sea level rise may result in higher water and higher waves reaching the structure.
  - ➢ Allow for increased future wave height in design
  - ➢ Raising the crest of the structure, using a crown wall or earth bund and additional Seabee units.

Seabee seawall Boigu Island, Torres Strait (Source: P. Riedel, 2005)



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Seabees are pattern-placed, hexagonal, interlocking units.
- Once interlocked, the units act as a blanket with a high structural integrity to mass ratio compared to random placed concrete armor units.
- Stability is dictated by layer thickness and, therefore, the size (width) of units can vary dependent on specific site requirements (placed by hand or machinery).
- While runup for this type of blanket structure is typically higher than for rock, runup can be reduced by using a “paired upstand” design, whereby every third unit is elevated, thus increasing roughness characteristics.
- The toe and ends of such blanket walls also require consideration as scour of the toe or outflanking of the ends may unravel the entire revetment.

Climate change adaptation

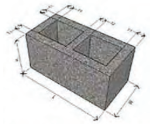
- Future sea level rise may result in higher water levels at the structure and higher waves reaching the structure.
  - ➢ Unit size generally cannot be increased with rebuild, so allow for increased future wave height in design
  - ➢ Increased overtopping can be reduced by raising the crest of the structure, using a crown wall or earth bund and additional Seabee units.

4.3. Concrete Block Revetment

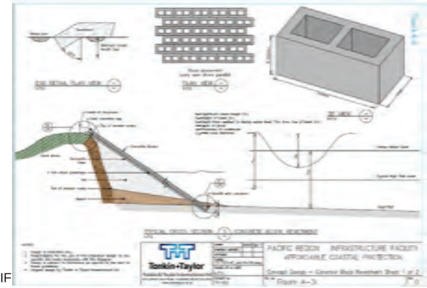
- **A revetment constructed of standard concrete masonry blocks (CMB) or Besser® blocks is proposed as a low-cost alternative.**
- **CMBs have the advantage of being widely available**
- **Without the need for heavy construction equipment.**
- **Disadvantages are that standard blocks are relatively small and low strength.**

Climate change adaptation

- **future sea level rise may result in higher water levels and higher waves reaching the structure.**
  - ➢ **Allow for increased future wave height in design or use alternative material**
  - ➢ **Raising the crest of the structure, using a crown wall or earth bund and additional CMB units.**



Schematic drawing of concrete masonry blocks and model revetment slope (Source: WRL, 2017)



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- A revetment constructed of standard concrete masonry blocks (CMB) or Besser® blocks is proposed as a low-cost alternative to the more established blanket systems, such as Seabees and Terrafix® blocks. CMBs have the advantage of being widely available and/or having existing established supply chains.
- They can be placed without the need for heavy construction equipment.
- Disadvantages are that standard blocks are relatively small and low strength, limiting their stability under wave attack and design life.

Climate change adaptation

- While the design life of this structure is not expected to be long, future sea level rise or a change in El Niño–Southern Oscillation (ENSO) conditions may result in higher water levels at the structure and higher waves reaching the structure.
  - ➢ Unit size cannot be increased, so allow for increased future wave height in design or use alternative material
  - ➢ Increased overtopping can be reduced by raising the crest of the structure, using a crown wall or earth bund and additional CMB units.

4.4. Geosynthetic Container Revetment

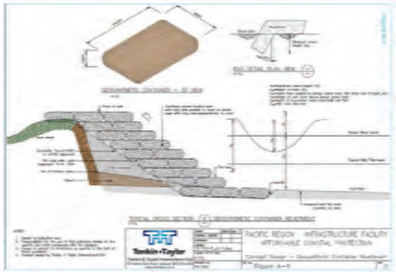
- **Geotextile containers (GSC) are commonly referred to as "geobags".**
- **They comprise a geotextile pillow filled with sand.**
- **Commonly available sizes: 2.5 cubic metres (m3) and 0.75 m3.**
- **Empty containers are light and can be transported readily; however, larger bags require filling frames and slurry pumps with mechanical plant.**

Climate change adaptation

- **Future sea level rise may result in higher water levels and allow higher waves to reach the structure.**
  - ➢ **Placing a larger GSC in front.**
  - ➢ **Increased wave height should be allowed for in design**
  - ➢ **Raising the crest of the structure, using additional GSCs.**

2.5 m3 Elcorock® revetment (James Carley, WRL UNSW)

Scale testing of small hand-placed geotextile bags at WRL



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Geotextile containers (GSC) are commonly referred to as "geobags".
- They comprise a geotextile pillow filled with sand.
- Their use in Australia has been documented in Coghlan et al. (2009) and Hornsey et al. (2011).
- They have been widely used throughout the world. Commonly available sizes in Australia are 2.5 cubic meters (m3) and 0.75 m3, although smaller bags can be manufactured.
- Empty containers are light and can be transported readily; however, larger bags require filling frames and slurry pumps with mechanical plant to assist in placement.

Climate change adaptation

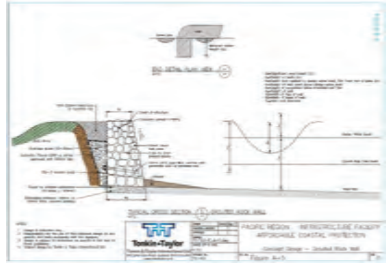
- Future sea level rise may result in higher water levels at the structure and allow higher waves to reach the structure.
  - ➢ GSCs cannot generally be upgraded, except by placing a larger GSC in front. Increased wave height should be allowed for in design
  - ➢ Increased overtopping can be reduced by raising the crest of the structure, using additional GSCs.

4.5. Grouted Rock Wall

- Grouted rock walls are constructed using stone or coral blocks, which are stacked and set in mortar
- Protection from wave impact and support the backing ground by using their weight
- Require a well-founded toe, ideally on a hard stratum
- Alternatively, a deeply embedded toe or rock toe protection can be considered.

Climate change adaptation
- Future sea level rise may result in higher water levels and higher waves reaching the structure.
- Raising the crest of the structure, using a crown wall.

A well-constructed grouted rock wall in New Zealand (left) and informal grouted rock wall in the Republic of the Marshall Islands (right)



Source: Guidance for coastal protection works in Pacific island counties, PRIF

- Grouted rock walls are constructed using stone or coral blocks, which are stacked and set in mortar with a geotextile and drainage layer behind, as well as drains through the structure.
- They provide protection from wave impact and support the backing ground by using their weight and having a broad foundation base to prevent sliding and overturning.
- These structures require a well-founded toe, ideally on a hard stratum, since undermining has the potential to cause rapid and catastrophic failure.
- Alternatively, a deeply embedded toe or rock toe protection can be considered, although these require special design consideration.

Climate change adaptation
- Future sea level rise may result in higher water levels at the structure and higher waves reaching the structure.
- Increased overtopping can be reduced by raising the crest of the structure, using a crown wall.

Summary of this presentation

1. Types of coastal protection structure
    - The types of coastal protection structure/ rigid/ semi-rigid/ dynamic and offshore structures as well as non-structural measures and EbA are explained.
    - The characteristics of these structures should be recognized to identify the optimum measures for your own coast as well as impact of climate change.
2. Impact to coastal protection structure
    - The major climate change impacts are sea level rise, intensification of cyclones, sea temperature rise, increase/ intensification of precipitation, change of ocean currents.
    - Characteristics: Static change (sea level rise) and Dynamic change (storm surge, wave)/ Extreme condition (coastal protection structure) and Daily condition (coastline, environment)
3. Adaptation options for coastal protection structure
    - Major Adaptation Measures in Coastal Protection Structure are divided into 3 categories: 1) beach & land protection, 2) coastal protection structure, and 3) hinterland.
    - Development/ Improvement of Coastal Structure/ Adaptive coastal management/ disaster risk reduction with town planning are explained.
4. Examples in the Pacific region
    - Five cases (rock/ seabee/ concrete block/ geosynthetic container revetment, grouted rock wall) in the Pacific region are explained.

THEORY OF CHANGE IN DEVELOPING BANKABLE PROJECT PROPOSALS

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INSTITUTE FOR GLOBAL ENVIRONMENTAL STRATEGIES
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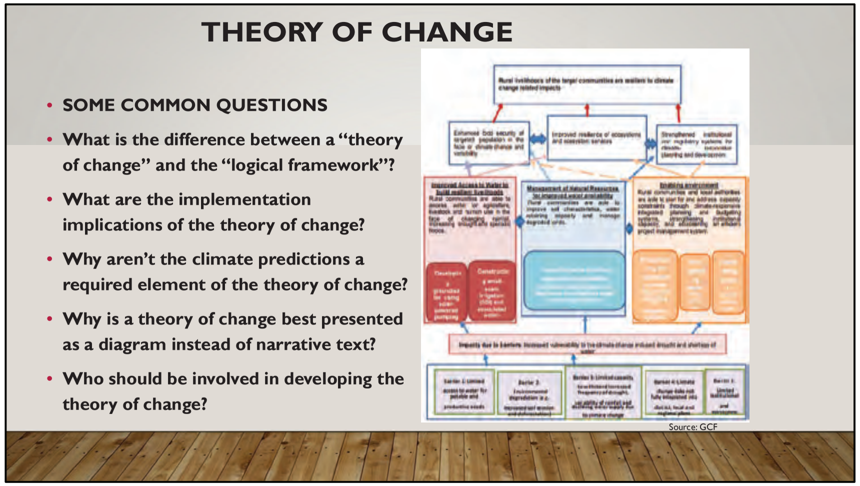
A Theory of Change in developing bankable project proposals.

GCF GUIDANCE ON THEORY OF CHANGE

- The project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address. This determination will form the starting point and basis for the theory of change diagram, which articulates how the project will address the identified problem.
- The theory of change, despite being called a "theory", is a methodological approach that allows AEs and project developers to design and plan a project by first setting up the long-term project goals and objectives then mapping backwards to identify the necessary preconditions to meeting those goals, the project outcomes and outputs, as well as the assumptions under which the theory of change is developed. In this way, the theory of change clearly articulates how the results chain will cascade from the theory of change statement to the project activities.
- The innovation of the theory of change lies in making the distinction between desired and actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on forms of intervention to achieve those outcomes.

GCF has provided guidance on a theory of change, and this presentation will help to understand exactly what GCF is looking for in relation to theory of change.
Firstly, the project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address.
Generally, that's done through a problem tree.
This determination will form the starting point and the basis for your theory of change diagram or narrative, which articulates how the project will address the identified problem.
The theory of change, despite being called a theory. is actually a methodological approach that allows accredited entities and project developers to design and plan a project by first setting up the long-term project goals and objectives and then mapping backwards to identify the necessary preconditions and inputs to meeting those goals.
The project outcomes and outputs as well as the assumptions under which the theory of change is developed.
In this way, a theory of change clearly articulates how the results chain will cascade from a theory of change statement to the project activities.
The innovation of the theory of change lies in making the distinction between what is a desired outcome and the actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on the forms of intervention to achieve those outcomes.



Now some common questions that are often asked in relation to the theory of change.
Firstly, what is the difference between a theory of change and the logical framework? Often, they appear to be used interchangeably.

What are the implementation implications of a theory of change? Why are climate predictions a required element of the theory of change? And why is the theory of change often best presented as a diagram instead of a narrative text?
And who should be involved in developing the theory of change? Well, we'll try and answer some of those questions as we go through the presentation.

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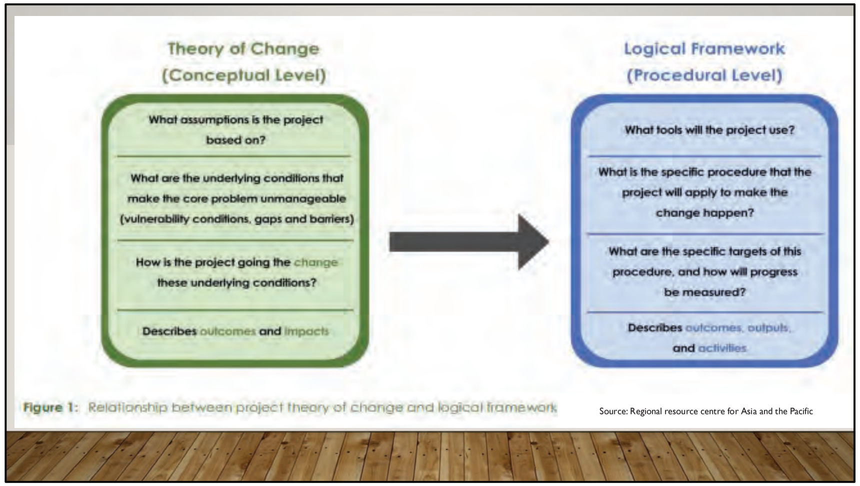


A good way to think about the difference between a theory of change and the logical framework is that the theory of change is essentially at a conceptual level.

So what assumptions is a project based on? What are the underlying conditions that make the core problem currently unmanageable, often through vulnerability assessments or identification of gaps and barriers?

And how is the project going to change these underlying conditions?
It will describe the outcomes and impacts at a high level of the logic chain.
The logical framework, however, is a more procedural arrangement where we look at what tools will a project use, what are the specific procedures that the project will apply to make the change that's desired actually happen?
And what are the specific targets of this procedure and how will progress be measured? And it describes the outcomes, the outputs and activities, as well as the input supports to achieve those activities.

4

LEVELS OF THE LOGIC MODEL

Impact level	Societal change?	Aggregate changes achieved in the GCF key strategic results areas
Outcome level	What changes?	Aggregate changes achieved in the country or region, as well as in the relevant policies and policy documents
Output/project result	What deliverables?	Changes achieved as a result of project or programme activities
Activity	How to deliver results?	Direct services provided through GCF investments
Input	What is needed?	GCF grants, concessional loans, guarantees or other financial instruments, as well as human effort

And there are different levels of the logic model that apply in the theory of change. At the impact level, which is the highest level, we're actually looking for societal change. What are the aggregate changes achieved in the GCF key strategic result areas?

At the outcome level, we're asking what changes? What changes are achieved in the country or region or project area, as well as in the relevant policies and policy documents at the national level? At the output or project result level we're really asking what are the tangible deliverables that the project will provide?
What are the changes achieved as a result of a project or programme activities?
At the activity level we're asking the question how do we deliver the results? And these are the direct services provided through GCF investments. And at the input level we ask what is needed to deliver the results?
These can be the GCF grants, concessional loans, guarantees or other financial instruments as well as the human effort that goes into project implementation.

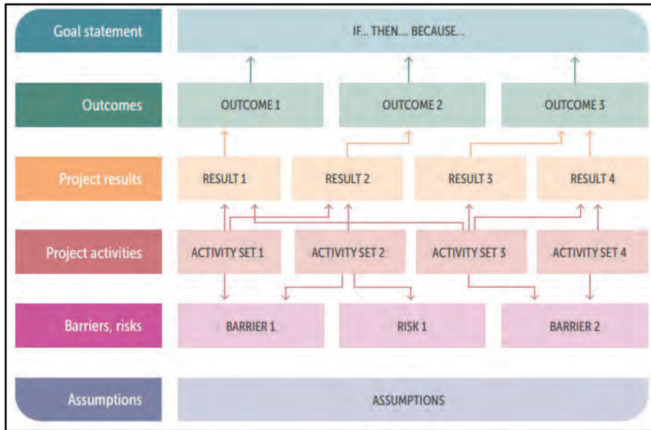
The **climate context** provides the scientific underpinning for evidence-based climate action decision-making and the theory of change for all activities funded by GCF. It ensures that the set of causal linkages between the climate and climate impacts/hazards and action and societal benefits is fully grounded in the best available climate data and science. It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and/or adaptation in terms of reducing GHG emissions or improving the resilience of people and communities and should meet at least one of the eight GCF results areas.

The **theory of change** explains to the funder (GCF) why you think your project will work, and why the funder should expect the project to bring about the results you envision for the project. A good theory of change is like the backbone of a well-designed and fundable project proposal. Many proposals are rejected because they don't include a theory of change, or because the theory of change doesn't adequately show how the project moves from problem to solution.

The climate context provides the scientific underpinning for evidence-based climate action, decision making and the theory of change for all activities funded by the GCF. It ensures that the set of causal linkages between the climate and climate impacts or hazards, and action and societal benefits is fully grounded in the best available and most up to date climate data and science.
It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and or adaptation in terms of reducing greenhouse gas emissions or improving the resilience of people and communities and should meet at least one of the eight GCF resolve areas.

The Theory of Change explains to the funder, that is the GCF, why you think your project will work and why the funder should expect the project to bring about the results you envision for the project.

A good theory of change, therefore, is like the backbone of a well designed and fundable project proposal. Many proposals, in fact, are rejected because they don't include a theory of change or because the theory of change doesn't adequately show how the project moves from problem to solution.



GCF Model Theory of Change

Ref: https://www.greenclimate.fund/sites/default/files/document/gcf-programming-manual_0.pdf

Inputs allow activities to be carried out that will deliver project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

The GCF has provided a standard diagram that is relatively easy to fill in and it basically moves from the understanding of that inputs will allow activities to be carried out that will deliver project outputs which in turn will meet the immediate purpose of the project and contribute to the longer term goal that GCF is trying to achieve through its overarching paradigm shift.
Importantly, the goal statement also operates on a logical basis and says if we carry out activity X then we achieve output Y because we have undertaken a series of inputs.

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TRANSITION FROM PROBLEMS TO OBJECTIVES

Every problem will have multiple causes, so the "art" of project design is to identify a core problem that can actually be solved.

Climate change will not be solved by a single project, but coastal flooding due to sea level rise can be solved.

Source: USAID

Now every problem will have multiple of course.

So the art of project design is to automatically identify a core problem that can actually be solved. Climate change is so enormous and so all encompassing it cannot be solved by a single project. But coastal flooding in a specific area due to sea level rise is something that can be solved through an adaptation project.
So it's really important then to identify a problem which is solvable and then the desired result is something which is actually achievable.

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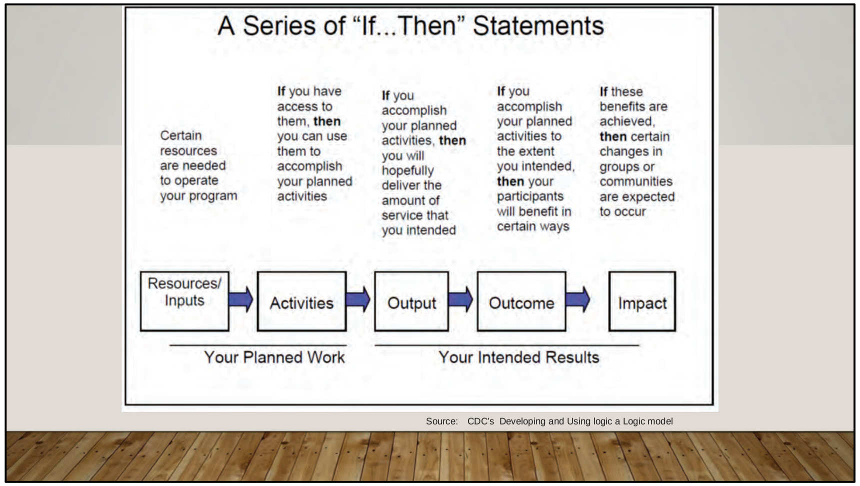


And the logic that underpins the theory of change is that you need certain resources to operate your programme or your project.

These are the inputs and if you have access to these inputs then you can use them to accomplish your planned activities. And if you accomplish your planned activities, then you will hopefully deliver the amount of products and or services that you intended as part of your project design.

And these are the outputs. And if you accomplish your outputs and planned activities to the extent you intended, then your participants or beneficiaries will benefit in certain ways. These are your outcomes.

And if these benefits to the participants and outcomes are achieved, then certain changes in organisations, communities or systems might be expected to occur and contribute to the impact that the GCF is looking for.

GOAL	Sustaining community resilience to climate change risks
GOAL STATEMENT	IF communities have access to safe shelter, water and food supplies all year-round and adopt climate resilient practices in their daily lives THEN community resilience can be sustained BECAUSE they are better prepared for climate change risks
RESULTS (Fund level) – defined by GCF	• A1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions • A2.0 Increased resilience of health and well-being, and food and water security • A3.0 Increased resilience of infrastructure and the built environment to climate change
OUTCOMES (Fund level) – defined by GCF	• A5.0 Strengthened institutional and regulatory systems for climate-responsive planning and development • A6.0 Increased generation and use of climate information in decision-making • A7.0 Strengthened adaptive capacity and reduced exposure to climate risks • A8.0 Strengthened awareness of climate threats and risk-reduction processes
RESULTS (Project level) – defined by the project	• An effective island /district and community development and CCDRR plans • Community-driven climate resilient interventions are implemented and sustained • Strengthened capacity of the Local Government and NGOs /CSOs to support community-based adaptation measures • Strengthened leadership in climate change and disaster risk reduction within the Local Government, NGOs /CSOs and the Community • An operational and effective community-based small grants programme

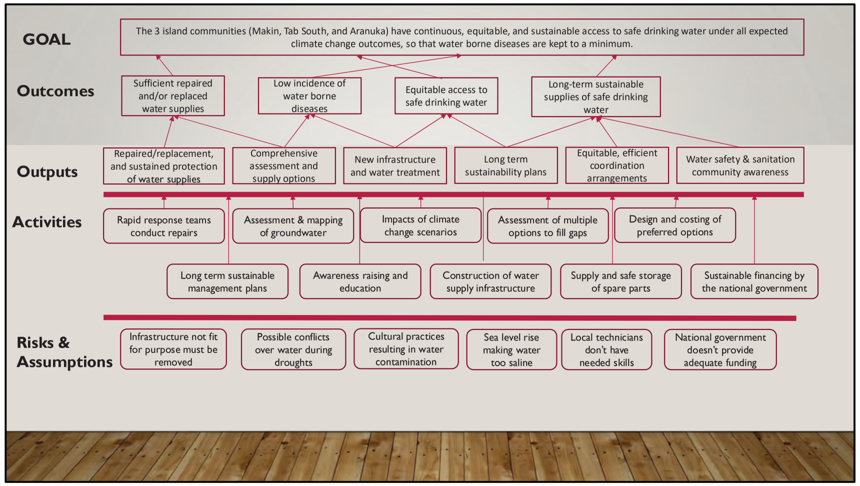
Here is a fairly typical narrative type approach for a theory of change. It starts with an overarching goal which is sustaining community resilience to climate change risks. It has this if then because goal statement if communities have access to safe shelter, water and food supplies all year round and adopt climate resilient practices in their daily lives, then community resilience can be sustained because they're better prepared for any future climate change risks.

And the results which are at the fund level and defined by the GCF are increased resilience and enhanced livelihoods, increased resilience of health and wellbeing, food and water security, increased resilience of infrastructure and the built environment to climate change and these are defined by the GCF and must be reflected in the project design.

Similarly, at the outcome level these are also defined by the GCF and in this case would be a 5.0 through to a 8.0 relating to strengthened institutional and regulatory systems, increased generation and use of climate information, strengthen adaptive capacity and reduced exposure to climate risks and strengthen awareness of climate threats and risk reduction processes.

And the results are actually defined at the project level and are defined by the project proponent and these may be things like an effective island or district and community development with climate change and disaster risk reduction plans. Community driven climate impact interventions are implemented and sustained.

Strengthen capacity of local government and NGOs, strengthen leadership in climate change and DRR within the local government, and an operational and effective community based small grants programme to provide the funding to carry out these interventions.



Here is another version, a simpler version of that rather complicated theory of change.
And here you can see that there is a logical connection between the various activities, the intended outputs, the outcomes and the ultimate goal of the project. And below the line there are the risks and assumptions that underpin the project design.

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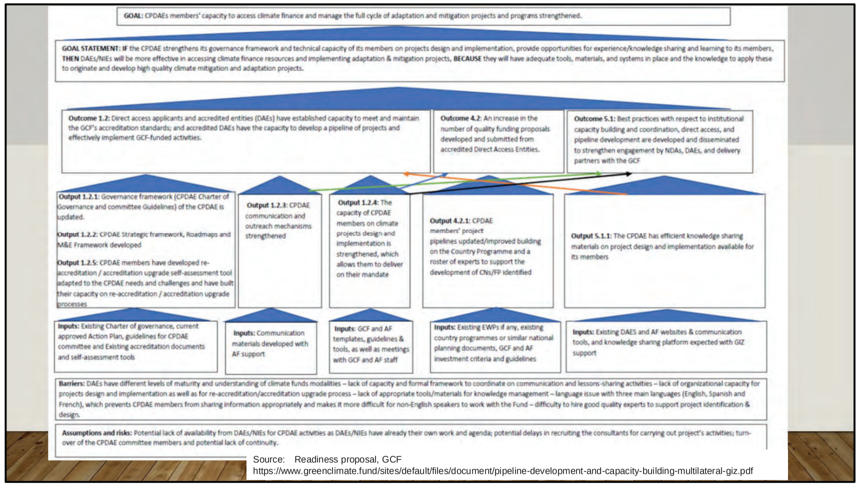

I won't go through the detail of this particular slide is simply to show the kind of diagrammatic format that the GCF is looking for.
In addition to the narrative type approach for the theory of change.

11

CBCRP-PCCC Training Course

“Climate Change Adaptation and Disaster Risk Reduction through structural approaches”

Government of Samoa, SPREP and JICA

Module 3. Problem and Objective trees and logical framework

3.2 Project objectives

Peter King | Senior Policy Advisor
IGES

Tetsuya Yoshida
JICA Short-term Expert
Oriental Consultants Global, Co., Ltd.

THANK YOU FOR YOUR ATTENTION

So I'll leave it there and thank you for your attention. I hope this has given you some insight into what is a theory of change and how important it is in designing a bankable project, particularly for the GCF.

CONTENTS

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Introduction

- In formulating *a climate change adaptation/ mitigation project*, the theory of change and the **logical framework** are key elements.
- They are described as tools of logic that connect cause and effect.
- All projects are designed to overcome a problem, but problems may have multiple causes.
- How do we know if we have identified the **core problem** and the **main causes**?
- All projects are intended to achieve a purpose or a goal and if it fails to achieve that end point (or ultimate effect) then the project is regarded as a failure. In the case of climate change adaptation projects, failure may also result in maladaptation.
- This session is intended to help you come to the right decisions that will lead to a convincing logical framework that will guide successful implementation.

3

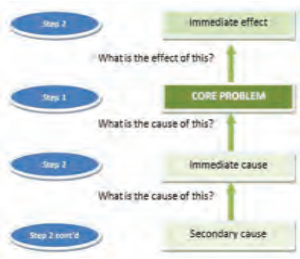
In formulating any climate change adaptation project, the theory of change in the logical framework are key elements but what do they really mean? They're described as tools of logic that connect cause and effect but how do we uncover those connections? Now all projects are designed to overcome a specific problem, but problems may have maltiple causes so how do we know if we have identified the core problem and the main causes? Again all projects are intended to achieve a purpose or a goal and if the project fails to achieve that in point or ultimate effect.

Then, the project is regarded as a failure. In the case of adaptation projects, failure may also result in what's called maladaptation or the opposite to what is expected. So, this session is intended to help you come to the right decisions that would lead to a convincing theory of change and a logical framework that will ultimately guide successful implementation.

Brainstorming a "Problem Tree"

Starting point: construct a **problem tree** that links causes and effects

1. Define "**core problem**"
   - Displacement due to flooding
   - Water/sanitation deficiencies
2. Identify **direct causes** and **direct effects**
   - Cause- Heavy rains
   - Cause- Overburdened infrastructure
   - Cause- Settlement in flood prone areas
   - Cause- Obstructed drains
   - Effect - Increased vulnerability
   - Effect - Damage to infrastructure
3. Identify **secondary (indirect) causes**
   - Rural-urban migration
   - Lack of planning
   - No responsible lead agency
   - Inadequate urban finance



Source: USAID

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We start off with brainstorming a problem tree. A problem tree is something that links causes and effects. It basically has 3 steps. The first step is to define what is a core problem you're trying to solve. It could be something like displacement due to flooding or it could be water or sanitation deficiencies.
Then, you identify the direct causes and the direct effects. The cause of flooding could be heavy rains or could be overburdened infrastructure or it could be settlements in flood-prone areas or obstructed drains. The effect could be an increase of vulnerability of communities or could be damage to roads and other infrastructure.
Then, the third step is to identify the secondary or underlying driving causes. These could be issues like so many people are moving from rural areas to urban areas, could be a lack of urban planning, could be that there is no responsible lead agency driving the process, or it could be that there is inadequate urban finance. The secondary cause leads to the immediate cause. The immediate cause leads to the core problem, and the core problem leads to the immediate effect. That's the logical chain of events that underpins a problem tree.

Brainstorming

- Break participants into small groups.
- Prepare flipcharts, post-it notes, marker pens, and a table to spread out.

- Step 1. Consider what you think **the main problem** is.
- Step 2. Analyse what is **the main cause** of that main problem.
- Step 3. Check if there is **any other cause** of that direct cause.
- Step 4. Re-arrange all the answers in a tree.
- Step 5. Do the same for the effects, identify the **direct effects** and **indirect effects** of that main problem.

- You will be asked to do the same in an exercise in this training course.

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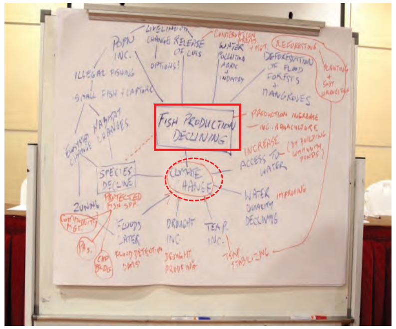
Now to get to the problem tree. The best way of doing this is through brainstorming.
With breaking participants into relatively small groups so that every voice is heard making sure that they're all well equipped with flip charts, post-it notes, marker pens and a table to spread out on. And you start by asking each person what they think the main problem is and write down their answers on a post-it note. In a second-round ask each person what they think is the main cause of that core problem, and in the third round ask if there is any other cause of that direct cause. You rearrange all the answers in the form of a tree with roots and a trunk and some branches, starting off with a consensus on what you believe to be the main or the core problem. Step back from that and check if any key cause has been missed. Now do the same for the effects starting with the direct effects and then possibly secondary or indirect effects.
Now take note of these directions because later on in the course you'll actually be asked to do this in an exercise.

The problem tree is the "engine" of the project design



Source: USAID

- Involve the project beneficiaries and ask them to brainstorm about what they think the problem is.
- Do not assume you know what the real problem is.
- Do not start from an assumption that climate change is the problem.

Useful tips:
- It is critical to identify the core problem right in formulating a project.
- Avoid including contributing causes in the core problem statement.
- Identify one most important issue as the core problem, and avoid including multiple elements in the core problem (e.g. property damage due to severe floods).

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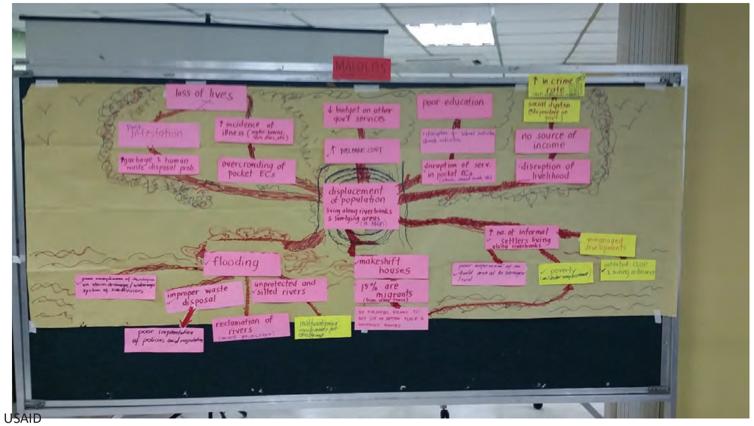
Now the problem tree is really the engine of the project design and it's always advisable to involve the project beneficiaries and ask them to brainstorm about what they think the problem is. As an expert don't assume you know what the real problem is. You may not have sufficient local knowledge. And don't start from an assumption that climate change is a problem simply because you're preparing a concept note for the GCF. In this particular case that I've shown here where the brainstorming is very messy, the participant started with an assumption that
climate change was the core problem but as the brainstorming progressed it was realized that actually the core problem was a decline in fish productivity and climate change was really just one of multiple causes.

Use post-it notes to move things around



Source: USAID

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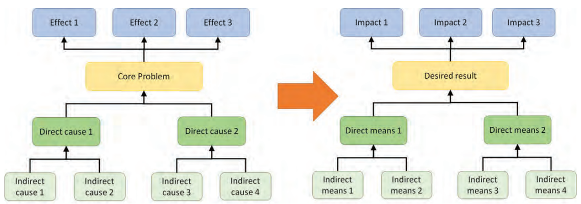
Now the reason we suggest to use post-it notes is so that you can move things around on the roots and branches of the tree that enables you to organize your thoughts in a more logical fashion.

Transition from Problem tree to Objectives tree



Tips:
- Problem tree and objectives tree are mirror images of each other – one negative, the other positive.
- The Means you identify in the Objectives Tree will be the basis of Project Activity in your Logical Framework.

- Every problem will have multiple causes.
- The “art” of project design is to identify a Core Problem that can actually be solved.
- Climate change will not be solved by a single project, but an eroding coastline due to sea level rise can be solved.
- Solving the Core Problem will provide the desired result at the end of the project. This result will contribute to other positive outcomes and long-term impacts.

Source: USAID

Once we have a problem tree worked out, it’s relatively simple to transition from a problem tree to an objectives tree. Every problem will have multiple causes so the art of project design is to firstly identify your core or focal problem that can actually be solved. Climate change is a global problem, it is not going to be solved by a single project but an eroding coastline in a specific location due to the sea level rise can be solved. Now solving the core problem will provide the desired result at the end of the project, but that result in turn will contribute to other positive outcomes and long-term impact beyond the scope of the specific project.

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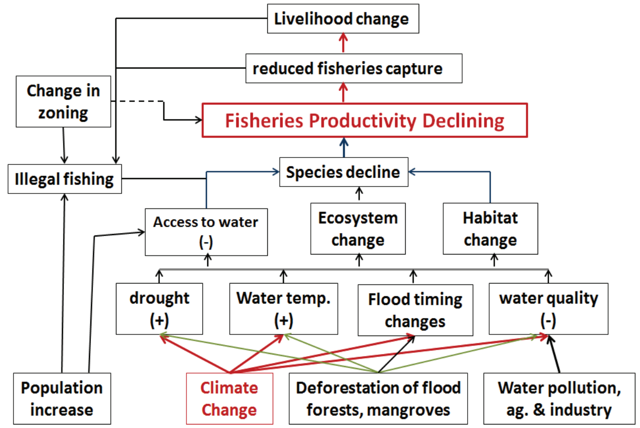
Reorganise the messy brainstorming



Source: USAID

Once you've done that then it's always good to try and reorganize the messy brainstorming approach into something which ultimately could go into a project document and demonstrate some clear thinking in terms of what are the causes, what is the core problem and what are the effects.

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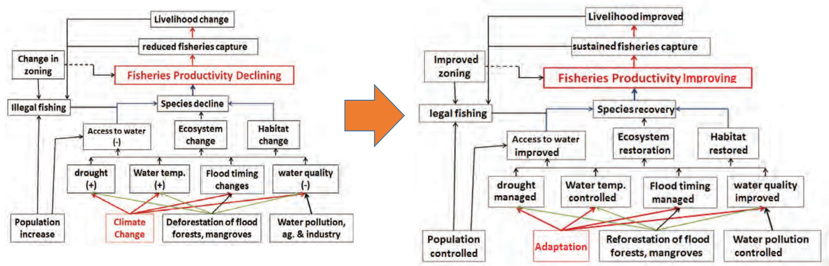
An Objectives Tree

- Objectives trees transform all problems from your Problem Tree into an objective – Each negative problem will become a positive objective.
- Each cause can be transformed into a possible project activity or component. For example, water pollution control or reforestation could be key activities.



Source: USAID

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We come up with an objectives tree by basically transforming all of your problems from your problem tree into an objective. So each negative problem is then turned around to become a positive objective. And note again that climate change might not be the core problem but it could be one of the contributing objectives. Below the core result or project output, each cause can be transformed into a possible project activity or component. For example, in this objectives tree, water pollution control, reforestation or ecosystem restoration could be key activities that ultimately contribute to species recovery and the improvement in fisheries productivity.

Check that no critical cause or effect has been missed

- Once your problem tree and objectives tree have been completed, stand back and discuss if anything has been missed or if a specific cause or effect is too minor to include.
- In the fisheries productivity example, one of the key elements that the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries.
- If this capacity issue was not addressed, then the whole project could fail. Later on we will see why the logical framework would have included this as a potential risk or assumption.

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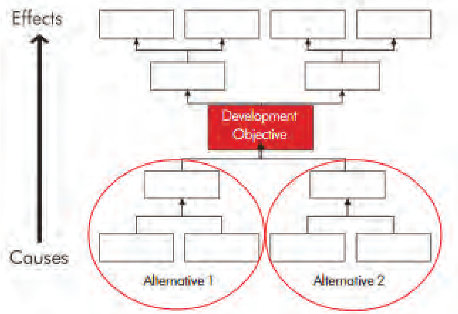
Once your problem tree and your objectives tree have been completed, stand back, have them side by side and discuss if anything is being missed or if a specific cause or effect is too minor to include. In the fisheries productivity example, one of the key elements with the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries. Now if this capacity issue was not addressed, then the whole project could fail and later on we'll see why the logical framework would have included this as a potential risk or an assumption.

Use the objectives tree to decide on project alternatives



- There may be several alternative ways that a project can contribute to the development objective.
- The objectives tree can help to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective.
- In some cases, the objectives tree might highlight the possibility of complementary projects that will combine to reach the central development objective.

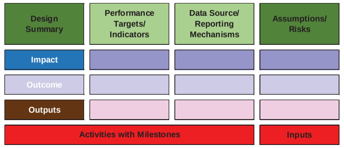
Useful tips:
- Direct Causes and Indirect Causes you identified in the Objectives Tree can be the basis of your Logical Framework (transformed as Project Activity and Inputs).
- You can put only the selected Causes in your Logical Framework which are relevant to your project objectives.

Source: ADB

Now we can also use the objectives tree to decide on project alternatives. There are often several alternative ways that a project can contribute to the development objectives. The objectives tree can help you to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective. In some cases, the objectives tree might also highlight the possibility of complementary projects that will each combine to reach the central development objective.

Logical Framework

- A logical Framework is also called:
  - Project Framework
  - Logframe
  - Project Decision Matrix
  - Results Framework
  - Design and Monitoring Framework

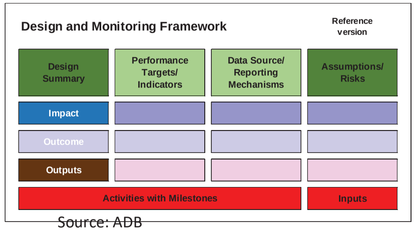


Source: ADB

- Standard sections:
  - **Four Columns** – Design Summary (Description), Performance Targets, Monitoring Mechanisms, and Assumptions and Risks;
  - **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Note hierarchical “logical” relationships vertically and horizontally, link all 20 frames.
- **Inputs** allow **activities** to be carried out that will deliver project **outputs**, which in turn will meet the immediate purpose (**outcome**) of the project and contribute to the longer-term **goal**.

Now turning to the logical framework, sometimes is also called the project framework or shortened to logframe. Sometimes it's called a project decision matrix, a results framework or a design and monitoring framework. These are essentially different terms for the same matrix. There are standard sections. There are four columns: a design summary or description, performance targets, monitoring mechanisms and assumptions and risks. And there are 5 rows: the goal, the purpose sometimes called an outcome, outputs, activities and inputs. So note that there is a hierarchical logical relationship both vertically and horizontally that links together all 20 frames of the logical framework. A way to understand this is that the inputs allow activities to be carried out that will deliver the project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

Performance targets



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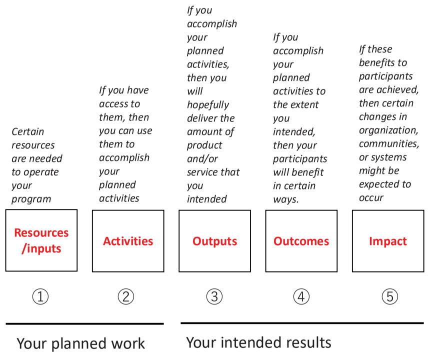

- To ensure that each design "element" is implemented as planned, performance **targets** are specified, as are the mechanisms for **measuring** these targets – plus the **risks** that could upset achievement are explicitly recognized and assumed to be mitigated (by another project, by the government agency, or by other means).
- Unmitigated or unforeseen risks could torpedo an otherwise well-developed project.

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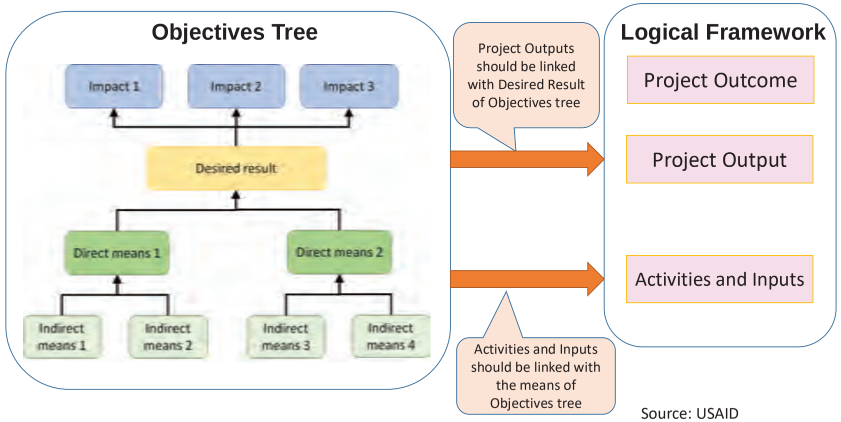
In relation to performance targets, it's important to ensure that each design element is implemented as planned. So, performance targets are specified as well as the mechanisms for measuring those targets. Then in turn, the risks that could upset achievement are explicitly recognized and assumed to be mitigated either by another project, by the government agency or by other means. Unmitigated or unforeseen risks could actually torpedo an otherwise well-developed project. Another way to think about the logic of the logical framework is that your planned work will consist of the resources and inputs that you have available to operate your program. These contribute to a certain number of activities, so if you have those inputs, you can use them to accomplish your planned activities. These in turn lead to your intended results. Firstly, if you accomplish your planned activities, then you will hopefully deliver the amount of product or service that you intended at the end of the project. If you achieve those outputs, then you may benefit wider outcomes at your national level, at the regional level, or at the global level and if you achieve those outcomes
then you may be able to contribute in some way to much broader impact, such as the Paris agreement for example.

Develop the Logical Framework from the Objectives Tree



Source: USAID

Going from the objectives tree to the logical framework is a simple process where the means in the objectives tree are basically what becomes the inputs and activities that lead to the end of project outputs, which is the same as the desired result of the objectives tree. The purpose or outcome and the goals or impacts of the extension beyond the project boundary is equivalent to the results both direct and indirect that come from the objectives tree.

additional indicators and there is a website where you can see those additional indicators that you may use in your own project designs.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 7 and 8 of the document “Mitigation and adaptation performance measurement frameworks” for details.

Logical framework approach of Green Climate Fund (GCF)

H.1.1. Paradigm Shift Objectives and Impacts at the Fund level[1]

Paradigm shift objectives						
Increased climate resilient sustainable development	Please elaborate on the paradigm shift objectives to which the project/programme contributes.					
Expected Result	Indicator	Means of Verification (MoV)	Baseline	Target: Mid-term (if applicable)	Target: Final	Assumptions
Fund-level impacts						
Choose appropriate expected results	*Please select relevant GCF indicators from the Fund's performance measurement framework. More than one indicator may be selected per expected impact result.*					

In this Logframe template (version 2.0), GCF specifies the ultimate goal (paradigm shift), fund-level impacts, and core indicators.
In addition to the core indicators, GCF also suggests additional indicators at:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
https://www.greenclimate.fund/document/integrated-results-management-framework

Paradigm shift objective: Increased climate resilient sustainable development
Fund-level impacts (adaptation):

- ✓ 1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions
- ✓ 2.0 Increased resilience of health and wellbeing, and food and water security
- ✓ 3.0 Increased resilience of infrastructure and the built environment to climate change threats
- ✓ 4.0 Improved resilience of ecosystems and ecosystem services

Core indicators (for adaptation): e.g. Total Number of direct and indirect beneficiaries; Number of beneficiaries relative to total population; Number and value of physical assets made more resilient to climate variability and change, considering human benefits (reported where applicable)

The way the Green Climate Fund approaches the logical framework is worthwhile getting a better understanding as you will often be involved in looking at this framework. The first thing to note is that the ultimate objective or the impact that is intended is specified as a paradigm shift objective of the GCF. Given that the overall mandate for the GCF is a paradigm shift. In the case of an adaptation project, this is increased climate-resilient sustainable development. The GCF also defines fund level impacts and in the case of an adaptation project, there are basically four of these:
increased resilience and enhanced livelihood with the most vulnerable people, communities and regions, increased resilience of health and well-being and food and water security, increased resilience of infrastructure and the built environment to climate change threats, or improved resilience of ecosystems and ecosystem services. Now for each of these impacts GCF has also indicated a number of core indicators. In the case of an adaptation project, it is the total number of direct and indirect beneficiaries plus the number of beneficiaries relative to the total population.
It could also be the number in value of physical assets made more resilient to climate variability and change considering human benefits where applicable. Note that GCF specifies the ultimate goal, the fund level impacts and the core indicators. In addition to these core indicators, the GCF also suggests

Logical framework approach of GCF (cont.)

H.1.2. Outcomes, Outputs, Activities and Inputs at Project/Programme level

Expected Result	Indicator	Means of Verification (MoV)	Baseline	Target Mid-term (if applicable)	Target Final	Assumptions
Project/programme outcomes	Outcomes that contribute to Fund-level impacts					
Choose expected outcome	*Please select relevant GCF indicators from the Fund's performance measurement framework. More than one indicator may be selected per expected impact result.*					
Specify other expected results						
Specify other expected results						
Project/programme outputs	Outputs that contribute to outcomes					
1.						
2.						
3.						
Activities	Description		Inputs	Description		
1.1.			1.1.1.			
1.2.			1.1.2.			
2.1.			1.1.3.			
...			...			

Outcomes (for adaptation)**:**

- 5.0 Strengthened institutional and regulatory systems for climate responsive planning and development
- 6.0 Increased generation and use of climate information in decision-making
- 7.0 Strengthened adaptive capacity and reduced exposure to climate risks
- 8.0 Strengthened awareness of climate threats and risk reduction processes

Outputs, Activities, Inputs:
to be uniquely designed by the project

The latest template of GCF funding proposal and results management framework can be found at:
https://www.greenclimate.fund/document/funding-proposal-template
https://www.greenclimate.fund/document/integrated-results-management-framework

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Moving further down in the logical framework to the outcomes. The GCF also specifies the outcomes. In the case of adaptation projects, these are again four: strength and institutional and regulatory systems for climate responsive planning and development, increased generation and use of climate information in decision-making, strengthened adaptive capacity and reduced exposure to climate risks, and strengthened awareness of climate threats and risk reduction processes. Then to go one step further down to the project or program outputs. These are left up to the program designer or the project designer to specify. Then you come down to the activities and a description of those and the inputs required to achieve each of those activities and again a description of those and that information then goes into your budget proposal.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 9 and 10 of the document "Mitigation and adaptation performance measurement frameworks" for outputs examples of GCF.

Summary of this presentation

- All projects are designed to overcome a problem, but problems may have multiple causes, so a **"problem tree"** helps to sort out cause and effect.
- Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that end point (or ultimate effect) then the project is regarded as a failure. An **"objectives tree"** helps to identify the means of achieving a desired result or **output** at the end of a project, as well as indicating the longer-term **outcomes** and impacts that the project can contribute to.
- The **objectives tree** is simply the mirror image of the problem tree, where all negatives are turned into positives. The objectives tree may also highlight alternative pathways to achieve the desired result as well as indicating the possibility of multiple, complementary projects.
- The objectives tree contributes the "bones" of the **logical framework**, which consists of **Four Columns** – Design Summary, Performance Targets, Monitoring Mechanisms, and Assumptions and Risks; and **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Most funding sources require a logical framework (or equivalent) as a crucial part of any project proposal. The Green Climate Fund (GCF) specifies the ultimate goal (paradigm shift), fund-level **impacts**, and core **indicators**. In addition to the core indicators, GCF also suggests additional indicators for the **outcome** level, while leaving the project **output** targets and indicators to the project designers.

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To summarize, all projects are designed to overcome a specific problem but problems may have multiple causes, so a problem tree helps to sort out cause and effect.
Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that endpoint or ultimate effect then the project is regarded as a failure. An objectives tree helps to identify the means of achieving a desired result or output at the end of a project as well as indicating the longer-term outcomes and impacts that the project can contribute to in some small way. The objectives tree is simply the mirror image of the problem tree where all of the negatives of the problem tree are turned into positives. The objectives tree also highlights alternative pathways to achieve the desired result of the project as well as indicating the possibility of multiple complementary projects to achieve the core objective. The objectives tree contributes
the bones of the logical framework which consists of 4 columns: a design summary, performance targets, monitoring mechanisms and assumptions and risks, and 5 rows: goal purpose, output activities and inputs giving a total of 20 elements that need to be filled in. Now most funding sources require a logical framework or its equivalent as a crucial part of any project proposal. The Green Climate Fund specifies the ultimate goal, that is a paradigm shift, the fund level impacts, which they have pre-defined and the core indicators. In

Reference materials related to GCF

Please note that the below information is as of December 2022 therefore the link to the reference will might be changed.

If the link does not work, please visit the GCF web site (https://www.greenclimate.fund/).

Mitigation and adaptation performance measurement frameworks:

https://www.greenclimate.fund/document/mitigation-and-adaptation-performance-measurement-frameworks

Integrated results management framework:

https://www.greenclimate.fund/document/integrated-results-management-framework

Funding Proposal template:

https://www.greenclimate.fund/document/funding-proposal-template

GCF Programming Manual:

https://www.greenclimate.fund/sites/default/files/document/gcf-programming-manual_0.pdf

Readiness proposal:

https://www.greenclimate.fund/sites/default/files/document/pipeline-development-and-capacity-building-multilateral-giz.pdf

addition to the core indicators, GCF also suggests additional indicators for the outcome level while leaving the project output targets and indicators to the project designers.

Open learning course: List of training materials (Ecosystem sector)

Section		Name of materiala		Type	Length
Module 1	**Understanding of climate risk and vulnerability of ecosystem**				
	Module 1.1	Climate and non-climate impacts on ecosystem			
			IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific	Movie file	14 min.
			Observed and projected climate change in the pacific	Movie file	18 min.
			Observed and projected climate change in the pacific	Movie file	26 min.
			Climate change impact on ecosystem	Movie file	3 min.
			Lecture slides and notes	PDF	-
	Module 1.2	Basic knowledge of the vulnerability assessment of ecosystem			
			Ecossytem and Socio-Economic Resilience Analysis and Mapping (ESRAM)	Movie file	15 min.
			Lecture slides and notes	PDF	-
Module 2	**Ecosystem-based adaptation and mitigation**				
	Module 2.1	Terrestrial and freshwater ecosystems			
			Ecosystem-based Adaptation and Ecosystem-based Mitigation in the context of Terrestrial and freshwater ecosystems	Movie file	2 min.
			Ecosystem-based adaptation and mitigation options for terrestrial and freshwater ecosystems, Option 1: Forest (Adaptation & Mitigation)	Movie file	20 min.
			Ecosystem-based adaptation and mitigation options for terrestrial and freshwater ecosystems, Option 2: Watershed & reservoir (Adaptation)	Movie file	9 min.
			Lecture slides and notes	PDF	-
	Module 2.2	Marine and coastal ecosystems			
			EbA in the context of Coastal and Marine ecosystems (part1)	Movie file	17 min.
			EbA in the context of Coastal and Marine ecosystems (part2)	Movie file	13 min.
			Coastal and Marine ecosystems, Option1, Option2	Movie file	17 min.
			Coastal and Marine ecosystems, Option3	Movie file	23 min.
			Lecture slides and notes	PDF	-
	Module 2.3	EbA Implementation: Cross-cutting Issues and Approaches			
			EbA Implementation: Cross-cutting Issues and Approaches	Movie file	19 min.
			Lecture slides and notes	PDF	-
Module 3	**Problem and Objective trees and Logical framework**				
	Module 3.1	Theory of change			
			Theory of change	Movie file	13 min.
			Lecture slides and notes	PDF	-
	Module 3.2	Project objectives			
			Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
			Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	12 min.
			Lecture slides and notes	PDF	-
	Module 3.3	Exercise			
		Reference: Mitigation - adaptation performance measures		PDF	-
		Template for exercise_logframe template		Word file	-

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CBCRP-PCCC Virtual Training Course

“Ecosystem-based Adaptation and Mitigation”

Government of Samoa, SPREP, and JICA

1. Understanding of risks of climate change impacts on Ecosystem
- **IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific**

Mr Koji Kuroiwa (Engineering)
JICA Short-term Expert
Overseas Business section, Business Management Department
Japan Weather Association

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CONTENTS

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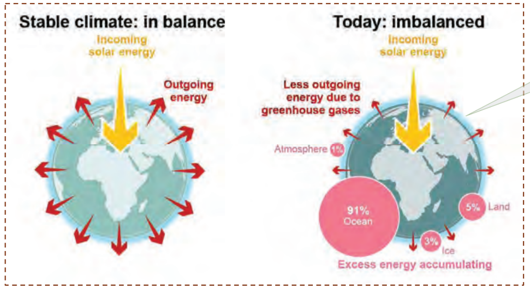
Introduction to climate change in the Pacific - I

Climate change and the Earth's energy budget

- Earth's climate is largely determined by the Earth's energy budget, i.e., the balance of incoming and outgoing energy.
- Since at least the1970s, less energy is flowing out than is flowing in, which leads to excess energy being absorbed by the ocean, land, ice and atmosphere, with the **ocean absorbing 91%**.



*Some of the solar energy is trapped by greenhouse gases such as CO_2, CH_4, and N_2O ; **Greenhouse effect.***

Source: IPCC[1]

Narrative Part

1. Roughly, global warming is the main driver of climate change, causing other various changes like heavier rains and more intense storms. In other words, climate change can be described as "global warming and its consequences".
2. Earth's average temperature is determined by the balance between incoming energy from the sun and the outgoing energy emitted back into space. The left panel shows how our planet receives vast amounts of energy every day in the form of sunlight. About a third of the sunlight is reflected back to space, and the rest is absorbed by the ocean, land, ice, and atmosphere. Normally, these incoming and outgoing energies are in balance, the earth's climate is stable, and the temperature remains constant.
3. In recent years, human activities have unbalanced these energy flows. The right panel shows that outgoing energy is less than incoming because part of the solar energy is trapped increasingly by some gasses in the atmosphere and warm the Earth; they are carbon dioxide, methane, and nitrous oxide - the greenhouse effect process and the cause of global warming.
4. Since the 1970s, the excess energy has warmed the ocean and land and melted ice sheets and glaciers. The ocean absorbs as much as 91% of the excess energy, which leads to long-term sea level rise.

Glossary

➢ **Greenhouse gas (GHG)**

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and

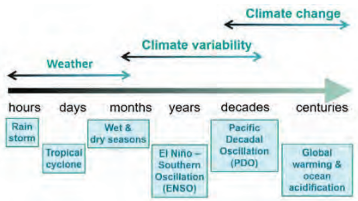
1. Introduction to climate change in the Pacific and IPCC risk-based conceptual framework

Introduction to climate change in the Pacific - III

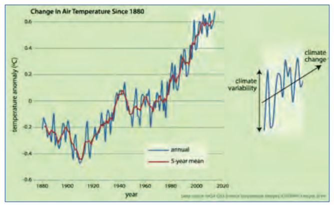
Weather and climate time-scales

- The difference between weather and climate is a matter of time-scale. Climate is sometimes understood as the "average weather" over a long period of time. Climate variability looks at changes that occur within smaller timeframes, such as months, years and decades, and climate change considers changes that occur over a longer period of time, typically over decades or longer.

Illustration of weather/climate time-scales (left) and climate variability/change (right)



Source: PACCSAP



Source: UCAR SciEd

Narrative Part

1. Weather, climate variability and climate change operate on different time scales. Different periods (hours/days/years/centuries) of weather, climate variability, and climate changes are shown on the left panel, including rainstorms that last a couple of hours and tropical cyclones for several days.
2. Weather is highly variable. Climate can be defined as the "average weather" over a long period. The classical period used for describing a climate is "30 years". While weather is variable, climate also shows variability due to internal and external factors.
3. The right panel shows the change in the surface temperature over the past century and suggests the difference between climate and climate variability. Climate variability occurs over months, years, and decades and are defined by climate patterns such as El-Niño Southern Oscillation (ENSO). Other than ENSO, Pacific Decadal Oscillation (PDO) and Interdecadal Pacific Oscillation (IPO) affect the regional climate over much longer terms on decadal scales.
4. The last category, "climate change", occurs over decades and centuries and even much longer time scale. A typical example is global warming.

Glossary

➢ **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

➢ **Pacific Decadal Oscillation (PDO)**

The pattern and time series of the first empirical orthogonal function of sea surface temperature over the North Pacific north of 20° N. The PDO broadened to cover the whole Pacific Basin is known as the Inter-decadal Pacific Oscillation. The PDO and IPO exhibit similar temporal evolution.

➢ **Inter-decadal Pacific Oscillation (IPO)**

A large-scale, long period oscillation that influences climate variability over the Pacific

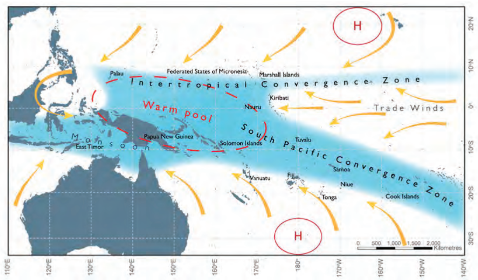
anthropogenic. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Introduction to climate change in the Pacific - II

Large-scale climate features in the W-Pacific

- The South Pacific Convergence Zone (SPCZ), the West Pacific Monsoon (WPM) and the Intertropical Convergence Zone (ITCZ) affect the regional pattern and seasonal cycle in rainfall, winds, tropical cyclone tracks and many other climate aspects of the western tropical Pacific.

Map showing the mean positions of SPCZ, ITCZ and WPM between Nov & Apr



Country	Main features and influences
Cook Islands	SPCZ, sub-tropical highs, trade winds, tropical cyclones, topography
Timor-Leste	WPM, topography
Federated States of Micronesia	ITCZ, WPM, trade winds
Fiji	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Kiribati	ITCZ, SPCZ, trade winds
Marshall Islands	ITCZ, WPM (in some years), tropical cyclones
Nauru	ITCZ, SPCZ, trade winds
Niue	SPCZ, trade winds, sub-tropical highs, tropical cyclones
Palau	WPM, ITCZ, trade winds
Papua New Guinea	WPM, ITCZ, topography
Samoa	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Solomon Islands	SPCZ, WPM, tropical cyclones, topography
Tonga	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Tuvalu	WPM, SPCZ, trade winds, sub-tropical highs, tropical cyclones
Vanuatu	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography

Source: PACCSAP

Narrative Part

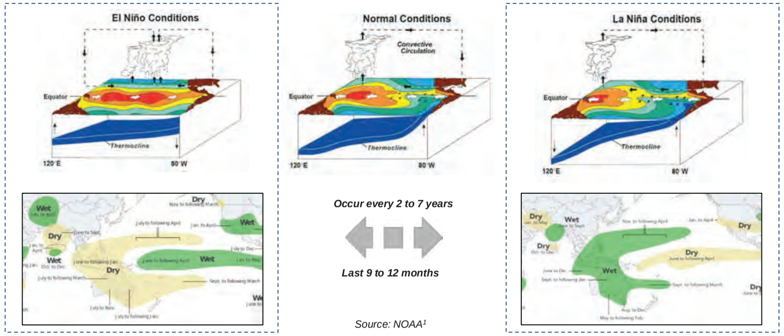
1. The Pacific Ocean covers almost a third of the Earth's surface. It plays an essential role in shaping the climate of the Pacific and the entire globe. The climate of the Pacific is characterized by large-scale climate features and different-sized land masses, which leads to regional variations in climate. At the same time, the El Niño-Southern Oscillation is the source of year-to-year climate variations.
2. The left map shows the average positions of the main features of the regional climate between November and April. The yellow arrows show surface winds; the blue shading represents the bands of rainfall or convergence; the dashed area shows the Pacific Warm Pool, which holds the warmest seawaters in the world. The two rounds stamped by H are high pressures. All these features affect the regional patterns and seasonal cycle of rainfall, winds, tropical cyclone tracks, ocean currents, and many other aspects of the environment of the Pacific.
3. The three extensive bands of large-scale wind convergence are closely associated with rainfall. They are the Intertropical Convergence Zone (ITCZ), the South Pacific Convergence Zone (SPCZ), and the West Pacific Monsoon (WPM).
4. The SPCZ significantly impacts most South Pacific countries, extending from near the Solomon Islands to the east of the Cook Islands. The SPCZ is strongest in the Southern Hemisphere wet season. It stretches across the Pacific just north of the equator and is strongest in the Northern Hemisphere wet season. West Pacific Monsoon is driven by large differences in temperature between the land and the ocean. It moves north to mainland Asia during the Northern Hemisphere summer and south to Australia in the Southern Hemisphere summer. The Monsoon's seasonal arrival usually switches from very dry to very wet conditions.
5. Other aspects of the climate, such as sub-tropical highs, trade winds and tropical cyclones, also impact countries in the Pacific.
6. On larger elevated islands, topography can have a significant effect, so the climate of the key location may not be the same several kilometres away. For example, in Fiji, rainfall is higher in Suva, which is exposed to the southeast trade winds, than in Nadi, which lies on what is predominantly the lee side of the same island. Notable differences in climate also occur within countries that are spread over a

Basin. The IPO operates at a multi-decadal scale, with phases lasting around 20 to 30 years. During the positive phase of the IPO, precipitation is generally higher than normal northeast of the South Pacific Convergence Zone and lower than normal southwest of the SPCZ. Mean sea level pressures are higher than normal to the west of the dateline and lower than normal to the east of the dateline. Due to these pressure differences, there is a southerly flow anomaly during the positive phase of the IPO.

Introduction to climate change in the Pacific - IV

El Niño-Southern Oscillation (ENSO)

- ENSO is a key driver of climate variability in the Pacific, causing short-term changes in climate, including **precipitation patterns** in particular.



Source: NOAA[1]

Narrative Part

1. Climate change is a decades-long event and fluctuates in shorter timescales of months to years, which we call climate variability. Various climate features drive the climate of the Pacific.
2. El Niño-Southern Oscillation (ENSO) is a predominant climate variability for the Pacific and significantly affects regional as well as global climate conditions. ENSO refers to the recurrence of two opposite climate episodes, El Niño and La Niña. Southern Oscillation is the term for atmospheric pressure changes between the east and west tropical Pacific, which accompanies El Niño and La Niña, like a seesaw. As a result, ENSO has distinct impacts on precipitation over most Pacific Island countries.
3. The middle panel shows normal ocean and atmospheric conditions over the Pacific. Typically, trade winds take warm water to the west to create Warm Pool in the western equatorial Pacific. As a result, more clouds are formed where the ocean is warm, and more rainfall is brought.
4. When El Niño occurs, which is shown on the left panel, trade winds weaken, and warm water is pushed back toward the east. Meanwhile, South Pacific Convergence Zone (SPCZ) migrates towards the equator. Typically, it results in wetter conditions in the central and eastern equatorial Pacific and drier conditions in the north of the equator and south-west Pacific.
5. In a La Nina (right panel), trade winds strengthen reversely and take the warm water further to the west. It causes opposite changes to El Nino. ITCZ and SPCZ tend to move away from the equator, drier near the equator, while wetter in the north and southwest Pacific.
6. ENSO events occur every 2 to 7 years and last 9 to 12 months. Typically, El Niño occurs more frequently than La Niña, but, in any case, their frequency is quite irregular.

large area, such as the northern and southern Cook Islands.

7. The right table summarizes the main features and influences on the climate in each country. For example, the Cook Islands are typically influenced by SPCZ, sub-tropical highs, trade winds, tropical cyclones and topography. But when we look at other countries in the west of the region, such as Papua New Guinea, they are typically influenced more by the West Pacific monsoon and the ITCZ. The table also shows that topography is a significant factor in impacting the climate of the mountainous islands.

Glossary

➢ **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

➢ **Inter-tropical Convergence Zone (ITCZ)**

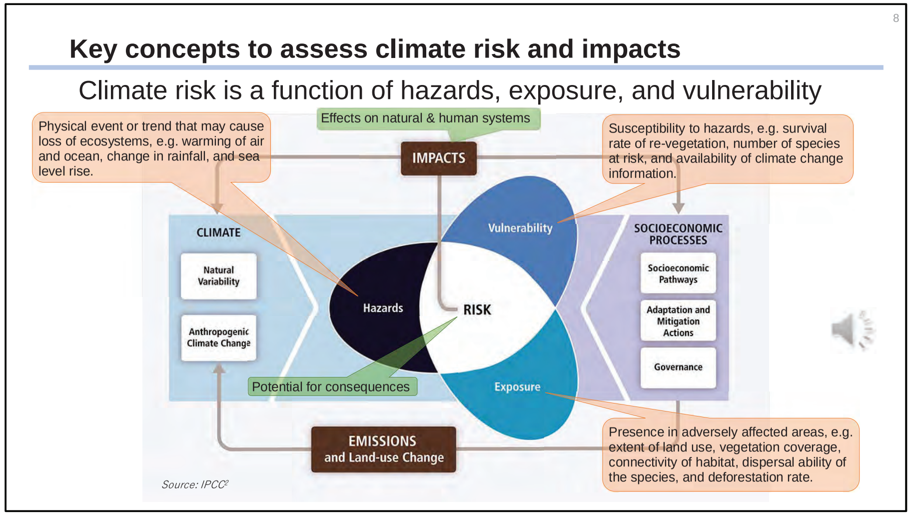
The Inter-Tropical Convergence Zone is an equatorial zonal belt of low pressure, strong convection and heavy precipitation near the equator where the northeast trade winds meet the southeast trade winds. This band moves seasonally.

➢ **South Pacific Convergence Zone (SPCZ)**

A band of low-level convergence, cloudiness and precipitation ranging from the west Pacific warm pool south-eastwards towards French Polynesia, which is one of the most significant features of subtropical Southern Hemisphere climate. It shares some characteristics with the ITCZ, but is more extratropical in nature, especially east of the Dateline.

➢ **Monsoon**

A monsoon is a tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.



Narrative Part

1. Risk-based conceptual framework is a basic scheme for climate risk assessment, which IPCC Working Group-2 (WGII) adopted in its 5th Assessment Report (AR5). Its fundamental philosophy is that risk management is the key to reducing climate change impacts. This concept underlies the discussion of adaptation and mitigation options in a series of PCCC training courses.
2. Various factors determine the rise and fall of Risk. The essence of the AR5's concept is to focus on three main factors of human and natural systems: Hazards, Vulnerability and Exposure
3. Risk emerges from the overlap of Hazards, Vulnerability, and Exposure. There are two approaches to reducing Risk; one is to control Hazards, which can be done through changes in emissions, including anthropogenic sources, and the other is to manage Vulnerability and Exposure. It should be noted that vulnerability and Exposure develop from many different socio-economic processes, and therefore, a wide range of measures to reduce Vulnerability and Exposure can be taken, such as through socio-economic pathways, adaptation and mitigation, and social governance.
4. For the reduction of Risk to Ecosystems, it is vital to identify the significant components of Hazards, Vulnerability, and Exposure related to this sector. Some examples are indicated in balloons in the chart. Hazards will include, for example, "warming of air and ocean", "precipitation change", and "sea-level rise". Regarding Vulnerability, "survival rate" "species at risk", and "availability of necessary information" are considered. For Exposure, you will think of; "change of land-use and habitat", "dispersal ability", and "de-forestation".
5. Vulnerability and Exposure in the Structures have both direct and indirect pathways. Consideration of different factors for Vulnerability and Exposure will provide valuable basics for this training course discussion.

Glossary (Definitions at AR5)

➢ **Hazard**

The potential occurrence of a natural or human-induced physical event or trend or

physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term *hazard* usually refers to climate-related physical events or trends or their physical impacts.

➢ **Exposure**

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

➢ **Vulnerability**

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

➢ **Impacts**

Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

➢ **Risk**

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

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2. Observed and projected climate changes in the Pacific

10

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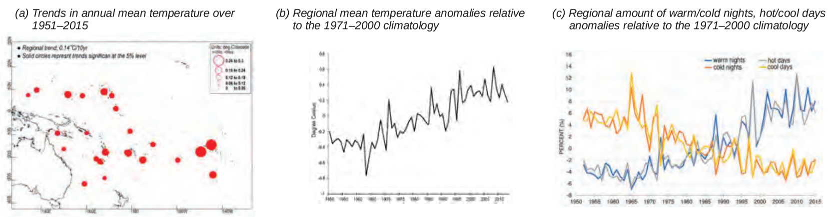
Observed Climate Change

Observed Climate Change – *Temperature II*

Regional surface temperatures

- Warming trends are clearly evident in the small islands, such as those in the Pacific, particularly over the latter half of the 20th century. *(IPCC[7])*
- Significant positive trends ranging from 0.15°C/10yr (1953–2010) to 0.18°C/10yr (1961–2011) are noted in the tropical Western Pacific. *(IPCC[8])*

Recent changes in temperature in the Western Pacific Islands



Source: McGree et al. 2019

Narrative Part

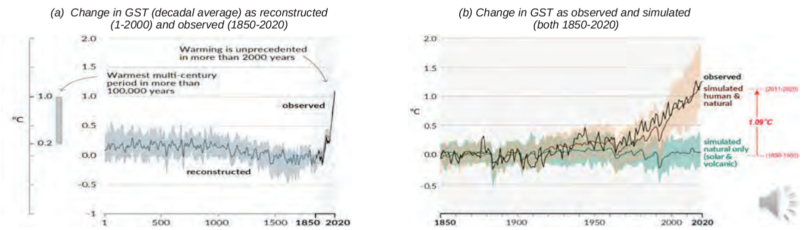
1. Along with the global mean surface temperatures, warming trends are clear at the Pacific Island countries. In the Southwest Pacific, 2020 was the second or third warmest year, depending on the data sets. The warmest year on record was observed in Southern French Polynesia and Tonga. The warming trends in the region have been examined and endorsed by a couple of climate studies, which suggest increases of roughly 0.15° C to 0.18° C per decade.
2. The left panel shows the results of McGree's study from 1951 to 2015 based on the data from 57 stations. Although regional differences exist, most locations indicate warming trends in annual mean temperatures from 0.06 to 0.30, resulting in a regional average of 0.14. In addition, increases in average temperature were found in all seasons throughout the study period.
3. The middle panel was also given from the McGree's, representing the time change of regional average temperature. A warming trend is clear, particularly during the latter half of the 20th century.
4. The study also revealed significant trends in extreme temperatures in the region. The right panel shows the rates of warm nights and cold nights and hot days and cool days, which were derived from daily maximum and minimum temperatures using a percentile analysis. In addition, it shows the increasing trend of hot days and warm nights, which are grey and blue colors, and the decreasing trend of cool days and cold nights, orange and red.
5. Overall, a widespread increase in mean temperature, fewer cool extremes and more warm extremes are represented from 1951-2015.

Observed Climate Change – *Temperature I*

Global surface temperature (GST)

- GST has increased faster since 1970 than in any other 50-year period over at least the **last 2000 years**. *(IPCC[4])*
- It was **1.09°C higher** in 2011-2020 than 1850-1900 with larger increases over land (**1.59°C**) than over the ocean (**0.88°C**). *(IPCC[5])*

Changes in global surface temperature (GST) relative to 1850-1900



Source: IPCC[6]

Narrative Part

1. In the bottom right panel, the black line shows the record of observations by instruments. Temperatures gradually increased from around 1900 after the industrial revolution and have grown much faster since 1970.
2. The brown line is the model simulations that considered the human drivers such as emission of GHGs and natural drivers such as solar and volcanic activities. The green line also shows the simulation of the temperatures but considers only natural effects. The brown lines coincide with observations and well adjust to reality.
3. The left panel shows the temperature change over the past 2,000 years. For the period before the observation started, temperatures were reconstructed from natural archives, such as tree ring data and sea sediments. A dashed line depicts the latest 70-year change in the right panel. The nearly vertical change shows how drastic the recent temperatures increase was. This panel's left is the estimated warmest temperatures over the past more than 100,000 years. It further endorses that the current warming is a historical incident.
4. These findings and the change of GHGs concentrations shown in the previous slide collectively endorse that global warming is attributed to anthropogenic greenhouse effect.

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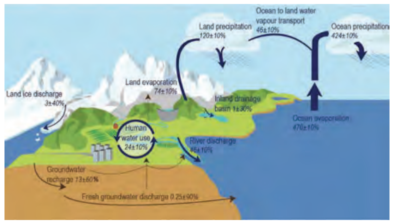
Global Water Cycle; water stores and fluxes

- Global water cycle is the continuous, naturally occurring movement of water through the climate system from its liquid, solid and gaseous forms among reservoirs of the ocean, atmosphere, cryosphere and land.
- While **saline ocean water accounts for 97%** of all water on Earth, **terrestrial freshwater represents less than 2%** and saline groundwater & lakes 1-2%.

Water stores (units in thousands of km³)

⇦ ***Total water on Earth; 1,380,000,000 km3)***

Water fluxes (units in thousands of km³ per year)



Source: IPCC[11]

Narrative Part

1. This slide shows an overview of the global water cycle in the climate system, including water stores or reservoirs on the left, and water fluxes or movement on the right. The water cycle is a complex system but is very important because it let us know how water reaches us.
2. What are water stores in the water cycle? The major stores of water are the ocean, ice caps, land including underground, and the atmosphere. Among these, the ocean is the primary reservoir storing 97% of all water on Earth, mostly as salt water. Liquid freshwater on land forms surface water such as lakes and rivers, soil moisture and groundwater stores, together accounting for less than 2% of global water.
3. What are water stores in the water cycle? The major stores of water are the ocean, ice caps, land including underground, and the atmosphere. Among these, the ocean is the primary reservoir storing 97% of all water on Earth, mostly as salt water. Liquid freshwater on land forms surface water such as lakes and rivers, soil moisture and groundwater stores, together accounting for less than 2% of global water.
4. Focusing freshwater, ice sheets, glaciers and snowpack account for approximately 96% of all freshwater resources, with less than 4% of freshwater considered easily accessible and available for human society's water resource needs.
5. Meantime, some water moves quickly from one place to another. It is illustrated in the right panel, where the continuous movement of water within the Earth and atmosphere is shown as water fluxes. Water fluxes consist of three major processes, that is "evaporation" where water changes phase from liquid to gas or vapor with solar energy, and "condensation" where water vapor cools and joins together into drops of water and clouds, and "precipitation" where water falls from clouds as rain and snow.
6. The largest component of the global water cycle operates over the ocean, where 85% of evaporation and 77% of precipitation occurs at the ocean-atmosphere interface. Meantime, regional evaporation is rather complex to measure, as it depends on a myriad of localized conditions, including wind speed, humidity, and

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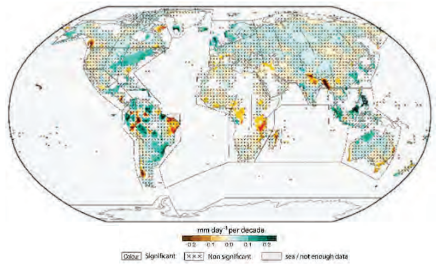
Observed Climate Change – *Precipitation*

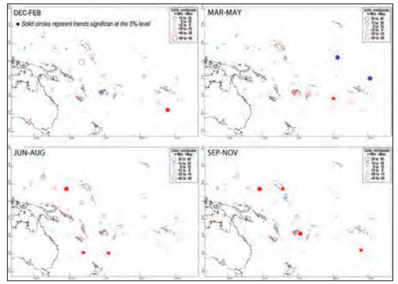
Trends on global and regional scales

- Trends vary spatially and seasonally over Small Island regions in the Pacific. Rainfall has decreased in parts of the Pacific islands poleward of 20° latitude in both hemispheres. However, **trends are not significant** across the globe, including the Pacific. *(IPCC[9])*

Trends of annual precipitation
(1961-2015; CRU TS 4.04)



Trends of quarterly precipitation (mm/decade) at PICs
(1951-2015; positive (blue) and negative (red))



Sources: IPCC[10] (left), McGree et al. 2019 (right)

Narrative Part

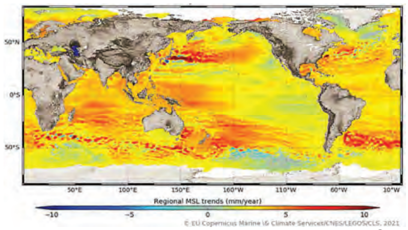
1. Precipitation is a major atmospheric variable, together with temperature. However, compared with temperature, it is much more difficult to find significant changes in precipitation. The left panel shows global trends of annual precipitation over the 55 years from 1961 to 2015. The widespread of x-marks indicates the regions where trends are not significant. A comparison between this chart and that of temperature two slides before demonstrates the difference.
2. The main reasons for the less significance in the precipitation trend analyses are the sparsity and less quality of data, particularly in developing countries, and the large natural variabilities that precipitation has.
3. Nevertheless, some significant increases in land areas are shown in this chart, such as North and South America, Eurasia and northwestern Australia, while decreases are apparent across tropical western and equatorial Africa and southern Asia.
4. Significant trends are not noticeable in the western Pacific region like the global views. Pacific is one of the most data-sparse areas of the world, while interannual and decadal variabilities drive long-term trends in rainfall, as we discussed previously.
5. Four panels on the righthand side depict the findings of regional precipitation trends from the same study in the previous slide. Results are shown in quarterly periods. In the study region, statistically significant annual precipitation trends were only found in the southern subtropics and southwest French Polynesia, both of which are negative. These were associated with negative trends in June to August and from December to February. Significant negative trends were also present from September to November in the north ITCZ and north PNG subregions.
6. Unlike the changes in temperature, which are dominated by background global warming, rainfall patterns in the Pacific are strongly influenced by natural climate variability. Such a regional characteristic makes it difficult to detect rainfall trends.

Observed Climate Change – *Sea Level Rise I*

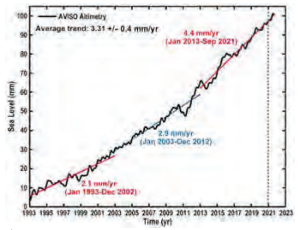
Global mean sea level (GMSL)

- GMSL rose faster in the 20th century than in any prior century over the last three millennia, with a 0.20 m rise over 1901-2018.
- GMSL rise has accelerated since the late 1960s, with an average rate of 2.3 mm/yr over 1971-2018, increasing to 3.7 mm/yr over 2006-2018. *(IPCC[12])*

Regional sea level trend for Jan-1993 to Dec-2020



GMSL evolution for Jan-1993 to Sep-2021



Source: AVISO altimetry

Narrative Part

1. Global mean sea level changes primarily result from ocean warming, leading to the thermal expansion of seawater and land ice melting and adding water to the ocean. As a result, the sea level is continually rising, and it has been found to be accelerating. This has gathered the increasing attention of world scientists.
2. Recent measurements by satellite altimeters revealed that the global mean sea level rise was 2.1 mm per year between 1993 and 2002, 2.9 between 2003 and 12, and 4.4 between 2013 and 21, as shown in the right panel. This rapid step-up was primarily due to the accelerated ice mass loss from glaciers and ice sheets.
3. The regional sea level trends in the left panel demonstrate a considerable variation between the basins. Much of the spatial variation results from natural climate variabilities—such as El Niño and the Pacific Decadal Oscillation—over time scales from months, about a year, to several decades. These climate variations shift surface winds, ocean currents, temperature, and salinity, affecting sea levels. Also accountable are Earth's geological changes, such as changes in Earth's gravity and vertical land motion.
4. The chart shows such variations also in the Pacific. The western tropical Pacific Ocean intensified sea-level rise during the 1990s and 2000s. Ten-year trends exceeded 20 mm yr-1, while sea level trends were negative on the North American west coast.

Glossary

➢ **Altimeter**

Satellites carrying radar altimeters record the surface topography along the satellite's ground track. They precisely measure a satellite's height above water, land or ice by timing the interval between the transmission and reception of very short radar pulses. This is the only technology that can measure, systematically and globally, changes in the height of the ocean – and is therefore essential for monitoring sea-level rise. (ESA)

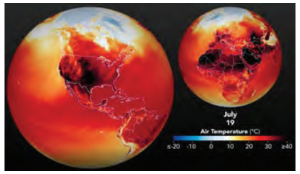
temperature.

7. Discharge of rivers, groundwater, and land ice, as well as water use by human, are also important components of water fluxes. In terms of drinking water and irrigation, recharge and discharge of groundwater is a major contributor in the water fluxes together with precipitation.

Recent topics in climate observation - (global)

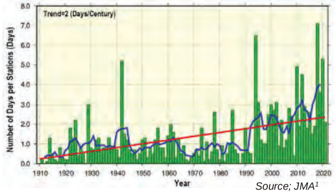
- ✓ Four key climate change indicators – **GHG** concentrations, **sea level rise**, **ocean heat** and ***ocean acidification*** – set **new records in 2021**. *(WMO)*
- ✓ **Over 40°C** was observed in parts of Portugal, Spain, France, US, and UK, which breached the 40°C for the first time. *(WMO)*
- ✓ The frequency of heatwaves **has also been increasing in Japan**. The annual average of the number of days of 35°C or higher for 1992-2021 has been **3.3 times the average** for 1910-1939. *(JMA)*

Daily maximum surface temperature on 19 July 2022



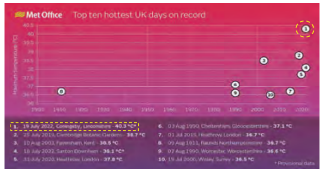
Source; NASA

Annual number of days with Max-temp ≥ 35 °C in Japan



Source; JMA[1]

Top ten hottest UK days on record



Source; Met Office

Narrative Part

1. Recently, the world climate monitoring system has been observing exceptional weather conditions across the globe. Some of the cases are unprecedented and highly suggestive of accelerating climate change. For example, in 2021, four key climate change indicators set new records. In addition to the record-breaking GHG concentration as well as the accelerating global mean sea level, as shown in the previous slides, scientists have revealed that ocean heat made a record high exceeding the 2020 value and that the ocean surface acidity was at its highest "for at least 26,000 years".
2. In 2022, the world had the third warmest July, with prolonged and intense heat waves affecting the US and parts of Europe and Asia. The top right panel displays a snapshot of the global surface temperatures in July. Nearly 40° C temperatures stand out in the US, Asia and Europe. Despite the weak La Niña, which has a cooling influence, northern hemisphere land masses saw well-above-average temperatures, almost predominantly. Temperatures measuring over 40° C were observed in parts of Portugal, Spain, France, and the UK, which breached 40 degrees for the first time. The World Health Organization witnessed more than 1,700 deaths in Spain and Portugal alone.
3. The top ten hottest days on record in the UK after 1900 are plotted on the bottom right panel. It shows nine out of 10 hottest days have been recorded since 1990, including the 40.3° C on 19 July this year.
4. The Japan Meteorological Agency has also noticed a similar trend over the past hundred years, as shown in the left panel. The number of days of 35° C or higher for 1992-2021, the latest 30-year statistical period, has been 3.3 times the average for 1910-1939, the first statistical period of the Agency. This same trend in the two countries clearly endorses the temperature findings in IPCC AR6.

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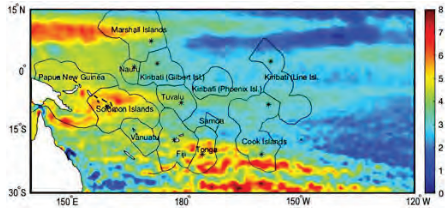
Observed Climate Change – *Sea Level Rise II*

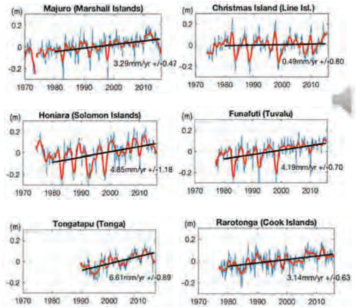
Regional sea level rise

- Across the globe, sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific over the period 1993–2018. *(IPCC[13])*

Rates of sea level rise from satellite altimetry for 1993-2017 (mm/yr)



Monthly and yearly running average of relative sea level measured at tide gauges for 1977-2017



Source: Aucan, J. 2018

Narrative Part

1. Mean sea level can fluctuate over a long period, even for decades. It should be noted that sea level is defined in two different ways: "absolute sea level", which refers to the sea level as measured from the center of the earth, and "relative sea level", which refers to the sea level relative to the coastal area of interest. Absolute sea levels have been monitored by satellite altimetry since 1993, while relative sea levels are by tide-gauges which started in the 1960s in the Pacific.
2. Regarding the sea levels in the Pacific, it's worth noting that satellite altimeters found sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific from 1993 to 2018, among all basins. This slide presents a recent study which demonstrates this typical trend. The left panel shows calculated rates of the regional sea level rise from 1993 to 2017. During this period, results show a rise in sea level of 3-6 mm/year for the Pacific islands, with notable differences between islands. Some islands in the Western Pacific, such as the Solomon Islands, Papua New Guinea, and the Marshall Islands, have experienced a higher rate of sea level rise (up to 6 mm/year), while other islands further east, such as Samoa and Kiribati are much lower. This difference in sea level rise is attributed to large-scale trends in trade winds.
3. Changes of the relative sea level at some selected stations are shown in the panels on the right. Data measured at tide-gauges combines the measurements of satellite altimeters. All show a rise in relative sea level over the past 30 to 40 years and the varied rates between islands. They also demonstrate inter-annual variability, which is attributed mostly to El-Niño Southern Oscillation.

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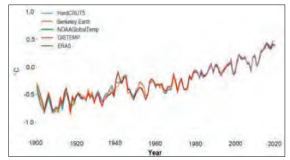
Recent topics in climate observation - (regional)

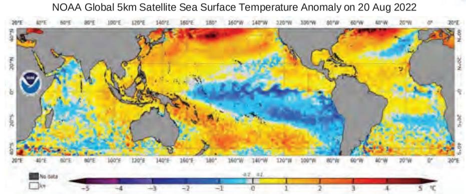
- ✓ In the South-West Pacific region, **2020 was the second or third warmest year** on record.
- ✓ 2020 was **a relatively wet** year over PNG, Solomon Islands, Vanuatu, Fiji, Tonga and Samoa, while many equatorial regions close to IDL were **dry**.
- ✓ PICs were affected straight by the **La Niña** events in 2020-21 and 2021-22. *(On 16 Aug., BoM suggested a 70% chance of a 3rd consecutive La Niña year forming.)*

Area average temperature anomalies from the 1981–2010



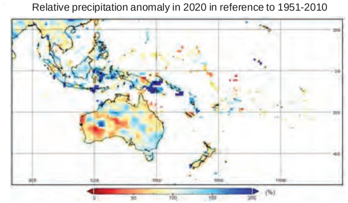
Source; WMO

NOAA Global 5km Satellite Sea Surface Temperature Anomaly on 20 Aug 2022



Source; NOAA

Relative precipitation anomaly in 2020 in reference to 1951-2010



Source; GPCC

Narrative Part

1. The 2020 climate report for the Southwest Pacific issued by WMO emphasized that the significant and growing impacts of extreme hydro-meteorological phenomena and tropical cyclones, plus new multi-dimensional threats, pose increasing challenges to communities in the region. Regarding regional averaged temperatures, 2020 was the second or third warmest year on record. The top right panel shows a consistent increase in the regional average temperature has been demonstrated over the past century.
2. In 2020, the Great Barrier Reef suffered a major marine heatwave. In February, sea surface temperatures over the region were 1.2° C above the 1961-1990 average, making it the hottest month on record. Such high temperatures affected the entire GBR, and widespread coral bleaching was reported.
3. The bottom right panel gives an overall regional rainfall condition in 2020. Under the 2020-21 La Nina and the 2021-22 La Nina, relatively wet conditions continued over the region from PNG and Solomon Islands to Fiji and Samoa from 2020 through early 2022, while lower-than-normal rainfall continued in the equatorial region. During these years, Australia suffered frequent floodings, including the 2022 eastern Australia floods, one of the nation's worst recorded flood disasters.
4. The Bureau of Meteorology stated on 16 August that a third consecutive La Niña is likely from late 2022. The latest monitoring of sea surface temperatures (SSTs) shown in the bottom left represents below-average SSTs extending from the eastern to central tropical Pacific and suggests the possible occurrence of La Nina soon.

18

19

Projected Climate Change

19

experiments involving multiple international modeling teams worldwide.

- CMIP has led to a better understanding of past, present and future climate change and variability in a multi-model framework.
- CMIP defines common experiment protocols, forcings and output.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

➢ **Representative Concentration Pathways (RCPs)**

Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. (Moss et al., 2010). For further description of future scenarios, see Box 1.1 of AR5/WG1.

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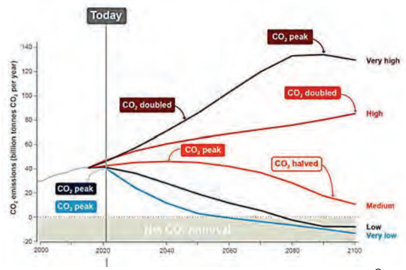
Projected Climate Change – *GHGs*

Greenhouse gases (emission scenario)

■ AR6 considers a set of **five new illustrative emissions scenarios** (Shared Socio-economic Pathways; SSPs). Coupled Model Intercomparison Project Phase 6 (CMIP6) was conducted using these scenarios, and its outcomes served as the main bases of AR6.

New scenarios (SSPs) of annual anthropogenic emission of CO_2 over 2015–2100 (AR6)



Source: IPCC[14]

➢ SSP5-8.5
Very high; Close to RCP*8.5 of AR5. Worst case scenario with no additional climate policy.

➢ SSP3-7.0
High; Between RCP8.5 and RCP6.0. Realistic worst-case with continuing CO_2 emission. Would result in serious consequences.

➢ SSP2-4.5
Medium; Close to RCP4.5 and later RCP6.0. More consistent with government polices but CO_2 emission remain above zero.

➢ SSP1-2.6
Low; Close to RCP2.6. CO_2 emission to plateau and decline after 2025. Temperatures to stay well below 2°C.

➢ SSP1-1.9
Very low; No equivalent RCP. Efforts to remove CO_2 needed. Will meet the Paris goal of limiting global warming to 1.5°C.

- *Representative Concentration Pathways (**RCPs**) are GHG emission scenarios used in AR5.*

Narrative Part

1. AR6 adopted five new scenarios for GHGs emissions called SSP scenarios instead of 4 RCP scenarios in AR5. The new scenarios represent five different socio-economic pathways. World climate scientists performed simulations of climate change based on these scenarios in the Coupled Model Intercomparison Project--Phase 6 (CMIP6), which formed the basis of AR6. The chart below shows SSP scenarios for CO2. IPCC produced SSP scenarios also for other Green House Gases.
    - SSP/585, the Very high emission scenario, is close to RCP8.5. It assumes no measures will be taken to reduce CO2 emissions. CO2 emissions soar up and double from current levels by 2050.
    - SSP/370, the High scenario, was newly introduced. CO2 emissions double from current levels by 2100.
    - SSP/245, the Medium scenario, is an update to RCP4.5. It assumes that climate protection measures are taken. CO2 emissions remain around current levels until the middle of the century.
    - SSP/126, the low scenario, is a remake of the RCP2.6. CO2 emissions decline to net zero around 2080 and goes into net negative emission.
    - SSP/119, the very low scenario, assumes CO2 emissions declines to net zero around 2050 and then net negative.
2. Roughly, Very high scenario is pessimistic as CO2 emissions are unregulated. And Low and Very low scenarios are optimistic as they require drastic measures to reduce CO2 emissions. The recently released AR6/WG3 report suggests that limiting warming to around 1.5° C requires global greenhouse gas emissions to peak before 2025 at the latest and be reduced by 43% by 2030. The next few years are critical.

Glossary

➢ **Coupled Model Intercomparison Project (CMIP)**

CMIP is a project of the World Climate Research Programme (WCRP)'s Working Group of Coupled Modelling (WGCM). Since 1995, CMIP has coordinated climate model cement emissions, land-use change emissions, ocean and land CO2 sinks, and the resulting atmospheric CO2 growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that that is estimated to limit global surface temperature to a given level above a reference period, taking into account global surface temperature contributions of other GHGs and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of equity, costs or efficiency.

➢ **Gigatons of Carbon Dioxide (GtCO2)**
GtCO2 refers to gigaton of carbon dioxide (a gigaton is equal to 1 billion metric tons). GTCO2 (or GtC) is used as the reference unit for the global carbon cycle (Gigaton of carbon = 1 GtC = 1015 grams of carbon. This corresponds to 3.667 GtCO2).

➢ **Carbon cycle**
The term used to describe the flow of carbon (in various forms, e.g., as carbon dioxide (CO2), carbon in biomass, and carbon dissolved in the ocean as carbonate and bicarbonate) through the atmosphere, hydrosphere, terrestrial and marine biosphere and lithosphere.

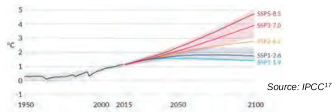
➢ **Cumulative emissions**
The total amount of emissions released over a specified period of time.

Projected Climate Change – *Temperature I*

Global surface temperature (GST)

- GST will continue to **increase until at least the mid-century** under all emissions scenarios. *(IPCC[15])*
- It was reaffirmed that there is a **near-linear relationship** between cumulative anthropogenic CO_2 emissions and the global warming they cause. *(IPCC[16])*

GST change relative to 1850-1900



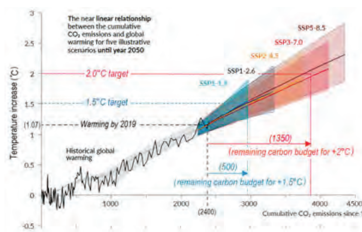
Source: IPCC[17]

Changes in GST under the 5 emissions scenarios

Scenario	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
SSP1-1.9	1.5	1.6	1.4
SSP1-2.6	1.5	1.7	1.8
SSP2-4.5	1.5	2.0	2.7
SSP3-7.0	1.5	2.1	3.6
SSP5-8.5	1.6	2.4	4.4

Source: IPCC[18]

GST increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Source: IPCC[19]

Narrative Part

1. This slide shows one of the main outcomes of CMIP6 projections - global surface temperatures. The top left panel shows the projected change of temperatures under all five scenarios. There is a slow turning point during the mid-century, where the trend becomes relatively flat or even starts to decline for Low and Very-low scenarios while continuing to grow for medium and higher scenarios. The difference can be seen more precisely in the table below.
2. The best estimates of the near-term temperatures are 1.5 degrees or higher for all scenarios. It provides new estimates of the chances of crossing the global warming level of 1.5° C in the following decades. The table also shows the significant difference between Very-low and Very-high scenarios in the long term; it is about 3 degrees.
3. More importantly, hot temperatures include heat waves and growing average temperatures. Such extreme events have highly serious impacts and are projected to occur far more frequently in the near future.
4. The right panel shows the near-linear relationship between temperature increase and cumulative CO2 emission until 2050. This diagram shows that the historical cumulative CO2 emissions from 1850 to 2019 were 2400 GtCO2, resulting in global warming of 1.07 degrees. If the emissions continue, Earth will also continue to warm in the same way.
5. This diagram suggests that if we hope to limit the warming to 1.5 degrees, the remaining carbon budget will be about 500 GtCO2. Similarly, for 2.0 degrees, it will be about 1350 GtCO2. So, it gives us an estimate of the allowable amount of additional CO2 emissions for limiting global warming to any target level. In this regard, we should note that the global emissions of GHGs in 2018 were more than 50 GtCO2 in total.

Glossary

➢ **Carbon budget**
This term refers to three concepts in the literature: (1) an assessment of carbon cycle sources and sinks on a global level, through the synthesis of evidence for fossil fuel and

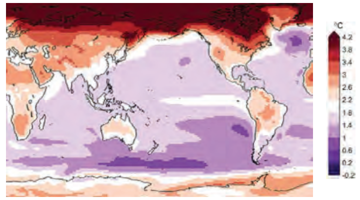
future periods and emissions scenarios or warming levels. A description of the datasets, temporal and spatial scales and dimensions of analysis, as well as the representation of robustness and uncertainty (Cross-chapter Box Atlas.1) are introduced in Atlas.1.

Projected Climate Change – *Temperature II*

Regional surface temperature (RST)

- It is very likely that the significant recent warming trends observed in the small islands **will continue in the 21st century**, which will likely further increase heat stress in these regions. *(IPCC[20])*

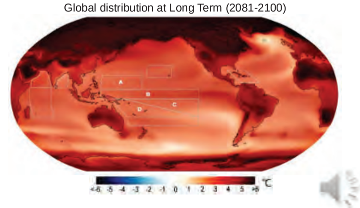
The multi model average projection of 2°C global warming with a color scale centered on +2°C.



Source: RCCAP

Projected changes (°C) relative to 1850-1900 under SSP3-7.0

Global distribution at Long Term (2081-2100)



Global and sub-regional means (°C) at 3 terms

*(**A**: NW-Tropics, **B**: Equatorial Pacific, **C**: Northeast SPCZ, **D**: Southwest SPCZ)*

Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	0.7	1.3	2.6
(B) Equatorial Pacific	0.8	1.4	2.8
(C) NE-SPCZ	0.7	1.2	2.4
(D) SW-SPCZ	0.7	1.2	2.4
GLOBAL	**1.5**	**2.1**	**3.6**

Source: IPCC[21]

Narrative Part

1. The projected warming over the Pacific Island region is relatively moderate compared with the global-average warming for all emissions scenarios. This is linked to the fact that the oceans are warming at a lower rate than land areas, and this clear trend in the observation part is noted.
2. The top right chart shows the increase of regional temperatures at the end of the 21st century under the high emission scenario. It indicates that warming is clear and almost universal. Looking at the western Pacific, changes are relatively uniform over the region; all are around 2 to 3 degrees.
3. Those of areal means of the four sub-regions; NW Tropics, Equatorial Pacific, NE SPCZ and SW SPCZ; were calculated for each of three terms with AR6-Interactive Atlas, where sub-regions are determined based on the average positions of the ITCZ and SPCZ. The results are listed in the table below. Sure enough, changes are roughly comparable from region to region. If anything, warming is slightly larger in the Equatorial Pacific. Anyhow, the smaller-than-global-average trend in the region is evident. The magnitudes of warming are roughly 50% of the global mean for the near term and 70% for the long term.
4. The left panel depicts the regional temperatures at a 2° C global warming. Changes are shown in a finer and specific color scale centered on plus 2° C. Red indicates the areas hotter than the global average, and purple is cooler than the average. It clearly shows that warming is less than the average across the entire ocean, and it is largely uniform over the western Pacific.

Glossary

➢ **IPCC WGI Interactive Atlas**

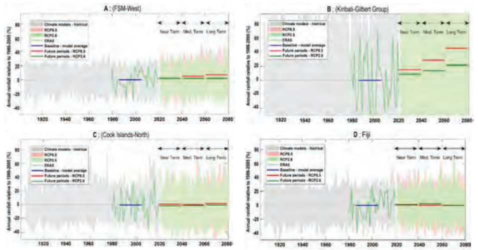
The Interactive Atlas regional information supports the assessment done in the AR6-WGI chapters, the Technical Summary (TS) and the Summary for Policymakers (SPM), allowing for flexible temporal and spatial analyses of trends and changes in key atmospheric and oceanic variables, extreme indices and climatic impact-drivers (CIDs), as obtained from several global and regional observational and model simulated datasets used in the report. These analyses are available for a range of historical and

Projected Climate Change – *Precipitation II*

Regional precipitation

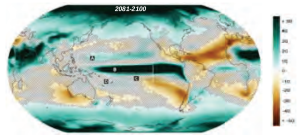
- ENSO will remain the dominant mode of interannual variability, and its influence will strengthen. It is very likely that **ENSO rainfall variability** will increase significantly over the 21st century.
- **Higher evapotranspiration** under a warming climate either amplifies or partially offsets, respectively, the effect of decreases or increases in rainfall. *(IPCC[25])*

Annual mean precipitation change (%) in sub-regions relative to 1850-1900



Source: RCCAP; CMIP5

Annual mean precipitation change (%) relative to 1850-1900 under SSP3-7.0



Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	2.2	3.7	6.2
(B) Equatorial Pacific	10.2	16.1	33.8
(C) NE-SPCZ	4.3	6.0	8.1
(D) SW-SPCZ	1.3	2.1	1.9
GLOBAL	–	–	**4.7**

Source: IPCC[26]

Narrative Part

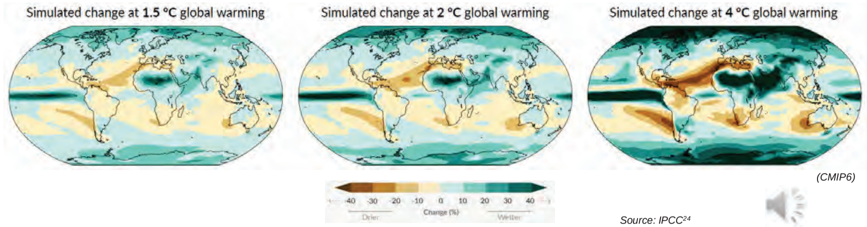
1. In the western tropical Pacific, increases in annual mean rainfall will stand out near the SPCZ and ITCZ.
2. However, as suggested earlier, it is rather challenging to find clear trends in the projection of precipitation changes in contrast to temperature. While the models used by scientists generally agree on how different parts of the Earth will warm, there is much less agreement about where and how precipitation will change. Such difficulties are even more on smaller scales.
3. This is mainly because of the complexity of the water cycle that we saw in the earlier slide. In addition, the scarcity of data, as well as the year-to-year variability of precipitation, is also highly challenging. These hurdles significantly increase uncertainty in model simulations.
4. Still, there were some findings in SMIP5 and 6. The right map is the projection with SMIP6. The models' average shows significant increases in precipitation in the equatorial Pacific, as suggested earlier. Yet, we note again that much of the Pacific region is hatched in the map, meaning the model agreement is low over a wide range.
5. Areal means of the projection were sought for the four sub-regions with the Interactive Atlas, the same as for temperatures in the earlier slide. The results are listed in the table below. Notable increases are shown in the Equatorial Pacific, while other sub-regions are rather flat.
6. Four panels on the left are time-series charts of multi-model means from RCCAP by SMIP5. Each represents the respective subregions. They show the same trend as SMIP6 but are relatively underestimated. In either case, we should note that those projections are just the mid-points of different results from different models with significant uncertainties.

Projected Climate Change – *Precipitation I*

Global precipitation

- **Precipitation is projected to increase** over high latitudes, the **equatorial Pacific** and parts of the monsoon regions but decrease over parts of the subtropics and limited areas in the tropics under Medium, High, and Very-high scenarios. *(IPCC[22])*
- It is very likely that **heavy precipitation events will intensify and become more frequent** in most regions with additional global warming, including the **western tropical Pacific.** *(IPCC[23])*

Annual mean precipitation change (%) relative to 1850-1900



Source: IPCC[24]

Narrative Part

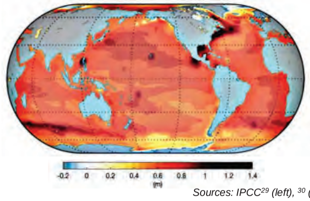
1. Precipitation has a unique characteristic as it represents opposite changing trends over time and space. Roughly, its contrast will become more significant between dry regions and wet regions and between the dry season and rainy seasons. A warmer climate will intensify very wet and dry weather, with implications for increasing flooding or drought.
2. The three maps on this slide show projected changes in annual mean precipitation for a global warming of 1.5 degrees on the left, 2 degrees in the middle, and 4 degrees on the right. The projection of global precipitation is roughly a half-and-half mixture of positive and negative trends. This is the crucial difference with the projection of temperatures. Precipitation will increase over high latitudes, the equatorial Pacific and parts of the monsoon regions but decrease over parts of the dry subtropical regions and in limited areas of the tropics. Models generally agree that precipitation, when it once occurs, will become more intense. Unlike average annual precipitation, almost the entire world is expected to see an increase in extreme precipitation along with global warming. Also, it's worth noting that rainfall variability related to the El Nino-Southern Oscillation (ENSO) is projected to be amplified by the second half of the 21st century under the Medium and higher scenarios.

Projected Climate Change – *Sea level I*

Global mean sea level (GMSL)

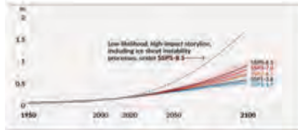
- GMSL will continue to rise over the 21st century; **0.63-1.01 m at 2100** under SSP5-8.5. *(IPCC[27])*
- In the longer term, **sea level is committed to rise for centuries to millennia** due to continuing **deep ocean warming** and ice sheet melt and will remain **elevated for thousands of** years. *(IPCC[28])*

Projected sea level changes at 2100 under SSP3-7.0



Projected GMSL changes relative to the 1900 level

Dashed lines show changes that could occur only in case of high-impact ice-sheet processes.



Sources: IPCC[29] (left), [30] (right)

(AR6)

Narrative Part

1. Projections of sea level rise under five scenarios are given in the two panels in the middle and on the right. The left shows that sea level rise will reach nearly 1 meter at 2100 and then approach 2 meters at 2150 under Very-high scenario. The vertical graph on the right shows further projections for 2300 under Very-low and Very-high scenarios. Sea levels rise will be 0.5 to 3 meters for Very-Low scenario and 2 to 7 meters for Very-high scenario.
2. Interesting to note in these charts is another storyline indicated by the broken lines. Although it is not included in the projections under five scenarios but suggests that, in case the ice-sheets become highly unstable, in Antarctica in particular, sea level rise could present quite a different storyline. It is shown by the dashed curve here; along this line, sea level rise could be 2 meters at 2100 and 5 meters at 2150. Further, at 2300, the sea level could rise by 15 meters or more.
3. Another point is that even if global temperatures peak by the end of this century, it will continue for centuries or even millennia to come, as the oceans, glaciers and ice sheets take time to reach an equilibrium state (or steady state, in other words). We are only at the starting line of the long-lasting sea level rise to come.
4. The global map on the left shows a snapshot of the rising regional sea levels under the high-emission scenario. Although it shows some regional trends, sea level rise should be recognized as a universal trend across the globe.

Projected Climate Change – *Sea level II*

Regional sea levels

- Relative sea-level rise (RSLR) is very likely to continue in the tropical Pacific, where regional-mean RSLR will be **0.4–1.0m** for 2081–2100 (relative to 1995–2014) under the high-emission scenario.
- Even a **5-10 cm** additional SLR will **double flooding frequency** in much of the tropical Pacific.

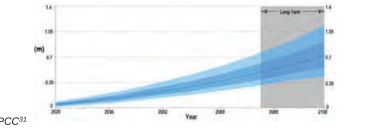
CMIP6-SLR projection relative to 1995–2014 under SSP3-7.0 for Near-, Mid-, and Long-Terms

Projection of SLR for 2081-2100

Sub-regional projections of median RSLR (m) for three terms

	N-Term (2021-2040)	M-Term (2041-2060)	L-Term (2081-2100)
NW-Tropics	0.1 [0.0-0.2]	0.2 [0.1-0.4]	0.7 [0.4-1.0]
EQ-Pacific	0.1 [0.0-0.2]	0.2 [0.1-0.3]	0.6 [0.4-0.9]
NE-SPCZ	0.1 [0.0-0.2]	0.2 [0.1-0.3]	0.6 [0.4-0.9]
SW-SPCZ	0.1 [0.0-0.2]	0.2 [0.1-0.4]	0.6 [0.4-0.9]

Time-series projection of the sub-regional mean for the Equatorial Pacific



Source: IPCC[31]

Narrative Part

1. In consideration of the sea level change on a global scale in the previous slide, we should narrow the focus on the Pacific region. Again, AR6's Interactive Atlas was used to see the results of CMIP6 for the sub-regions under the high-emission scenario. As shown in the top table's multi-model averages for three terms and the time-series projection in the bottom chart, you can see that regional sea-levels will be 0.4-1.0m higher than in 1995-2014 in the long term. Also, together with the projected unique pattern in the long-term on the left, it is clear that differences between the regions are minimal—about 0.1m for the near-term and 0.6m for the long-term.
2. Interestingly, the magnitude of regional sea-level rise projections by models has gradually increased over the past decade, along with global projections. For example, sea-level rise in the western tropical Pacific was projected to be 0.26 to 0.82 m by 2100 under the very high emission scenario in the PCCSP report in 2011. Further, we should note that extreme sea-level events are projected to be more intense and frequent. For example, AR6 estimated that even a small amount of sea-level rise, say 5 to 10cm, could increase the frequency of flooding in the tropical Pacific as early as 2030.

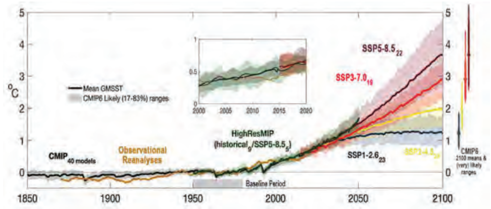
27

Projected Climate Change – *Sea surface temperature (SST)*

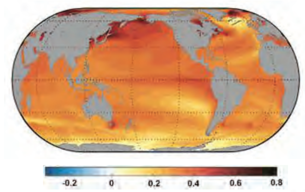
Global mean SST

- Past GHG emissions since 1750 have committed the global ocean to future warming. Over the rest of the 21st century, likely ocean warming ranges from **2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5)** the 1971–2018 change. *(IPCC[32])*

Global mean (SST); modern history and model projections to 2100



SSP5-8.5 CMIP Change Rate (2005-2100)



Source: IPCC[33]

Narrative Part

1. The global ocean has warmed since 1970 and has taken up more than 90% of the excess heat in the climate system, as we have learned in the earlier slide. Regionally, tropical oceans, including the western Pacific, have been warming faster than other regions since 1950.
2. As shown in the left panel, this ocean warming trend is consistent through the 21st century, except for the very-low emission scenario. The right panel shows the SST changes with time. Under the Very-high scenario, ocean warming could range from 4 to 8 times the 1971-2018 temperatures.
3. Notably, the warming of the ocean is irreversible on centennial to millennial time scales. It is also worth noting that the warming will lead to extreme heat conditions across the basins. Marine heatwaves will become more frequent, and the largest increases will be found in the tropical ocean, especially over the western Pacific.

27

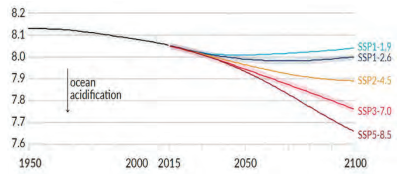
28

Projected Climate Change – *Acidification*

Acidification

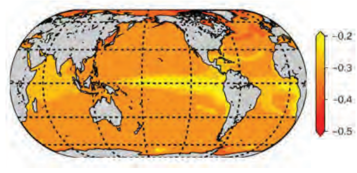
- Upper ocean stratification, ocean acidification and ocean deoxygenation **will continue to increase in the 21st century**, at rates dependent on future emissions. *(IPCC[34])*

Change in global ocean surface pH based on CMIP6 model simulations



Source: IPCC[35]

Change in ocean surface pH for 2081-2100 relative to 1986-2005 under RCP8.5



Source: JMA[2]

Narrative Part

1. Sea water is becoming more acidic across the entire ocean. Along with sea surface temperatures, this acidification trend will continue all through this century under medium or higher emission scenarios. Please take a look at the left panel. Under the Very-high scenario, the ocean pH will reach around 7.7 or less at the end of the century, which is about 0.4 units lower than the present value. Globally, acidification will be faster over the Equatorial Pacific, as shown in the right panel.

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Projected Climate Change – *Tropical Cyclone (TC) I*

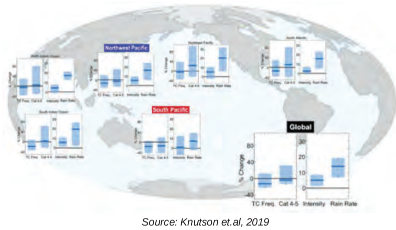
TC projection on the global scale for a 2°C global warming *(AR6)*

- Average peak TC wind speeds
- Proportion of category 4-5 TCs
- Average & Max rain rates associated with TCs
- Peak wind speeds of the most intense TCs

→ **Increase** *(all high confidence)*

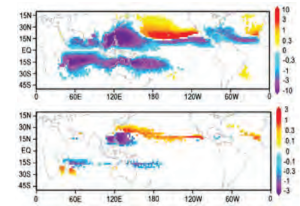
- ◻ Frequency of all TCs → **Decrease or unchanged** *(medium confidence)*

Regional TC projections for a 2 °C global warming



Source: Knutson et.al, 2019

Projected frequency of TCs of all categories (top) and category 4-5 (bottom) for a 4 °C warming.



Source: Yoshida et al, 2017

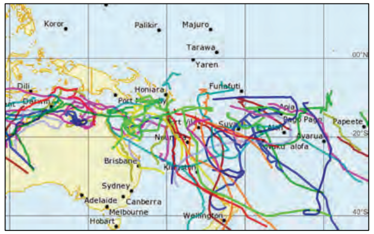
Narrative Part

1. This slide presents the results of two recent studies on tropical cyclones. One is shown in the left map by Knutson et al., indicating the future status under 2 degrees warming, and the other is the two panels on the right by Yoshida et al., showing the projected TC frequencies of all categories on the top and 4-5 categories in the bottom.
2. Regarding tropical cyclones, confidence is low in identifying their long-term trends, such as frequency or intensity, due to changes in the technology used to collect best-track data. In addition, for projection, the simulation capabilities of global models are still challenging. However, recent studies, including those in this slide, suggested several essential features.
3. In summary, mainly from the Knutson's and AR6, average peak TC wind speeds and the proportion of Category 4-5 TCs will very likely increase globally with warming. However, over the western North Pacific, the frequency of Category 4-5 TCs will likely increase in limited regions. This trend in the western North Pacific is suggested in the bottom panel of Yoshida's. Also, average TC rain rates will likely increase with warming, and, finally, the frequency of TCs overall categories will decrease or remain unchanged.
4. Although degrees of some changes are different between the basins, tendencies are less similar for all seven basins, including NW and SW Pacific.

Projected Climate Change – *Tropical Cyclone (TC) II*

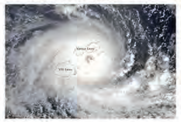
TC projections on the regional scale for S-Pacific *(by RCCAP based on Knutson's)*

- Average TC intensity will increase; *(mid to high confidence)*
- Frequency of category 4-5 TCs will change; *(low confidence)*
- TC rainfall rates will increase; *(mid to high confidence)*
- Sea level rise will increase TC-related storm surge events; *(high confidence)*
- ◻ Frequency of all TCs will decrease; *(high confidence)*



✓ ***All TC tracks during the six seasons from 2012/13 to 2017/18***

TC Winston hit Fiji, Feb. 2016



Source: Southern Hemisphere Tropical Cyclone Data Portal

Narrative Part

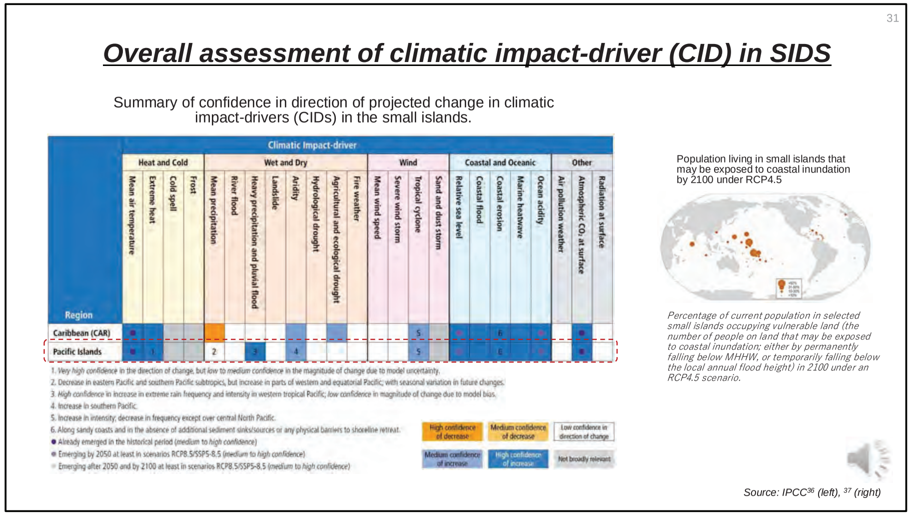
1. Compared with the assessment of TC projections on a global scale, it is much more difficult to discuss it for a specific basin, including the South Pacific. It is partly because of the limited ability of climate models to simulate various climate features and variabilities that influence tropical cyclones, such as ENSO and the SPCZ activity.
2. This slide summarizes the regional assessment by RCCAP for the South Pacific. Assessment is made based on Knutson's and therefore has a lot of commonalities with the global assessment in the previous slide.
3. Points to be underlined are; 1) a clear view that TC frequency will decrease, and 2) an increase of TC-related storm surge is emphasized. Sea level rise will lead to a higher impact of storm surges. It needs to be considered with the projection of more intense TC rainfalls because it could cause the combined effect of storm surge and river flooding in coastal areas.

7. Regarding the “Coastal and Oceanic”, it is notable that all the drivers are categorized as “High confidence of increase”, including acidification, heatwave, sea level, coastal flood and erosion, and sea level rise. In particular, the effect of sea-level rise is considered to continue to be a major threat to small islands and atolls, as it exacerbates the impacts, coupled with storm surges and swells. Projections indicate that shoreline retreat will occur over most of the Pacific and Caribbean small islands throughout the 21st century.
8. The chart on the right illustrates the impact of coastal inundation on small islands. It represents the potential effect of the percentage of the population that may be exposed to coastal inundation. It considers not only environmental but also political and socioeconomic factors and demonstrates the vulnerability of an island to sea level rise. As shown here, it is noteworthy that the islands in the Pacific are far more vulnerable than those of other regions, including the Caribbean.

Glossary

➢ **Climatic impact-driver (CID)**

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral or a mixture of each across interacting system elements and regions. See also Risk, Hazard and Impacts (consequences, outcomes).



Narrative Part

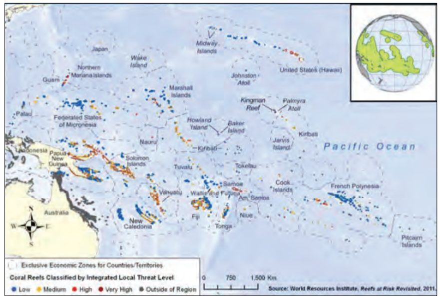
1. In AR6, WGI has introduced the term “climatic impact-drivers”. A climatic impact-driver or CID refers to a long-term condition or an extreme event that directly affects society or ecosystems.
2. The table on this slide shows the regional assessment of CIDs change in the small islands of the Pacific and the Caribbean for mid-century under RCP4.5, the medium scenario. They are most relevant to small islands and will lead to “hazards” in the five primary domains, i.e., (1) “Heat and Cold”, (2) “Wet and Dry”, (3) “Wind”, (4) “Coastal and Oceanic”, and (5) “Other”.
3. The table assesses each CID by representing the confidence in its projected change and thereby suggests the level of confidence which is determined by the existence of robust evidence and model agreement. So, it will help identify the drivers of greater significance to the region. The level of confidence is indicated by the orange colour for decrease, blue for increase, white for no significant trend, and grey for not applicable.
4. Regarding “Heat and Cold”, “Mean air temperature”, and “Extreme heat” are identified as “High confidence of increase”. It suggests significant recent warming trends will continue in the 21st century with an increase in intensity and frequency of temperature extremes, particularly in the Pacific. So, a considerable increase in heat stress will be inevitable.
5. There are many white squares found in “Wet and Dry”. It is mainly because of the complexity of the global water cycle, scarcity of regional datasets, and complex climate variability of the regions. Nonetheless, high confidence is solely given to the increase of “Heavy precipitation and pluvial flood” in the Pacific. It reflects the increase in frequency and intensity of extreme rainfall events in the western tropical Pacific in the 21st century, even for the Low emission scenario. Meanwhile, the increase in “Aridity” is classified with medium confidence for the southern Pacific.
6. For Wind, again, many are in white due to the scarcity of data. Regarding “Tropical cyclones”, the Pacific region will generally face fewer but more intense storms, as we saw in the previous slides. However, we should note that there is a large variance between regions.

31

Climate change impacts – I

- The Pacific region has a rich biodiversity. Its ecosystem services provide vital support for the island nations and their sustainable development. However, the geological features and growing economies of this region make the ecosystems more vulnerable to changing climates.

*Map of estimated **threat level** to coral reefs of Oceania*



Source: World Resources Institute, Reefs at Risk Revisited, 2011

- ✓ *With their isolated nature, Pacific island ecosystems are unique, diverse, and pristine, with large numbers of endemic species.*
- ✓ *Island species populations are, however, relatively small and localized and thus highly vulnerable to natural and anthropogenic disturbances.*
- ✓ *About 23% of the endemic species of the Oceania region are currently threatened, according to the IUCN Red List of Threatened Species.*

Narrative Part

1. The richness of the biodiversity of the Pacific islands is recognized worldwide and is also a significant asset to global biodiversity. At the same time, Pacific islanders enjoy an enormous amount of services from the various ecosystems of terrestrial, freshwater, marine and coastal domains.
2. However, island ecosystems of the Pacific are very fragile because species populations are small, localized, and highly specialized. Corals, for example. The map of this slide suggests that quite a few coral reefs in our region are under significant threat levels.
3. Due to their geographic features, many islands of the Pacific are susceptible to changing climates, including higher air and ocean temperatures, sea level rise, acidification, and more intense storms. All these inevitably affect the Pacific's terrestrial, freshwater, marine and coastal ecosystems.
4. These impacts will be examined in the following slides.

3. Climate Change Impact on Ecosystem

Climate change impacts – II

■ **Terrestrial and freshwater ecosystems**

- ✓ **<u>Terrestrial ecosystems</u>** are threatened mainly by ***precipitation, and temperature patterns change.*** It will make forests more susceptible to ***invasive species*** *and* ***fire*** and lead to broad ecosystem shifts or complete loss of habitat. Endemic species and atoll species have a higher risk of extinction. The species which are already degraded by ***non-climatic threats*** will be increasingly vulnerable to climate change.
- ✓ **<u>Freshwater ecosystems</u>** will be primarily impacted by ***changing precipitation regimes***. Decreasing precipitation regimes will lead to ecosystem transformation, biodiversity loss, contraction of watershed area, and loss of freshwater lens. Increasing precipitation will have largely positive impacts on freshwater ecosystems where they maintain intrinsic integrity.
- ✓ Due to ***<u>strong linkages between marine and terrestrial ecosystems</u>*** on small islands, adverse impacts to one ecosystem will impact other linked ecosystems and species and may result in a decoupling of species linkages and failure of reproduction and biodiversity loss.

Terrestrial ecosystems (SPREP)

Tree snail; Invasive species (PIRCA)

Wetlands of Wallis & Futuna (SPREP)

Source: Pacific Island Biodiversity, Ecosystems and Climate Change Adaptation

<u>Narrative Part</u>

1. Roughly, terrestrial ecosystems in the Pacific Islands are divided between low islands, such as atolls, and high islands, such as volcanic and sub-continental. Warming at high elevations could provoke invasive species problems and alter the distribution of native species. Also, forest loss could seriously affect the richness and abundance of terrestrial ecosystems. In addition, changes in precipitation patterns may lead to increased coastal erosion, a decrease in coastal water quality, and changes in terrestrial species distribution.
2. While the change in precipitation and temperature is a significant threat to terrestrial ecosystems, low island ecosystems lack the elevation gradient and land area for species to adjust their distributions in response to climate change effects. In addition, Atoll species are at additional risk due to habitat loss from sea level rise.
3. Freshwater ecosystems are vital for ecosystem services globally, but they are quite sensitive to the impacts of environmental change. One of the most critical and significant impacts caused by climate change will be the freshwater flow regime. In most cases, climate change and other human-induced stressors will cause much damage to freshwater ecosystems.

Climate change impacts – III

■ **Marine and coastal ecosystems**

- ✓ **<u>Mangrove ecosystems</u>** are threatened by ***sea level rise (SLR).*** In response to SLR, mangroves may migrate landward or increase peat production in place. Where migration is difficult, its ecosystem area will decline or be lost. ***Changes to precipitation*** may influence phase shifts of its systems into other tidal wetland systems, such as salt marshes.
- ✓ **<u>Coral reef ecosystems</u>** are highly threatened by the cumulative threats of ***ocean acidification***, ***rising sea temperature***, ***SLR*** and ***increased storm activity***. These threats will synergistically accelerate the degradation of coral reef ecosystems over the coming decades. Many coral reef ecosystems may lose the structural topology of reefs fundamental to ecosystem service provision.
- ✓ **<u>Seagrass ecosystems</u>** are threatened largely by ***SLR*** and ***rising sea temperatures***. Rapid SLR will generally result in seagrass die-off if species are unable to migrate to a new habitat. Rising sea temperatures will lead to species shifts and seagrass loss.

Mangrove forest damaged by typhoon (Japan Forest Agency)

Coral bleaching of GBR (SPREP)

Seagrass habitat in Fiji (Dr. A. N'Yuert)

Source: Pacific Island Biodiversity, Ecosystems and Climate Change Adaptation

<u>Narrative Part</u>

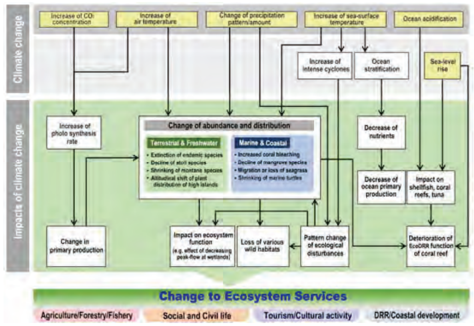
1. For the Pacific marine and coastal ecosystems, changes in sea surface temperature, sea level rise, ocean acidification, precipitation, and storm intensities are the main factors of climate change impact.
2. Sea level rise may already be causing erosion and inundation and makes mangroves to shift landward in the island regions. It is most serious if there is no path for landward migration. Shift in rainfall pattern could alter the freshwater flows to the habitat, changing the salinity and mangrove composition and structure. Mangrove forests are seriously affected by intense storms, but we should also focus our eyes on their important role as a natural defense against the cyclones.
3. Climate change is already impacting coral reefs through bleaching. Increased seawater temperatures are correlated with increased frequency and intensity of mass coral bleaching events and associated mortality in the region. Increase of seawater temperatures is also linked with El Nino which is projected to be more frequent and intense along with climate change.
4. For seagrass meadows, sea level rise and increase of seawater temperature pose main threats to their species distribution and growth rate. Over the past decades there have been several global die-off events. Climate change and additional anthropogenic factors such as runoff of sediments and land-based pollution will be resulting in increasing losses of the ecosystem services from seagrass.

management approaches, or the sustainable management of ecosystems, with disaster risk reduction (DRR) methods, such as early warning systems and emergency planning, in order to have more effective disaster prevention, reduce the impact of disasters on people and communities, and support disaster recovery. Eco-DRR also aims to produce societal benefits in a fair and equitable way, in a manner that promotes transparency and broad participation. (UNDRR)

Climate change impacts on Pacific ecosystems – Summary

- Climate change affects ecosystems through complex and synthesis processes. Its special feature is that the impacts closely interact with human activities through the benefits we receive from the systems, i.e. "*ecosystem services*".

Schematic view of climate change impacts on Pacific ecosystems



- ✓ *Human society relies heavily on various ecosystem services which encompass provision of food and materials, DRR, improvement of air and water quality, and cultural and aesthetic values.*
- ✓ *Such invaluable services may be deteriorated or lost if ecosystems impairs their normal functioning due to climate change impacts.*

Source: Ministry of the Environment, Japan

Narrative Part

1. This slide intends to briefly review the climate change impacts on ecosystems encompassing all the chains, including ecosystem services. Climate change impacts on ecosystems deeply influence a wide range of human activities.
2. The diagram ives a whole picture of climate change impacts on Pacific ecosystems. In addition, it includes some flows that were not covered in the earlier slides of this presentation. Although details are not shown for each flow, attention should be given first to a set of primary climate change variables. Specifically, "change of CO2", "temperatures", "precipitation", "SST", "acidification", and "sea-level rise" at the top of the panel, and their various impacts in the middle part of the diagram are emphasized. We should also note the "change of abundance and distribution of ecosystems" and the relevant sectors at the bottom are affected by the change in ecosystem services↓
3. Human activities, including the primary industries such as agriculture and fishery, social and civil life, tourism, cultural activity, and even disaster risk reduction, are all critical sectors of the Pacific region that benefited from ecosystem services. Therefore, when we discuss the impact of climate change impact on ecosystems, it will be essential for us to look at it from a broader perspective, including this critical aspect of ecosystem services and the continuation of their provision.

Glossary

➢ **Ecosystem services**

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling. (Millennium Ecosystem Assessment: MEA)

➢ **EcoDRR**

Ecosystem-based disaster risk reduction (Eco-DRR) entails combining natural resources

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4. Non-climate factors

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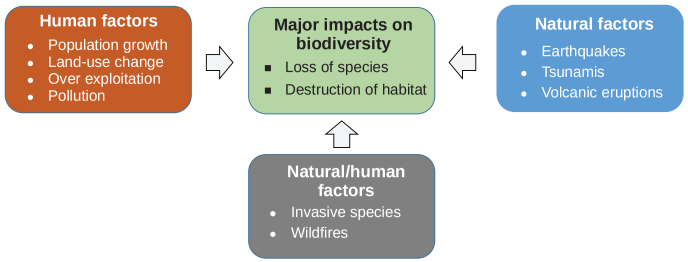
Introduction

- While marine, freshwater and terrestrial ecosystems are faced with such climate hazards as air- /ocean warming, sea-level rise and acidification, the systems are also subject to non-climate factors of natural and human (anthropogenic) origin.
- Ecosystems that are affected by such non-climate stressors will highly increase their vulnerability to climate change.



Narrative Part

1. In this section, non-climate factors affecting ecosystems but not related to climate change are discussed. Such factors affect biodiversity in terms of loss of species and habitat destruction.
2. Similar to the hazards in general, there are three types of non-climate factors. First is those induced by human activities, second is those of natural origin and not affected by human beings, and third is a combination of the two.
3. Indeed, the most immediate threats to Pacific Island biodiversity and ecosystems are non-climate factors. While projected climate change impacts will emerge in the coming decades, these non-climate factors are immediate, severe, and locally generated. As a result, they are a more significant source of ecosystem decline and species loss. Be aware that these factors also increase ecosystem vulnerability to future climate changes.
4. Consideration of various factors affecting ecosystems and recognition of the difference between climate and non-climate factors are vital for making adaptation measures most concentrated.

Human factors – II

➢ Over-exploitation

In the Pacific region, people are heavily dependent on fisheries for food. Over-fishing and exploitation reduce species richness and abundance of marine ecosystems. It also causes ecological shifts, affecting ecosystem productivity and food security. Population decline is detected, particularly for large tuna, sharks and sea turtles.

➢ Pollution

The rapid development of PICs increases liquid, solid and hazardous wastes that undermine ecosystem health and diversity. Pollution from land-based sources includes industrial waste and sewage waste, as well as plastic debris. Ship-based pollution is often widespread and serious, as typified by oil spills from tankers.

Fishing in Solomons (ESRAM)

Solid waste disposal is common to PICs (SPREP)

Plastic threatens marine life (UN)

Oil-spill cleanup in Mauritius, 2020 (UNCTAD)

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Narrative Part

1. Unsustainable exploitation of fish is now common in almost all the countries and territories in the region, involving a wide range of species being exploited beyond their maximum sustainable yield. It is causing a decline in coastal resources, particularly close to urban areas. In the meantime, traditional utilization and management of reefs have been lost in many islands following the change in historical lifestyles and population increase.
2. Pollution affects living resources in many of the heavily populated areas in the region. This includes heavy metals, human waste, solid waste, and agricultural run-off↓. Chemical and solid waste pollution is entirely related to human settlements and activities. It will worsen as populations become more urbanized and adopt disposal-oriented lifestyles. The consequences of pollution significantly impact the health of inshore ecosystems, especially coral reefs, mangroves↑, and seagrasses. Plastic waste is now causing greater concern. More than 100,000 sea animals are estimated to die from swallowing plastic bags.

Human factors – I

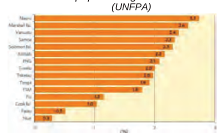
➢ Population growth

Economic development in the Pacific region has led to high-rate urbanization and agricultural expansion. The growing population leads to an increase in pressure on natural resources for food, water and energy. It results in the destruction of habitats and pollution and has come at a high environmental cost, causing degradation and loss of biodiversity.

➢ Land-use change

Land-use change converts terrestrial ecosystems to agricultural, urban, or other human-dominated systems and is a major driver of biodiversity loss. Direct threats include logging, burning and alteration of flow.

Natural population growth rate in 2014 (UNFPA)



Urbanization (SPREP)

Logging for roads (FAO)

Cultivation for farming (FAO)

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Narrative Part

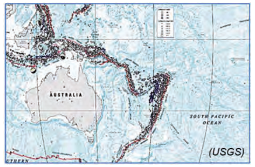
1. Population growth has led to a rapid increase in pressure on natural resources for food, water, and energy in the Pacific. The continued increase of people in this region is an underlying driver of most of the threats to the region's ecosystems. An increase in the population and human activities will place even more significant pressure on the already strained natural resources in the region - resulting in over-exploitation, increased waste and pollution, more invasive species, and habitat destruction.
2. Land-use change, such as for agriculture and forestry, is a process of economic activities and one of the consequential aspects of population growth. Land use and land cover change are significant drivers of biodiversity loss and ecosystem degradation, particularly for terrestrial and freshwater ecosystems. It will affect the structure of the ecosystems, impacting the functions and values of the ecosystem and ecosystem services. Land use and ecosystem services influence each other, and such changes seriously affect human well-being. One thing to note is that land-based development could cause negative impacts of sedimentation on coral reefs.

Natural factors

- Earthquakes, tsunamis and volcanic eruptions

  Earthquakes, tsunamis and volcanic eruptions are geological hazards. They often cause devastating impacts to ecosystems of PICs in terms of loss of species and habitat, primarily due to geographic isolation and limited topographies. Along with the Circum-Pacific Belt of active volcanoes, PICs are inevitably subject to these geological hazards.

Seismicity of SW Pacific for 1900-2018



2009 tsunami in Samoa (SPREP)

Yasur Volcano, Vanuatu (SPREP)

Narrative Part

1. Earthquakes, tsunamis, and volcanic eruptions are all geological hazards and, unfortunately, very common phenomena for many of the Pacific Islands; they are located around the active volcanic zone called the Pacific Ring of Fire. As we all know, their impacts are often catastrophic and take place in a moment. The Great East Japan Earthquake that occurred in 2012 seriously affected the marine and coastal ecosystems, mainly through tsunamis. Damage was enormous for the ecosystem services, fishery and marine culture, and ecosystem-based DRR such as wind-break forests. In the context of limited geographical features, the ecosystems of most of the Pacific Islands are extremely vulnerable to those geological hazards.

Glossary

- **Circum-Pacific seismic belt (Pacific Ring of Fire)**

The world's most significant earthquake belt is found along the rim of the Pacific Ocean, where about 81 percent of our planet's largest earthquakes occur. The belt exists along the boundaries of tectonic plates, where plates of mostly oceanic crust are sinking (or subducting) beneath another plate. Slips between plates and ruptures within plates cause earthquakes in these subduction zones.

- **Tsunamis**

By far, the most destructive tsunamis are generated from large, shallow earthquakes with an epicenter or fault line near or on the ocean floor. These usually occur in regions of the earth characterized by tectonic subduction along tectonic plate boundaries. The high seismicity of such regions is caused by the collision of tectonic plates. When these plates move past each other, they cause large earthquakes, which tilt, offset, or displace large areas of the ocean floor from a few kilometers to as much as a 1,000 km or more. The sudden vertical displacements over such large areas, disturb the ocean's surface, displace water, and generate destructive tsunami waves. (UNESCO/IOC)

Once generated, tsunamis radiate outward in all directions from their source. Unlike wind waves that affect just the surface of the ocean, tsunamis propagate (move) through the entire depth of the ocean, from the surface to the floor. They move at great speeds and have tremendous energy. Large tsunamis can move across entire oceans. The speed of a tsunami depends on the depth of the water it is traveling through. The deeper the water, the faster the tsunami. In the deep ocean, tsunamis can move as fast as a jet plane, over 800 km/h, and can cross entire oceans in less than a day. Pacific Island Countries (PICs) should therefor be attentive also to distant tsunamis from other tsunamigenic regions, the west coast of South America (WSA) for example. (NOAA)

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Natural/human factors

- Invasive species

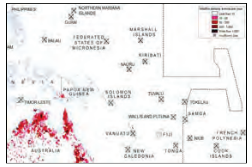
  Invasive species are responsible for more species extinctions than any other threat. Some species arrive naturally on islands (e.g. flying) and other are carried by people either deliberately (e.g. food) or accidentally. With harmful impacts on the natural resources, they can have a great impact on Pacific islanders' traditional activities and modern livelihoods.

- Fires

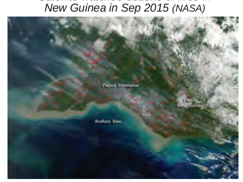
  Most fires are caused by people. Forest fires may lead to broad ecosystem shifts, loss of services in that area, or a loss of habitat completely. Fire is a key threat to terrestrial ecosystems of Pacific Islands.

Invasive species; Giant African Snails (SPREP)

Wildfire density for 1997-2013 (OCHA)



Satellite watched dozens of fires in New Guinea in Sep 2015 (NASA)



Narrative Part

1. Pacific island flora and fauna are particularly vulnerable to invasive alien species, given the historical absence of mammalian predators, grazing herbivores and aggressive weeds (SPREP 2014).
2. Invasive species are introduced species that become destructive to the environment or human interests on Pacific Island terrestrial and marine protected areas. Invasive species can also include some native species that proliferate and become destructive following environmental changes caused by human activities. Native species are plants, animals and other organisms that occur naturally on an island or offshore in a marine environment, having either evolved there or arrived there without human intervention. (SPREP)
3. Every year fires affect an estimated 350 million hectares of land, with damage to property and livelihoods and frequent loss of life. Uncontrolled vegetation fires also contribute to global warming, air pollution, desertification and loss of biodiversity. Fire prevention is one of the most effective counter-measures, and efficient fire monitoring can help in early warning, intervention decision- making and measuring impacts.
4. Developing countries are often the most susceptible to the damaging impacts of fire which causes loss of human lives and property and destruction of natural resources. (FAO)

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   - [3]: WGI AR6; SPM-9 (A.2.1)
   - [4]: WGI AR6; SPM-9 (A.2.2)
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   - [30]: WGI AR6; Figure SPM.8 d)-middle, e)-right
   - [31]: WGI Interactive Atlas; CMIP6 projections
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   - [34]: WGI AR6; SPM-28, B.5.1
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CBCRP-PCCC Training Course

“Ecosystem-based Adaptation and Mitigation”

Government of Samoa, SPREP and JICA

Module 1.2 Basic knowledge of vulnerability assessment of ecosystem

Ecosystem and Socio-Economic Resilience Analysis and Mapping (ESRAM)

Fred Siho Patison – Climate Change Finance Readiness Advisor
Secretariate of the Pacific Regional Environment Programme
Email: fredp@sprep.org

1

SPREP PROE

Presentation Outline;

- What is Ecosystem-based Adaptation to Climate Change.
- What is the ESRAM and Objectives
- Major Steps in the ESRAM Process
- Wagina ESRAM Case Study

2

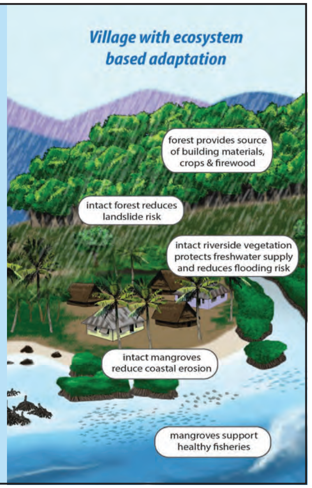
SPREP PROE

Ecosystem- based adaptation (EbA)

- EbA Definition;

“the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.” CBD Ad Hoc Technical Expert Group on Biodiversity and Climate Change

3



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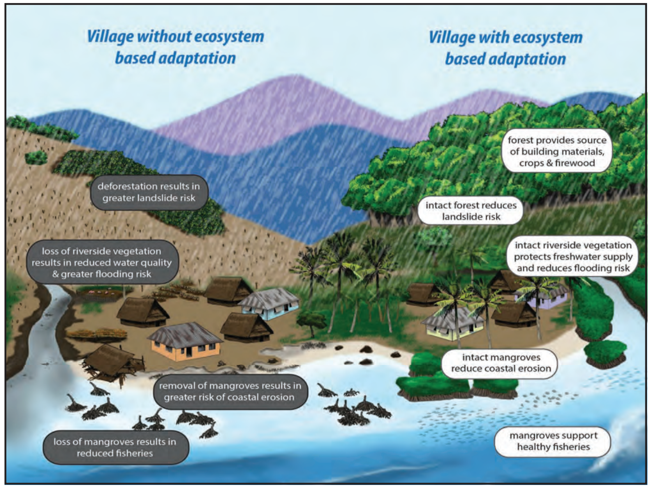

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SPREP PROE

What is Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM)?

An assessment methodology to provide a baseline overview of ecosystems and ecosystem services and their vulnerability to climate change impacts to inform subsequent EbA options and interventions.

6

SPREP PROE

Ecosystem- based Adaptation Options Project Implementation Process phases……

1) ESRAM: ecosystems and socio-economic resilience analysis and mapping → 2) EbA Options: Assessment, prioritisation, → 3) Implementation → 4) Integration:

Present ESRAM Component

7

SPREP PROE

The objectives of the ESRAM study

1. Identify ecosystem types, ecosystem services and threats in the context of ecosystem types present, the present condition or health of the ecosystems; key ecosystem services in terms of direct community dependencies; the role of ecosystem services in providing socio-ecological resilience; critical ecosystem linkages or dependencies; and the main existing threats to an ecosystem and/or ecosystem service.
2. Map key ecosystems and related ecosystem services (where possible), including high-use areas and/or major threats based on existing spatial data.
3. Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and governance factors.
4. Undertake a total economic valuation to define the economic value of key ecosystem services relevant to ESRAM.
5. Assess the vulnerability of ecosystem services to the effects of climate change based on climate change projections and in the context of other existing threats.
6. Provide broad recommendations regarding strategic EbA options.

8

Major Steps in the ESRAM Process

Step 1 Ecosystem baseline and threat assessment

- Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios,governance factors.
- Identify ecosystem types, ecosystem services and threats.
- Identify ecosystem services that are valued by the community.
- Map key ecosystems and related ecosystem services, including high-use areas and/or major threats basedon existing spatial data.

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Step 2: Ecosystem valuation

Undertake a 'total economic valuation' to define the economic value of key ecosystems services relevant to the ESRAM study.

Step 3 Condition and threat analysis from CC and other sources

- Assess the vulnerability of ecosystems services to the effects of climate change based on climate change projections.
- Identify the ecosystem services most vulnerable to future climate and non-climate threats and effects.

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Step 4: EbA Options Master Plan and Implementation

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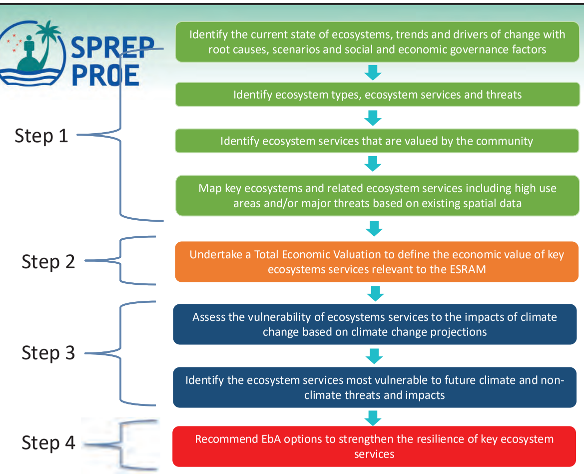

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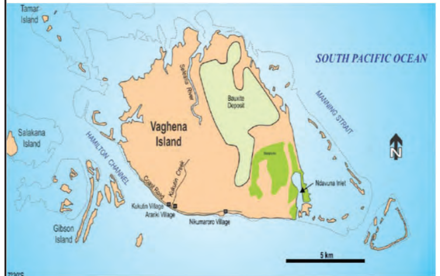
ESRAM Case study: Wagina Island, Choiseul Province, Solomon Islands



- ❑ Wagina was freehold land under the British Protectorate government and
- ❑ British settle the I-Kiribati people who were relocated from the Gilbert and Ellice Islands colony (GEIC) in the 1960s
- ❑ Population, just below 3000 and distributed through 4 main village areas
- ❑ The people of Wagina are heavily dependent on the sea for their food and any income.

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Step 1 : Ecosystem baseline and threat assessment

- **Identification of key ecosystems, ecosystem services and existing threats**
  - Informed by local knowledge of Wagina residents
  - Stakeholder participation and liaison/consultation
  - Local knowledge of project team
  - Targeted site inspections and associated field work
- **Spatial mapping of ecosystems and ecosystems services**
  - National gov ministries & SOLGEO spatial data
  - Interactive mapping outputs from the stakeholder workshops (i.e. manual mapping directly on high-res satellite imagery, digitised)
  - Remote sensing – using publicly available satellite imagery to remotely digitise ecosystems (e.g. forest extent, rivers etc.) where existing data were not available, inadequate or required fine-tuning
  - Field surveys and on-ground validation

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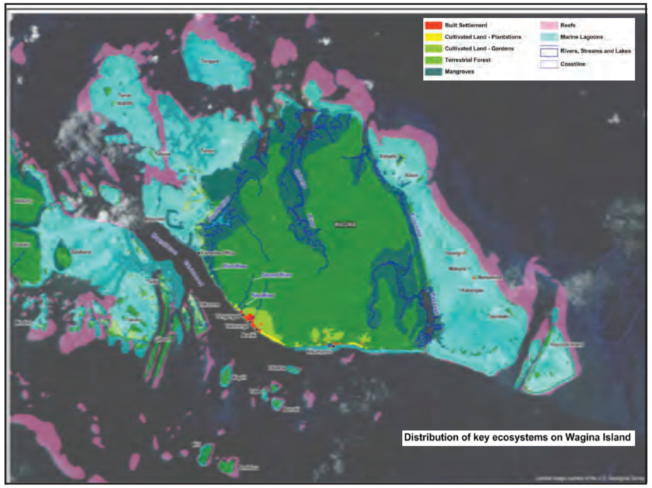

Distribution of key ecosystems on Wagina Island

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Summary of ecosystem sources for key ecosystem services

Key Ecosystems	Food (land)	Food (sea, river)	Water (drinking)	Water (other)	Building materials	Timber (fuel)	Timber (other)	Mats and other materials	Toilet/sanitation	Transport service	Waste disposal	Industry (seaweed)	Industry (other) / commercial	Medicine	Recreation
Terrestrial forest	✓				✓	✓	✓		✓				✓		
Lowland swamps	✓				✓										
Gardens	✓												✓		
Sandy beaches and islands	✓				✓					✓					
Other substrates					✓										
Rivers, streams and freshwater springs	✓	✓	✓	✓	✓	✓			✓	✓	✓				
Mangroves		✓			✓	✓	✓					✓			
Marine lagoons		✓										✓	✓		
Groundwater			✓	✓											
Reefs		✓			✓								✓		
Marine (other)		✓											✓	✓	
Terrestrial (Pandanus)	✓				✓			✓						✓	
Terrestrial Plantations	✓				✓			✓					✓		
Terrestrial (other)	✓				✓					✓				✓	✓
Seashore									✓	✓	✓				✓
Other (rainfall)			✓												

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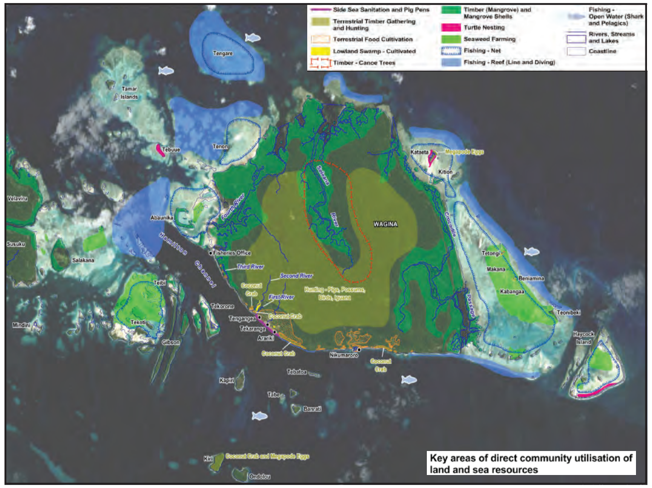

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Step 2 . Ecosystem valuations

Service Valuation – Mangrove Example

Local Values

Ecosystem good	Estimate value SBD2008$	Standardised $ values	Source	Method	Additional information
Firewood	$2275 – 4550 per household p.a.	SI$ or US$ 2016	Warren Rhodes et al (2011)	Based on a range of market prices and the cost of purchasing the same amount of goods.	This value constitutes 38%-76% of the average annual cash income.
Building materials	SBD2008 $110 per household p.a.	SI$ or US$ 2016	Warren Rhodes et al (2011)	Based on a range of market prices and the cost of purchasing the same amount of goods.	
Fishing in mangroves	$4012 per household p.a.	SI$ or US$ 2016	Warren Rhodes et al (2011)	Based on a range of market prices and the cost of purchasing the same amount of goods.	Includes total for fish traded and consumed.

Global Values de

Groot et al (2012)

Service category	Service	Int.$/ha/year, 2007	Standardised $ values
Provisioning services	Water	$1,217.00	SI$ or US$ 2016
	Genetic resources	$10.00	SI$ or US$ 2016
	Medicinal resources	$301.00	SI$ or US$ 2016
Regulating services	Climate regulation	$65.00	SI$ or US$ 2016
	Disturbance moderation	$5,351.00	SI$ or US$ 2016
	Waste treatment	$162,125.00	SI$ or US$ 2016
	Erosion prevention	$3,929.00	SI$ or US$ 2016
	Nutrient cycling	$45.00	SI$ or US$ 2016
Habitat services	Nursery service	$10,648.00	SI$ or US$ 2016
	Genetic diversity	$6,490.00	SI$ or US$ 2016
Cultural services	Recreation	$2,193.00	SI$ or US$ 2016
Total	-	$192,374	SI$ or US$ 2016

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Step 3. Ecosystem Climate Change Assessment

Drought

Extreme rainfall

Sea level rise

Sea & air temperature

Ocean Acidification

Extreme temperatures

Cyclones

- Current climate summary
- Future climate projections - Pacific-Australia Climate Chane Science and Adaptation Planning (PACCSAP) – BoM & CSIRO
- Climate change threats
- Climate change vulnerability assessment

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Climate Projections for Solomon Islands

Climate threats	2030	2090
Sea level rise	5–15 cm increase	20–60 cm increase
Air and sea temperature increase	1.0°C increase	2.0–4.0°C increase
Ocean acidification	Aragonite levels decrease to 3.5 (optimum growth levels for coral are >4)	Aragonite levels < 3.0 (coral have not been recorded at aragonite saturation states < 3.0)
More extreme rainfall	1-in-20-yr increase by 9mm	1-in-20-yr increase by 43 mm & become 1-in-4-year event by 2090

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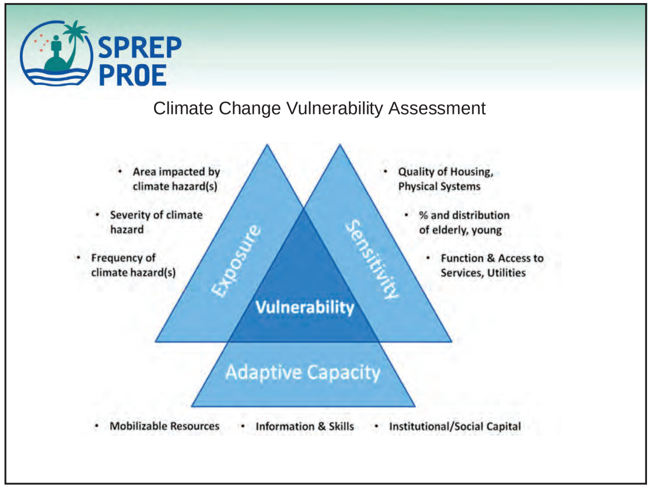

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Wagina's Highly Vulnerable Ecosystem Services

Ecosystem	Ecosystem Services	2030 Sea Level Rise	2030 Extreme Rainfall	2090 Sea Level Rise	2090 Increased Sea Temp	2090 Extreme Rainfall Events	2090 Extreme Air Temp	2090 Annual Air Temp	2090 Ocean Acidific-ation
Beaches and sand islands	Food source	✓		✓					
	Land source (for housing, transport, services	✓		✓					
Cultivated land (gardens)	Food source					✓			
Groundwater	Groundwater dependent ecosystems	✓		✓					
	Water supply (human)	✓		✓					
Lowland swamps	Biodiversity			✓					
	Flood control					✓			
	Giant swamp taro, sago – food security	✓		✓					
	Raw materials (e.g. sago)	✓		✓					
Mangroves	Biodiversity				✓				✓
	Coastal Protection								
	Food source (fish, molluscs, crustaceans)				✓				✓
Marine (open water)	Food/trade (fish, shark, turtle)				✓		✓	✓	✓
Marine lagoons	Biodiversity				✓		✓	✓	✓
	Food/trade source (fish, molluscs, crustaceans)				✓		✓	✓	✓
	Medicine (e.g. seagrass)				✓		✓	✓	
	Primary industry – seaweed farming	✓		✓	✓		✓	✓	
Reefs	Biodiversity				✓		✓	✓	✓
	Coastal Protection				✓		✓	✓	✓
	Coral source – coral rock . lime				✓		✓	✓	✓
	Food/trade source (fish, molluscs, crustaceans, turtle)				✓		✓	✓	✓
	Sand source				✓		✓	✓	✓
Rivers, streams and freshwater springs	Food source (stream side gardens)					✓			
	Fresh water source		✓	✓		✓			
Terrestrial forest	Erosion control					✓			

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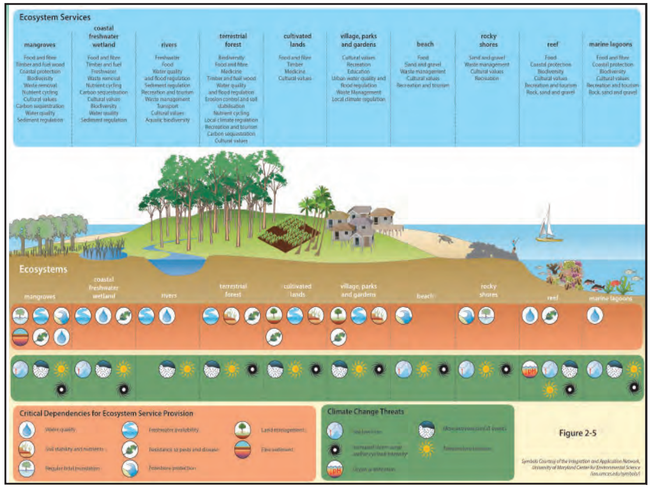

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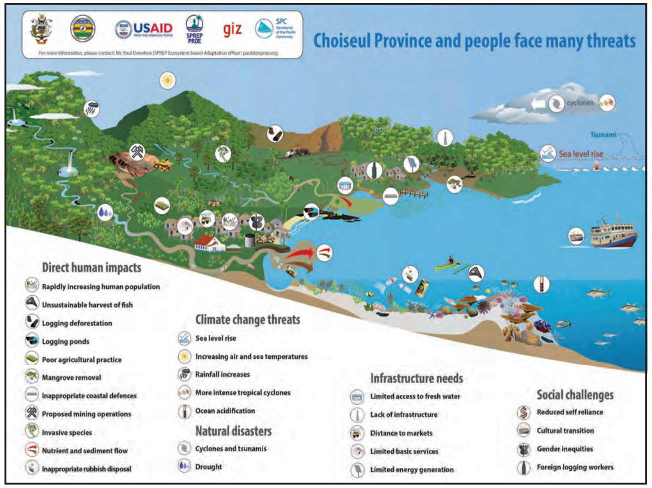

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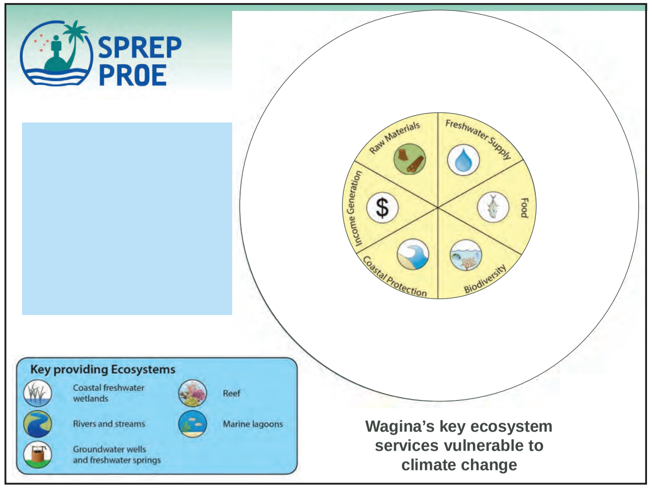
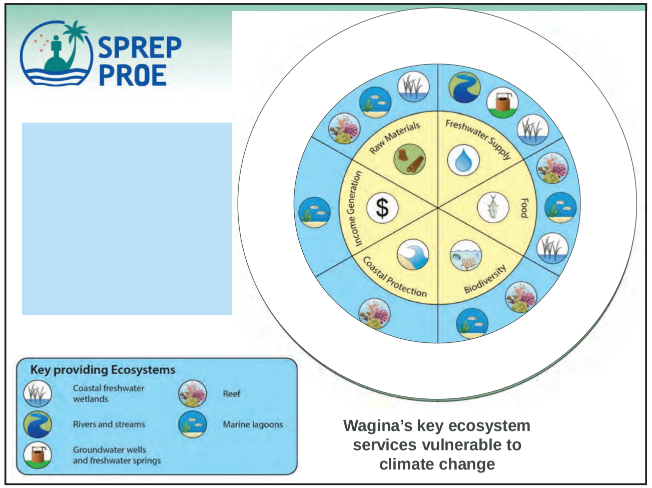

SPREP
PROE
Raw Materials
Freshwater Supply
Income Generation
Food
Coastal Protection
Biodiversity
Key providing Ecosystems
Coastal freshwater wetlands
Reef
Rivers and streams
Marine lagoons
Groundwater wells and freshwater springs
Wagina's key ecosystem services vulnerable to climate change

25


SPREP
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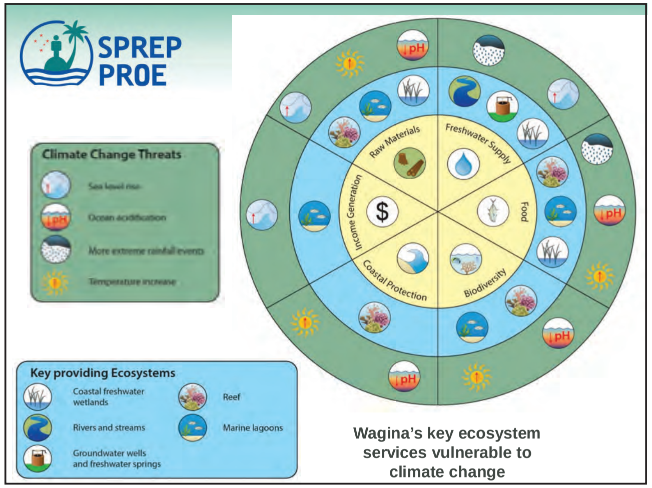
SPREP
PROE
Climate Change Threats
Sea level rise
Ocean acidification
More extreme rainfall events
Temperature increase
pH
Raw Materials
Freshwater Supply
Income Generation
Food
Coastal Protection
Biodiversity
Key providing Ecosystems
Coastal freshwater wetlands
Reef
Rivers and streams
Marine lagoons
Groundwater wells and freshwater springs
Wagina's key ecosystem services vulnerable to climate change

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SPREP
PROE
Step 4: EbA options development
EbA options development & prioritisation with stakeholders
Develop EbA implementation plans

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CBCRP-PCCC Training Course

“Ecosystem-based Adaptation and Mitigation”

Government of Samoa, SPREP and JICA

Module 2. Ecosystem-based adaptation and mitigation

2.1 Terrestrial and freshwater ecosystems

Option 1 Forest

Option 2 Watershed & Reservoir

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Examples

Ecosystem Service – **provision of drinking and domestic water;**

Ecosystems - groundwater wells, surface expressions and freshwater springs

Climate threats:
- saline intrusion from sea level rise
- prolonged dry periods/ drought
- extreme rainfall causing sedimentation

Anthropogenic threats:
- pollution
- poor waste and sanitation practices
- proposed developments

EbA Options?

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CONTENTS

1. EbA and EbM in the context of Terrestrial and freshwater ecosystems

Ecosystem-based Adaptation (EbA)

- ✓ Uses biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the impact of climate change.

Ecosystem-based Mitigation

- ✓ Underscores specifically the importance of forest ecosystems in terms of afforestation, reforestation and avoided deforestation and marine and coastal ecosystems to contribute to climate change mitigation.

- **Ecosystem-based Adaptation and Mitigation** is subsets of Ecosystem-based Management (EbM)
- **Ecosystem-based Management (EbM)** is an integrated, holistic approach to achieving environmental, social and economic goals combining land use and development planning with environmental protection and production needs.

Source: SPREP

Ecosystem-based Adaptation (EbA)

- ✓ EbA, involving the conservation, sustainable management and restoration of ecosystems, uses biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the impact of climate change.
- ✓ EbA harnesses biodiversity and ecosystem services to increase resilience and reduce the vulnerability of human communities and natural systems to climate change.

Ecosystem-based-Mitigation

- ✓ Ecosystem-based-Mitigation activities specifically underscore the importance of forest ecosystems (in terms of afforestation, reforestation and avoided deforestation) and marine and coastal ecosystems (e.g. mangroves, peatlands, tidal salt marshes, kelp forests and seagrass beds) to contribute to climate change mitigation.

Ecosystem-based adaptation and mitigation as subsets of Ecosystem-based Management (EbM).

Ecosystem-based Management (EbM), overarching Ecosystem-based adaptation and mitigation, is an integrated, holistic approach to achieving environmental, social and economic goals combining land use and development planning with environmental protection and production needs.

(Source: IUCN, SPREP)

IUCN: Adaptation and Mitigation

https://www.iucn.org/commissions/commission-ecosystem-management/our-work/cems-thematic-groups/adaptation-and-mitigation

SPREP: Pacific Ecosystem-based Management (EBM) and Adaptation (EbA)

https://www.sprep.org/attachments/Publications/FactSheet/Oceans/pacific-ecosystem-based-management-adaptation.pdf

2. Ecosystem-based adaptation and mitigation options

~Terrestrial and Freshwater Ecosystems~

4

Option 1. Forest

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Climate Change and Forest Ecosystems

Function and Service of Forest Ecosystem

- Regulate ecosystems, support extensive biodiversity and play an integral part in the carbon cycle.
- Provide countless goods and services to people, in the form of food, fuel, medicine, employment and income (e.g. wood and NTFP)

Forests' role in climate change: both a cause and a solution for greenhouse gas emission.

To maximise the climate benefits of forests, keeping more forest landscapes intact, managing them more sustainably, and restoring more of those landscapes which we have lost are indispensable.

(Source: IUCN)

Function of Forest Ecosystem
Forests are a stabilizing force for the climate. They not only regulate ecosystems, protect biodiversity, and play an integral part in the carbon cycle, but also support livelihoods, and supply goods and services that can drive sustainable growth.
Forests' role in climate change
Forests' role in climate change is two-fold, acting as **both a cause and a solution for greenhouse gas emissions**.

i) **Cause**: Around 25% of global emissions come from the land sector, the second largest source of greenhouse gas emissions after the energy sector. About half of these (5-10 $GtCO_2$ annually) comes from **deforestation** and **forest degradation**.

ii) **Solution**: Forests are also one of the most important solutions to addressing the effects of climate change. Approximately 2.6 $GtCO_2$, one-third of the **CO_2 released from burning fossil fuels, is absorbed by forests** every year. Estimates show that nearly two billion hectares of degraded land across the world – an area the size of South America – offer opportunities for restoration. Increasing and maintaining forests is therefore an essential solution to climate change.

(Source: IUCN)
Website: Forests and climate change
https://www.iucn.org/resources/issues-briefs/forests-and-climate-change#:~:text=Forests%20are%20a%20stabilising%20force,that%20can%20drive%20sustainable%20growth.&text=Increasing%20and%20maintaining%20forests%20is%20therefore%20an%20essential%20solution%20to%20climate%20change.

Synergies between Climate Mitigation and Adaptation in Forest Landscape Restoration
https://portals.iucn.org/library/sites/library/files/documents/2015-013.pdf

Climate Change Impacts on Forest Ecosystems

(Source:FAO)

Principal climate change impacts on forest ecosystem

- **Forest ecosystems** are threatened mainly by **precipitation and temperature patterns change**.

Consequent changes

- Increase in forest fires due to droughts
- Changes in species composition, productivity and biodiversity
  -> Spread of invasive species
  -> Reduced production of wood and wood products
- Rise in incidence of pest outbreaks
- Decrease in the availability of water in forested watersheds

Sustainable forest management is crucial to reduce vulnerabilities of forests and the human populations dependent on them.

Principal climate change impacts on forest ecosystem

- **Forest ecosystems** are threatened mainly by **precipitation and temperature patterns change**.
- Forests are not only being affected by climate change impacts such as precipitation and temperature pattern changes and consequent flooding and droughts but also by non-climate threats such as land use, pollution and overexploitation
- Climate change impacts humans directly, and can affect both humans and biodiversity indirectly through its influence on forest landscapes (e.g. local communities reliant on forest/biodiversity).

Consequent changes

- Increase in forest fires due to droughts
- Changes in species composition, productivity and biodiversity
  -> Spread of invasive species
  -> Reduced production of wood and wood products lead to losses in income for forest communities and the timber industry
- Changes in the defenses of host species and in the abundance of parasites and predators
  -> Rise in incidence of pest outbreaks
- Decrease in the availability of water in forested watersheds, thus decreasing the goods and services they provide

*** Productivity**
The increase in the concentration of atmospheric CO2 due to change in climate, will directly affect forest growth and production. On the other hand, changes in temperature and precipitation will result in indirect impacts through complex interactions in the forest ecosystems.

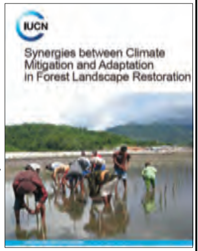
*** Species composition & Biodiversity**

Adaptation and Mitigation in Forest Sector

Mitigation strategies
- Reducing emissions from deforestation and forest degradation (e.g. REDD+)
- Enhancing forest **carbon sinks**
- Product substitution

Types of adaptation
- **Forests for adaptation** to reduce the vulnerability of the forest dependent populations
- **Adaptation for forests** to decrease the vulnerability of forests
- To implement **Ecosystem-based Adaptation (EbA)** options, '**adaptation for forests**' is needed to ensure the role of '**forests for adaptation**'

Linkage between mitigation and adaptation
- Involvement of local communities in mitigation efforts enhance their adaptive capacity
- EbA underlines the linkage between mitigation and adaptation through the provision of ecosystem services



Mitigation strategies in the forest sector
Forests act as both a cause (i.e. deforestation and forest degradation) and a solution (CO2 absorption) for greenhouse gas emission. **Mitigation** strategies in the forest sector that address the cause and enhance the solution can be grouped into the main categories below:
- Reducing emissions from deforestation and forest degradation (e.g. REDD+)
- Enhancing forest carbon sinks; and
- Product substitution (use of wood instead of fossil fuels for energy and the use of wood fiber in place of materials such as cement, steel and aluminum that involve the emission of larger quantities of GHGs).

Countries are being encouraged, especially through REDD+, to undertake mitigation actions in forest landscapes, by incorporating the above strategies.

Types of adaptation in the forest sector
In forest landscapes, **adaptation** means changing management practices in order to decrease the vulnerability of forests to climate change (**Adaptation for Forests**) as well as implementing activities to reduce the vulnerability of the forest dependent populations (**Forests for Adaptation**), and adopting climate smart restoration and management approaches, for example, restoration with species appropriate to the evolving changes in climate.

Linkage between mitigation and adaptation in forest sector
Involvement of local communities in mitigation efforts through forest restoration will result in enhancing the communities' adaptive capacity to climate change. It is thus critical to better understand the links between mitigation and adaptation. Since EbA aims at reducing human vulnerabilities through the provision of ecosystem services, it is clear that well managed and conserved forest ecosystems can help people to both adapt to climate change, and enhance their benefit flows. In this respect, mitigation measures such as afforestation, reforestation, and conservation and sustainable management of forests can all provide ecosystem services that will help communities

Forest biodiversity will be impacted as forests shift towards the poles and vulnerable species could be lost.
(Source: IUCN)

Synergies between Climate Mitigation and Adaptation in Forest Landscape Restoration
https://portals.iucn.org/library/sites/library/files/documents/2015-013.pdf

Adaptation and Mitigation Options

Typical ecosystem-based adaptation and mitigation options in the forest interface

- Protection of natural forest
- Native tree afforestation and reforestation
- Agroforestry

to adapt to the impacts of climate change by reducing vulnerabilities and increasing resilience.

(Source: IUCN, FAO)
IUCN: Synergies between Climate Mitigation and Adaptation in Forest Landscape Restoration
https://portals.iucn.org/library/sites/library/files/documents/2015-013.pdf

FAO: Climate change guidelines for forest managers. FAO Forestry Paper No. 172
http://www.fao.org/3/i3383e/i3383e.pdf

Afforestation and Reforestation (1)

Type of tree planting

- **Afforestation**: converting <u>long-time non-forested land</u> into forest (50 years according to UNFCCC)
- **Reforestation**: converting <u>recently non-forested land</u> into forest
  - ✓ Planting <u>native, climate-resilient and multi-use species</u> that benefit local communities (e.g. by providing NTFPs, shade and wind breaks) is desirable.
  - ✓ Extension and improvement of the tree nursery is necessary to provide a steady supply of plants for afforestation and reforestation.

Climate change impacts targeted

Landslides and slope failure resulting from increasingly frequent and extreme rainfall

(Source: SPREP)

Type of tree planting
Afforestation: converting <u>long-time non-forested land</u> into forest (50 years according to UNFCCC)
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Landslides and slope failure resulting from increasingly frequent and extreme rainfall

(Source: Climate ADAPT)
[Adaptation option] Afforestation and reforestation as adaptation opportunity
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/afforestation-and-reforestation-as-adaptation-opportunity

Protection of Natural Forest -Forest Protected Areas-

Importance of forest protected areas in the adaptation to climate change

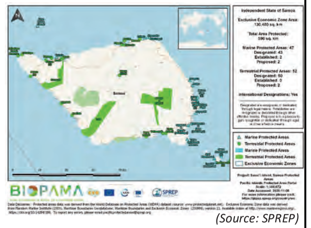
- <u>Supporting species</u> to adapt to changing climate patterns and sudden climate events
- <u>Protecting people</u> from sudden climatic events and reducing vulnerability to weather-induced problems
- Indirectly <u>supporting economies</u> to adapt to climate change

Designing protected areas

- A well-planned protected area network without barriers and obstacles between protected areas is necessary.
- Size, shape and altitudinal gradients contribute to a protected area's resilience to climate change and to species' freedom of movement.

Managing protected areas

- Restoration focusing on resilient habitats within and around protected areas



(Source: SPREP)

Importance of forest protected areas in the adaptation to climate change

- <u>Supporting species</u> to adapt to changing climate patterns and sudden climate events by providing refuges and migration corridors
- <u>Protecting people</u> from sudden climatic events and reducing vulnerability to floods, droughts and other weather-induced problems
- Indirectly <u>supporting economies</u> to adapt to climate change by reducing the costs of climate-related negative impacts

Designing protected areas

- A well-planned protected area network without barriers and obstacles between protected areas is necessary to help species that are present in few fragmented patches of habitat to adapt to climate change (e.g. buffers, connections, and corridors)
- Size, shape and altitudinal gradients contribute to a protected area's resilience to climate change and to species' freedom of movement

Managing protected areas

- Protected area management to ensure adaptation to climate change may include restoration, focusing on resilient habitats, managing specifically for anticipated threats such as fire and pests, and addressing other threats (which can be exacerbated by climate change).

(Source: FAO)
The role of forest protected areas in adaptation to climate change
http://www.fao.org/3/i0670e/i0670e.pdf

and risk of setting up afforestation and/or reforestation in their lands)

- Stakeholder participation (e.g. governments, NGOs and civil society organizations, private sectors and research institutions)

(Source: Climate ADAPT, UNEP)
Climate ADAPT: [Adaptation option] Afforestation and reforestation as adaptation opportunity
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/afforestation-and-reforestation-as-adaptation-opportunity

UNEP: EbA in different ecosystems: placing measures in context
https://wedocs.unep.org/bitstream/handle/20.500.11822/28176/Eba3.pdf?sequence=1&isAllowed=y

Afforestation and Reforestation (2)

Benefits and co-benefits
- Stabilize slopes and prevent landslides, mud flows and debris flows
- Maintain other ecosystem services and local benefits
- Promote carbon sequestration

Elements of outcome indicators
- Frequency and severity of landslides
- Measures of damage from slope failure

Success and limiting Factors
- Land ownership: Rights and access to forests
- Transferring ownership of larger areas of common forest to local communities, and the associated income based on improved carbon storage

Benefits and co-benefits

- Stabilize slopes and prevent landslides, mud flows and debris flows, thus limiting risks to life, property and livelihoods
- Maintain other ecosystem services and local benefits (e.g. watershed protection, provision of fuelwood and fodder, protection of wildlife, biodiversity habitats and invasive species buffer)
- Promote carbon sequestration

Elements of outcome indicators
- Frequency and severity of landslides
- Measures of damage from slope failure (e.g. loss of life, damage to property, and impact on livelihoods)

Success and limiting Factors
- Land ownership: Rights and access to forests
- Transferring ownership of larger areas of common forest to local communities, and the associated income based on improved carbon storage

Other factors
- Socio-demographic characteristics of landholders (i.e. farm size and tenure)
- Social acceptability of afforestation by the community (e.g. not having conflict with agriculture goals)
- Landholders skills, knowledge and experience relevant for afforestation and reforestation
- Sharing information on the synergies between adaptation and mitigation approaches among farmers (e.g. opportunities, including marketing opportunities,

Example of afforestation/reforestation project in the Pacific

Whole-of-island Reforestation and Agroforestry Programme in Taveuni, Fiji

(One of the EbA demonstration projects of PEBACC)

Interventions listed in the island-wide EbA master plan included:
- Establishment of nurseries and reforestation
- Agroforestry
- Coral reef improvement
- Mangrove planting

- A central native tree nursery was constructed by the Project and handed over to the Ministry of Forestry
- 4 500 native trees were planted
- Committees under the Provincial Councils were established to help drive conservation and natural resource management

(Source: SPREP)
FINAL SUMMARY REPORT: Pacific Ecosystem-based Adaptation to Climate Change Project
https://www.sprep.org/sites/default/files/documents/publications/Pacific-Ecosystem-based-adaptation-climate-change.pdf

Afforestation and Reforestation (3)

Cost and Benefits

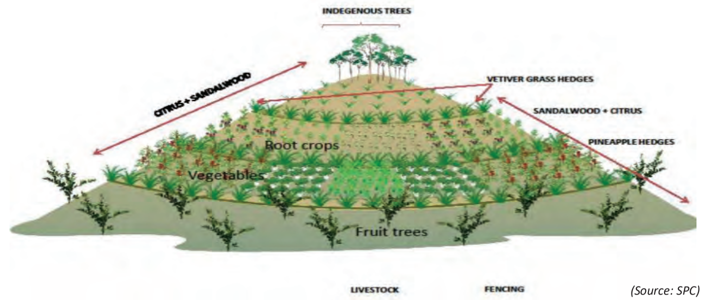
- The adoption of afforestation and reforestation as adaptation practices could:
  - help in overcoming financial barriers to adaptation by integrating mitigation objectives; and (e.g. CDM, REDD+, voluntary carbon markets).
  - help in increasing local mitigation co-benefits, and the local capacity to cope with climate change.
    - Ensure social, economic and environmental improvements
    - Contribute to the increase in productivity and resilience of land, and provide additional income generation
    - Contribute to guarantee ecosystems services by reducing vulnerability to climate change

Cost and Benefits
- The adoption of afforestation and reforestation as adaptation practices, by integrating mitigation objectives, could help in overcoming financial barriers to adaptation as it can benefit from carbon funding (CDM, REDD+, voluntary carbon markets).
- As adaptation practices, they can also help in increasing local mitigation co-benefits, and the local capacity to cope with climate change.
  - ensure social, economic and environmental improvements
  - contribute to the sustainable development (e.g. increase productivity and resilience of land) and provide additional income generation
  - contribute to guarantee ecosystems services by reducing vulnerability to climate change (i.e. forests help in regulating natural resources, controlling hydrological processes and land degradation, maintaining species biodiversity and reducing pests and diseases attack).

(Source: Climate ADAPT, UNEP)
Climate ADAPT: [Adaptation option] Afforestation and reforestation as adaptation opportunity
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/afforestation-and-reforestation-as-adaptation-opportunity

Agroforestry (1)

- **Agroforestry** is a dynamic, ecologically based, natural resource management system that diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels through the integration of trees on farms and in the agricultural landscape.



(Source: SPC)

Three main types of agroforestry systems:

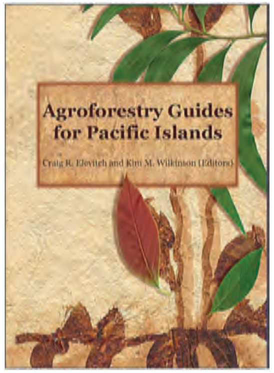
- **Agrisilvicultural** systems are a combination of crops and trees, such as alley cropping or homegardens.
- **Silvopastoral systems** combine forestry and grazing of domesticated animals on pastures, rangelands or on-farm.
- The three elements, namely trees, animals and crops, can be integrated in what are called **agrosylvopastoral** systems and are illustrated by homegardens involving animals as well as scattered trees on croplands used for grazing after harvests.

(Source: FAO)
FAO: [Agroforestry] Definition
http://www.fao.org/forestry/agroforestry/80338/en/#:~:text=Agroforestry%20is%20a%20collective%20name,spatial%20arrangement%20or%20temporal%20sequence.
SPC: Presentation "Promoting Agroforestry to Develop Resilience to Climate Change and Food Security of Communities in Pacific Island Countries"
http://www.asiapacificadapt.net/adaptationforum/sites/default/files/4.%20APAN%20Presentation%20-%20Cenon%20Padolina%2025Sept2014.pdf

Agroforestry (2)

Agroforestry in the Pacific

- **Traditional Practice:** Agroforestry had been practiced in the Pacific Islands for thousands of years.
- "**Agrodeforestation**": Starting in the colonial era and intensifying in the 20th century, Pacific Islands agroforestry systems were rapidly displaced in favor of monocultures.
- **Global attention to agroforestry for its mitigation and adaptation roles**



Agroforestry in the Pacific
Traditional Practice: Agroforestry had been practiced in the Pacific Islands for thousands of years.
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Global attention to Agroforestry for its mitigation and adaptation roles:
Agroforestry has received attention in global climate discussions for its carbon sink potential playing a defining role in offsetting greenhouse gases, providing sustainable livelihoods, localizing Sustainable Development Goals and achieving biodiversity targets.

(Source: Craig R., et al.)
Agroforestry Guides for Pacific Islands
https://agroforestry.org/images/pdfs/Infores.pdf

Agroforestry (3)

Benefits and co-benefits
- Make more efficient use of natural resources
- Provide a more favorable environment for sustained production
- Be more profitable
- Improve the environment
- Be culturally compatible
- Promote carbon sequestration

Elements of outcome indicators
- Measures of soil quality and erosion
- Agricultural yields and income

Benefits and co-benefits
- Make more efficient use of natural resources (i.e. soil, sun, and water)
- Provide a more favorable environment for sustained production (i.e. shade, wind protection, soil conservation, nutrient cycling and habitat diversity)
- Be more profitable (i.e. reduced expenses, diversified products, continuous flow of products, greater self-reliance)
- Improve the environment (i.e. reduced pressure on natural forests, species diversity, resource conservation, and decreased pollution)
- Be culturally compatible (i.e. locally-based, adaptable and acceptable)
- Promote carbon sequestration

Elements of outcome indicators

Measures of soil quality and erosion

Agricultural yields and income (home consumption and market)

(Source: FAO, UNEP)

FAO: Advancing Agroforestry on the Policy Agenda: A guide for decision-makers

http://www.fao.org/3/i3182e/i3182e00.pdf

UNEP: EbA in different ecosystems: placing measures in context

https://wedocs.unep.org/bitstream/handle/20.500.11822/28176/Eba3.pdf?sequence=1&isAllowed=y

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Agroforestry (4)

Examples of selection criteria of tree species for agroforestry in the Pacific

Trees that provide:
- Timber, fuels, handicrafts, food, fruits and nuts
- Soil nutrition and protection
- Forage and fodder
- Medicine and cultural goods

Trees that contribute to environmental protection, biological conservation and carbon sequestration

Issues and challenges
- Unclear status of land and tree resources
- Limited awareness of the advantages of agroforestry
- Delayed return on investment
- Under-developed markets
- Lack of coordination between sectors
- Emphasis on commercial agriculture
- Adverse regulations

Issues and challenges

Unclear status of land and tree resources: Unsecured or ambiguous land tenure, common in developing countries, results in confusion about land delineation and rights, which may discourage people from introducing or continuing agroforestry practices. In many places, lack of long-term rights to land inhibits long-term investments such as agroforestry. In other cases, forest regulations preclude tree growing on farms by restricting the harvesting, cutting or selling of tree products.

Limited awareness of the advantages of agroforestry: Overdependence on conventional agricultural methods and inadequate knowledge of sustainable approaches restrict the interest of policy-makers in agroforestry development. This in turn influences negatively the amount of resources dedicated for research, dissemination, market information and propagation of quality germplasm, which are all crucial for wide adoption of agroforestry practices.

Under-developed markets: Markets for tree products are both less efficient and less developed than for crop and livestock commodities and value chains related to agroforestry systems receive little support.

Delayed return on investment: Despite the fact that trees become profitable as they produce positive net present values over time, the breakeven point for some agroforestry systems may occur only after a number of years.

Lack of coordination between sectors: As an intervention affecting multiple sectors – including agriculture, forestry, livestock, rural development, environment, energy, health, water and commerce – agroforestry is often subject to policy conflicts and omissions, creating gaps or adverse incentives that work against its development. Moreover, the various organizational cultures and objectives within the different departments may not allow room for agroforestry.

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Example of agroforestry project in the Pacific

Strengthening Capacity for Household Integrated Agro-forestry and Food Crops Production in Nauru *(FAO, 2014-2016)*

Total funding: USD 259,000
Implementing agency: Ministry of Commerce, Industry and Environment
Objective:
- Facilitate household engagement in agro-forestry
- Encourage the production of selected fruit trees, root crops, vegetables and valued forest species

Key outcomes:
- Improved food and nutrition security through increased household production and utilisation of fruits, vegetables, food crops and multipurpose tree species
- Adequately trained staff and locals in agro-forestry and crops production for improved household nutrition
- Improved soil fertility
- Reduced imports and strengthening the domestic market to offer a broad range of local fruits, food crops and handicraft for sale

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- Improved food and nutrition security through increased household production and utilisation of fruits, vegetables, food crops and multipurpose tree species
- Adequately trained staff and locals in agro-forestry and crops production for improved household nutrition
- Improved soil fertility through heavy mulch and the production of organic matter from planting of fruit trees, leguminous plant species and green manure crops
- Reduced imports and strengthening the domestic market to offer a broad range of local fruits, food crops and handicraft for sale

(Source: FAO)
Strengthening Capacity for Household Integrated Agro-forestry and Food Crops Production in Nauru
http://www.fao.org/sids/resources/projects/detail/en/c/281990/

Emphasis on commercial agriculture: Agricultural policies often offer incentives for agriculture that promote certain agricultural models, such as monoculture systems, and tax exemptions are usually aimed at industrial agricultural production. Agricultural price supports or favourable credit terms which are granted for certain agricultural activities but hardly ever for trees, are also discouraging agroforestry adoption.

Adverse regulations: Frequently agricultural policies penalize practices needed to implement agroforestry, while supporting a large-volume, large-scale approach to agricultural, food and fuel products. The tax regime may also be less advantageous for forests compared with agricultural lands. Even when a programme or policy aims to promote agroforestry, bureaucratic processes involved may be complicated or not elaborated in a manner specific to agroforestry and its potential users.

(Source: FAO, SPC)
FAO: Advancing Agroforestry on the Policy Agenda: A guide for decision-makers
http://www.fao.org/3/i3182e/i3182e00.pdf
SPC :Presentation on "Promoting Agroforestry to Develop Resilience to Climate Change and Food Security of Communities in Pacific Island Countries"
http://www.asiapacificadapt.net/adaptationforum/sites/default/files/4.%20APAN%20Presentation%20-%20Cenon%20Padolina%2025Sept2014.pdf

Option 2. Watershed & Reservoir

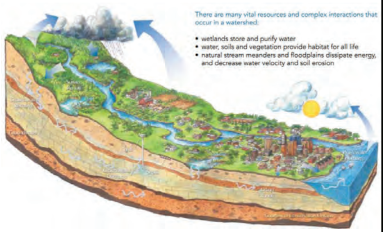
Freshwater Ecosystem -Watershed & Reservoir-

Definition

- A **watershed** is the geographical area drained by a watercourse

Functions and services of watershed

- Attenuate terrestrial run-off to the marine environment
- Provide freshwater
- Regulate water flow and maintain water quality
- Provide and protect natural resources for local livelihoods
- Protect against natural hazards
- Conserve biodiversity



(Source: FAO)

Definition

- A **watershed** is the geographical area drained by a watercourse.
- The concept applies at various scales – from, for example, a farm drained by a creek (a “micro-watershed”) to a large river basin (or a lake basin).
- Forests and trees play crucial roles in hydrological processes in watersheds, particularly on sloping lands.
- The concept of watershed management is developed based on the relationship between upstream land use and water yields and quality downstream.

Typical watershed in the Pacific

- **Upper zone** on mountain and hilltops: Natural forest and deeply cut tributaries
- The lower-elevated **middle zone**: River flood plains where the vast majority of development is occurring
- The **lower zone**: Mangrove forest at sea level, making it a nursery for many marine creatures.

Functions and services of watershed

- Attenuate terrestrial run-off to the marine environment
- Provide freshwater (particularly upland watersheds)
- Regulate water flow and maintain water quality
- Provide and protect natural resources for local livelihoods
- Protect against natural hazards (e.g. local floods and landslides)
- Conserve biodiversity

(Source: FAO, GEF)
FAO: Sustainable Forest Management (SFM) Toolbox -Watershed Management-
http://www.fao.org/sustainable-forest-management/toolbox/modules/watershed-management/basic-knowledge/en/

Climatic change impacts on watershed & reservoir ecosystems

Watershed & reservoir ecosystems will be primarily impacted by **changing precipitation regimes**.

Consequent changes

- Erosion and the depletion of soil productivity
- Sedimentation of watercourses, reservoirs and coasts
- Increased runoff and flash flooding
- Reduced infiltration to groundwater
- Reduced water quality
- Loss of aquatic habitat and biodiversity


(Source: SPREP)

<u>**Watershed ecosystems**</u> will be primarily impacted by ***changing precipitation regimes***. Decreasing precipitation regimes will lead to ecosystem transformation, biodiversity loss, contraction of watershed area, and loss of freshwater lens. Increasing precipitation will have largely positive impacts in freshwater ecosystems where they maintain intrinsic integrity.
Non-climate threats that impact watershed include deforestation, uncontrolled timber harvesting, overgrazing, pollution and the invasion of alien species.

The deterioration of watershed functions has significant negative impacts:

- Erosion and the depletion of soil productivity
- Sedimentation of watercourses, reservoirs and coasts
- Increased runoff and flash flooding
- Reduced infiltration to groundwater
- Reduced water quality
- Loss of aquatic habitat and biodiversity

(Source: FAO)
FAO: Sustainable Forest Management (SFM) Toolbox –Watershed Management-
http://www.fao.org/sustainable-forest-management/toolbox/modules/watershed-management/basic-knowledge/en/

GEF Pacific IWRM Project: Sustainable Pacific Island Watersheds
https://www.pbslearningmedia.org/resource/prcc12.sci.ess.ccwatershed/sustainable-pacific-island-watersheds/

Adaptation and Mitigation Options

Types of Ecosystem-based adaptation options in the watershed & reservoir interface

- ➢ Protection of natural forest
- ➢ Restoration of plant cover in the watershed – planting native vegetation as riparian buffers-

(Source: Pacific R2R– Ridge to Reef)

Climate change impact targeted

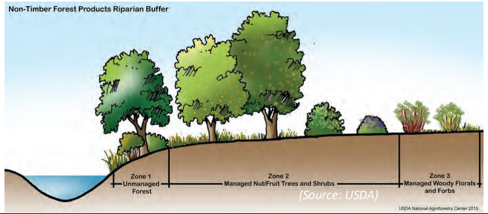
Flooding and soil erosion/sediment deposition resulting from extreme rainfall, rainfall variability and increasingly frequent and severe cyclones

Establishment and reforestation of riparian buffers (1)

Riparian Buffers:

Strips of vegetation along the banks of waterways that maintain or improve water quality by trapping and removing various nonpoint source pollutants from both overland and shallow subsurface flow.

- ➢ A general, multi-purpose, riparian buffer design consists of a strip of grass, shrubs, and trees between the normal bank-full water level and cropland.
- ➢ Planting <u>native, climate-resilient and multi-use species</u> that benefit local communities (e.g. by providing NTFPs such as nut and fruit) is desirable.
- ➢ Considered as an option of Ecosystem-based Disaster Risk Reduction (Eco-DRR).



(Source: USDA)

Riparian Buffers:
Strips of vegetation along the banks of waterways (lakes, rivers, streams, etc.) that maintain or improve water quality by trapping and removing various nonpoint source pollutants from both overland and shallow subsurface flow.

- ➢A general, multi-purpose, riparian buffer design consists of a strip of grass, shrubs, and trees between the normal bank-full water level and cropland.
- ➢Planting <u>native, climate-resilient and multi-use species</u> that benefit local communities (e.g. by providing NTFPs such as nut and fruit) is desirable.
- ➢Considered as an option of Ecosystem-based Disaster Risk Reduction (Eco-DRR) as well.

(Source: Climate ADAPT, USDA)
Climate ADAPT: [Adaptation option] Establishment and restoration of riparian buffers
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/establishment-and-restoration-of-riparian-buffer-s

USDA: Riparian Forest Buffers
https://www.fs.usda.gov/nac/practices/riparian-forest-buffers.php#:~:text=A%20riparian%20forest%20buffer%20is,primarily%20to%20provide%20conservation%20benefits.

Establishment and reforestation of riparian buffers (2)

Benefits and co-benefits

- Reduce vulnerability to floods
- Maintain or improve water quality
- Provide direct shade and thus avoiding an increase in water temperature
- Provide (additional) habitat for aquatic species
- Promote carbon sequestration by planting trees

Elements of outcome indicators

- Frequency and severity of floods
- Sediment load
- Measures of water quality
- Measures of flood damage (e.g. infrastructure, households, crops)
- Agricultural yields and income, if any

(Source: Pacific R2R - Ridge to Reef)

Benefits and co-benefits

- Reduce vulnerability to floods by acting as a shield against overland flow from agricultural fields by reducing the run-off of sediments and pollutants reaching the watercourse
- Maintain or improve water quality by trapping and removing various nonpoint source pollutants from both overland and shallow subsurface flow
- Provide direct shade for the water body, reducing the influx of solar radiation on it and thus avoiding the corresponding increase in water temperature
- Provide (additional) habitat for aquatic species
- Promote carbon sequestration by planting trees

(Source: Climate ADAPT, USDA)
Climate ADAPT: [Adaptation option] Establishment and restoration of riparian buffers
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/establishment-and-restoration-of-riparian-buffer-s
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UNEP: EbA in different ecosystems: placing measures in context
https://wedocs.unep.org/bitstream/handle/20.500.11822/28176/Eba3.pdf?sequence=1&isAllowed=y

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Establishment and reforestation of riparian buffers (3)

Success and limiting factors:

- **Success** of buffer strips is strongly dependent on characteristics such as buffer zone width, slope of the adjacent fields, soil type and variety, and density of vegetation
- **Temporary negative side-effects** may happen during the plantation of vegetation and related works along the water body, but medium to long term effects are in general positive if the option is carefully designed and planned
- A variety of social and economic factors that can **curb the adoption of riparian buffers** include lack of incentive programme, poorly defined goals, lack of maintenance, and opposition from landowners.

(Source: Climate ADAPT)
[Adaptation option] Establishment and restoration of riparian buffers
https://climate-adapt.eea.europa.eu/metadata/adaptation-options/establishment-and-restoration-of-riparian-buffer-s

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Example in the Pacific

Restoration and reforestation of the riparian zone of the lower Tagabe river in Port Vila, Vanuatu

(One of the EbA demonstration project of PEBACC)

➢ Approximately 3,000 native trees, fruit trees and vetiver grass were planted along the Blacksands coastline and from the river mouth up to the Destination area.

➢ The plants help reduce erosion and eventually provide shade along the river, reducing sunlight, which curbs the growth of invasive aquatic plants.

(Source: SPREP)

Blacksands Community carrying out a planting activity, Tagabe River, Efate, Vanuatu. *(Source: SPREP)*

(Source: SPREP)
FINAL SUMMARY REPORT: Pacific Ecosystem-based Adaptation to Climate Change Project
https://www.sprep.org/sites/default/files/documents/publications/Pacific-Ecosystem-based-adaptation-climate-change.pdf

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Reference

EbA and EbM in the context of Terrestrial and freshwater ecosystems

- **IUCN**: Adaptation and Mitigation
- **SPREP**: Pacific Ecosystem-based Management (EBM) and Adaptation (EbA)

Ecosystem-based adaptation and mitigation options

Option 1. Forest

- **IUCN**: Synergies between Climate Mitigation and Adaptation in Forest Landscape Restoration
- **FAO**: Climate change guidelines for forest managers. FAO Forestry Paper No. 172
- **World Bank**: Convenient Solutions to an Inconvenient Truth : Ecosystem-based Approaches to Climate Change
- Drew, W.M. **Agroforestry Guides for Pacific Islands**. C. R. Elevitch and K. M. Wilkinson (eds). *Agroforestry Systems* **55,** 161–163 (2002).
- **Climate ADAPT**: [Adaptation option] Afforestation and reforestation as adaptation opportunity
- **UNEP**: EbA in different ecosystems: placing measures in context
- **FAO**: Advancing Agroforestry on the Policy Agenda A guide for decision-makers

Option 2. Watershed & Reservoir

- **FAO**: Sustainable Forest Management (SFM) Toolbox -Watershed Management-
- **World Bank**: Convenient Solutions to an Inconvenient Truth : Ecosystem-based Approaches to Climate Change
- **Climate ADAPT**: [Adaptation option] Establishment and restoration of riparian buffers
- **USDA**: Riparian Forest Buffers
- **UNEP**: EbA in different ecosystems: placing measures in context
- **SPREP**: FINAL SUMMARY REPORT -Pacific Ecosystem-based Adaptation to Climate Change Project-

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CBCRP-PCCC Training Course

“Ecosystem-based Adaptation and Mitigation”

Government of Samoa, SPREP and JICA

Module 2. Ecosystem-based adaptation and mitigation

2.2 EbA in the context of Coastal and Marine ecosystems

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CONTENTS

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Coastal and Marine Ecosystems comprise of:

- Coastal wetlands (saltwater marshes, estuaries and lagoons)
- Mangrove swamps
- Seagrass
- Coral reefs
- Dunes and beaches
- Rocky shores
- Sea mounts

Coastal wetlands defines an area of land that is permanently or seasonally inundated with fresh, brackish, or saline water and contains a range of plant species that are uniquely adapted to the degree of inundation, the type of water that is present, as well as the soil condition. They include saltwater marshes, mudflats, estuaries and lagoons including mangrove swamps.

Mangroves are small trees or large shrubs that grow in the intertidal, coastal swamps in sub-tropical and tropical regions. They have numerous tangled roots that grow above ground and form dense thickets.

Seagrass are typically flowering plant species that grow underwater on the sandy substrate of shallow coastal zones.

Coral reefs are large underwater structures composed of the skeletons of colonial marine invertebrates called coral.

Sand dunes are coastal landforms composed of wind or water-driven sand that typically take the form of mounds, ridges, or hills.

Sandy beaches are intertidal areas of seacoasts where loose sand has accumulated by the deposition of sediments (silica and carbonate) by currents and waves.

Rocky shores are intertidal areas of seacoasts where solid rock predominates.

Sea mounts are underwater mountains formed by volcanic activity

Direct Climate Change Resilience benefits derived from Coastal and Marine Ecosystems

- Coral reefs, seagrass, mangroves and coastal vegetation attenuate wave energy protecting shorelines during storm events
- Mangrove swamps provide sheltered areas for mooring boats during cyclones
- Rocky shores, sand dunes and sandy beaches buffer the land from storm surges and extreme high tides

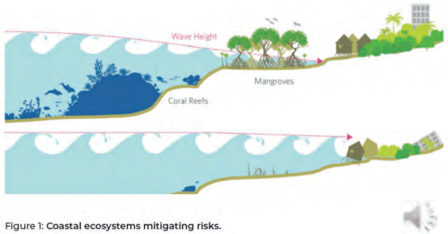

Figure 1: Coastal ecosystems mitigating risks.
Source: Losada et al. 2018

ROLE OF COASTAL AND MARINE ECOSYSTEMS IN PROTECTING SHORELINES IS EXTREMELY IMPORTANT BECAUSE:

- The bulk of the population lives along the coast - 90% of Pacific Islanders live within 5 km of the coast (excluding PNG)
- Most of the road network and infrastructure is located along the coast
- Most cities and economic activities occur in the coastal zone and are growing

In the past few years a growing number of countries have formulated, or are formulating, their national Blue Economy strategies and road maps, to diversify their economic base to further include ocean and coastal goods and services.

Annual value of coastal protection from ecosystems in Tonga is USD19mil, greater than inshore-and off-shore fisheries combined (USD8.3mil)

THREATS

Source: PIFS-SPREP project

Most cities and economic activities occur in the coastal zone and are growing which places coastal ecosystems at increased risk from anthropogenic impacts such as increased levels of pollution, hard infrastructure development and ecosystem modification/conversion.

EbA recognises that the main current drivers of ecosystem degradation are related to unsustainable development processes

Development Threats
- Soil erosion from terrestrial landuse (forestry, mining, agriculture) leading to reductions in water quality and smothering of corals
- Foreshore clearing and land reclamation
- Mining (bauxite, deep sea minerals)
- Over fishing and use of illegal gears
- Unplanned and uncoordinated spatial development
- Mass tourism
- Pollution and waste

Climate related Threats
- Extreme events such as cyclones, storm surges, tsunamis with associated impacts of coastal erosion, damage to infrastructure and sea-water inundation
- Ocean warming leading to coral bleaching
- Ocean acidification
- Sea Level Rise

Important note on Inshore Fisheries

In-direct Climate Change Resilience benefits derived from Coastal and Marine Ecosystems

Support to sustainable livelihoods and economies through the provision of Ecosystem Services:

- Provisioning services; e.g. fish, seafood, construction materials, fuel, tourism
- Regulating services; e.g. flood control, climate regulation
- Support services; e.g. hydrological cycle, nutrient cycling, primary production

Professor Johann Bell

WWF- South Pacific.

Commercial Fisheries: Commercial fisheries major contributor to PIC GDPs, e.g. commercial fisheries contributed USD1bil to Kiribati in 2013. Greatest contribution comes from sale of fishing licenses to foreign fleets.

Artisanal Fisheries: High proportion of Pacific islanders depend on inshore artisanal fisheries for bulk of nutrition requirements (56% in Vanuatu; 92% in SI)

Tourism: Tourism spend in Fiji in 2019 was just under USD1.5bil, 40% of GDP and employing 120,000 people (33% of the workforce). The diversity and high quality of Fiji's coastal and marine ecosystems is the main drawcard for tourists

Other Services: Annual value of marine ecosystem services in Fiji valued at USD1.7bill in 2014 (excluding tourism and fisheries)

Ecosystem-based Adaptation Options

- Mangrove conservation and restoration
- Coastal wetland conservation and restoration
- Seagrass/kelp conservation and restoration
- Coral reef conservation and restoration
- Dune and beach conservation and restoration incl. coastal vegetation
- Diversification and protection of ecosystem-based livelihoods
- Sustainable fisheries management
- Marine protected areas
- Coastal retreats
- Living breakwaters

Mangrove conservation and restoration
Mangroves are small trees or large shrubs that grow in the intertidal zones of tropical and subtropical regions. The structural diversity of mangrove roots and their position at the interface between land and sea offer crucial ecosystem services such as providing habitats for numerous species, improving water quality and nutrient transfer, and offering coastal protection. Additionally, mangrove ecosystems act as a refuge for corals from ocean acidification and as carbon sinks. They also reduce the vulnerability of coastal communities to climate-related coastal hazards, such as intense tidal surges. As a result, mangrove planting schemes and restoration initiatives are increasingly valued as an ecosystem-based disaster risk reduction and adaptation measure to climate change.

Coastal wetland conservation and restoration
Coastal wetlands include saltwater marshes, estuaries and lagoons. They offer critical functions for climate-change adaptation such as weakening wave and tidal energy and reducing the risk of flooding from extreme weather events and rising sea levels (owing to their capacity to absorb excess water). Additional benefits include providing ecosystem services, such as breeding and nursery grounds for a variety of birds, fish and mammals. Establishing protected areas to safeguard wetland ecosystems should be a primary consideration. Where restoration is the only option, projects should consider the hydrology of the local environment (eg, coastal wetlands such as mangroves rely on a balance of salt and freshwater).

Seagrass/kelp conservation and restoration
Seagrass/kelp beds are typically flowering plant species that grow underwater

The coastal fisheries of the Melanesian region are widely assumed to be exploited at or near maximum capacity, with non-commercial and artisanal catches declining by 2-8 per cent per year since 2000 – suggesting that demand will greatly exceed the capacity of coastal systems to produce. The population in Melanesia likely to increase by 3.7mil by 2030 and it is estimated that 60 per cent more fish will be required compared to 2010.

Note on 'hard infrastructure': Coast is located in a highly dynamic and fragile biophysical area where the land meets the sea – when undisturbed, coastal and marine ecosystems are in a dynamic state of balance. To maintain this balance coastal and intertidal ecosystems such as mangroves, seagrass and coastal vegetation needs to be able to move with changing conditions. Inappropriately designed hard infrastructure can upset the temporal migration of these ecosystems leading to their degradation and loss of services vulnerability to climate change and must be adaptable to ecological changes in order to increase resilience and sustainability. Since ecosystem-based livelihoods are often linked to community values, culture and identity, EbA measures must be formed from community-led processes that identify areas where diversification could strengthen, rather than hinder, community resilience. The identification of sustainable, context-specific coastal livelihood strategies that support local development and income generation is key. This includes activities such as butterfly farming for export and modern beekeeping, as well as mariculture options such as promoting the farming of marine water shrimps, milkfish, mud crabs and oyster for meat and pearl production. Likewise, seaweed farming is another potential opportunity, particularly for women in the coastal zone.

Sustainable fisheries management
This integrated process seeks to attain an optimal state that balances ecological, economic, social and cultural objectives for fisheries. Management strategies have increasingly turned towards the ecosystem approach to fisheries management (EAFM) in order to ensure a broad range of interdependent relationships within ecosystems. The key features of EAFM include consideration of ecological, social and governance processes over broad spatial and temporal scales; focus on resilience; adaptive management, co-management, institutional cooperation and coordination; and a precautionary approach. Effective EAFM can achieve multiple objectives that increase coastal communities' resilience to climate change.

Marine protected areas
MPAs are areas set aside to protect marine ecosystems. They are an example of an area-based management measure relevant to EbA (others include integrated coastal management and marine spatial planning). MPAs have a clearly defined geographical space that is managed through legal or other effective means. They are a tool used to conserve species and habitats, maintain ecosystem functions and resilience, manage fisheries, reduce risks from natural disasters and protect natural and cultural resources and values important to human well-being.
Fisheries and livelihood management initiatives are also included under EbA so long as they seek to improve fishing practices and use MPAs to expand important habitats that are essential for the maintenance of diverse fishery stocks on which local communities depend for their wellbeing.

Coastal retreats
A coastal retreat, which includes managed realignment and/or coastal setbacks, is the proactive determination and implementation of realistic

on the sandy substrate of shallow coastal zones. Seagrasses/kelp are important because they can reduce current velocity, dissipate wave energy and stabilize the sediment in shallow water environments. Reducing wave energy can lessen vulnerability to flooding and coastal erosion; two climate-related hazards that are likely to increase in severity. In addition, seagrass/kelp habitats support livelihoods and are vital for the lifecycle of many species within and around these ecosystems. Common approaches to conserving seagrass/kelp ecosystems include the management of common threats (eg, pollution, damage by boats), restoration and rehabilitation through harvesting and transplanting seagrass/kelp, and the monitoring of restored sites.

Coral reef conservation and restoration
Coral reefs are marine ecosystems located in shallow coastal zones of tropical and subtropical regions. While coral reefs occupy a small percentage of the world's oceans, they contain a disproportionately high share of its biodiversity. Coral reefs are critical not only for the ecosystem services they provide but also for their adaptation function to climate change. Coral reefs act as natural barriers, reducing wave intensity and minimising coastal erosion. They too serve as carbon sinks. In recognising both the vulnerability of these ecosystems and their important function in adapting to climate change, approaches to conserving coral reefs include farming, transplanting and monitoring coral reef species and, in some cases, establishing MPAs to allow for the natural, on-site rehabilitation of coral species.

Dune and beach conservation and restoration
Sand dunes are naturally dynamic environments that are highly sensitive to forcing factors such as wind, wave and tidal variations. Sand dunes represent a spatial transition between terrestrial and marine ecosystems, and therefore act as a natural buffer between the land and sea. Furthermore, dune aquifers offer important water regulation and purification services, as well as protected spaces for rare species of flora and fauna. In the context of climate change, sand dunes are increasingly valued for their function in protecting coastlines from rising sea levels. Conservation and restoration efforts include minimising disturbances, implementing physical barriers to trap sand, and using hybrid approaches to stabilise dune ridges, including planting schemes that use indigenous species to biologically fix or reforest the dune ridge.

Diversification and protection of ecosystem-based livelihoods
People living in coastal communities are often dependent on natural resources and ecosystem services for their livelihoods, particularly fisheries, agriculture and eco-tourism. However, these ecosystem services are sensitive to climate change impacts. Therefore, livelihoods are strongly linked to peoples'

Key success factors

- Participatory research
- Participatory and spatial planning
- Effective governance arrangements
- Adaptive management
- Monitoring
- Sustainable financing

Participatory research
- roles that ecosystems play in supporting community resilience
- status and trends in ecosystem condition = ability to continue providing services
- drivers of degradation
- local experiences and projections for climate change
- potential impacts on ecosystems and their services

Participatory planning
- Identification of key problems and problem analysis
- Identifying range of appropriate interventions/options
- Establishing criteria and screening options
- Development of an EbA implementation plan

Spatial planning
- Establishing appropriate planning boundaries (e.g. watershed, land-seascape, R2R)
- Factoring in ecosystem connectivity (e.g. R2R, MPA networks)
- Marine Spatial Planning – zoning of different land and sea uses
- Spatial modeling to identify socio-ecological linkages

Management
- Integration with local level governance systems
- Nested – governance spans local to national levels
- Multi-sector
- Private sector support
- Clear roles and responsibilities and reporting mechanisms

setback lines along coasts. Managed realignment is the deliberate altering of flood defences to allow planned flooding of a presently defended area. Coastal setback is a planning tool that identifies an area next to the existing shoreline that is then managed as a buffer zone. Both managed realignment and coastal setbacks create the potential for new habitats for biodiversity. They are often used in integrated adaptation schemes, which also include technical or structural adaptation measures.

Living breakwaters
Hybrid approaches such as living breakwaters are offshore submerged structures that form a barrier between the sea and land. The term 'living breakwaters' is often used when such structures have been deliberately constructed to provide a habitat for species or to aid the restoration of coastal reef ecosystems and support the services that they provide. A popular example of this is the creation of oyster reefs and oyster shell barriers. Artificial reefs refer to artificial structures that aim to mimic some of the characteristics of natural reefs, including their function as breakwaters. Living breakwaters/artificial reefs are considered an example of a 'hybrid' approach, which combines natural and built infrastructure and can enhance coastal resilience by providing coastal protection as well as other social and environmental co-benefits.

Monitoring

- Capacity building
- Identification of appropriate social and ecological indicators
- Systems in place for regular monitoring
- Capacity building and equipping
- Adaptive management

Sustainable financing

- Incentives
- Link with private sector
- Payment for ecosystem services

3

Key messages

- Healthy ecosystems are the best defense against climate change impacts to livelihoods
- Ridge to reef management protects habitats for all stages of life
- Inland and coastal communities need to manage their actions and resources together
- Public health and livelihoods depend on healthy environments
- Effective management depends on good governance and inputs from stakeholders
- Management at a suitable scale
- Learning from experience
- Adaptive management

Figure 4. The cycle of adaptive management.

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Option 1: Marine Protected Areas (MPAs)

An area of the marine environment especially dedicated to, or achieving, through adequate protection, the maintenance and/or recovery of biological diversity at the habitat and ecosystem level in a healthy functioning state.

Management measures usually include:

- No-take marine reserves
- Temporally closed zones (e.g. tabu areas)
- Restrictions on gear, species, size and access

MPA networks: a collection of individual MPAs or reserves operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve

While smaller in size, MPA networks can potentially deliver most of the benefits of well managed individual marine protected areas, but with less costs due to greater flexibility and diversity in size, shape, distribution and location.

Marine Protected Areas (MPAs) are defined as any clearly-delineated, marine managed area that contributes to protection of natural resources in some manner. They include, but are not limited to, areas with a variety of regulations including marine reserves (areas of ocean that are protected from extractive and destructive activities) and areas with fisheries restrictions upon gear, species, size and access. They also include areas with different governance systems, including government and community managed marine areas.

Networks of MPAs refer to a collection of individual areas that are ecologically connected. For the same amount of spatial coverage, MPA networks can potentially deliver most of the benefits of well managed individual marine protected areas, but with less costs due to greater flexibility and diversity in size, shape, distribution and location. They can also deliver additional benefits by acting as mutually replenishing networks to facilitate recovery after disturbance. Because of the flexibility in design and application, MPA networks are particularly suited to addressing multiple objectives in various contexts.

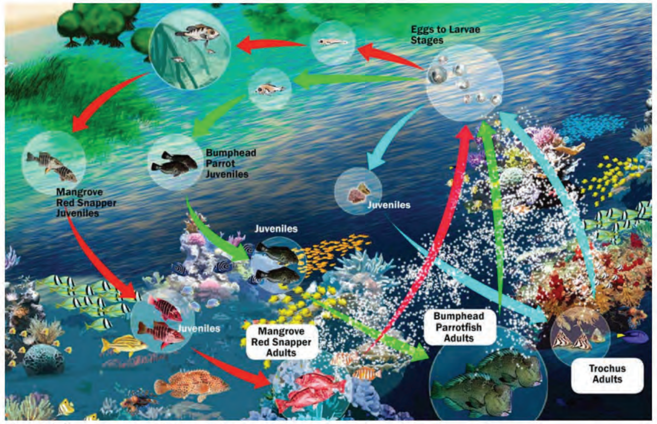

Figure 4. Some species use different habitats at different times in their lives.

Source : Green, A., White, A., Kilarski, S. (Eds.) 2013

General guidelines for the establishment of MPAs

- Develop a clear understanding of the state of and pressures on particular marine and coastal ecosystems, the likelihood that MPAs can address these, and the range of stakeholders involved.
- Clearly define the management goals and objectives of the MPA, and the required level of protection to achieve these
- Estimate the expected costs and benefits of MPAs
- Site MPAs in a strategic manner
- Develop an MPA management plan
- Establish monitoring and reporting protocols
- Compliance and enforcement
- Establish MPA financing strategies

Baseline research
Develop a clear understanding of the state of and pressures on particular marine and coastal ecosystems, the likelihood that MPAs can address these, and the range of stakeholders involved. This will entail a combination of biological and socio-economic research using participatory processes to consult with local communities. The potential impacts of climate change on marine ecosystems needs to be considered alongside other pressures, including alien invasive species.

Management Goals
These should be stated at an operational level, so as to be specific, measurable, achievable, realistic and time-bound (SMART), and accompanying indicators should be identified that will enable the eventual assessment of whether the objectives are being met. Traditionally MPAs have been designed around either conservation or fisheries goals. Using an Ecosystem-based Management approach there is a growing movement towards managing for a combination of conservation, fisheries and climate change resilience goals (described in the next slide)

Costs and Benefits
Enables decision makers to better evaluate the net benefits to society from investing in an MPA and to prioritise efforts amongst various possible MPAs if resources are limited. It can also provide
insights on how these net benefits are distributed (i.e. over time, different geographic scales and between different user groups) and thus how they can best be managed. Understanding the costs associated with MPAs also enables planners to budget and to help secure sufficient finance for the

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▲ **MPAs that are designed as part of an ecosystem-based approach to management consider the human context of the ecosystem.**

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effective long-term management of the MPA.

Siting of MPAs
Considerations with regard to the siting of MPAs are provided in the next set of slides.

MPA Management Plan
The management plan is the key instrument guiding stakeholders and managers. Owing to the dynamic nature of coastal and marine ecosystems, it is important that the management plan be regularly reviewed and amended if need be based on data derived from monitoring. The management plan therefore needs to cater for an ‘adaptive management’ approach.

Monitoring
Important both initially in order to establish ecological and socioeconomic baseline data, as well as regularly thereafter, to assess trends in performance over time. Indicators selected
should be able to determine whether the objective(s) of the MPA are being achieved.

Compliance and enforcement
Few MPAs have a robust compliance and enforcement regime in place, which has been cited as an important reason for lack of MPA effectiveness.
Systems for compliance and enforcement need to be adequately resourced and need to be supported by coastal communities. The probability of detection or the sanctions must be high so as to offset the potential economic gains from MPA violations.

MPA financing
Strategies, which include identifying the financing needs, and the possible instruments through which additional finance can be mobilised, should form an integral component of a MPA management plan. Instruments such as taxes, fines and other revenue generating mechanisms, which are also in line with the polluter pays principle, should be considered.

Designing MPA networks for achieving fisheries, biodiversity and climate change objectives in tropical marine ecosystems

Principle 1: Prohibit destructive activities throughout the management area
Principle 2: Represent 20-40% of each habitat within marine reserves
Principle 3: Replicate protection of habitats within marine reserves
Principle 4: Ensure marine reserves include critical habitats
Principle 5: Ensure MPAs are in place for the long-term
Principle 6: Create a multiple use MPA that is as large as possible

Source : Green, A., White, A., Kilarski, S. (Eds.) 2013

Principle 1: Prohibit destructive activities throughout the management area
e.g. blast fishing, poison fishing, spearfishing on scuba, bottom trawling, long-lining, gill netting, coral mining, fishing on hookah, and night time spearing)
Destructive activities also decrease ecosystem resilience to other stressors.

Principle 2: Represent 20-40% of each habitat within marine reserves
Higher levels if fishing pressure is high and/or there is no additional effective protection
Lower levels (20%) can be applied in areas with low fishing pressure or in areas where effective protection is offered outside of marine reserves (e.g. effective fisheries management).

Principle 3: Replicate protection of habitats within marine reserves
Protection of habitats in at least three widely separated MPAs, ideally in marine reserves, minimizes the risk that all examples of a habitat will be adversely impacted by the same disturbance (Figure 5).40,51 Thus if some protected habitats survive the disturbance, they can act as a source of larvae to facilitate recovery in other areas.

Principle 4: Ensure marine reserves include critical habitats
e.g. spawning aggregation sites for groupers, snappers, emperors and rabbitfishes. For these species, such gatherings are the only opportunities to reproduce, and they are crucial to the maintenance of the population.
Unmanaged fishing of spawning aggregations can rapidly deplete fish populations with undesirable impacts on the livelihoods of those who depend

Principle 7: Apply minimum and variable sizes to MPAs

Principle 8: Separate marine reserves by 1 to 20 km

Principle 9: Include an additional 15% of key habitats in shorter term marine reserves.

Principle 10: Locate MPA boundaries both within habitats and at habitat edges.

Principle 11: Have MPAs in more square or circular shapes

Principle 12: Minimize and avoid local threats

Principle 13: Include resilient sites in marine reserves

Principle 14: Include special or unique sites in marine reserves

Principle 15: Locate more protection upstream

Principle 6: Create a multiple use marine protected area that is as large as possible

To maximize fisheries benefits and the range of biodiversity and habitats protected, and to mitigate against risks (including climate change impacts), all of the ecosystem
should be included within a multiple-use MPA that includes but is not limited to marine reserves. Within a multiple use MPA, different zones can be used to: help protect sensitive
natural resources from over use; separate conflicting uses; and preserve the diversity of marine life in an area.

Principle 7: Apply minimum and variable sizes to MPAs

Where fishing pressure is high and there is no additional effective fisheries management for wide ranging species, then networks of both small (a minimum of 0.4 km2) and large (e.g. 4 to 20 km across) marine reserves will be required to achieve biodiversity, climate change and fisheries objectives.

Principle 8: Separate marine reserves by 1 to 20 km

Distance between MPAs, particularly marine reserves, is important because it influences the degree to which populations are connected through adult, juvenile and larval movement. This connectivity among populations helps maintain fish stocks, diversity and build ecosystem resilience by ensuring that marine reserves are mutually replenishing to facilitate recovery after disturbance. So varying he spacing of marine reserves from 1-20 km apart (with a mode of 1 to 10 km) will accommodate the larval dispersal patterns of most species

on them.

Principle 5: Ensure MPAs are in place for the long-term (20-40 years), preferably permanently

Long-term protection in marine reserves allows the entire range of species and habitats to recover, then maintain, ecosystem health and associated fishery benefits. Shorter term protection may fail to achieve fisheries, biodiversity and ecosystem resilience objectives, because the benefits of improved ecosystem function and fisheries productivity can be quickly lost when marine reserves revert back to open access in heavily fished areas such as isolated habitats that often have unique assemblages and populations, habitats that are important for rare, threatened or endemic species; and areas that are highly biodiverse

Principle 15: Locate more protection upstream
To the degree that currents influence larval dispersal, MPAs will contribute disproportionately more to genetic connectivity and population recruitment of locations down-current.

There are often information gaps and socio-economic, cultural, political and other reasons that can prevent the full application of all the principles. When required to compromise, the authors recommend that field practitioners aim to achieve as many principles as possible, and that the principles be prioritized in the order presented. Adaptive management systems should also be used that will allow managers to improve protection as more information becomes available.

Principle 9: Include an additional 15% of key habitats in shorter term marine reserves.
E.g. seasonal, rotational, periodically harvested closed no-take zones. These shorter term reserves can provide additional benefits by: protecting critical areas at critical times (e.g. fish spawning aggregations sites or nursery areas) if they are not protected in long term marine reserves; and by stockpiling resources that can be harvested to raise cash or harvest food for important community events.

Principle 10: Locate MPA boundaries both within habitats and at habitat edges.
Boundaries that are located at habitat edges (e.g. beyond the edge of coral reef habitats) are recommended for achieving biodiversity, climate change and some fisheries production objectives, since they minimize spillover of adult fished species and maintain the integrity of the MPA.

Principle 11: Have MPAs in more square or circular shapes
These compact shapes limit adult spillover more than other shapes (e.g. long rectangles or triangles), which helps maintain the integrity of the protected areas and, therefore, the sustainability of their contribution to biodiversity protection, fisheries production and and ecosystem resilience.40, 51 Other factors, such as the use of natural landmarks, should also be considered if they will facilitate compliance.

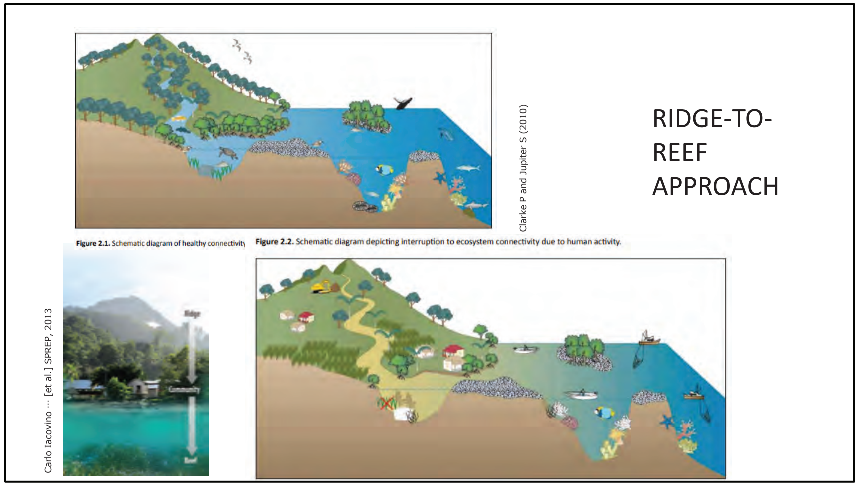
Principle 12: Minimize and avoid local threats
Choose areas for protection that have been, and are likely to be, subjected to lower levels of damaging impacts such as land based runoff, pollution, and other damaging human uses. These areas are likely to be more resilient to climate change and contribute more, and more quickly, to ecosystem health and fisheries productivity.

Principle 13: Include resilient sites in marine reserves
Resilient sites (refugia) for key habitats include areas most likely to withstand climate change impacts such as: those known to have withstood environmental changes (or extremes) in the past; areas with historically variable sea surface temperature and ocean carbonate chemistry, which may be more likely to withstand changes in those parameters in future; and coastal habitats
(e.g. mangroves, turtle nesting areas) which have adjacent, low-lying inland areas without infrastructure that they can expand into as sea levels rise

Principle 14: Include special or unique sites in marine reserves

planning and implementation processes.

7. Supporting National and Regional Planning
Aligning the R2R Framework at national and regional levels to global and regional agreements and strategies – the Sustainable Development Goals, the Samoa Pathway, Smaller Island States (SIS) Regional Strategy and the Framework for Pacific Regionalism.



KEY PRINCIPLES IN APPLYING A RIDGE-TO-REEF APPROACH IN SMALL ISLAND DEVELOPING STATES

1. Acknowledging inter-connections of Land, Water and Coastal Systems
Recognising the linkages and shared impacts between land, water and coastal systems

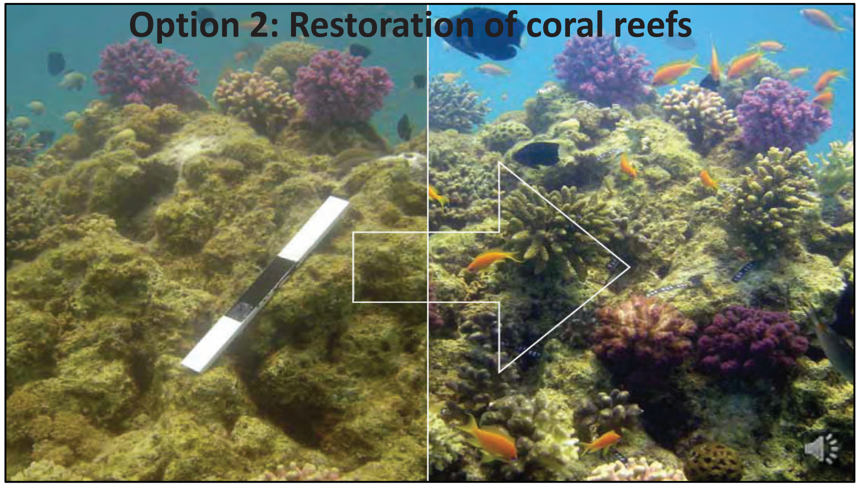
2. Promotion of R2R Community to Cabinet Approaches:
Promoting integration of communities from grassroots to cabinet for cross-sectoral planning and implementation for inclusive and sustainable development outcomes.

3. Catalyzing community action via locally driven solutions:
Understanding local contexts and supporting locally driven solutions are key to fostering ownership, sustainability and resilience.

4. Doing is Seeing the Need
Promote national demonstration projects aimed at strengthening local experience in linking Integrated Water Resource Management (IWRM) to Integrated Coastal Management (ICM).

5. Investment in island-based human capital
Supporting local capacity development to enable informed decision making and resilience building.

6. Gender Mainstreaming
Recognising the value in gender diversity for an integrated approach during



Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed

Although restoration can enhance conservation efforts, restoration is always a poor second to the preservation of original habitats

Active reef restoration should be viewed as just one option within a broader integrated coastal management plan. It is not an alternative to management and unless the causes of reef degradation are under control, active restoration will ultimately fail.

2020 -2030 has been declared by the UN as the ‘decade of ecosystem rehabilitation’ so we can expect an increase in the number of coral reef restoration initiatives.

Over the next 20 years, scientists estimate about 70 to 90% of all coral reefs will disappear primarily as a result of warming ocean waters, ocean acidity, and pollution.

Edwards, A.J. (ed.) (2010).

Initial Scoping
<u>Things you need to know</u>
What type of coral reef community you are trying to restore.
What caused the reef to become degraded.
That damaging human impacts on the reef ecosystem have stopped or are under control (e.g. effective management is in place).
That the site is unlikely to recover naturally (e.g. because it is recruitment limited).
That transplants will not be damaged by shifting sand and rubble.
<u>Key questions to answer:</u>
Did the site support a coral community prior to disturbance?
What caused the degradation?
Have the causes of degradation stopped?
Is the site recruitment limited?
Does the substrate require stabilisation?
What are the aims of the restoration?
What are the main risks?

Fact-finding for rehabilitation plan
What areas within the site are suitable for restoration?
Can previous coral community or a reference site be identified?
What is the extent of the areas requiring transplantation?
Which coral species would be appropriate as transplants at sites selected for transplantation?
What density of transplants is appropriate to assist recovery?
Calculate likely needs in terms of coral transplants over time
Is there a suitable local source of transplants for the selected coral species?

Establishment of coral nursery

- Simple in situ coral nurseries can be constructed from readily available and inexpensive materials and, with some guidance, operated by NGOs or local communities.
- Site selection very important – sheltered and good water quality

Collection of coral fragments

- ensure that collection does as little collateral damage to healthy reefs as possible
- 'Corals of opportunity'- natural fragments, detached coral colonies, or recruits on unstable substrates that have little chance of surviving naturally but have a good chance of survival if reared in a nursery, or transplanted directly and securely fixed to the natural reef.
- Choose species based on management objectives

Fast growing branching species such as acroporids and pocilloporids may generate a rapid increase in structural complexity (and are thus sometimes called "engineering species") but tend to be more vulnerable to both bleaching and predators than slower growing massive, submassive and encrusting species such as poritids and faviids.

The environment at the nursery should be sufficiently similar to that at the site being rehabilitated (or more benign) so that transplants will be adequately adapted to the
conditions when outplanted.

Developing a rehabilitation plan
Is nursery rearing required?
What are your detailed objectives?
What are your criteria for success?
How will achievement of success criteria be monitored?
Developing a monitoring plan

Implementation of rehabilitation plan and monitoring
Construct coral nursery with capacity to generate sufficient transplants (over one or multiple cycles)
Collect and prepare source material and stock nursery
Grow coral colonies until large enough for outplanting (or fragmentation)
Transplant nursery-reared colonies to rehabilitation site
OR
Wild stock is available in sufficient quantities.
Collect and prepare source material
Deploy transplants to rehabilitation site.

Monitoring and maintenance of transpant sites
Monitoring should be aligned to the management objectives
Maintaining transplantation sites to control of macroalgae and coral predators

Outplanting

- Branching species ready for outplanting at around 7–10 cm diameter
- Massive, sub-massive and encrusting species at around 4–5 cm
- Attachment types: Cable ties, bamboo sheaths, adhesives, cement
- Corals should be encouraged to self-attach
- Transplant corals at times of year when they are likely to be least stressed and prone to disease

Monitoring and maintenance of transplants

- Establish baseline 'control' sites as reference points
- Regular visual checks (e.g. to remove predators such as Drupella or Crown-of-thorns starfish
- Reattachment of detached transplants
- Removal of loose fouling materials (flotsam) and organisms (macroalgae, sponges and tunicates)
- Semi-annual or annual systematic surveys to show progress towards goals

To cover costs look at rearing some corals for sale to the commercial coral trade

Choice of sps - most logical choice is one that occurs naturally at the rehabilitation site and is relatively common on nearby potential source reefs. Make sure that these are sourced from sites with environmental conditions that are as similar as possible to the rehabilitation site.

Try to encourage self-attachment of transplants to the reef substrate by transplanting them such that living coral tissue is in contact with the substrate. Should also be no movement.

Timing: outside the warmest months and not during the main spawning time for seasonal spawners. For more exposed rehabilitation sites, avoid transplanting in the months just before or
during the stormy season.

semi-annual or annual systematic surveys to show progress towards goals (such as increasing coral cover or build up of reef fish biomass).

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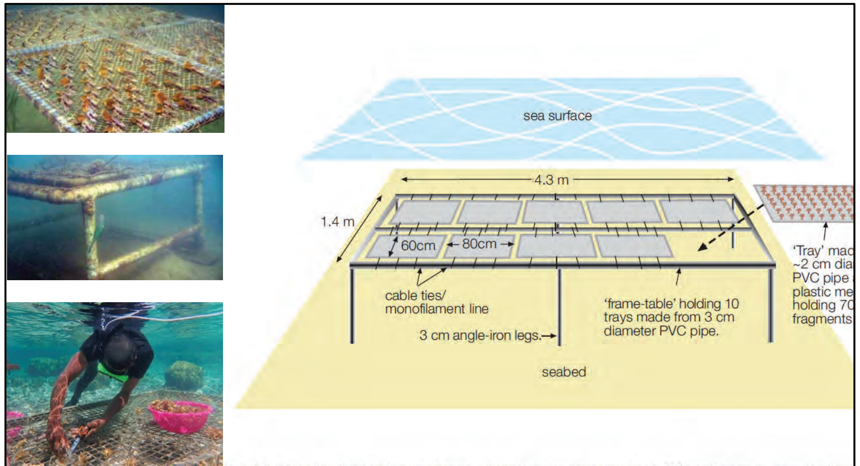

Source: Edwards, A.J. (ed.) (2010). **Figure 4.2.** Design for a fixed modular tray nursery with the capacity to rear up to about 700 coral fragments - based on Shai

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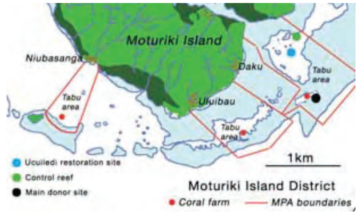
Option 3: Conservation and Restoration of mangroves

Source: Asian Development Bank. 2018.

Case Studies

Transplantation of coral colonies to create new patch reefs on Funafuti Atoll (Tuvalu)

Transplantation of corals to a traditional no-fishing area affected by coral bleaching (Moturiki Island, Fiji)



[Edwards, A.J. (ed.) (2010). Reef Rehabilitation Manual. Coral Reef Targeted Research & Capacity Building for Management Program: St Lucia, Australia] that of savannah (Donato et al. 2012). Deforestation in these systems releases a disproportionate amount of carbon into the atmosphere as the carbon protected by mangroves is released. Their ability to trap organic sediment and thus store carbon is why mangroves, among other systems, are referred to as 'blue carbon' sinks. It should be recognised that older stands of mangroves generally have accumulated large amounts of peat below them and thus store more carbon, therefore providing greater climate change mitigation benefits.

Mangroves are trees or large shrubs which are salt tolerant and grow in intertidal zones in tropical and subtropical regions.

'There is good evidence that, in the right circumstances, mangroves can help to reduce vulnerability to climate-related coastal hazards'

Mangroves are unique and highly productive ecosystems. Ecosystem services derived from mangroves related to structural diversity of mangrove roots and their position at the interface between land and sea.

Ecosystem services:
- Provide coastal protection and erosion control
- Serve as a habitat and nursery ground for fish and other marine species
- Support diversified livelihoods
- Sequester and store carbon 10 x more efficiently than inland tropical forests
- Nutrient cycling

Mangrove forests can reduce wave energy, erosion, and storm surge water levels and by doing so mitigate coastal flooding (Gedan et al. 2011). This is particularly relevant in the context of climate change, as coastal flooding and erosion are predicted to increase in severity as sea levels rise.

Mangroves may keep pace with sea level rise - There is evidence that mangroves support soil stabilization and sediment capture, and are able to build up soil levels vertically (accrete) through formation of layers of peat (Lee et al. 2014). This ability means that mangroves are able, in the right conditions, to keep pace with sea level rise

Mangroves may provide a refuge from ocean acidification - It has been recently been found that mangroves may provide a refuge for coral reef species from climate change.

Mangroves serve as a habitat and nursery ground for fish and other marine species, supporting fisheries and livelihoods -Many commercially important marine species utilize mangroves for some, or all, parts of their lifecycle, for example species of snapper, mullet, shrimp, crab and sharks. There is often ecological connectivity with nearby seagrass and coral reef habitats.

Mangroves support diversified livelihoods - Wood for construction and fuel. Non-timber mangrove forest products can provide significant revenue through the provisioning of, for example, honey, dye, fodder, herbal remedies and fruits

Mangroves sequester and store carbon more efficiently than upland tropical forests - more than twice the carbon storage of upland forests and five times

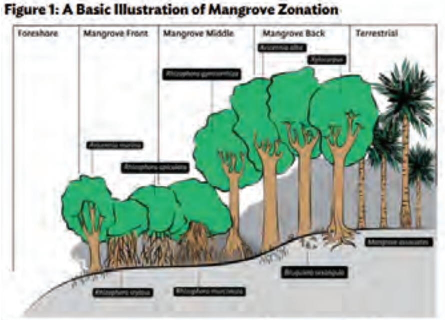
Source: How Mangrove Forests Protect The Coast Video

4

Important to understand which species occur in what places along a shoreline gradient

North Pacific	Mangrove species (hybrids)
Palau	14 (1)
Guam	12
Northern Marianas	3
Federated States of Micronesia	15 (1)
Marshall Islands	5
South Pacific	
Papua New Guinea	31 (2)
Solomon Islands	17 (2)
New Caledonia	15 (3)
Vanuatu	14 (3)
Nauru	2
Fiji	7 (1)
Tonga	7
Samoa	3

Figure 1: A Basic Illustration of Mangrove Zonation



A. marina *Sonneratia* *R. stylosa* *R. apiculata*	*R. apiculata* *R. mucronata* *B. gymnorrhiza*	*A. alba* *A. officinalis* *B. sexangula* *Xylocarpus*	*Mangrove associates*
Mud, sandy, sandy loam, gravelly sand, rocky or coral rubble	Mud, sandy loam, muck	Mud, sandy loam, sandy	Terrestrial soil

Asian Development Bank. 2018.

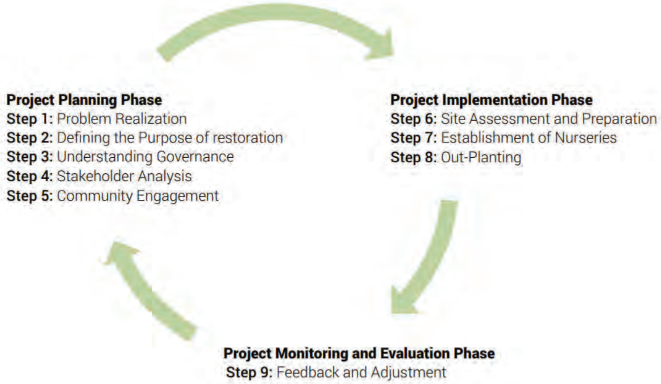
5

Threats to mangroves

- Conversion for development purposes (houses, resorts, factories, warehouses, agriculture)
- Over harvesting for fuel and construction wood
- Hard infrastructure preventing inland migration with sea level rise (e.g. roads)
- Trampling
- Loss of connectivity
- Extreme weather events (e.g. cyclones)
- Solid waste pollution

Mangrove land is highly prized by developers as, once cleared and filled in, it provides 'flat' land which is scarce in volcanic islands, Also land tenure arrangements are normally easier to negotiate as mangrove land normally is state land for which 'foreshore leases' are available.

Threshold rates of sea-level rise are likely to exist, beyond which mangrove surface elevation changes are no longer able to keep up



Source: Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region. UNEP

PROJECT PLANNING PHASE

Questions to consider during project planning for mangrove restoration

-- What caused the loss and degradation of mangroves?
-- What is preventing natural regeneration to occur in the area?
-- Why should we plant mangroves in the degraded site?
-- Who has ownership of where planting is intended?
-- Who should be involved in the restoration initiatives?

Problem Realisation

Realizing that there is a problem, leads to determining whether there is need to take any action to resolve the problem, which is critical for subsequent steps. Requires rapid consultative field surveys with key actors, including communities. This exercise is important for rapid understanding of the values and benefits of mangroves, priorities, preferences, willingness and support to their restoration.

Defining the Purpose of restoration

Mangrove restoration often has multiple goals that include timber production, coastal protection, biodiversity conservation, fishery support, ecotourism, and education. These should be carefully aligned when assessing and preparing a restoration site (Step 6) to ensure that it supports the defined aims.

Understanding Governance

Land and resource tenure rights (access and user) is fundamental to successful mangrove restoration. In most countries where mangroves occur, there are laws and legislations for their management. Any activities within mangroves (including restoration) might, therefore, require permission from the

necessary
Plant seedlings, propagules, or wildlings collected as close as possible to the restoration site.
Monitor your site long-term (usually 5 years) and make necessary corrections and adjustments

Establishment of Nurseries
The site for nursery should be selected in the inter-tidal area, in close proximity to creeks with drainage channels. Water quality should be good and the area should be fenced, to prevent disturbance by human or animals. The nursery should comprise of a seed germination bed, potting shed, hardening off beds. For more operational details on establishing a mangrove nursery see *Guidelines on Mangrove Ecosystem Restoration for the Western Indian Ocean Region. UNEP.*

Outplanting
Protection of the roots during collection and planting of saplings is an important handling technique to ensure survival after planting. See *Mangrove restoration. Technical Guide (undated). International Coral Reef Initiative* for detailed operational information.

PROJECT MONITORING AND EVALUATION PHASE

Monitoring is important in any restoration initiative. For this to be practically realized, achievable and measurable, success criteria must be defined and incorporated into a monitoring program prior to initiation of restoration activities. For proper monitoring, a plan must
be in place to provide guidance of what will be monitored, the methodology, who will be involved in that process and the monitoring schedule.

responsible regulatory agencies.

Stakeholder Analysis
Mangroves are multiple use systems, providing multiple resources to multiple users. This often leads to multiple conflicts that warrants adequate stakeholder identification, consultations and engagements to ensure that the interests of each group are collaboratively
and consensually taken into consideration. Appropriate engagements of particularly local stakeholders are important in ascertaining stakeholder’s interests and expectations, and hence determine where restoration intervention(s) is most practical, useful and acceptable.

Community Engagement
Engagement should extend along the entire restoration process to ensure that interests of local communities are recognized, appreciated and safeguarded

PROJECT IMPLEMENTATION PHASE

Questions to consider during implementation phase of a restoration project

Is there a need to gather information on biophysical features, including; soil depth and
hydrology etc.?
-- Is a species inventory of the designated site required?
-- Which species should be planted?
-- What are the best approaches to return the lost mangroves?
-- Which approach is best to use: direct planting, nursery raised or natural regeneration

Site Assessment and Preparation
Normally, the site to be restored should be accessible and devoid of strong waves. Planting should be restricted to vegetated areas where the forest has been degraded and lost.
Golden Rules:
Understand why natural regeneration is not occurring
Plant close to where that species is naturally occurring
Do not plant mangroves too densely
Small-scale test planting
Do not plant in any water channels, seagrass beds, mudflats
Make sure the local community members are fully involved
Ensure the site is protected from people, boats and livestock, fenced if

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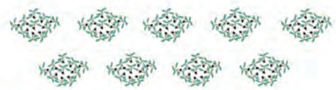
Figure 7: An Example of Strip Planting Viewed from Above

Figure 8: An Example of Inverted-V Planting Viewed from Above

Source: Mazella Maniwavie.

Figure 9: Cluster Planting Viewed from Above



Source: Mazella Maniwavie.

9

EBA IN COASTAL AND MARINE AREAS - SUMMARY OF KEY PRINCIPLES AND CHALLENGES

Key Principles

- Managing for uncertainty = monitoring and adaptive management
- Focus on ecological, social and economic connectivity
- Prioritise ecosystem services that build resilience to and mitigate climate change
- Maximise co-benefits
- Requires community buy-in and active participation

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Challenges

- Ad-hoc and fragmented coastal and marine planning
- Competing interests and trade-offs
- Weakly developed policy context
- Financing
- Inadequate use of spatial planning tools
- Coordination between agencies
- Lack of awareness raising and education

11

CBCRP-PCCC Training Course

"Ecosystem-based Adaptation and Mitigation"

Government of Samoa, SPREP and JICA

Module 2.3 EbA Implementation: Cross-cutting Issues and Approaches

Fred Siho Patison – Climate Change Finance Readiness Advisor
SPREP
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1

Presentation outline

- What is Ecosystem-based Management and EbA
- Different management approaches and features of EbA
- Ecosystem-based Adaptation Options Development
- Case study 1- Choiseul Province, Solomon Islands
- Case study 2- Honiara Botanical Gardens, Solomon Islands
- Lessons Learned – cross cutting issues and multiple experts

Source: Solomon Islands REDD+ Roadmap

2

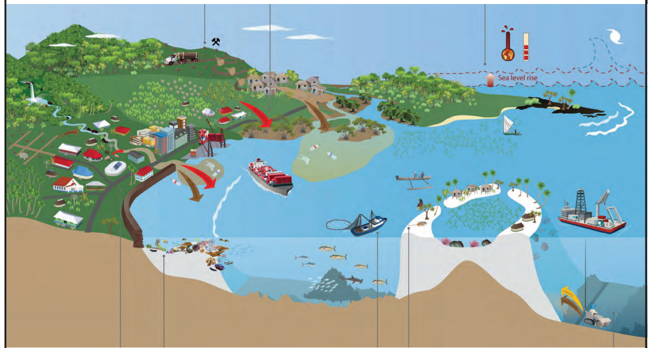
Actions needed

- Awareness raising at all levels
- Review and tightening of policy and legislation for mangrove, coral reef and seagrass conservation
- Mainstream EbA and related concepts like EBM, R2R, Blue Carbon, Marine Spatial Planning into climate change, disaster risk management, national development and sector policies and plans
- Integrate ecosystem values into national accounting processes
- Strengthen coordination between land and sea resource management agencies and promote integrated planning and programming
- Increase budget allocations in recognition of growing importance
- Promote public – private – community partnerships
- Introduce incentives (e.g. conservation leases and new livelihood opportunities)

12

Multiple threats to Pacific Ecosystems

Mining and Logging
Pollution and Waste
Climate Change



Coastal Development
Unsustainable Fishing
Invasive Species
Emerging Uses

3

There are many management strategies, with different degrees of integration

Least integrated

Most integrated

- Fisheries management
- Marine Protected Areas
- Integrated forest management
- Watershed management
- Marine Spatial Planning
- Integrated Coastal Zone Management
- Ecosystem Based Management

4

Fisheries management

Source: Stuart Chape Presentation (SPREP)

Conventional fisheries management focuses on commercially targeted fish stocks; however, there has been an effort to move from single to multispecies management, and essential fish habitat protections have incorporated linkages to a variety of habitats.

5

Marine Protected Areas

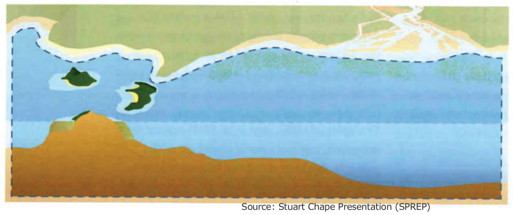
Source: Stuart Chape Presentation (SPREP)

MPAs can vary in scope from small no-take zones targeting the water column and/or benthos, to large MPAs that include vast areas of land and sea.

6

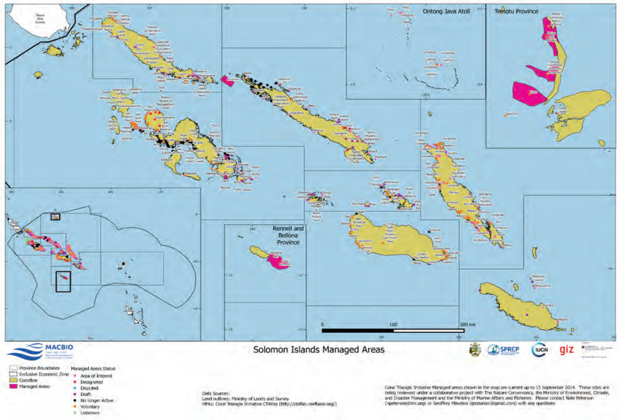
Integrated Forest Management

Marine Spatial Planning



Source: Stuart Chape Presentation (SPREP)

MSP covers the marine environment, either within a single jurisdiction (such as territorial seas or within federal waters) or across many jurisdictions (provincial or state waters, territorial seas, and even areas beyond national jurisdiction).



Integrated Coastal Zone Management

Source: Stuart Chape Presentation (SPREP)

ICZM focuses on the land side of the coastal zone, typically encompassing the coastal plain as well as the near shore marine environment.

Ecosystem Based Management

Source: Stuart Chape Presentation (SPREP)

The geographic scope of EBM can collectively cover that of all five of the main management strategies: 1) the coastal lands and nearshore environment of ICZM; 2) the marine environment of MSP; 3) the rivers and drainage basins in watersheds that drain into the sea; 4) the waters supporting exploited fish stocks; and 5) the coastal and marine environments encompassed by MPAs.

11

EBM can be implemented to different extents

No EBM or Low EBM	Incremental EBM	Comprehensive EBM
Individual species management	Managing groups of species	Managing whole ecosystems
Single sector management — fisheries, for example	Integrated management of two sectors — fisheries and offshore energy, for example, to avoid user conflicts	Integrating all sectors that impact, or are impacted by, the ecosystem
Restricted scale management — local only, for example	Coordinated management at local and state levels	Coordinated management at all levels relevant to the ecosystem
Short-term perspective: what do we need from the ecosystem this year?	Medium-term perspective: what services do we need the ecosystem to provide 5 years from now?	Long-term perspective: what will the ecosystem look like in 20 years with climate change?
Managing commodities	Managing activities with those commodities in mind	Managing activities with system functioning in mind

Source: Stuart Chape Presentation (SPREP)

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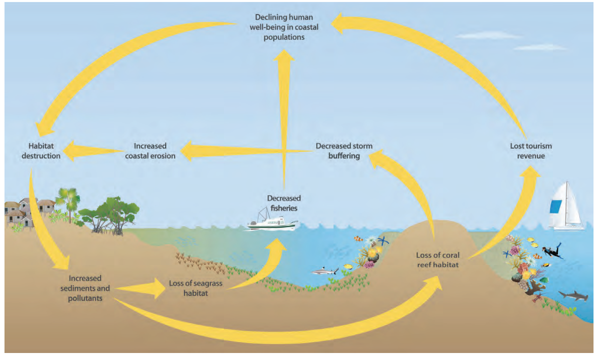
EBM recognizes the connections within and across ecosystems



Source: Stuart Chape Presentation (SPREP)

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EBM recognizes diverse ecosystem services

Source: Stuart Chape Presentation (SPREP)

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SPREP PROE

EBM approach to Climate Change Impacts: Ecosystem-based Adaptation (EbA)

- ***Reduces* vulnerability** while maintaining secondary ecosystem services
- ***Increases* resilience** by promoting healthy ecosystems
- ***Supports livelihoods*** and sustainable development

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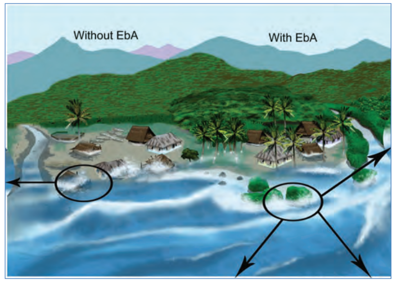
SPREP PROE

Ecosystem based Adaptation Example: Planting coastal vegetation to reduce storm surge



Source: Stuart Chape Presentation (SPREP)

Primary service:
Reduce coastal flooding

Secondary services:
Fish habitat and nursery habitat increased
sediment stabilization
Source of firewood
Carbon sequestration
nutrient and sediment trapping

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SPREP PROE

Key Features of EBM approaches applicable to EbA

- It is a holistic approach and considers whole ecosystem level.
- Considers the human and climate change impacts.
- Implementation of interventions requires clear baseline assessments.
- Involve a lot of cross-cutting issues around development issues, governance, broader environmental issues and livelihood.
- The community are part of the solution in protection ecosystems and managing natural resources.
- Multiple thematic areas of focus and so the need for diverse expertise and interest groups.

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SPREP PROE

Ecosystem- based adaptation (EbA)

- EbA Definition;

"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change." CBD Ad Hoc Technical Expert Group on Biodiversity and Climate Change

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ESRAM

Step 1
- Identify the current state of ecosystems, trends and drivers of change with root causes, scenarios and social and economic governance factors
- Identify ecosystem types, ecosystem services and threats
- Identify ecosystem services that are valued by the community
- Map key ecosystems and related ecosystem services including high use areas and/or major threats based on existing spatial data

Step 2
- Undertake a Total Economic Valuation to define the economic value of key ecosystems services relevant to the ESRAM

Step 3
- Assess the vulnerability of ecosystems services to the impacts of climate change based on climate change projections
- Identify the ecosystem services most vulnerable to future climate and non-climate threats and impacts

Step 4
- Recommend EbA options to strengthen the resilience of key ecosystem services

Source : Honiara Ecosystem and Socio-economic Resilience Analysis and Mapping

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Examples

Ecosystem Service – **provision of drinking and domestic water;**

Ecosystems - groundwater wells, surface expressions and freshwater springs

Climate threats:
- saline intrusion from sea level rise
- prolonged dry periods/ drought
- extreme rainfall causing sedimentation

Anthropogenic threats:
- pollution
- poor waste and sanitation practices
- proposed developments

EbA Options?

Wagina Ecosystem and Socio-economic Resilience Analysis and Mapping

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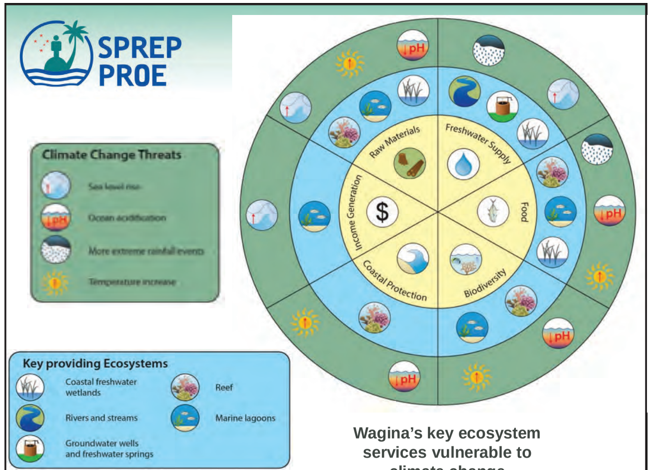

Wagina's key ecosystem services vulnerable to climate change

Source: Simon Albert, University of Queensland

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Typical List of Ecosystem Services and Ecosystems

1. **Freshwater quality for drinking, domestic and irrigation purposes,** provided by rivers and streams and terrestrial watershed
2. **Income generation** (fisheries, aquaculture, logging and agriculture), provided by coastal, marine and freshwater ecosystems, and terrestrial watershed
3. **Food** provision services, provided by reefs, mangroves, rivers and streams, terrestrial watershed, cultivated land
4. **Biodiversity**, provided by reefs, forests and land
5. **Land stability and erosion control,** provided by the terrestrial watershed
6. **Raw materials**, provided by mangroves and reefs
7. **Coastal protection** provided by reefs

What Intervention can address these ecosystem services and ecosystems?

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SPREP PROE

EbA Options Selections Considerations

- **The EbA approach, scope and focus;**
  - Policy and Guidelines
  - Awareness and Education
  - Further technical research and assessments
  - On ground demonstration implementation
- **The EbA scale, costs and time of intervention;**
  - Geographic focus of the areas of intervention
  - What specific intervention and costs involved
- **EbA Crosscutting Issues;**
  - What kind of expert you need subject to the approach and focus.
  - Other governance and contextual issues for consideration
  - What is already happening on the ground that you can build on (partnerships)

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SPREP PROE

EbA options selection criteria

Criterion	Considerations	Qualitative Performance Measures and Scores Awarded			
1. Benefits of implementation	• Addresses core objectives of the program through reducing vulnerability to and impacts of climate change • Protection/enhancement of high priority ecosystem services (e.g. provisioning services) • Provision of new or enhanced services (e.g. increased tourism, education, health improvements) • Value-add benefits (i.e. provision of additional benefits other than adaptation)	Very high	High	Medium	Low
2. Cost of implementation	• Implementation, ongoing management and maintenance	Low	Medium	High	
3. Feasibility of implementation – how feasible it is to implement the option?	• Tenure and landowner considerations • Likely timing and logistical requirements • Extent of integration with existing policy and/or programs • Stakeholder/Community supports the option	Yes	Uncertain	No	
4. Sustainability of implementation	Yields long-lasting benefits	Very high	High	Medium	
5. Existing projects /activities	Existing projects are addressing this issue/threat	Nil	Few (1-2)	Several (3-5)	Many (6+)

Source: Planning for Ecosystem-based Adaptation in Honiara, Solomon Island, Synthesis Report

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Prioritising EbA options

Each EbA option was prioritized using six selection criteria;

Descriptions and scoring matrix of the six selection criteria used to prioritise EbA options.

Criteria	Description	Scores			
BENEFITS	Increasing social / ecological resilience through protection or enhancement of ecosystem functions/services, or provision of additional benefits	Very high (1)	High (2)	Medium (3)	Low (4)
COST	Cost of implementation, including ongoing monitoring, management, and maintenance	Low <USD 10K (1)	Medium USD 10–50K (2)	High USD 50K+ (3)	-
FEASIBILITY	Community support, land tenure and ownership, logistical requirements, partnership opportunities	Yes 1	Uncertain 2	No 3	-
SUSTAINABILITY	Potential for long lasting benefits with minimal maintenance	Very high 1	High 2	Medium 3	-
EXISTING PROJECTS	Current projects addressing this issue/ threat/opportunity	Nil 1	Few (1–2) 2	Several (3–5) 3	Many (6+) 4
COST EFFECTIVENESS	This scoring process resulted in a shortlist of priority actions which were subjected to a separate cost effectiveness assessment.	Ranked 1st 1	Ranked 2nd 2	Ranked 3rd 3	Ranked 4th 4

Source: Planning for Ecosystem-based Adaptation in Honiara, Solomon Island, Synthesis Report

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Cost effectiveness Analysis

The final prioritized EbA options are subject to a cost effectiveness analysis. This was a replicable five step process;

Ranking of the top five EbA options for Honiara based on six selection criteria.

Honiara ecosystem-based adaptation options	Benefits	Cost	Feasibility	Sustainability	Existing projects	Cost effectiveness	SCORE
Barana and Queen Elizabeth Park management plan	2	3	1	2	1	2	11
Support Botanical Gardens to be a formal protected area	2	3	1	1	1	3	11
Environmental compliance training for government staff and stakeholders	2	3	1	2	2	1	11
Mataniko River bank rehabilitation and information centre	2	3	1	2	1	4	13
Beautifying and creating green space for the Honiara CBD	2	3	1	3	1	5	15

Source: Planning for Ecosystem-based Adaptation in Honiara, Solomon Island, Synthesis Report

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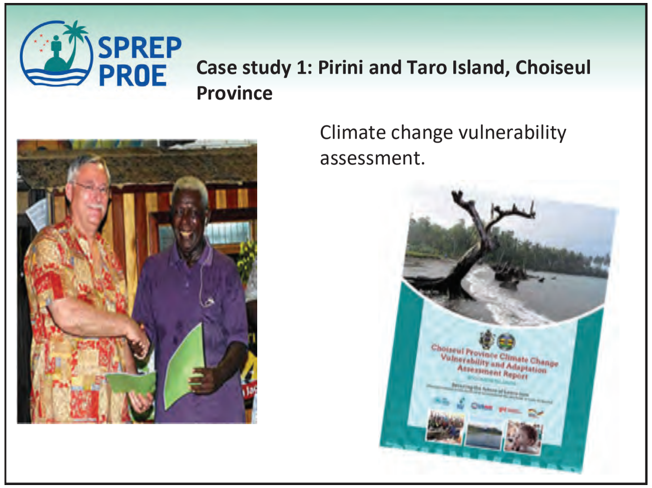
SPREP
PROE
Case study 1: Pirini and Taro Island, Choiseul Province
Climate change vulnerability assessment.

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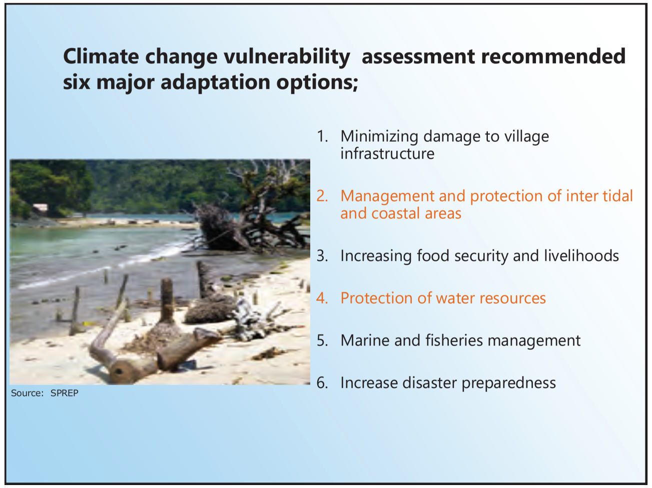
Climate change vulnerability assessment recommended six major adaptation options;
1. Minimizing damage to village infrastructure
2. Management and protection of inter tidal and coastal areas
3. Increasing food security and livelihoods
4. Protection of water resources
5. Marine and fisheries management
6. Increase disaster preparedness
Source: SPREP

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1.Sasamuga Community - Pirini watershed
EbA Options;
▪ Water catchment management for long term water security
- Hybrid intervention

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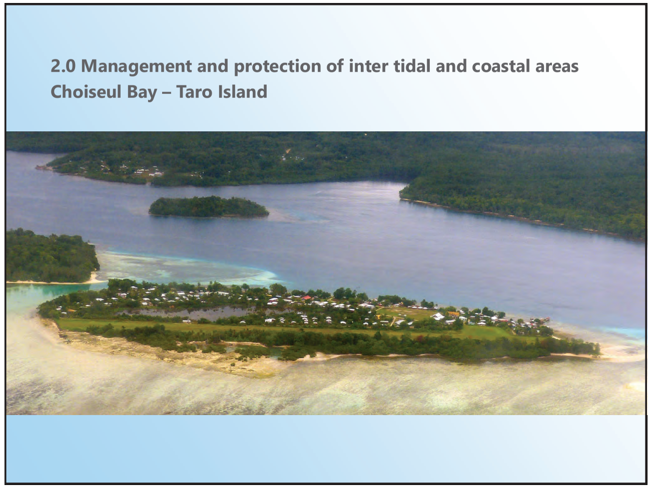
2.0 Management and protection of inter tidal and coastal areas
Choiseul Bay – Taro Island

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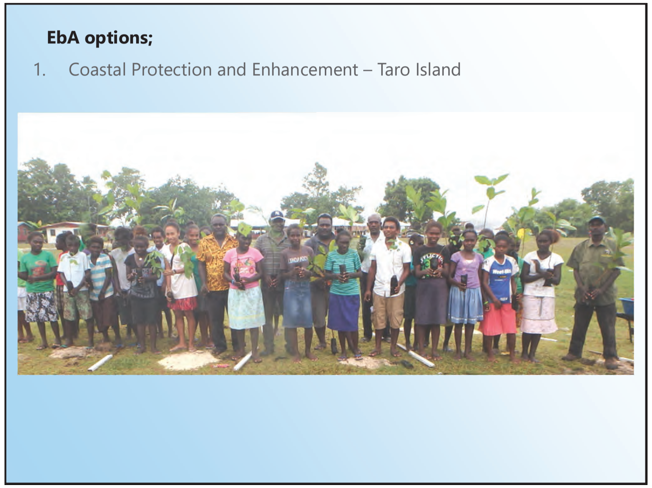
EbA options;
1. Coastal Protection and Enhancement – Taro Island

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3. EbA Implementation

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Case study 2: Rehabilitation of the Botanical Gardens, Honiara.

Source: SPREP

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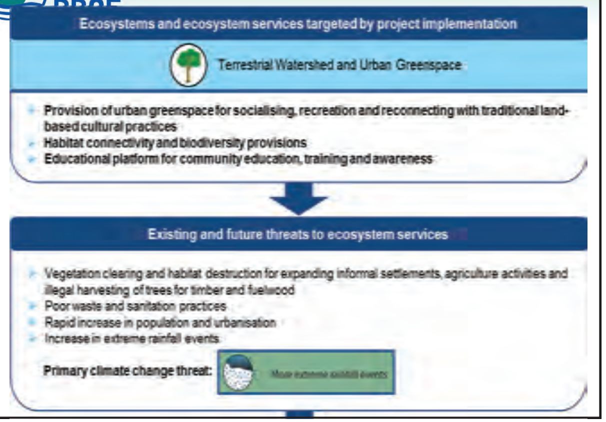

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Key project interventions

- ❑ Establishment of the Honiara Botanical Gardens Management Committee
- ❑ Support establishment of a learning centre and development of footpaths and walkways
- ❑ Support refurbishment of a Botanical Gardens Nursery
- ❑ Formulation of a management and Busines Plan
- ❑ Improved waste management and collection for the Gardens

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Multi-sector management committee established to oversee rehabilitation of Honiara Botanical Garden

- PEBACC supporting development of management and business plan
- Exploring partnership with Toledo Zoo to establish a wildlife conservation and education facility

"This initiative is greatly welcomed by the council." - Mr Charles Kelly, Honiara City Council Clerk and co-chair of the committee

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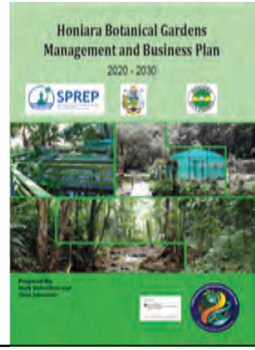
Botanical Gardens Management and Business Plan

SPREP PROE



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Key Lessons Learned – Case Studies

SPREP PROE

- ❑ EbA interventions will need long term indicators and activity-based indicators (project based)
- ❑EbA approaches require diverse specialist expertise Eg. Forestry and Water Resources etc and national project offices .
- ❑Use existing mechanism and arrangement Eg. MECDM Mataniko Project, R-Wash and G-Province
- ❑Questions around resilience framework with clear indicators at the national level.
- ❑ Achieve biodiversity conservation outcomes and links to Sendai Framework, SDG and Paris Agreement indicators.

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Key Lessons Learned – Case Studies

SPREP PROE

- ❑ Building resilience through EbA at community level is an on-going process and a long-term goal. It may also means doing everything environmental whilst thinking livelihood options.
- ❑ Livelihood options is an integral part of EbA interventions. E.g. eco-tourism and sustainable landuse
- ❑Develop partnerships for capacity building and development eg. SINU, Youth at work, HCC Youth, Honiara Council of Women, R-WASH
- ❑Engage other government partners for long sustainability and other co-benefits Eg. SIVB, Ministry of Tourism and Culture, HCC, SPC Ridge to Reef
- ❑Use local expertise and experience eg. Forest and Water Resources Experts

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THANK YOU

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THEORY OF CHANGE IN DEVELOPING BANKABLE PROJECT PROPOSALS

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INSTITUTE FOR GLOBAL ENVIRONMENTAL STRATEGIES

BANGKOK REGIONAL CENTRE

A Theory of Change in developing bankable project proposals.

SPREP PROE

KEY QUESTIONS AND CONCEPTS

Which of the following is an EBM example?
A. Marine Protected Area
B. Ridge to Reef Management
C. Integrated Coastal Management
D. All the above

Which of the following is a feature of both EBM and EbA?
A. Focus on one species only
B. Focus on human population only
C. Take a whole ecosystem level approach
D. Focus on development

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What are some of the crosscutting issues related to EbA implementation?
A.The assessment requires understanding the non-climate change issues and related issues.
B. You will need multiple and diverse expertise and skills.
C. You will need to consider the approach you will take based on context and need.
D. All of the above.

EbA interventions are cost-effective but require long term indicators? Explain in a short paragraph?

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GCF GUIDANCE ON THEORY OF CHANGE

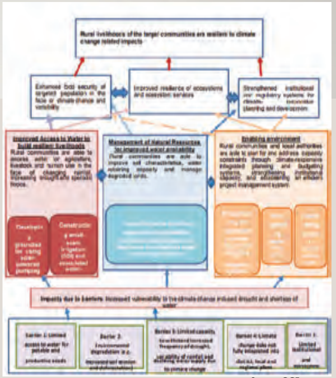
- The project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address. This determination will form the starting point and basis for the theory of change diagram, which articulates how the project will address the identified problem.
- The theory of change, despite being called a "theory", is a methodological approach that allows AEs and project developers to design and plan a project by first setting up the long-term project goals and objectives then mapping backwards to identify the necessary preconditions to meeting those goals, the project outcomes and outputs, as well as the assumptions under which the theory of change is developed. In this way, the theory of change clearly articulates how the results chain will cascade from the theory of change statement to the project activities.
- The innovation of the theory of change lies in making the distinction between desired and actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on forms of intervention to achieve those outcomes.

GCF has provided guidance on a theory of change, and this presentation will help to understand exactly what GCF is looking for in relation to theory of change.
Firstly, the project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address.
Generally, that's done through a problem tree.
This determination will form the starting point and the basis for your theory of change diagram or narrative, which articulates how the project will address the identified problem.
The theory of change, despite being called a theory. is actually a methodological approach that allows accredited entities and project developers to design and plan a project by first setting up the long-term project goals and objectives and then mapping backwards to identify the necessary preconditions and inputs to meeting those goals.
The project outcomes and outputs as well as the assumptions under which the theory of change is developed.
In this way, a theory of change clearly articulates how the results chain will cascade from a theory of change statement to the project activities.
The innovation of the theory of change lies in making the distinction between what is a desired outcome and the actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on the forms of intervention to achieve those outcomes.

2

THEORY OF CHANGE

- **SOME COMMON QUESTIONS**
- **What is the difference between a "theory of change" and the "logical framework"?**
- **What are the implementation implications of the theory of change?**
- **Why aren't the climate predictions a required element of the theory of change?**
- **Why is a theory of change best presented as a diagram instead of narrative text?**
- **Who should be involved in developing the theory of change?**



Source: GCF

Now some common questions that are often asked in relation to the theory of change.
Firstly, what is the difference between a theory of change and the logical framework? Often, they appear to be used interchangeably.

What are the implementation implications of a theory of change? Why are climate predictions a required element of the theory of change? And why is the theory of change often best presented as a diagram instead of a narrative text?
And who should be involved in developing the theory of change? Well, we'll try and answer some of those questions as we go through the presentation.

3

The **climate context** provides the scientific underpinning for evidence-based climate action decision-making and the theory of change for all activities funded by GCF. It ensures that the set of causal linkages between the climate and climate impacts/hazards and action and societal benefits is fully grounded in the best available climate data and science. It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and/or adaptation in terms of reducing GHG emissions or improving the resilience of people and communities and should meet at least one of the eight GCF results areas.

The **theory of change** explains to the funder (GCF) why you think your project will work, and why the funder should expect the project to bring about the results you envision for the project. A good theory of change is like the backbone of a well-designed and fundable project proposal. Many proposals are rejected because they don't include a theory of change, or because the theory of change doesn't adequately show how the project moves from problem to solution.

The climate context provides the scientific underpinning for evidence-based climate action, decision making and the theory of change for all activities funded by the GCF. It ensures that the set of causal linkages between the climate and climate impacts or hazards, and action and societal benefits is fully grounded in the best available and most up to date climate data and science.
It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and or adaptation in terms of reducing greenhouse gas emissions or improving the resilience of people and communities and should meet at least one of the eight GCF resolve areas.

The Theory of Change explains to the funder, that is the GCF, why you think your project will work and why the funder should expect the project to bring about the results you envision for the project.

A good theory of change, therefore, is like the backbone of a well designed and fundable project proposal. Many proposals, in fact, are rejected because they don't include a theory of change or because the theory of change doesn't adequately show how the project moves from problem to solution.

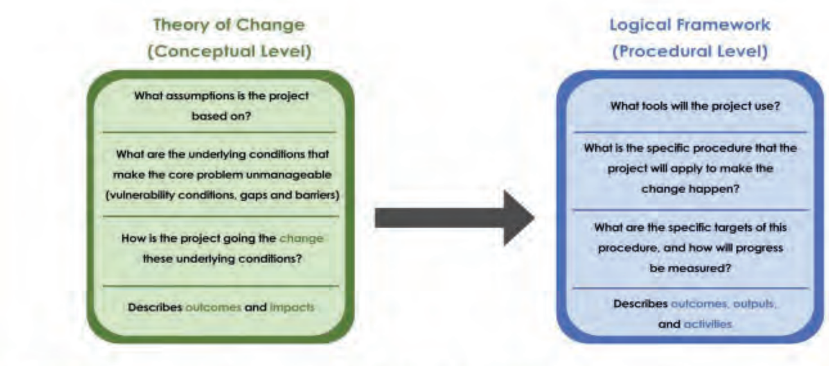


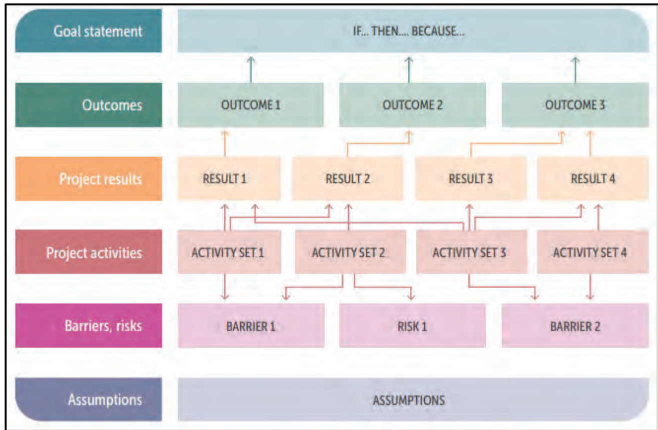
Figure 1: Relationship between project theory of change and logical framework

Source: Regional resource centre for Asia and the Pacific

A good way to think about the difference between a theory of change and the logical framework is that the theory of change is essentially at a conceptual level.

So what assumptions is a project based on? What are the underlying conditions that make the core problem currently unmanageable, often through vulnerability assessments or identification of gaps and barriers?

And how is the project going to change these underlying conditions?
It will describe the outcomes and impacts at a high level of the logic chain.
The logical framework, however, is a more procedural arrangement where we look at what tools will a project use, what are the specific procedures that the project will apply to make the change that's desired actually happen?
And what are the specific targets of this procedure and how will progress be measured? And it describes the outcomes, the outputs and activities, as well as the input supports to achieve those activities.



GCF Model Theory of Change

Ref: https://www.greenclimate.fund/sites/default/files/document/gcf-programming-manual_0.pdf

Inputs allow activities to be carried out that will deliver project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

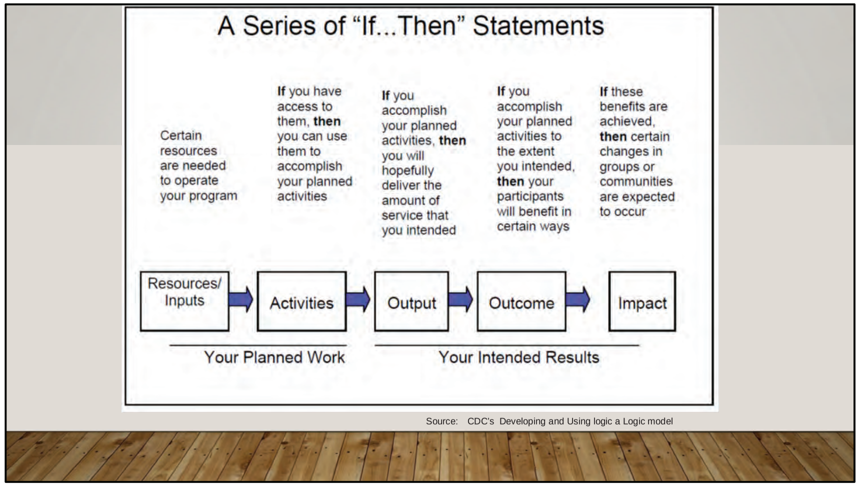
The GCF has provided a standard diagram that is relatively easy to fill in and it basically moves from the understanding of that inputs will allow activities to be carried out that will deliver project outputs which in turn will meet the immediate purpose of the project and contribute to the longer term goal that GCF is trying to achieve through its overarching paradigm shift.
Importantly, the goal statement also operates on a logical basis and says if we carry out activity X then we achieve output Y because we have undertaken a series of inputs.

LEVELS OF THE LOGIC MODEL

Impact level	Societal change?	Aggregate changes achieved in the GCF key strategic results areas
Outcome level	What changes?	Aggregate changes achieved in the country or region, as well as in the relevant policies and policy documents
Output/project result	What deliverables?	Changes achieved as a result of project or programme activities
Activity	How to deliver results?	Direct services provided through GCF investments
Input	What is needed?	GCF grants, concessional loans, guarantees or other financial instruments, as well as human effort

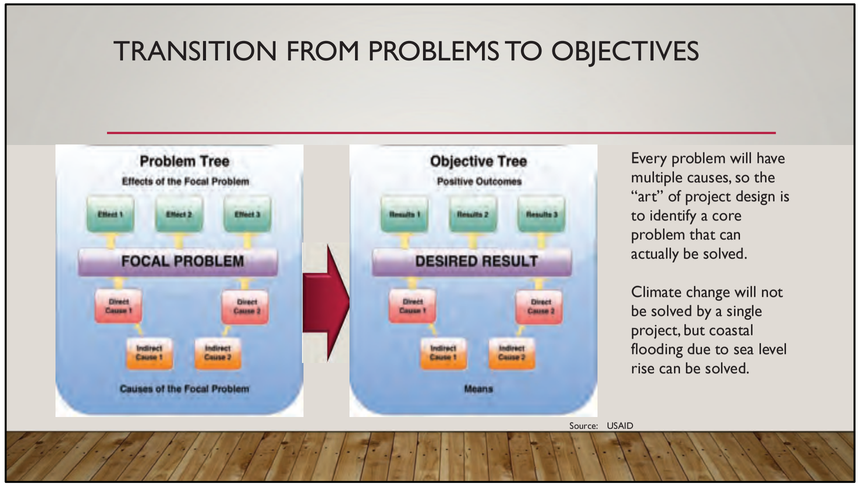
And there are different levels of the logic model that apply in the theory of change. At the impact level, which is the highest level, we're actually looking for societal change. What are the aggregate changes achieved in the GCF key strategic result areas?

At the outcome level, we're asking what changes? What changes are achieved in the country or region or project area, as well as in the relevant policies and policy documents at the national level? At the output or project result level we're really asking what are the tangible deliverables that the project will provide?
What are the changes achieved as a result of a project or programme activities?
At the activity level we're asking the question how do we deliver the results? And these are the direct services provided through GCF investments. And at the input level we ask what is needed to deliver the results?
These can be the GCF grants, concessional loans, guarantees or other financial instruments as well as the human effort that goes into project implementation.



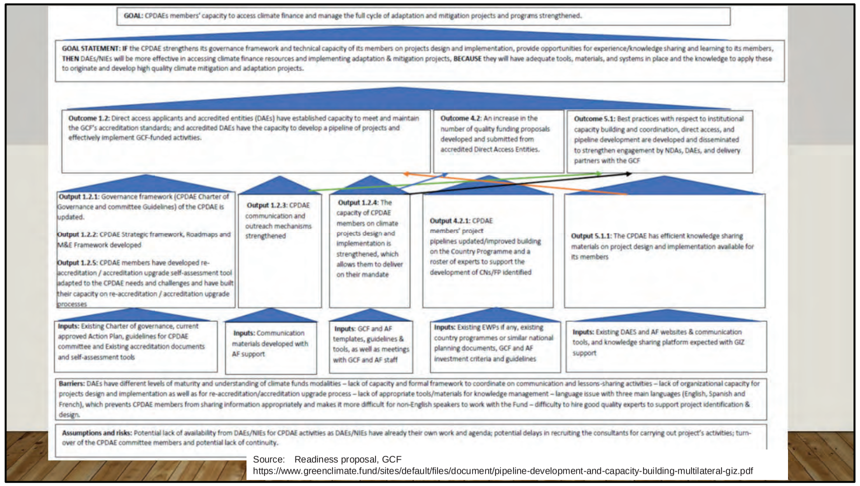
And the logic that underpins the theory of change is that you need certain resources to operate your programme or your project.
These are the inputs and if you have access to these inputs then you can use them to accomplish your planned activities. And if you accomplish your planned activities, then you will hopefully deliver the amount of products and or services that you intended as part of your project design.
And these are the outputs. And if you accomplish your outputs and planned activities to the extent you intended, then your participants or beneficiaries will benefit in certain ways. These are your outcomes.

And if these benefits to the participants and outcomes are achieved, then certain changes in organisations, communities or systems might be expected to occur and contribute to the impact that the GCF is looking for.



Now every problem will have multiple of course.

So the art of project design is to automatically identify a core problem that can actually be solved. Climate change is so enormous and so all encompassing it cannot be solved by a single project. But coastal flooding in a specific area due to sea level rise is something that can be solved through an adaptation project.
So it's really important then to identify a problem which is solvable and then the desired result is something which is actually achievable.



I won't go through the detail of this particular slide is simply to show the kind of diagrammatic format that the GCF is looking for.
In addition to the narrative type approach for the theory of change.

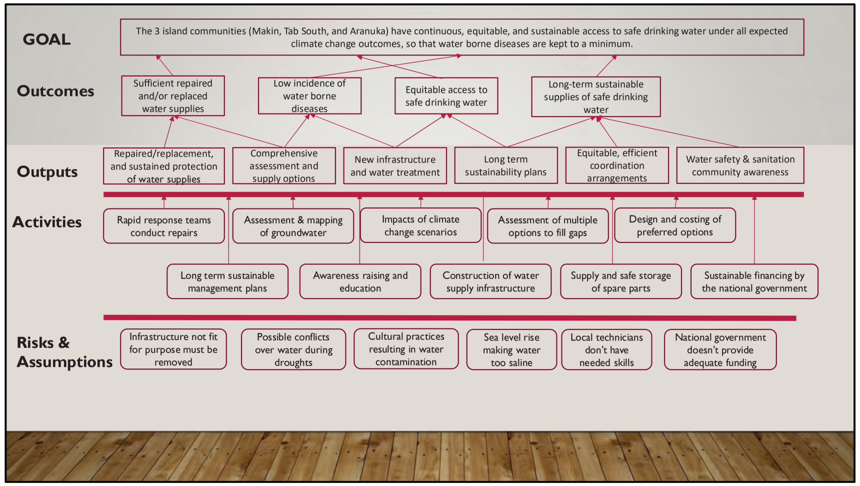
GOAL	Sustaining community resilience to climate change risks
GOAL STATEMENT	IF communities have access to safe shelter, water and food supplies all year-round and adopt climate resilient practices in their daily lives THEN community resilience can be sustained BECAUSE they are better prepared for climate change risks
RESULTS (Fund level) – defined by GCF	• A1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions • A2.0 Increased resilience of health and well-being, and food and water security • A3.0 Increased resilience of infrastructure and the built environment to climate change
OUTCOMES (Fund level) – defined by GCF	• A5.0 Strengthened institutional and regulatory systems for climate-responsive planning and development • A6.0 Increased generation and use of climate information in decision-making • A7.0 Strengthened adaptive capacity and reduced exposure to climate risks • A8.0 Strengthened awareness of climate threats and risk-reduction processes
RESULTS (Project level) – defined by the project	• An effective island /district and community development and CCDRR plans • Community-driven climate resilient interventions are implemented and sustained • Strengthened capacity of the Local Government and NGOs /CSOs to support community-based adaptation measures • Strengthened leadership in climate change and disaster risk reduction within the Local Government, NGOs /CSOs and the Community • An operational and effective community-based small grants programme

Here is a fairly typical narrative type approach for a theory of change. It starts with an overarching goal which is sustaining community resilience to climate change risks. It has this if then because goal statement if communities have access to safe shelter, water and food supplies all year round and adopt climate resilient practices in their daily lives, then community resilience can be sustained because they're better prepared for any future climate change risks.

And the results which are at the fund level and defined by the GCF are increased resilience and enhanced livelihoods, increased resilience of health and wellbeing, food and water security, increased resilience of infrastructure and the built environment to climate change and these are defined by the GCF and must be reflected in the project design.

Similarly, at the outcome level these are also defined by the GCF and in this case would be a 5.0 through to a 8.0 relating to strengthened institutional and regulatory systems, increased generation and use of climate information, strengthen adaptive capacity and reduced exposure to climate risks and strengthen awareness of climate threats and risk reduction processes.

And the results are actually defined at the project level and are defined by the project proponent and these may be things like an effective island or district and community development with climate change and disaster risk reduction plans. Community driven climate impact interventions are implemented and sustained.
Strengthen capacity of local government and NGOs, strengthen leadership in climate change and DRR within the local government, and an operational and effective community based small grants programme to provide the funding to carry out these interventions.



Here is another version, a simpler version of that rather complicated theory of change.
And here you can see that there is a logical connection between the various activities, the intended outputs, the outcomes and the ultimate goal of the project. And below the line there are the risks and assumptions that underpin the project design.

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So I'll leave it there and thank you for your attention. I hope this has given you some insight into what is a theory of change and how important it is in designing a bankable project, particularly for the GCF.

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CBCRP-PCCC Training Course

“Ecosystem-based Adaptation and Mitigation”

Government of Samoa, SPREP and JICA

Module 3. Problem and Objective trees and logical framework

3.2 Project objectives

Peter King | Senior Policy Advisor
IGES

Tetsuya Yoshida
JICA Short-term Expert
Oriental Consultants Global, Co., Ltd.

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CONTENTS

1. Introduction
2. Problem tree
3. Objective tree
4. Logical framework
5. Summary

2

Introduction

- In formulating *a climate change adaptation/ mitigation project*, the theory of change and the **logical framework** are key elements.
- They are described as tools of logic that connect cause and effect.
- All projects are designed to overcome a problem, but problems may have multiple causes.
- How do we know if we have identified the **core problem** and the **main causes**?
- All projects are intended to achieve a purpose or a goal and if it fails to achieve that end point (or ultimate effect) then the project is regarded as a failure. In the case of climate change adaptation projects, failure may also result in maladaptation.
- This session is intended to help you come to the right decisions that will lead to a convincing logical framework that will guide successful implementation.

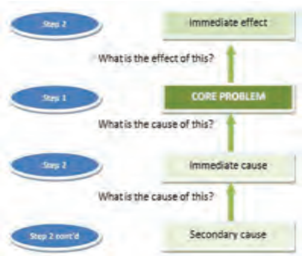
In formulating any climate change adaptation project, the theory of change in the logical framework are key elements but what do they really mean? They're described as tools of logic that connect cause and effect but how do we uncover those connections? Now all projects are designed to overcome a specific problem, but problems may have maltiple causes so how do we know if we have identified the core problem and the main causes? Again all projects are intended to achieve a purpose or a goal and if the project fails to achieve that in point or ultimate effect.

Then, the project is regarded as a failure. In the case of adaptation projects, failure may also result in what's called maladaptation or the opposite to what is expected. So, this session is intended to help you come to the right decisions that would lead to a convincing theory of change and a logical framework that will ultimately guide successful implementation.

Brainstorming a "Problem Tree"

Starting point: construct a **problem tree** that links causes and effects

1. Define "**core problem**"
   - Displacement due to flooding
   - Water/sanitation deficiencies
2. Identify **direct causes** and **direct effects**
   - Cause- Heavy rains
   - Cause- Overburdened infrastructure
   - Cause- Settlement in flood prone areas
   - Cause- Obstructed drains
   - Effect - Increased vulnerability
   - Effect - Damage to infrastructure
3. Identify **secondary (indirect) causes**
   - Rural-urban migration
   - Lack of planning
   - No responsible lead agency
   - Inadequate urban finance



Source: USAID

We start off with brainstorming a problem tree. A problem tree is something that links causes and effects. It basically has 3 steps. The first step is to define what is a core problem you're trying to solve. It could be something like displacement due to flooding or it could be water or sanitation deficiencies. Then, you identify the direct causes and the direct effects. The cause of flooding could be heavy rains or could be overburdened infrastructure or it could be settlements in flood-prone areas or obstructed drains. The effect could be an increase of vulnerability of communities or could be damage to roads and other infrastructure.

Then, the third step is to identify the secondary or underlying driving causes. These could be issues like so many people are moving from rural areas to urban areas, could be a lack of urban planning, could be that there is no responsible lead agency driving the process, or it could be that there is inadequate urban finance. The secondary cause leads to the immediate cause. The immediate cause leads to the core problem, and the core problem leads to the immediate effect. That's the logical chain of events that underpins a problem tree.

Brainstorming

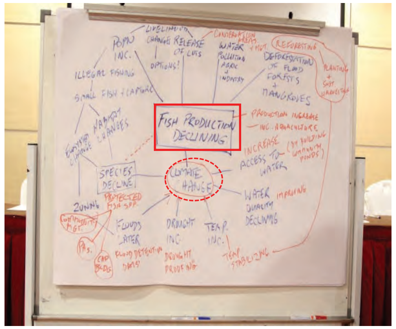
- Break participants into small groups.
- Prepare flipcharts, post-it notes, marker pens, and a table to spread out.

- Step 1. Consider what you think **the main problem** is.
- Step 2. Analyse what is **the main cause** of that main problem.
- Step 3. Check if there is **any other cause** of that direct cause.
- Step 4. Re-arrange all the answers in a tree.
- Step 5. Do the same for the effects, identify the **direct effects** and **indirect effects** of that main problem.

- You will be asked to do the same in an exercise in this training course.

Now to get to the problem tree. The best way of doing this is through brainstorming.
With breaking participants into relatively small groups so that every voice is heard making sure that they're all well equipped with flip charts, post-it notes, marker pens and a table to spread out on. And you start by asking each person what they think the main problem is and write down their answers on a post-it note. In a second-round ask each person what they think is the main cause of that core problem, and in the third round ask if there is any other cause of that direct cause. You rearrange all the answers in the form of a tree with roots and a trunk and some branches, starting off with a consensus on what you believe to be the main or the core problem. Step back from that and check if any key cause has been missed. Now do the same for the effects starting with the direct effects and then possibly secondary or indirect effects.
Now take note of these directions because later on in the course you'll actually be asked to do this in an exercise.

The problem tree is the "engine" of the project design



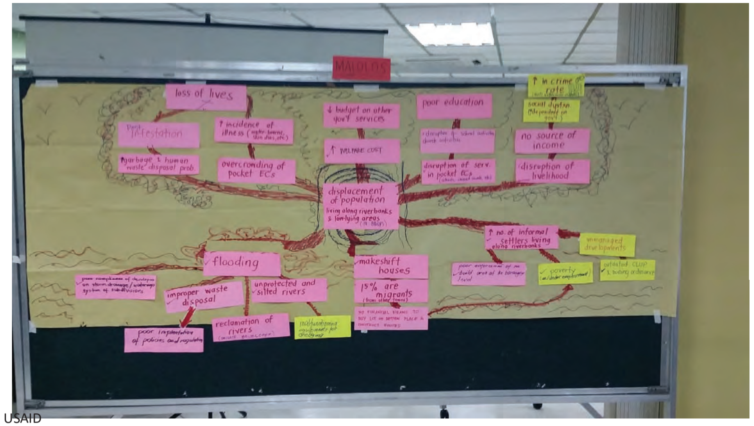
Source: USAID

- Involve the project beneficiaries and ask them to brainstorm about what they think the problem is.
- Do not assume you know what the real problem is.
- Do not start from an assumption that climate change is the problem.

Useful tips:
- It is critical to identify the core problem right in formulating a project.
- Avoid including contributing causes in the core problem statement.
- Identify one most important issue as the core problem, and avoid including multiple elements in the core problem (e.g. property damage due to severe floods).

Now the problem tree is really the engine of the project design and it's always advisable to involve the project beneficiaries and ask them to brainstorm about what they think the problem is. As an expert don't assume you know what the real problem is. You may not have sufficient local knowledge. And don't start from an assumption that climate change is a problem simply because you're preparing a concept note for the GCF. In this particular case that I've shown here where the brainstorming is very messy, the participant started with an assumption that
climate change was the core problem but as the brainstorming progressed it was realized that actually the core problem was a decline in fish productivity and climate change was really just one of multiple causes.

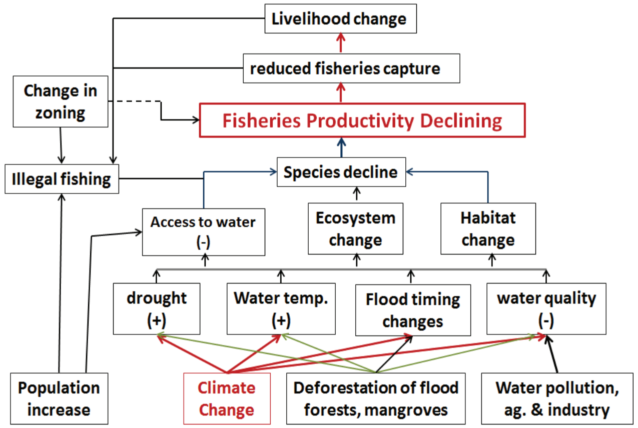
Use post-it notes to move things around



Source: USAID

Now the reason we suggest to use post-it notes is so that you can move things around on the roots and branches of the tree that enables you to organize your thoughts in a more logical fashion.

Reorganise the messy brainstorming

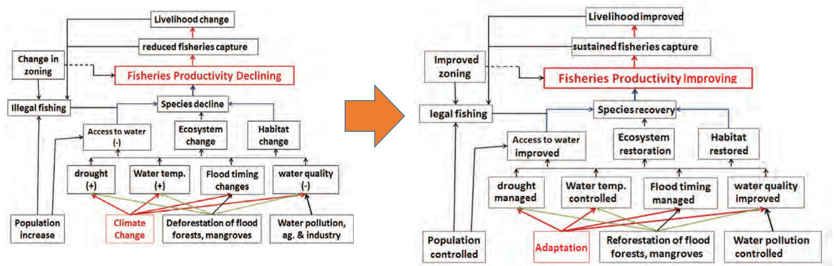


Source: USAID

Once you've done that then it's always good to try and reorganize the messy brainstorming approach into something which ultimately could go into a project document and demonstrate some clear thinking in terms of what are the causes, what is the core problem and what are the effects.

An Objectives Tree

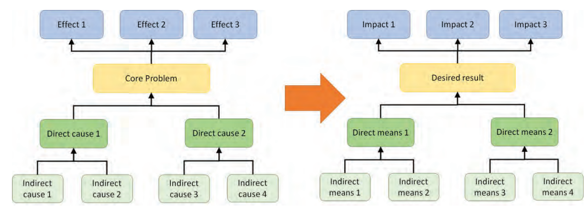
- Objectives trees transform all problems from your Problem Tree into an objective – Each negative problem will become a positive objective.
- Each cause can be transformed into a possible project activity or component. For example, water pollution control or reforestation could be key activities.



Source: USAID

We come up with an objectives tree by basically transforming all of your problems from your problem tree into an objective. So each negative problem is then turned around to become a positive objective. And note again that climate change might not be the core problem but it could be one of the contributing objectives. Below the core result or project output, each cause can be transformed into a possible project activity or component. For example, in this objectives tree, water pollution control, reforestation or ecosystem restoration could be key activities that ultimately contribute to species recovery and the improvement in fisheries productivity.

Transition from Problem tree to Objectives tree



Tips:
- Problem tree and objectives tree are mirror images of each other – one negative, the other positive.
- The Means you identify in the Objectives Tree will be the basis of Project Activity in your Logical Framework.

- Every problem will have multiple causes.
- The "art" of project design is to identify a Core Problem that can actually be solved.
- Climate change will not be solved by a single project, but an eroding coastline due to sea level rise can be solved.
- Solving the Core Problem will provide the desired result at the end of the project. This result will contribute to other positive outcomes and long-term impacts.

Source: USAID

Once we have a problem tree worked out, it's relatively simple to transition from a problem tree to an objectives tree. Every problem will have multiple causes so the art of project design is to firstly identify your core or focal problem that can actually be solved. Climate change is a global problem, it is not going to be solved by a single project but an eroding coastline in a specific location due to the sea level rise can be solved. Now solving the core problem will provide the desired result at the end of the project, but that result in turn will contribute to other positive outcomes and long-term impact beyond the scope of the specific project.

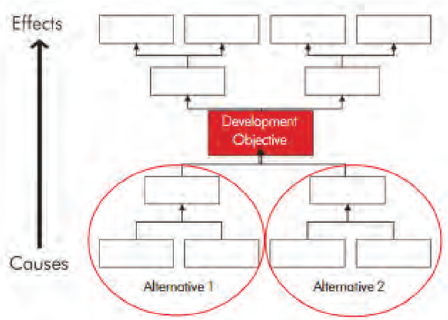
Check that no critical cause or effect has been missed

- Once your problem tree and objectives tree have been completed, stand back and discuss if anything has been missed or if a specific cause or effect is too minor to include.
- In the fisheries productivity example, one of the key elements that the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries.
- If this capacity issue was not addressed, then the whole project could fail. Later on we will see why the logical framework would have included this as a potential risk or assumption.

Once your problem tree and your objectives tree have been completed, stand back, have them side by side and discuss if anything is being missed or if a specific cause or effect is too minor to include. In the fisheries productivity example, one of the key elements with the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries. Now if this capacity issue was not addressed, then the whole project could fail and later on we'll see why the logical framework would have included this as a potential risk or an assumption.

11

Use the objectives tree to decide on project alternatives



- There may be several alternative ways that a project can contribute to the development objective.
- The objectives tree can help to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective.
- In some cases, the objectives tree might highlight the possibility of complementary projects that will combine to reach the central development objective.

Useful tips:
- Direct Causes and Indirect Causes you identified in the Objectives Tree can be the basis of your Logical Framework (transformed as Project Activity and Inputs).
- You can put only the selected Causes in your Logical Framework which are relevant to your project objectives.

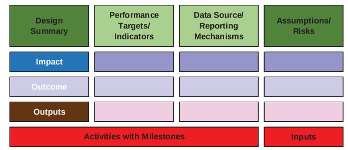
Source: ADB

Now we can also use the objectives tree to decide on project alternatives. There are often several alternative ways that a project can contribute to the development objectives. The objectives tree can help you to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective. In some cases, the objectives tree might also highlight the possibility of complementary projects that will each combine to reach the central development objective.

12

Logical Framework

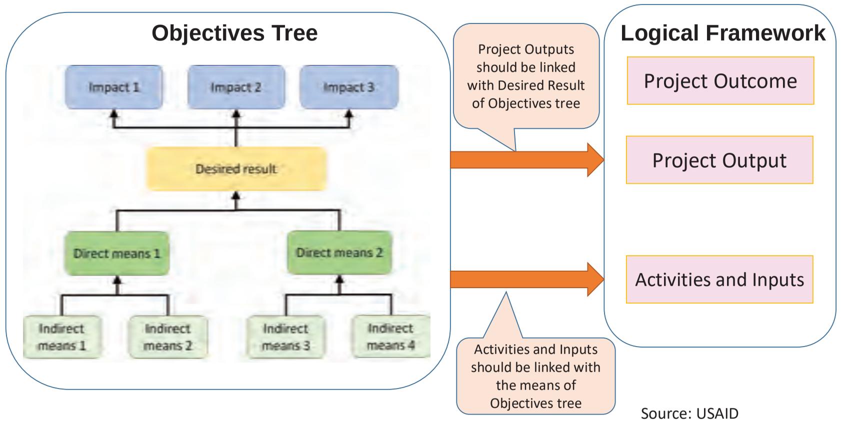
- A logical Framework is also called:
  - Project Framework
  - Logframe
  - Project Decision Matrix
  - Results Framework
  - Design and Monitoring Framework
- Standard sections:
  - **Four Columns** – Design Summary (Description), Performance Targets, Monitoring Mechanisms, and Assumptions and Risks;
  - **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Note hierarchical "logical" relationships vertically and horizontally, link all 20 frames.
- **Inputs** allow **activities** to be carried out that will deliver project **outputs**, which in turn will meet the immediate purpose (**outcome**) of the project and contribute to the longer-term **goal**.



Source: ADB

Now turning to the logical framework, sometimes is also called the project framework or shortened to logframe. Sometimes it's called a project decision matrix, a results framework or a design and monitoring framework. These are essentially different terms for the same matrix. There are standard sections. There are four columns: a design summary or description, performance targets, monitoring mechanisms and assumptions and risks. And there are 5 rows: the goal, the purpose sometimes called an outcome, outputs, activities and inputs. So note that there is a hierarchical logical relationship both vertically and horizontally that links together all 20 frames of the logical framework. A way to understand this is that the inputs allow activities to be carried out that will deliver the project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

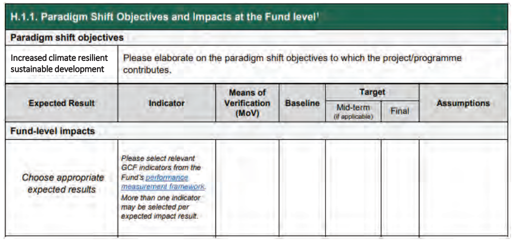
Develop the Logical Framework from the Objectives Tree



Source: USAID

Going from the objectives tree to the logical framework is a simple process where the means in the objectives tree are basically what becomes the inputs and activities that lead to the end of project outputs, which is the same as the desired result of the objectives tree. The purpose or outcome and the goals or impacts of the extension beyond the project boundary is equivalent to the results both direct and indirect that come from the objectives tree.

Logical framework approach of Green Climate Fund (GCF)



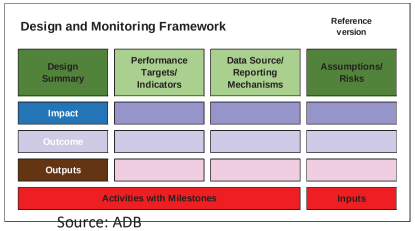
In this Logframe template (version 2.0), GCF specifies the ultimate goal (paradigm shift), fund-level impacts, and core indicators.
In addition to the core indicators, GCF also suggests additional indicators at:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
https://www.greenclimate.fund/document/integrated-results-management-framework

Paradigm shift objective: Increased climate resilient sustainable development
Fund-level impacts (adaptation):
- ✓ 1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions
- ✓ 2.0 Increased resilience of health and wellbeing, and food and water security
- ✓ 3.0 Increased resilience of infrastructure and the built environment to climate change threats
- ✓ 4.0 Improved resilience of ecosystems and ecosystem services

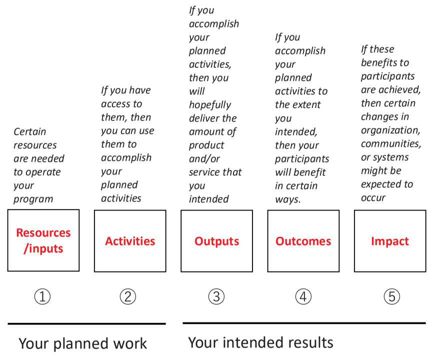
Core indicators (for adaptation): e.g. Total Number of direct and indirect beneficiaries; Number of beneficiaries relative to total population; Number and value of physical assets made more resilient to climate variability and change, considering human benefits (reported where applicable)

The way the Green Climate Fund approaches the logical framework is worthwhile getting a better understanding as you will often be involved in looking at this framework. The first thing to note is that the ultimate objective or the impact that is intended is specified as a paradigm shift objective of the GCF. Given that the overall mandate for the GCF is a paradigm shift. In the case of an adaptation project, this is increased climate-resilient sustainable development. The GCF also defines fund level impacts and in the case of an adaptation project, there are basically four of these:
increased resilience and enhanced livelihood with the most vulnerable people, communities and regions, increased resilience of health and well-being and food and water security, increased resilience of infrastructure and the built environment to climate change threats, or improved resilience of ecosystems and ecosystem services. Now for each of these impacts GCF has also indicated a number of core indicators. In the case of an adaptation project, it is the total number of direct and indirect beneficiaries plus the number of beneficiaries relative to the total population.
It could also be the number in value of physical assets made more resilient to climate variability and change considering human benefits where applicable. Note that GCF specifies the ultimate goal, the fund level impacts and the core indicators. In addition to these core indicators, the GCF also suggests

Performance targets



Source: ADB



- ➢ To ensure that each design “element” is implemented as planned, performance **targets** are specified, as are the mechanisms for **measuring** these targets – plus the **risks** that could upset achievement are explicitly recognized and assumed to be mitigated (by another project, by the government agency, or by other means).
- ➢ Unmitigated or unforeseen risks could torpedo an otherwise well-developed project.

In relation to performance targets, it’s important to ensure that each design element is implemented as planned. So, performance targets are specified as well as the mechanisms for measuring those targets. Then in turn, the risks that could upset achievement are explicitly recognized and assumed to be mitigated either by another project, by the government agency or by other means. Unmitigated or unforeseen risks could actually torpedo an otherwise well-developed project. Another way to think about the logic of the logical framework is that your planned work will consist of the resources and inputs that you have available to operate your program. These contribute to a certain number of activities, so if you have those inputs, you can use them to accomplish your planned activities. These in turn lead to your intended results. Firstly, if you accomplish your planned activities, then you will hopefully deliver the amount of product or service that you intended at the end of the project. If you achieve those outputs, then you may benefit wider outcomes at your national level, at the regional level, or at the global level and if you achieve those outcomes
then you may be able to contribute in some way to much broader impact, such as the Paris agreement for example.

additional indicators and there is a website where you can see those additional indicators that you may use in your own project designs.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 7 and 8 of the document "Mitigation and adaptation performance measurement frameworks" for details.

Logical framework approach of GCF (cont.)

H.1.2. Outcomes, Outputs, Activities and Inputs at Project/Programme level

Expected Result	Indicator	Means of Verification (MoV)	Baseline	Target Mid-term (if applicable)	Target Final	Assumptions
Project/programme outcomes	**Outcomes that contribute to Fund-level impacts**					
Choose expected outcome	*Please select relevant GCF indicators from the Fund's performance measurement framework. More than one indicator may be selected per expected impact result.*					
Specify other expected results						
Specify other expected results						
Project/programme outputs	**Outputs that contribute to outcomes**					
1.						
2.						
3.						

Activities	**Description**	**Inputs**	**Description**
1.1.		1.1.1.	
1.2.		1.1.2.	
2.1.		1.1.3.	
...		...	

Outcomes (for adaptation)**:**
- 5.0 Strengthened institutional and regulatory systems for climate responsive planning and development
- 6.0 Increased generation and use of climate information in decision-making
- 7.0 Strengthened adaptive capacity and reduced exposure to climate risks
- 8.0 Strengthened awareness of climate threats and risk reduction processes

Outputs, Activities, Inputs:
to be uniquely designed by the project

The latest template of GCF funding proposal and results management framework can be found at:
https://www.greenclimate.fund/document/funding-proposal-template
https://www.greenclimate.fund/document/integrated-results-management-framework

Moving further down in the logical framework to the outcomes. The GCF also specifies the outcomes. In the case of adaptation projects, these are again four: strength and institutional and regulatory systems for climate responsive planning and development, increased generation and use of climate information in decision-making, strengthened adaptive capacity and reduced exposure to climate risks, and strengthened awareness of climate threats and risk reduction processes. Then to go one step further down to the project or program outputs. These are left up to the program designer or the project designer to specify. Then you come down to the activities and a description of those and the inputs required to achieve each of those activities and again a description of those and that information then goes into your budget proposal.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 9 and 10 of the document "Mitigation and adaptation performance measurement frameworks" for outputs examples of GCF.

addition to the core indicators, GCF also suggests additional indicators for the outcome level while leaving the project output targets and indicators to the project designers.

Summary of this presentation

- All projects are designed to overcome a problem, but problems may have multiple causes, so a **"problem tree"** helps to sort out cause and effect.
- Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that end point (or ultimate effect) then the project is regarded as a failure. An **"objectives tree"** helps to identify the means of achieving a desired result or **output** at the end of a project, as well as indicating the longer-term **outcomes** and impacts that the project can contribute to.
- The **objectives tree** is simply the mirror image of the problem tree, where all negatives are turned into positives. The objectives tree may also highlight alternative pathways to achieve the desired result as well as indicating the possibility of multiple, complementary projects.
- The objectives tree contributes the "bones" of the **logical framework**, which consists of **Four Columns** – Design Summary, Performance Targets, Monitoring Mechanisms, and Assumptions and Risks; and **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Most funding sources require a logical framework (or equivalent) as a crucial part of any project proposal. The Green Climate Fund (GCF) specifies the ultimate goal (paradigm shift), fund-level **impacts**, and core **indicators**. In addition to the core indicators, GCF also suggests additional indicators for the **outcome** level, while leaving the project **output** targets and indicators to the project designers.

To summarize, all projects are designed to overcome a specific problem but problems may have multiple causes, so a problem tree helps to sort out cause and effect.
Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that endpoint or ultimate effect then the project is regarded as a failure. An objectives tree helps to identify the means of achieving a desired result or output at the end of a project as well as indicating the longer-term outcomes and impacts that the project can contribute to in some small way.
The objectives tree is simply the mirror image of the problem tree where all of the negatives of the problem tree are turned into positives. The objectives tree also highlights alternative pathways to achieve the desired result of the project as well as indicating the possibility of multiple complementary projects to achieve the core objective. The objectives tree contributes
the bones of the logical framework which consists of 4 columns: a design summary, performance targets, monitoring mechanisms and assumptions and risks, and 5 rows: goal purpose, output activities and inputs giving a total of 20 elements that need to be filled in. Now most funding sources require a logical framework or its equivalent as a crucial part of any project proposal.
The Green Climate Fund specifies the ultimate goal, that is a paradigm shift, the fund level impacts, which they have pre-defined and the core indicators. In

Reference materials related to GCF

Please note that the below information is as of December 2022 therefore the link to the reference will might be changed.

If the link does not work, please visit the GCF web site (https://www.greenclimate.fund/).

Mitigation and adaptation performance measurement frameworks:

https://www.greenclimate.fund/document/mitigation-and-adaptation-performance-measurement-frameworks

Integrated results management framework:

https://www.greenclimate.fund/document/integrated-results-management-framework

Funding Proposal template:

https://www.greenclimate.fund/document/funding-proposal-template

GCF Programming Manual:

https://www.greenclimate.fund/sites/default/files/document/gcf-programming-manual_0.pdf

Readiness proposal:

https://www.greenclimate.fund/sites/default/files/document/pipeline-development-and-capacity-building-multilateral-giz.pdf

Open learning course: List of training materials (Water sector)

Section		Name of materiala	Type	Length
Module 1	**Understanding of climate change risks and vulnerabilities of rural water access**			
		IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific	Movie file	14 min.
		Observed and projected climate change in the pacific	Movie file	18 min.
		Observed and projected climate change in the pacific	Movie file	26 min.
		Climate change impact on rural water access	Movie file	10 min.
		Lecture slides and notes	PDF	-
Module 2	**Adaptation and mitigation options with innovative approaches**			
	Module 2.1	Technical solutions for safe water access from water source to households		
		How to identify and manage water resource? tools, surveys and data		
		Part 1	Movie file	19 min.
		Part 2	Movie file	23 min.
		Part 3	Movie file	15 min.
		Part 4	Movie file	15 min.
		What innovative technologies, devices and tools are available to deliver and monitor safe water for households?	Movie file	23 min.
		How renewable energy can be used to reduce use of fossil fuels? What innovative devices and solutions are available to encourage water and energy saving?	Movie file	9 min.
		Case in the Pacific: Ecological Purification Systems (EPS) in Fiji	Movie file	25 min.
		Lecture slides and notes: How to identify, develop and manage water resource? Tools, surveys and data	PDF	-
		Lecture slides and notes: Technical solutions for safe water access from water source to households	PDF	-
		Lecture slides and notes: Renewable Energy Energy Saving	PDF	-
		Lecture slides and notes: Renewable Energy Energy Saving_supplement material	PDF	-
		Lecture slides and notes: EPS project in Fiji	PDF	-
	Module 2.2	Community-based management for rural safe water access: Case study in Samoa		
		Ownership arrangement	Movie file	8 min.
		Operation and maintenance of water supply systems	Movie file	9 min.
		Social and gender inclusion	Movie file	7 min.
		Disaster preparedness and post-disaster response	Movie file	6 min.
		From short to mid-term plan and management	Movie file	6 min.
		Lecture slides and notes	PDF	-
	Module 2.3	Projects in the Pacific		
		Enhancing the Climate Resilience of vulnerable island communities in Federated States of Micronesia (Adaptation Fund)	Movie file	25 min.
		Managing Coastal Aquifers in Selected Pacific SIDS (Global Environment Facility)	Movie file	24 min.
		South Tarawa Water Supply Project in Kiribati (Green Climate Fund)	Movie file	18 min.
		Addressing Climate Vulnerability in the Water Sector (ACWA) in the Marshall Islands	Movie file	12 min.
		Lecture slides and notes: Adaptation fund project in FSM	PDF	-
		Lecture slides and notes: Managing Coastal Aquifers in Selected Pacific SIDS	PDF	-
		Lecture slides and notes: Kiribati South Tarawa Water Supply Project	PDF	-
		Lecture slides and notes: RMI ACWA Project	PDF	-
Module 3	**Problem and Objective trees and Logical framework**			
	Module 3.1	Theory of change		
		Theory of change	Movie file	13 min.
		Lecture slides and notes	PDF	-
	Module 3.2	Project objectives		
		Project objectives_part1 (1. Introduction, 2. Problem trees, 3. Objectives trees)	Movie file	10 min.
		Project objectives_part2 (4. Logical framework, 5. Summary)	Movie file	12 min.
		Lecture slides and notes	PDF	-
	Module 3.3	Exercise		
		Reference: Mitigation - adaptation performance measures	PDF	-
		Template for exercise_logframe template	Word file	-

1

CBCRP-PCCC Virtual Training Course

“Enhancing Climate Resilience & Safe Water Access in Rural Areas in the Pacific”

Government of Samoa, SPREP, and JICA

1. Understanding of risks of climate change impacts on rural water access

- IPCC risk-based conceptual framework and updates of observed and projected climate change in the Pacific

Mr Koji Kuroiwa (Engineering)
JICA Short-term Expert
Overseas Business section, Business Management Department
Japan Weather Association

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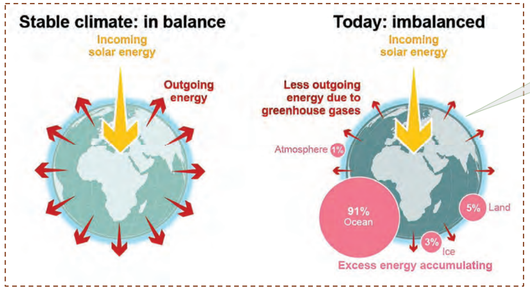
CONTENTS

1. Introduction to climate change in the Pacific and IPCC risk-based conceptual framework
2. Observed and projected climate change in the Pacific
   - Observed climate changes
   - Projected climate changes for near- to long-terms
3. Climate change impact on rural water access
4. Non-climate factors

Introduction to climate change in the Pacific - I

Climate change and the Earth's energy budget

- Earth's climate is largely determined by the Earth's energy budget, i.e., the balance of incoming and outgoing energy.
- Since at least the1970s, less energy is flowing out than is flowing in, which leads to excess energy being absorbed by the ocean, land, ice and atmosphere, with the **ocean absorbing 91%**.



Some of the solar energy is trapped by greenhouse gases such as CO_2, CH_4, and N_2O ; ***Greenhouse effect.***

Source: IPCC[1]

Narrative Part

1. Roughly, global warming is the main driver of climate change, causing other various changes like heavier rains and more intense storms. In other words, climate change can be described as "global warming and its consequences".
2. Earth's average temperature is determined by the balance between incoming energy from the sun and the outgoing energy emitted back into space. The left panel shows how our planet receives vast amounts of energy every day in the form of sunlight. About a third of the sunlight is reflected back to space, and the rest is absorbed by the ocean, land, ice, and atmosphere. Normally, these incoming and outgoing energies are in balance, the earth's climate is stable, and the temperature remains constant.
3. In recent years, human activities have unbalanced these energy flows. The right panel shows that outgoing energy is less than incoming because part of the solar energy is trapped increasingly by some gasses in the atmosphere and warm the Earth; they are carbon dioxide, methane, and nitrous oxide - the greenhouse effect process and the cause of global warming.
4. Since the 1970s, the excess energy has warmed the ocean and land and melted ice sheets and glaciers. The ocean absorbs as much as 91% of the excess energy, which leads to long-term sea level rise.

Glossary

➢ **Greenhouse gas (GHG)**

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

1. Introduction to climate change in the Pacific and IPCC risk-based conceptual framework

A large-scale, long period oscillation that influences climate variability over the Pacific Basin. The IPO operates at a multi-decadal scale, with phases lasting around 20 to 30 years. During the positive phase of the IPO, precipitation is generally higher than normal northeast of the South Pacific Convergence Zone and lower than normal southwest of the SPCZ. Mean sea level pressures are higher than normal to the west of the dateline and lower than normal to the east of the dateline. Due to these pressure differences, there is a southerly flow anomaly during the positive phase of the IPO.

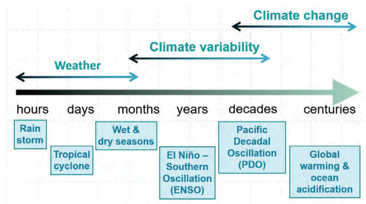
5

Introduction to climate change in the Pacific - III

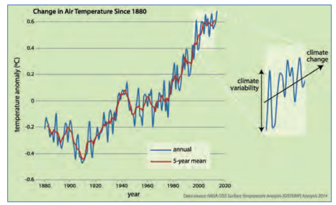
Weather and climate time-scales

- The difference between weather and climate is a matter of time-scale. Climate is sometimes understood as the "average weather" over a long period of time. Climate variability looks at changes that occur within smaller timeframes, such as months, years and decades, and climate change considers changes that occur over a longer period of time, typically over decades or longer.

Illustration of weather/climate time-scales (left) and climate variability/change (right)



Source: PACCSAP



Source: UCAR SciEd

Narrative Part

1. Weather, climate variability and climate change operate on different time scales. Different periods (hours/days/years/centuries) of weather, climate variability, and climate changes are shown on the left panel, including rainstorms that last a couple of hours and tropical cyclones for several days.
2. Weather is highly variable. Climate can be defined as the "average weather" over a long period. The classical period used for describing a climate is "30 years". While weather is variable, climate also shows variability due to internal and external factors.
3. The right panel shows the change in the surface temperature over the past century and suggests the difference between climate and climate variability. Climate variability occurs over months, years, and decades and are defined by climate patterns such as El-Niño Southern Oscillation (ENSO). Other than ENSO, Pacific Decadal Oscillation (PDO) and Interdecadal Pacific Oscillation (IPO) affect the regional climate over much longer terms on decadal scales.
4. The last category, "climate change", occurs over decades and centuries and even much longer time scale. A typical example is global warming.

Glossary

➢ **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

➢ **Pacific Decadal Oscillation (PDO)**

The pattern and time series of the first empirical orthogonal function of sea surface temperature over the North Pacific north of 20° N. The PDO broadened to cover the whole Pacific Basin is known as the Inter-decadal Pacific Oscillation. The PDO and IPO exhibit similar temporal evolution.

➢ **Inter-decadal Pacific Oscillation (IPO)**

Notable differences in climate also occur within countries that are spread over a large area, such as the northern and southern Cook Islands.

7. The right table summarizes the main features and influences on the climate in each country. For example, the Cook Islands are typically influenced by SPCZ, sub-tropical highs, trade winds, tropical cyclones and topography. But when we look at other countries in the west of the region, such as Papua New Guinea, they are typically influenced more by the West Pacific monsoon and the ITCZ. The table also shows that topography is a significant factor in impacting the climate of the mountainous islands.

Glossary

- **Warm Pool**

An extensive pool of the world's warmest water, with temperatures exceeding 28–29° C extending from the central Pacific to the far eastern Indian Ocean.

- **Inter-tropical Convergence Zone (ITCZ)**

The Inter-Tropical Convergence Zone is an equatorial zonal belt of low pressure, strong convection and heavy precipitation near the equator where the northeast trade winds meet the southeast trade winds. This band moves seasonally.

- **South Pacific Convergence Zone (SPCZ)**

A band of low-level convergence, cloudiness and precipitation ranging from the west Pacific warm pool south-eastwards towards French Polynesia, which is one of the most significant features of subtropical Southern Hemisphere climate. It shares some characteristics with the ITCZ, but is more extratropical in nature, especially east of the Dateline.

- **Monsoon**

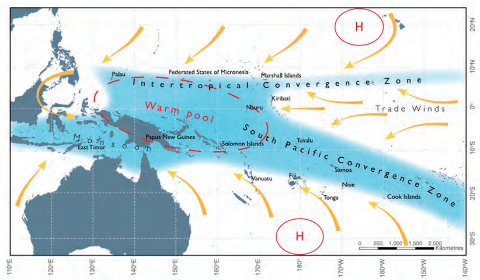
A monsoon is a tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.

Introduction to climate change in the Pacific - II

Large-scale climate features in the W-Pacific

- The South Pacific Convergence Zone (SPCZ), the West Pacific Monsoon (WPM) and the Intertropical Convergence Zone (ITCZ) affect the regional pattern and seasonal cycle in rainfall, winds, tropical cyclone tracks and many other climate aspects of the western tropical Pacific.

Map showing the mean positions of SPCZ, ITCZ and WPM between Nov & Apr



Country	Main features and influences
Cook Islands	SPCZ, sub-tropical highs, trade winds, tropical cyclones, topography
Timor-Leste	WPM, topography
Federated States of Micronesia	ITCZ, WPM, trade winds
Fiji	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Kiribati	ITCZ, SPCZ, trade winds
Marshall Islands	ITCZ, WPM (in some years), tropical cyclones
Nauru	ITCZ, SPCZ, trade winds
Niue	SPCZ, trade winds, sub-tropical highs, tropical cyclones
Palau	WPM, ITCZ, trade winds
Papua New Guinea	WPM, ITCZ, topography
Samoa	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Solomon Islands	SPCZ, WPM, tropical cyclones, topography
Tonga	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography
Tuvalu	WPM, SPCZ, trade winds, sub-tropical highs, tropical cyclones
Vanuatu	SPCZ, trade winds, sub-tropical highs, tropical cyclones, topography

Source: PACCSAP

Narrative Part

1. The Pacific Ocean covers almost a third of the Earth's surface. It plays an essential role in shaping the climate of the Pacific and the entire globe. The climate of the Pacific is characterized by large-scale climate features and different-sized land masses, which leads to regional variations in climate. At the same time, the El Niño-Southern Oscillation is the source of year-to-year climate variations.
2. The left map shows the average positions of the main features of the regional climate between November and April. The yellow arrows show surface winds; the blue shading represents the bands of rainfall or convergence; the dashed area shows the Pacific Warm Pool, which holds the warmest seawaters in the world. The two rounds stamped by H are high pressures. All these features affect the regional patterns and seasonal cycle of rainfall, winds, tropical cyclone tracks, ocean currents, and many other aspects of the environment of the Pacific.
3. The three extensive bands of large-scale wind convergence are closely associated with rainfall. They are the Intertropical Convergence Zone (ITCZ), the South Pacific Convergence Zone (SPCZ), and the West Pacific Monsoon (WPM).
4. The SPCZ significantly impacts most South Pacific countries, extending from near the Solomon Islands to the east of the Cook Islands. The SPCZ is strongest in the Southern Hemisphere wet season. It stretches across the Pacific just north of the equator and is strongest in the Northern Hemisphere wet season. West Pacific Monsoon is driven by large differences in temperature between the land and the ocean. It moves north to mainland Asia during the Northern Hemisphere summer and south to Australia in the Southern Hemisphere summer. The Monsoon's seasonal arrival usually switches from very dry to very wet conditions.
5. Other aspects of the climate, such as sub-tropical highs, trade winds and tropical cyclones, also impact countries in the Pacific.
6. On larger elevated islands, topography can have a significant effect, so the climate of the key location may not be the same several kilometres away. For example, in Fiji, rainfall is higher in Suva, which is exposed to the southeast trade winds, than in Nadi, which lies on what is predominantly the lee side of the same island.

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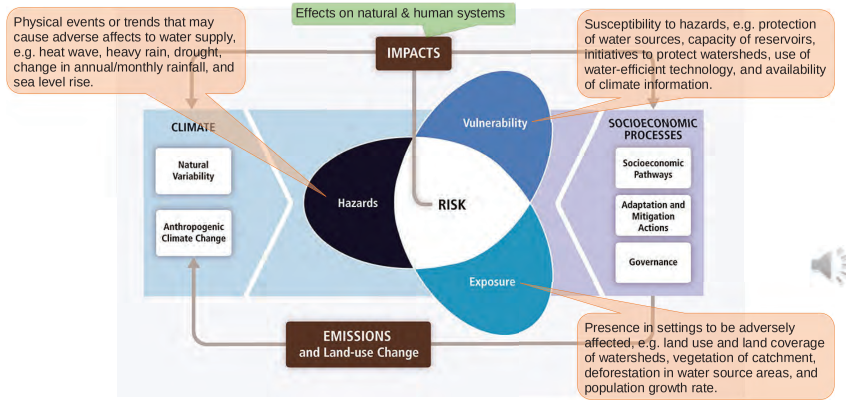
Risk-based conceptual framework of IPCC/WG2 - I

Climate risk is a function of hazards, exposure, and vulnerability



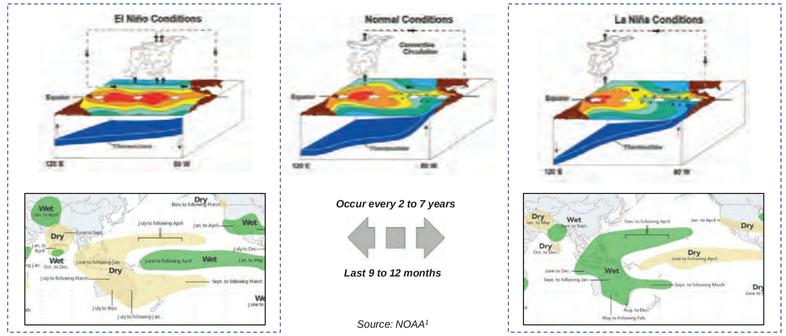
Narrative Part

1. The risk-based conceptual framework is a basic scheme for climate risk assessment, which IPCC Working Group-2 (WGII) adopted in its 5th Assessment Report (AR5). Its fundamental philosophy is that risk management is the key to reducing climate change impacts. This concept underlies the discussion of adaptation and mitigation options in a series of PCCC training courses.
2. Various factors determine the rise and fall of Risk. The essence of AR5's concept is to focus on three main factors of human and natural systems: Hazards, Vulnerability and Exposure.
3. Risk emerges from the overlap of Hazards, Vulnerability, and Exposure. There are two approaches to reducing Risk; one is to control Hazards, which can be done through changes in emissions, including anthropogenic sources, and the other is to manage Vulnerability and Exposure. It should be noted that vulnerability and Exposure develop from many different socio-economic processes, and therefore, a wide range of measures to reduce Vulnerability and Exposure can be taken, such as through socio-economic pathways, adaptation and mitigation, and social governance.
4. For the reduction of Risk to the Water Sector, it is vital to identify the significant components of Hazards, Vulnerability, and Exposure related to this sector. Some examples are indicated in balloons in the chart.
5. Hazards to Water Sector have, for example, "heat waves", "heavy rain", and "sea-level rise". Meanwhile, Vulnerability and Exposure of the Water Sector need to be considered from both physical and social aspects. Vulnerability includes "protection of water resources", "capacity of reservoirs", "initiatives to protect watersheds", "use of water-efficient technologies", and "availability of climate information". Exposure includes "land use and land coverage of watersheds", "vegetation of catchment", "deforestation in water source areas", and "population growth rate".
6. Consideration of different factors for Vulnerability and Exposure will provide valuable basics for this training course discussion.

Introduction to climate change in the Pacific - IV

El Niño-Southern Oscillation (ENSO)

- ENSO is a key driver of climate variability in the Pacific, causing short-term changes in climate, including **precipitation patterns** in particular.



Narrative Part

1. Climate change is a decades-long event and fluctuates in shorter timescales of months to years, which we call climate variability. Various climate features drive the climate of the Pacific.
2. El Niño-Southern Oscillation (ENSO) is a predominant climate variability for the Pacific and significantly affects regional as well as global climate conditions. ENSO refers to the recurrence of two opposite climate episodes, El Niño and La Niña. Southern Oscillation is the term for atmospheric pressure changes between the east and west tropical Pacific, which accompanies El Niño and La Niña, like a seesaw. As a result, ENSO has distinct impacts on precipitation over most Pacific Island countries.
3. The middle panel shows normal ocean and atmospheric conditions over the Pacific. Typically, trade winds take warm water to the west to create Warm Pool in the western equatorial Pacific. As a result, more clouds are formed where the ocean is warm, and more rainfall is brought.
4. When El Niño occurs, which is shown on the left panel, trade winds weaken, and warm water is pushed back toward the east. Meanwhile, South Pacific Convergence Zone (SPCZ) migrates towards the equator. Typically, it results in wetter conditions in the central and eastern equatorial Pacific and drier conditions in the north of the equator and south-west Pacific.
5. In a La Nina (right panel), trade winds strengthen reversely and take the warm water further to the west. It causes opposite changes to El Nino. ITCZ and SPCZ tend to move away from the equator, drier near the equator, while wetter in the north and southwest Pacific.
6. ENSO events occur every 2 to 7 years and last 9 to 12 months. Typically, El Niño occurs more frequently than La Niña, but, in any case, their frequency is quite irregular.

2. Observed and projected climate changes in the Pacific

Glossary (Definitions at AR5)

- **Hazard**

  The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term *hazard* usually refers to climate-related physical events or trends or their physical impacts.

- **Exposure**

  The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

- **Vulnerability**

  The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

- **Impacts**

  Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

- **Risk**

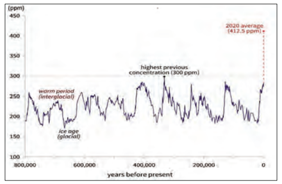
  The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

Observed Climate Change – *GHGs*

Greenhouse gases (GHGs)

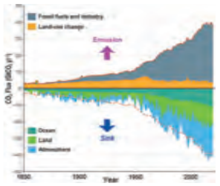
- In 2019, atmospheric CO_2 concentrations were higher than at any time in at least **2 million years**, and concentrations of CH_4 and N_2O were higher than at any time in at least **800,000 years**. *(IPCC[3])*
- Despite a 6% to 7% drop in emissions from reduced activity amid the pandemic, the concentration of GHGs in Earth's atmosphere reached a **new record in 2020.** *(WMO)*

Carbon Dioxide (CO_2) over 800,000 years



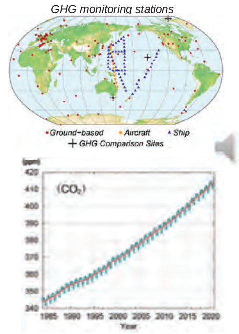
Source: NOAA[2]

Emissions and their partioning



Source: Global carbon project

GHG monitoring network (top) and recent concentration of CO_2 (bottom)



Source : WMO[1]

Narrative Part

1. Global monitoring of GHGs started in the 1950s, and now carbon dioxide, methane, and nitrous oxide are continuously monitored by the WMO monitoring network (right panel). About 30 ground stations plus aircraft and ships carry out the measurement. Its recent results of CO2 shown in the bottom right panel indicate that the concentration of CO2 has been continually increasing during the last three to four decades. Recently, it has been found that the CO2 concentration reached 412.5 ppm in 2020, the highest ever recorded.
2. The bottom left panel depicts the change in the CO2 concentration over 800,000 years. The CO2 data before the 1950s was derived from the paleo-climate studies of ice core of polar and mountain glaciers and ice caps worldwide. In this long-term graph, the recent 70-year change is shown by the dotted line demonstrating that the recent CO2 increase is just a momentary event over the past 800,000 years. The ice-core data also supported that the present concentrations of Methane and Nitrous Oxide were higher than at any time during this period.
3. The CO2 data for even more ancient times can be given from the deep-sea sediments. Based on those data, IPCC says with high confidence that the latest CO2 concentrations were higher than at any time in at least 2 million years.
4. The middle panel shows the global change of emission and sink of CO2 as well as their sources in the Earth system. In recent years, about 90% of CO2 emissions have come from fossil fuel consumption, and 10% is from land use changes such as deforestation. Meanwhile, 24% of the emitted CO2 is absorbed by the ocean, 32% by land, such as forests, and 45% remains in the atmosphere. From the emission sources, the increase in fossil fuels since the industrial revolution is significant. In terms of the sink, the increase in the ocean is notable, which leads to ocean acidification.
5. The COVID-19 pandemic affects the concentrations of GHGs, and the economic recession was estimated to have reduced carbon emissions by 6 to 7 % during 2020. However, the annual average CO2 concentration in 2020 was found to be about 2.5 ppm more than in 2019. Accordingly, WMO stated that the decrease in

Observed Climate Change

CO2 concentration due to COVID-19 is practically indistinguishable.

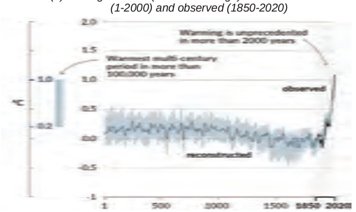
Observed Climate Change – *Temperature I*

Global surface temperature (GST)

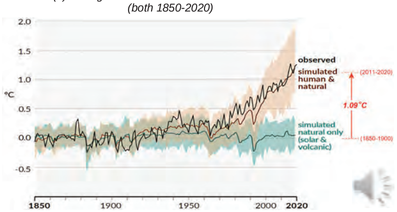
- GST has increased faster since 1970 than in any other 50-year period over at least the **last 2000 years**. *(IPCC[4])*
- It was **1.09°C higher** in 2011-2020 than 1850-1900 with larger increases over land (**1.59°C**) than over the ocean (**0.88°C**). *(IPCC[5])*

Changes in global surface temperature (GST) relative to 1850-1900

(a) Change in GST (decadal average) as reconstructed (1-2000) and observed (1850-2020)



(b) Change in GST as observed and simulated (both 1850-2020)



Source: IPCC[6]

Narrative Part

1. In the bottom right panel, the black line shows the record of observations by instruments. Temperatures gradually increased from around 1900 after the industrial revolution and have grown much faster since 1970.
2. The brown line is the model simulations that considered the human drivers such as emission of GHGs and natural drivers such as solar and volcanic activities. The green line also shows the simulation of the temperatures but considers only natural effects. The brown lines coincide with observations and well adjust to reality.
3. The left panel shows the temperature change over the past 2,000 years. For the period before the observation started, temperatures were reconstructed from natural archives, such as tree ring data and sea sediments. A dashed line depicts the latest 70-year change in the right panel. The nearly vertical change shows how drastic the recent temperatures increase was. This panel's left is the estimated warmest temperatures over the past more than 100,000 years. It further endorses that the current warming is a historical incident.
4. These findings and the change of GHGs concentrations shown in the previous slide collectively endorse that global warming is attributed to anthropogenic greenhouse effect.

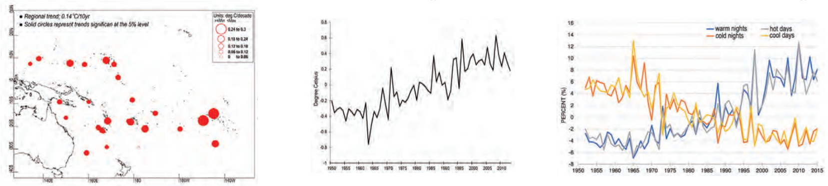
Observed Climate Change – *Temperature II*

Regional surface temperatures

- Warming trends are clearly evident in the small islands, such as those in the Pacific, particularly over the latter half of the 20th century. *(IPCC[7])*
- Significant positive trends ranging from 0.15°C/10yr (1953–2010) to 0.18°C/10yr (1961–2011) are noted in the tropical Western Pacific. *(IPCC[8])*

Recent changes in temperature in the Western Pacific Islands

(a) Trends in annual mean temperature over 1951–2015 *(b) Regional mean temperature anomalies relative to the 1971–2000 climatology* *(c) Regional amount of warm/cold nights, hot/cool days anomalies relative to the 1971–2000 climatology*



Source: McGree et al. 2019

Narrative Part

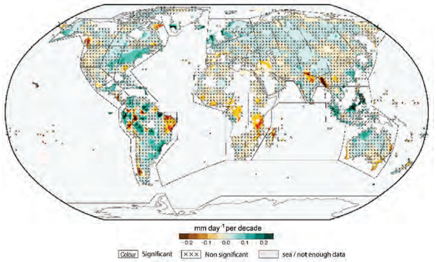
1. Along with the global mean surface temperatures, warming trends are clear at the Pacific Island countries. In the Southwest Pacific, 2020 was the second or third warmest year, depending on the data sets. The warmest year on record was observed in Southern French Polynesia and Tonga. The warming trends in the region have been examined and endorsed by a couple of climate studies, which suggest increases of roughly 0.15° C to 0.18° C per decade.
2. The left panel shows the results of McGree's study from 1951 to 2015 based on the data from 57 stations. Although regional differences exist, most locations indicate warming trends in annual mean temperatures from 0.06 to 0.30, resulting in a regional average of 0.14. In addition, increases in average temperature were found in all seasons throughout the study period.
3. The middle panel was also given from the McGree's, representing the time change of regional average temperature. A warming trend is clear, particularly during the latter half of the 20th century.
4. The study also revealed significant trends in extreme temperatures in the region. The right panel shows the rates of warm nights and cold nights and hot days and cool days, which were derived from daily maximum and minimum temperatures using a percentile analysis. In addition, it shows the increasing trend of hot days and warm nights, which are grey and blue colors, and the decreasing trend of cool days and cold nights, orange and red.
5. Overall, a widespread increase in mean temperature, fewer cool extremes and more warm extremes are represented from 1951-2015.

Observed Climate Change – *Precipitation*

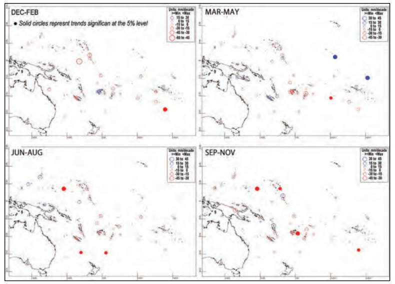
Trends on global and regional scales

- Trends vary spatially and seasonally over Small Island regions in the Pacific. Rainfall has decreased in parts of the Pacific islands poleward of 20° latitude in both hemispheres. However, **trends are not significant** across the globe, including the Pacific. *(IPCC[9])*

Trends of annual precipitation (1961-2015; CRU TS 4.04)



Trends of quarterly precipitation (mm/decade) at PICs (1951-2015; positive (blue) and negative (red))



Sources: IPCC[10] (left), McGree et al. 2019 (right)

Narrative Part

1. Precipitation is a major atmospheric variable, together with temperature. However, compared with temperature, it is much more difficult to find significant changes in precipitation. The left panel shows global trends of annual precipitation over the 55 years from 1961 to 2015. The widespread of x-marks indicates the regions where trends are not significant. A comparison between this chart and that of temperature two slides before demonstrates the difference.
2. The main reasons for the less significance in the precipitation trend analyses are the sparsity and less quality of data, particularly in developing countries, and the large natural variabilities that precipitation has.
3. Nevertheless, some significant increases in land areas are shown in this chart, such as North and South America, Eurasia and northwestern Australia, while decreases are apparent across tropical western and equatorial Africa and southern Asia.
4. Significant trends are not noticeable in the western Pacific region like the global views. Pacific is one of the most data-sparse areas of the world, while interannual and decadal variabilities drive long-term trends in rainfall, as we discussed previously.
5. Four panels on the righthand side depict the findings of regional precipitation trends from the same study in the previous slide. Results are shown in quarterly periods. In the study region, statistically significant annual precipitation trends were only found in the southern subtropics and southwest French Polynesia, both of which are negative. These were associated with negative trends in June to August and from December to February. Significant negative trends were also present from September to November in the north ITCZ and north PNG subregions.
6. Unlike the changes in temperature, which are dominated by background global warming, rainfall patterns in the Pacific are strongly influenced by natural climate variability. Such a regional characteristic makes it difficult to detect rainfall trends.

depends on a myriad of localized conditions, including wind speed, humidity, and temperature.

7. Discharge of rivers, groundwater, and land ice, as well as water use by human, are also important components of water fluxes. In terms of drinking water and irrigation, recharge and discharge of groundwater is a major contributor in the water fluxes together with precipitation.

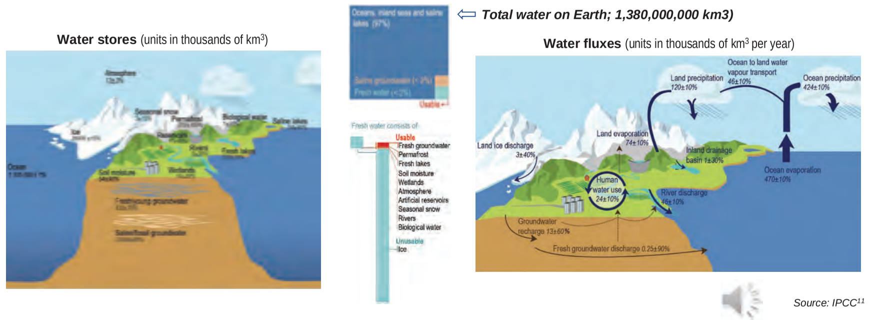
Global Water Cycle; water stores and fluxes

- Global water cycle is the continuous, naturally occurring movement of water through the climate system from its liquid, solid and gaseous forms among reservoirs of the ocean, atmosphere, cryosphere and land.
- While **saline ocean water accounts for 97%** of all water on Earth, **terrestrial freshwater represents less than 2%** and saline groundwater & lakes 1-2%.

⇦ ***Total water on Earth; 1,380,000,000 km3)***

Water stores (units in thousands of km^3)

Water fluxes (units in thousands of km^3 per year)



Source: IPCC[11]

Narrative Part

1. This slide shows an overview of the global water cycle in the climate system, including water stores or reservoirs on the left, and water fluxes or movement on the right. The water cycle is a complex system but is very important because it let us know how water reaches us.
2. What are water stores in the water cycle? The major stores of water are the ocean, ice caps, land including underground, and the atmosphere. Among these, the ocean is the primary reservoir storing 97% of all water on Earth, mostly as salt water. Liquid freshwater on land forms surface water such as lakes and rivers, soil moisture and groundwater stores, together accounting for less than 2% of global water.
3. What are water stores in the water cycle? The major stores of water are the ocean, ice caps, land including underground, and the atmosphere. Among these, the ocean is the primary reservoir storing 97% of all water on Earth, mostly as salt water. Liquid freshwater on land forms surface water such as lakes and rivers, soil moisture and groundwater stores, together accounting for less than 2% of global water.
4. Focusing freshwater, ice sheets, glaciers and snowpack account for approximately 96% of all freshwater resources, with less than 4% of freshwater considered easily accessible and available for human society's water resource needs.
5. Meantime, some water moves quickly from one place to another. It is illustrated in the right panel, where the continuous movement of water within the Earth and atmosphere is shown as water fluxes. Water fluxes consist of three major processes, that is “evaporation” where water changes phase from liquid to gas or vapor with solar energy, and “condensation” where water vapor cools and joins together into drops of water and clouds, and “precipitation” where water falls from clouds as rain and snow.
6. The largest component of the global water cycle operates over the ocean, where 85% of evaporation and 77% of precipitation occurs at the ocean-atmosphere interface. Meantime, regional evaporation is rather complex to measure, as it

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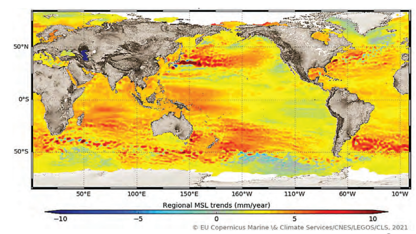
Observed Climate Change – *Sea Level Rise I*

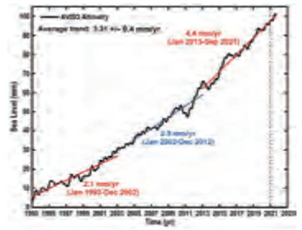
Global mean sea level (GMSL)

- GMSL rose faster in the 20th century than in any prior century over the last three millennia, with a 0.20 m rise over 1901-2018.
- GMSL rise has accelerated since the late 1960s, with an average rate of 2.3 mm/yr over 1971-2018, increasing to 3.7 mm/yr over 2006-2018. *(IPCC[12])*

Regional sea level trend for Jan-1993 to Dec-2020



GMSL evolution for Jan-1993 to Sep-2021



Source: AVISO altimetry

Narrative Part

1. Global mean sea level changes primarily result from ocean warming, leading to the thermal expansion of seawater and land ice melting and adding water to the ocean. As a result, the sea level is continually rising, and it has been found to be accelerating. This has gathered the increasing attention of world scientists.
2. Recent measurements by satellite altimeters revealed that the global mean sea level rise was 2.1 mm per year between 1993 and 2002, 2.9 between 2003 and 12, and 4.4 between 2013 and 21, as shown in the right panel. This rapid step-up was primarily due to the accelerated ice mass loss from glaciers and ice sheets.
3. The regional sea level trends in the left panel demonstrate a considerable variation between the basins. Much of the spatial variation results from natural climate variabilities—such as El Niño and the Pacific Decadal Oscillation—over time scales from months, about a year, to several decades. These climate variations shift surface winds, ocean currents, temperature, and salinity, affecting sea levels. Also accountable are Earth's geological changes, such as changes in Earth's gravity and vertical land motion.
4. The chart shows such variations also in the Pacific. The western tropical Pacific Ocean intensified sea-level rise during the 1990s and 2000s. Ten-year trends exceeded 20 mm yr-1, while sea level trends were negative on the North American west coast.

Glossary

➢ **Altimeter**

Satellites carrying radar altimeters record the surface topography along the satellite's ground track. They precisely measure a satellite's height above water, land or ice by timing the interval between the transmission and reception of very short radar pulses. This is the only technology that can measure, systematically and globally, changes in the height of the ocean – and is therefore essential for monitoring sea-level rise. (ESA)

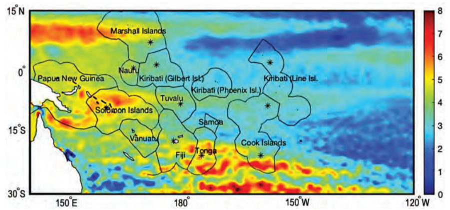
17

Observed Climate Change – *Sea Level Rise II*

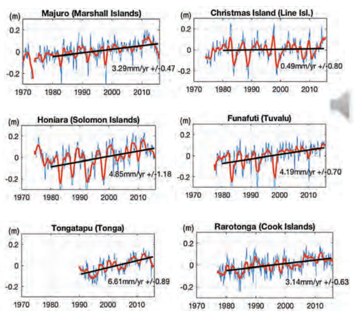
Regional sea level rise

- Across the globe, sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific over the period 1993–2018. *(IPCC[13])*

Rates of sea level rise from satellite altimetry for 1993-2017 (mm/yr)



Monthly and yearly running average of relative sea level measured at tide gauges for 1977-2017



Source: Aucan, J. 2018

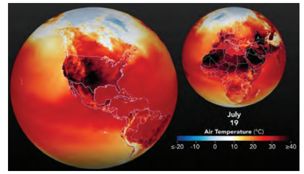
Narrative Part

1. Mean sea level can fluctuate over a long period, even for decades. It should be noted that sea level is defined in two different ways: "absolute sea level", which refers to the sea level as measured from the center of the earth, and "relative sea level", which refers to the sea level relative to the coastal area of interest. Absolute sea levels have been monitored by satellite altimetry since 1993, while relative sea levels are by tide-gauges which started in the 1960s in the Pacific.
2. Regarding the sea levels in the Pacific, it's worth noting that satellite altimeters found sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific from 1993 to 2018, among all basins. This slide presents a recent study which demonstrates this typical trend. The left panel shows calculated rates of the regional sea level rise from 1993 to 2017. During this period, results show a rise in sea level of 3-6 mm/year for the Pacific islands, with notable differences between islands. Some islands in the Western Pacific, such as the Solomon Islands, Papua New Guinea, and the Marshall Islands, have experienced a higher rate of sea level rise (up to 6 mm/year), while other islands further east, such as Samoa and Kiribati are much lower. This difference in sea level rise is attributed to large-scale trends in trade winds.
3. Changes of the relative sea level at some selected stations are shown in the panels on the right. Data measured at tide-gauges combines the measurements of satellite altimeters. All show a rise in relative sea level over the past 30 to 40 years and the varied rates between islands. They also demonstrate inter-annual variability, which is attributed mostly to El-Niño Southern Oscillation.

Recent topics in climate observation - (global)

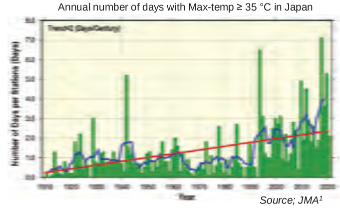
- ✓ Four key climate change indicators – **GHG** concentrations, **sea level rise**, **ocean heat** and ***ocean acidification*** – set **new records in 2021**. *(WMO)*
- ✓ **Over 40°C** was observed in parts of Portugal, Spain, France, US, and UK, which breached the 40°C for the first time. *(WMO)*
- ✓ The frequency of heatwaves **has also been increasing in Japan**. The annual average of the number of days of 35°C or higher for 1992-2021 has been **3.3 times the average** for 1910-1939. *(JMA)*

Daily maximum surface temperature on 19 July 2022



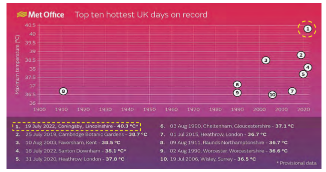
Source; NASA

Annual number of days with Max-temp ≥ 35 °C in Japan



Source; JMA[1]

Top ten hottest UK days on record



Source; Met Office

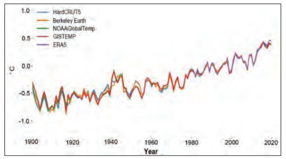
Narrative Part

1. Recently, the world climate monitoring system has been observing exceptional weather conditions across the globe. Some of the cases are unprecedented and highly suggestive of accelerating climate change. For example, in 2021, four key climate change indicators set new records. In addition to the record-breaking GHG concentration as well as the accelerating global mean sea level, as shown in the previous slides, scientists have revealed that ocean heat made a record high exceeding the 2020 value and that the ocean surface acidity was at its highest "for at least 26,000 years".
2. In 2022, the world had the third warmest July, with prolonged and intense heat waves affecting the US and parts of Europe and Asia. The top right panel displays a snapshot of the global surface temperatures in July. Nearly 40° C temperatures stand out in the US, Asia and Europe. Despite the weak La Niña, which has a cooling influence, northern hemisphere land masses saw well-above-average temperatures, almost predominantly. Temperatures measuring over 40° C were observed in parts of Portugal, Spain, France, and the UK, which breached 40 degrees for the first time. The World Health Organization witnessed more than 1,700 deaths in Spain and Portugal alone.
3. The top ten hottest days on record in the UK after 1900 are plotted on the bottom right panel. It shows nine out of 10 hottest days have been recorded since 1990, including the 40.3° C on 19 July this year.
4. The Japan Meteorological Agency has also noticed a similar trend over the past hundred years, as shown in the left panel. The number of days of 35° C or higher for 1992-2021, the latest 30-year statistical period, has been 3.3 times the average for 1910-1939, the first statistical period of the Agency. This same trend in the two countries clearly endorses the temperature findings in IPCC AR6.

Recent topics in climate observation - (regional)

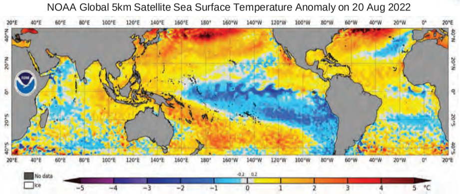
- ✓ In the South-West Pacific region, **2020 was the second or third warmest year** on record.
- ✓ 2020 was **a relatively wet** year over PNG, Solomon Islands, Vanuatu, Fiji, Tonga and Samoa, while many equatorial regions close to IDL were **dry**.
- ✓ PICs were affected straight by the **La Niña** events in 2020-21 and 2021-22. *(On 16 Aug., BoM suggested a 70% chance of a 3rd consecutive La Niña year forming.)*

Area average temperature anomalies from the 1981–2010



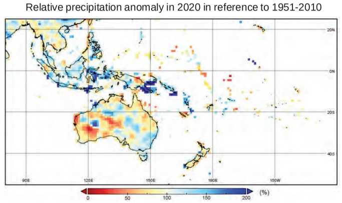
Source; WMO

NOAA Global 5km Satellite Sea Surface Temperature Anomaly on 20 Aug 2022



Source; NOAA

Relative precipitation anomaly in 2020 in reference to 1951-2010



Source; GPCC

Narrative Part

1. The 2020 climate report for the Southwest Pacific issued by WMO emphasized that the significant and growing impacts of extreme hydro-meteorological phenomena and tropical cyclones, plus new multi-dimensional threats, pose increasing challenges to communities in the region. Regarding regional averaged temperatures, 2020 was the second or third warmest year on record. The top right panel shows a consistent increase in the regional average temperature has been demonstrated over the past century.
2. In 2020, the Great Barrier Reef suffered a major marine heatwave. In February, sea surface temperatures over the region were 1.2° C above the 1961-1990 average, making it the hottest month on record. Such high temperatures affected the entire GBR, and widespread coral bleaching was reported.
3. The bottom right panel gives an overall regional rainfall condition in 2020. Under the 2020-21 La Nina and the 2021-22 La Nina, relatively wet conditions continued over the region from PNG and Solomon Islands to Fiji and Samoa from 2020 through early 2022, while lower-than-normal rainfall continued in the equatorial region. During these years, Australia suffered frequent floodings, including the 2022 eastern Australia floods, one of the nation's worst recorded flood disasters.
4. The Bureau of Meteorology stated on 16 August that a third consecutive La Niña is likely from late 2022. The latest monitoring of sea surface temperatures (SSTs) shown in the bottom left represents below-average SSTs extending from the eastern to central tropical Pacific and suggests the possible occurrence of La Nina soon.

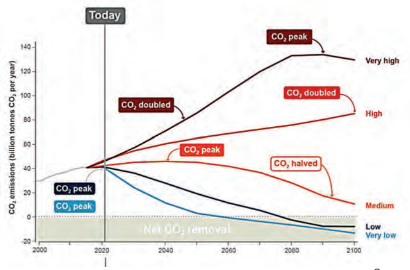
Projected Climate Change

Projected Climate Change – *GHGs*

Greenhouse gases (emission scenario)

- AR6 considers a set of **five new illustrative emissions scenarios** (Shared Socio-economic Pathways; SSPs). Coupled Model Intercomparison Project Phase 6 (CMIP6) was conducted using these scenarios, and its outcomes served as the main bases of AR6.

New scenarios (SSPs) of annual anthropogenic emission of CO_2 over 2015–2100 (AR6)



- SSP5-8.5 **Very high**; Close to RCP*8.5 of AR5. Worst case scenario with no additional climate policy.
- SSP3-7.0 **High**; Between RCP8.5 and RCP6.0. Realistic worst-case with continuing CO_2 emission. Would result in serious consequences.
- SSP2-4.5 **Medium**; Close to RCP4.5 and later RCP6.0. More consistent with government polices but CO_2 emission remain above zero.
- SSP1-2.6 **Low**; Close to RCP2.6. CO_2 emission to plateau and decline after 2025. Temperatures to stay well below 2°C.
- SSP1-1.9 **Very low**; No equivalent RCP. Efforts to remove CO_2 needed. Will meet the Paris goal of limiting global warming to 1.5°C.

Source: IPCC[14]

- *Representative Concentration Pathways (**RCPs**) are GHG emission scenarios used in AR5.*

Narrative Part

1. AR6 adopted five new scenarios for GHGs emissions called SSP scenarios instead of 4 RCP scenarios in AR5. The new scenarios represent five different socio-economic pathways. World climate scientists performed simulations of climate change based on these scenarios in the Coupled Model Intercomparison Project--Phase 6 (CMIP6), which formed the basis of AR6. The chart below shows SSP scenarios for CO2. IPCC produced SSP scenarios also for other Green House Gases.
   - SSP/585, the Very high emission scenario, is close to RCP8.5. It assumes no measures will be taken to reduce CO2 emissions. CO2 emissions soar up and double from current levels by 2050.
   - SSP/370, the High scenario, was newly introduced. CO2 emissions double from current levels by 2100.
   - SSP/245, the Medium scenario, is an update to RCP4.5. It assumes that climate protection measures are taken. CO2 emissions remain around current levels until the middle of the century.
   - SSP/126, the low scenario, is a remake of the RCP2.6. CO2 emissions decline to net zero around 2080 and goes into net negative emission.
   - SSP/119, the very low scenario, assumes CO2 emissions declines to net zero around 2050 and then net negative.
2. Roughly, Very high scenario is pessimistic as CO2 emissions are unregulated. And Low and Very low scenarios are optimistic as they require drastic measures to reduce CO2 emissions. The recently released AR6/WG3 report suggests that limiting warming to around 1.5° C requires global greenhouse gas emissions to peak before 2025 at the latest and be reduced by 43% by 2030. The next few years are critical.

Glossary

➢ **Coupled Model Intercomparison Project (CMIP)**

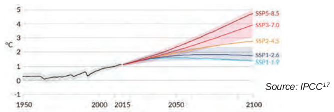
CMIP is a project of the World Climate Research Programme (WCRP)'s Working Group

Projected Climate Change – *Temperature I*

Global surface temperature (GST)

- GST will continue to **increase until at least the mid-century** under all emissions scenarios. *(IPCC[15])*
- It was reaffirmed that there is a **near-linear relationship** between cumulative anthropogenic CO_2 emissions and the global warming they cause. *(IPCC[16])*

GST change relative to 1850-1900



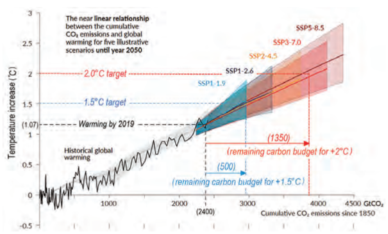
Source: IPCC[17]

Changes in GST under the 5 emissions scenarios

Scenario	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
SSP1-1.9	1.5	1.6	1.4
SSP1-2.6	1.5	1.7	1.8
SSP2-4.5	1.5	2.0	2.7
SSP3-7.0	1.5	2.1	3.6
SSP5-8.5	1.6	2.4	4.4

Source: IPCC[18]

GST increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Source: IPCC[19]

Narrative Part

1. This slide shows one of the main outcomes of CMIP6 projections - global surface temperatures. The top left panel shows the projected change of temperatures under all five scenarios. There is a slow turning point during the mid-century, where the trend becomes relatively flat or even starts to decline for Low and Very-low scenarios while continuing to grow for medium and higher scenarios. The difference can be seen more precisely in the table below.
2. The best estimates of the near-term temperatures are 1.5 degrees or higher for all scenarios. It provides new estimates of the chances of crossing the global warming level of 1.5° C in the following decades. The table also shows the significant difference between Very-low and Very-high scenarios in the long term; it is about 3 degrees.
3. More importantly, hot temperatures include heat waves and growing average temperatures. Such extreme events have highly serious impacts and are projected to occur far more frequently in the near future.
4. The right panel shows the near-linear relationship between temperature increase and cumulative CO2 emission until 2050. This diagram shows that the historical cumulative CO2 emissions from 1850 to 2019 were 2400 GtCO2, resulting in global warming of 1.07 degrees. If the emissions continue, Earth will also continue to warm in the same way.
5. This diagram suggests that if we hope to limit the warming to 1.5 degrees, the remaining carbon budget will be about 500 GtCO2. Similarly, for 2.0 degrees, it will be about 1350 GtCO2. So, it gives us an estimate of the allowable amount of additional CO2 emissions for limiting global warming to any target level. In this regard, we should note that the global emissions of GHGs in 2018 were more than 50 GtCO2 in total.

Glossary

➢ **Carbon budget**

This term refers to three concepts in the literature: (1) an assessment of carbon cycle

of Coupled Modelling (WGCM). Since 1995, CMIP has coordinated climate model experiments involving multiple international modeling teams worldwide.

- CMIP has led to a better understanding of past, present and future climate change and variability in a multi-model framework.
- CMIP defines common experiment protocols, forcings and output.
- CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway.
- CMIP's central goal is to advance scientific understanding of the Earth system.
- CMIP model simulations have also been regularly assessed as part of the IPCC Climate Assessments Reports and various national assessments.

➢ **Representative Concentration Pathways (RCPs)**

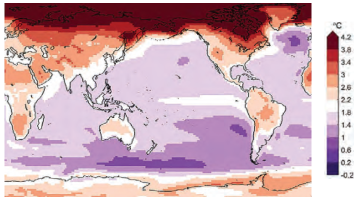
Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. (Moss et al., 2010). For further description of future scenarios, see Box 1.1 of AR5/WG1.

Projected Climate Change – *Temperature II*

Regional surface temperature (RST)

- It is very likely that the significant recent warming trends observed in the small islands **will continue in the 21st century**, which will likely further increase heat stress in these regions. *(IPCC[20])*

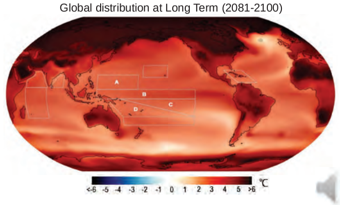
The multi model average projection of 2°C global warming with a color scale centered on +2°C.



(Source: RCCAP)

Projected changes (°C) relative to 1850-1900 under SSP3-7.0

Global distribution at Long Term (2081-2100)



Global and sub-regional means (°C) at 3 terms

*(**A**; NW-Tropics, **B**: Equatorial Pacific, **C**: Northeast SPCZ, **D**: Southwest SPCZ)*

Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	0.7	1.3	2.6
(B) Equatorial Pacific	0.8	1.4	2.8
(C) NE-SPCZ	0.7	1.2	2.4
(D) SW-SPCZ	0.7	1.2	2.4
GLOBAL	**1.5**	**2.1**	**3.6**

Source: IPCC[21]

Narrative Part

1. The projected warming over the Pacific Island region is relatively moderate compared with the global-average warming for all emissions scenarios. This is linked to the fact that the oceans are warming at a lower rate than land areas, and this clear trend in the observation part is noted.
2. The top right chart shows the increase of regional temperatures at the end of the 21st century under the high emission scenario. It indicates that warming is clear and almost universal. Looking at the western Pacific, changes are relatively uniform over the region; all are around 2 to 3 degrees.
3. Those of areal means of the four sub-regions; NW Tropics, Equatorial Pacific, NE SPCZ and SW SPCZ; were calculated for each of three terms with AR6-Interactive Atlas, where sub-regions are determined based on the average positions of the ITCZ and SPCZ. The results are listed in the table below. Sure enough, changes are roughly comparable from region to region. If anything, warming is slightly larger in the Equatorial Pacific. Anyhow, the smaller-than-global-average trend in the region is evident. The magnitudes of warming are roughly 50% of the global mean for the near term and 70% for the long term.
4. The left panel depicts the regional temperatures at a 2° C global warming. Changes are shown in a finer and specific color scale centered on plus 2° C. Red indicates the areas hotter than the global average, and purple is cooler than the average. It clearly shows that warming is less than the average across the entire ocean, and it is largely uniform over the western Pacific.

Glossary

➢ **IPCC WGI Interactive Atlas**

The Interactive Atlas regional information supports the assessment done in the AR6-WGI chapters, the Technical Summary (TS) and the Summary for Policymakers (SPM), allowing for flexible temporal and spatial analyses of trends and changes in key atmospheric and oceanic variables, extreme indices and climatic impact-drivers (CIDs), as obtained from several global and regional observational and model simulated

sources and sinks on a global level, through the synthesis of evidence for fossil fuel and cement emissions, land-use change emissions, ocean and land CO2 sinks, and the resulting atmospheric CO2 growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that that is estimated to limit global surface temperature to a given level above a reference period, taking into account global surface temperature contributions of other GHGs and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of equity, costs or efficiency.

➢ **Gigatons of Carbon Dioxide (GtCO2)**

GtCO2 refers to gigaton of carbon dioxide (a gigaton is equal to 1 billion metric tons). GTCO2 (or GtC) is used as the reference unit for the global carbon cycle (Gigaton of carbon = 1 GtC = 1015 grams of carbon. This corresponds to 3.667 GtCO2).

➢ **Carbon cycle**

The term used to describe the flow of carbon (in various forms, e.g., as carbon dioxide (CO2), carbon in biomass, and carbon dissolved in the ocean as carbonate and bicarbonate) through the atmosphere, hydrosphere, terrestrial and marine biosphere and lithosphere.

➢ **Cumulative emissions**

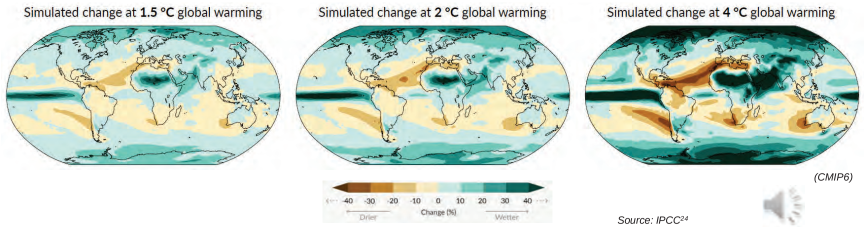
The total amount of emissions released over a specified period of time.

Projected Climate Change – *Precipitation I*

Global precipitation

- **Precipitation is projected to increase** over high latitudes, the **equatorial Pacific** and parts of the monsoon regions but decrease over parts of the subtropics and limited areas in the tropics under Medium, High, and Very-high scenarios. *(IPCC[22])*
- It is very likely that **heavy precipitation events will intensify and become more frequent** in most regions with additional global warming, including the **western tropical Pacific.** *(IPCC[23])*

Annual mean precipitation change (%) relative to 1850-1900



Source: IPCC[24]

Narrative Part

1. Precipitation has a unique characteristic as it represents opposite changing trends over time and space. Roughly, its contrast will become more significant between dry regions and wet regions and between the dry season and rainy seasons. A warmer climate will intensify very wet and dry weather, with implications for increasing flooding or drought.
2. The three maps on this slide show projected changes in annual mean precipitation for a global warming of 1.5 degrees on the left, 2 degrees in the middle, and 4 degrees on the right. The projection of global precipitation is roughly a half-and-half mixture of positive and negative trends. This is the crucial difference with the projection of temperatures. Precipitation will increase over high latitudes, the equatorial Pacific and parts of the monsoon regions but decrease over parts of the dry subtropical regions and in limited areas of the tropics. Models generally agree that precipitation, when it once occurs, will become more intense. Unlike average annual precipitation, almost the entire world is expected to see an increase in extreme precipitation along with global warming. Also, it's worth noting that rainfall variability related to the El Nino-Southern Oscillation (ENSO) is projected to be amplified by the second half of the 21st century under the Medium and higher scenarios.

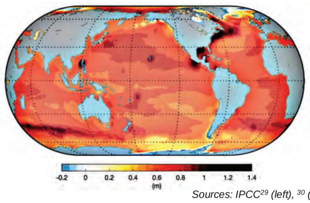
datasets used in the report. These analyses are available for a range of historical and future periods and emissions scenarios or warming levels. A description of the datasets, temporal and spatial scales and dimensions of analysis, as well as the representation of robustness and uncertainty (Cross-chapter Box Atlas.1) are introduced in Atlas.1.

Projected Climate Change – *Sea level I*

Global mean sea level (GMSL)

- GMSL will continue to rise over the 21st century; **0.63-1.01 m at 2100 under SSP5-8.5.** *(IPCC[27])*
- In the longer term, **sea level is committed to rise for centuries to millennia** due to continuing deep ocean warming and ice sheet melt and will remain elevated for thousands of years. *(IPCC[28])*

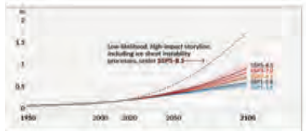
Projected sea level changes at 2100 under SSP3-7.0



Sources: IPCC[29] (left), [30] (right)

Projected GMSL changes relative to the 1900 level

Dashed lines show changes that could occur only in case of high-impact ice-sheet processes.



(17th-83rd percentile ranges)

(AR6)

Narrative Part

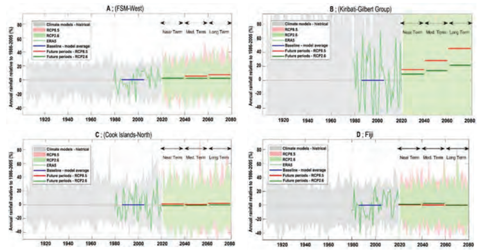
1. Projections of sea level rise under five scenarios are given in the two panels in the middle and on the right. The left shows that sea level rise will reach nearly 1 meter at 2100 and then approach 2 meters at 2150 under Very-high scenario. The vertical graph on the right shows further projections for 2300 under Very-low and Very-high scenarios. Sea levels rise will be 0.5 to 3 meters for Very-Low scenario and 2 to 7 meters for Very-high scenario.
2. Interesting to note in these charts is another storyline indicated by the broken lines. Although it is not included in the projections under five scenarios but suggests that, in case the ice-sheets become highly unstable, in Antarctica in particular, sea level rise could present quite a different storyline. It is shown by the dashed curve here; along this line, sea level rise could be 2 meters at 2100 and 5 meters at 2150. Further, at 2300, the sea level could rise by 15 meters or more.
3. Another point is that even if global temperatures peak by the end of this century, it will continue for centuries or even millennia to come, as the oceans, glaciers and ice sheets take time to reach an equilibrium state (or steady state, in other words). We are only at the starting line of the long-lasting sea level rise to come.
4. The global map on the left shows a snapshot of the rising regional sea levels under the high-emission scenario. Although it shows some regional trends, sea level rise should be recognized as a universal trend across the globe.

Projected Climate Change – *Precipitation II*

Regional precipitation

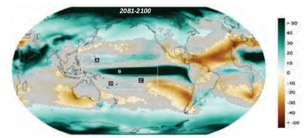
- ENSO will remain the dominant mode of interannual variability, and its influence will strengthen. It is very likely that **ENSO rainfall variability** will increase significantly over the 21st century.
- **Higher evapotranspiration** under a warming climate either amplifies or partially offsets, respectively, the effect of decreases or increases in rainfall. *(AR6)*

Annual mean precipitation change (%) in sub-regions relative to 1850-1900



(Source: RCCAP; CMIP5)

Annual mean precipitation change (%) relative to 1850-1900 under SSP3-7.0



Region	Near term (2021-2040)	Mid term (2041-2060)	Long term (2081-2100)
(A) NW-Tropics	2.2	3.7	6.2
(B) Equatorial Pacific	10.2	16.1	33.8
(C) NE-SPCZ	4.3	6.0	8.1
(D) SW-SPCZ	1.3	2.1	1.9
GLOBAL	–	–	**4.7**

Source: IPCC26

Narrative Part

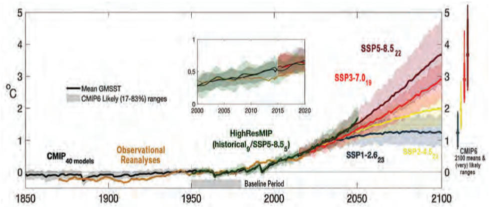
1. In the western tropical Pacific, increases in annual mean rainfall will stand out near the SPCZ and ITCZ.
2. However, as suggested earlier, it is rather challenging to find clear trends in the projection of precipitation changes in contrast to temperature. While the models used by scientists generally agree on how different parts of the Earth will warm, there is much less agreement about where and how precipitation will change. Such difficulties are even more on smaller scales.
3. This is mainly because of the complexity of the water cycle that we saw in the earlier slide. In addition, the scarcity of data, as well as the year-to-year variability of precipitation, is also highly challenging. These hurdles significantly increase uncertainty in model simulations.
4. Still, there were some findings in SMIP5 and 6. The right map is the projection with SMIP6. The models' average shows significant increases in precipitation in the equatorial Pacific, as suggested earlier. Yet, we note again that much of the Pacific region is hatched in the map, meaning the model agreement is low over a wide range.
5. Areal means of the projection were sought for the four sub-regions with the Interactive Atlas, the same as for temperatures in the earlier slide. The results are listed in the table below. Notable increases are shown in the Equatorial Pacific, while other sub-regions are rather flat.
6. Four panels on the left are time-series charts of multi-model means from RCCAP by SMIP5. Each represents the respective subregions. They show the same trend as SMIP6 but are relatively underestimated. In either case, we should note that those projections are just the mid-points of different results from different models with significant uncertainties.

Projected Climate Change – *Sea surface temperature (SST)*

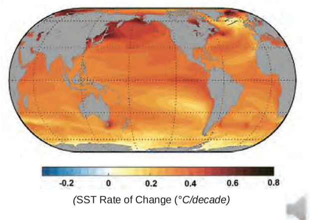
Global mean SST

- Past GHG emissions since 1750 have committed the global ocean to future warming. Over the rest of the 21st century, likely ocean warming ranges from **2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5)** the 1971–2018 change. *(IPCC[32])*

Global mean (SST); modern history and model projections to 2100



SSP5-8.5 CMIP Change Rate (2005-2100)



Source: IPCC[33]

Narrative Part

1. The global ocean has warmed since 1970 and has taken up more than 90% of the excess heat in the climate system, as we have learned in the earlier slide. Regionally, tropical oceans, including the western Pacific, have been warming faster than other regions since 1950.
2. As shown in the left panel, this ocean warming trend is consistent through the 21st century, except for the very-low emission scenario. The right panel shows the SST changes with time. Under the Very-high scenario, ocean warming could range from 4 to 8 times the 1971-2018 temperatures.
3. Notably, the warming of the ocean is irreversible on centennial to millennial time scales. It is also worth noting that the warming will lead to extreme heat conditions across the basins. Marine heatwaves will become more frequent, and the largest increases will be found in the tropical ocean, especially over the western Pacific.

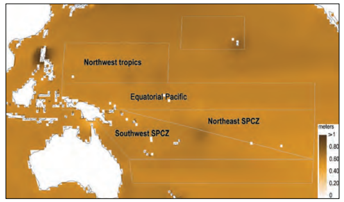
Projected Climate Change – *Sea level II*

Regional sea levels

- Relative sea-level rise (RSLR) is very likely to continue in the tropical Pacific, where regional-mean RSLR will be **0.4–1.0m** for 2081–2100 (relative to 1995–2014) under the high-emission scenario.
- Even a **5-10 cm** additional SLR will **double flooding frequency** in much of the tropical Pacific.

CMIP6-SLR projection relative to 1995–2014 under SSP3-7.0 for Near-, Mid-, and Long-Terms

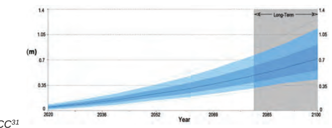
Projection of SLR for 2081-2100



Sub-regional projections of median RSLR (m) for three terms

	N-Term (2021-2040)	M-Term (2041-2060)	L-Term (2081-2100)
NW-Tropics	**0.1** [0.0-0.2]	**0.2** [0.1-0.4]	**0.7** [0.4-1.0]
EQ-Pacific	**0.1** [0.0-0.2]	**0.2** [0.1-0.3]	**0.6** [0.4-0.9]
NE-SPCZ	**0.1** [0.0-0.2]	**0.2** [0.1-0.3]	**0.6** [0.4-0.9]
SW-SPCZ	**0.1** [0.0-0.2]	**0.2** [0.1-0.4]	**0.6** [0.4-0.9]

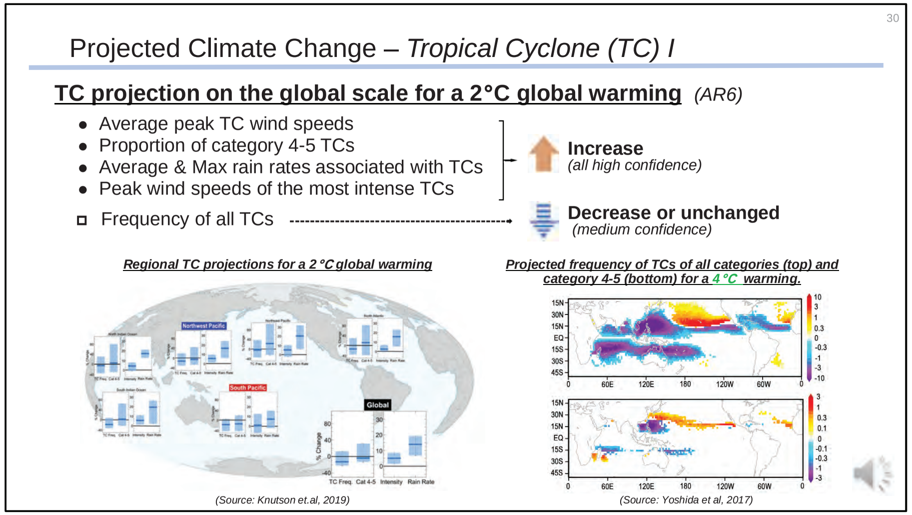
Time-series projection of the sub-regional mean for the Equatorial Pacific



Source: IPCC[31]

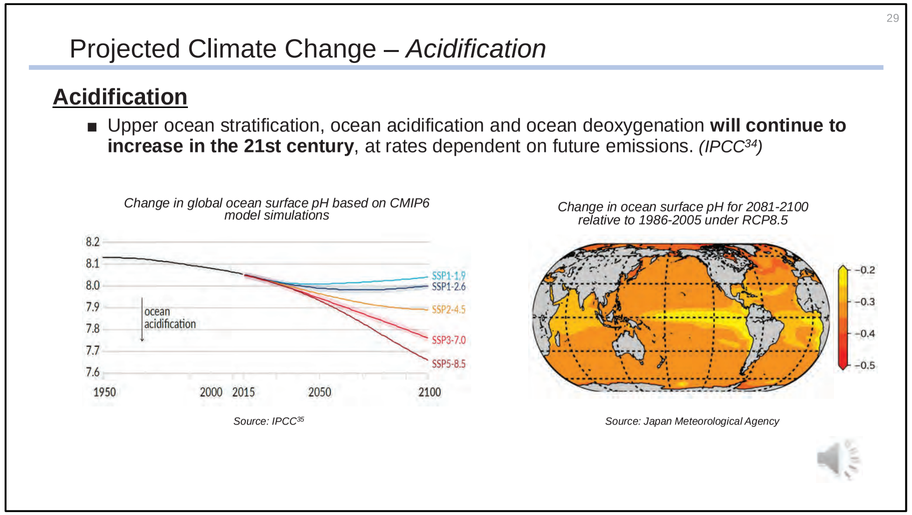
Narrative Part

1. In consideration of the sea level change on a global scale in the previous slide, we should narrow the focus on the Pacific region. Again, AR6's Interactive Atlas was used to see the results of CMIP6 for the sub-regions under the high-emission scenario. As shown in the top table's multi-model averages for three terms and the time-series projection in the bottom chart, you can see that regional sea-levels will be 0.4-1.0m higher than in 1995-2014 in the long term. Also, together with the projected unique pattern in the long-term on the left, it is clear that differences between the regions are minimal—about 0.1m for the near-term and 0.6m for the long-term.
2. Interestingly, the magnitude of regional sea-level rise projections by models has gradually increased over the past decade, along with global projections. For example, sea-level rise in the western tropical Pacific was projected to be 0.26 to 0.82 m by 2100 under the very high emission scenario in the PCCSP report in 2011. Further, we should note that extreme sea-level events are projected to be more intense and frequent. For example, AR6 estimated that even a small amount of sea-level rise, say 5 to 10cm, could increase the frequency of flooding in the tropical Pacific as early as 2030.



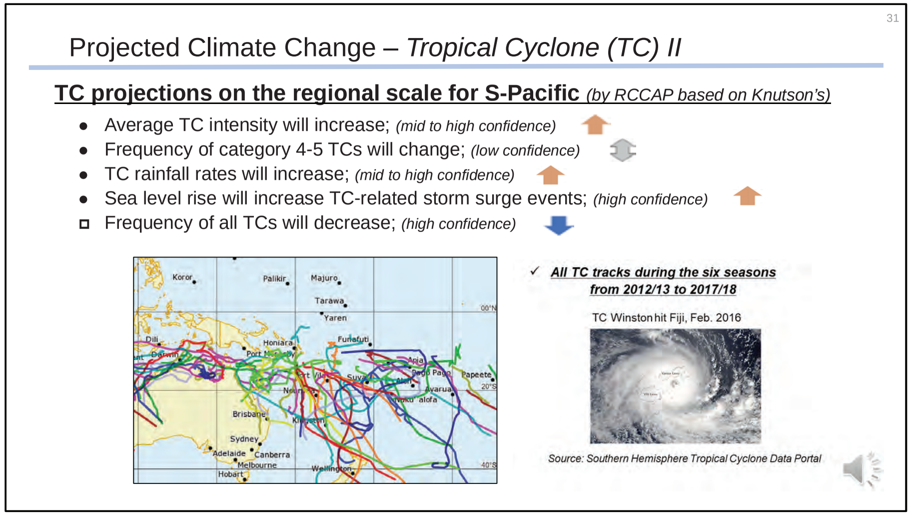
Narrative Part

1. This slide presents the results of two recent studies on tropical cyclones. One is shown in the left map by Knutson et al., indicating the future status under 2 degrees warming, and the other is the two panels on the right by Yoshida et al., showing the projected TC frequencies of all categories on the top and 4-5 categories in the bottom.
2. Regarding tropical cyclones, confidence is low in identifying their long-term trends, such as frequency or intensity, due to changes in the technology used to collect best-track data. In addition, for projection, the simulation capabilities of global models are still challenging. However, recent studies, including those in this slide, suggested several essential features.
3. In summary, mainly from the Knutson's and AR6, average peak TC wind speeds and the proportion of Category 4-5 TCs will very likely increase globally with warming. However, over the western North Pacific, the frequency of Category 4-5 TCs will likely increase in limited regions. This trend in the western North Pacific is suggested in the bottom panel of Yoshida's. Also, average TC rain rates will likely increase with warming, and, finally, the frequency of TCs overall categories will decrease or remain unchanged.
4. Although degrees of some changes are different between the basins, tendencies are less similar for all seven basins, including NW and SW Pacific.



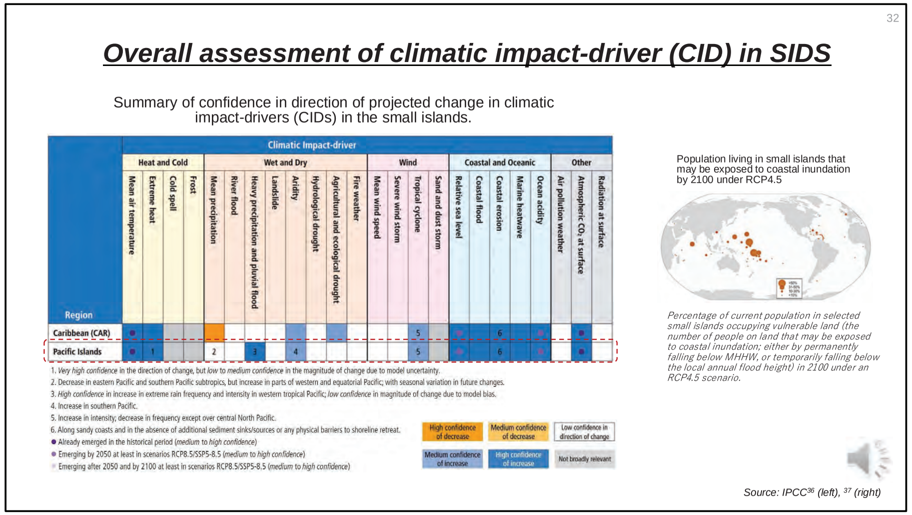
Narrative Part

1. Sea water is becoming more acidic across the entire ocean. Along with sea surface temperatures, this acidification trend will continue all through this century under medium or higher emission scenarios. Please take a look at the left panel. Under the Very-high scenario, the ocean pH will reach around 7.7 or less at the end of the century, which is about 0.4 units lower than the present value. Globally, acidification will be faster over the Equatorial Pacific, as shown in the right panel.



Narrative Part

1. Compared with the assessment of TC projections on a global scale, it is much more difficult to discuss it for a specific basin, including the South Pacific. It is partly because of the limited ability of climate models to simulate various climate features and variabilities that influence tropical cyclones, such as ENSO and the SPCZ activity.
2. This slide summarizes the regional assessment by RCCAP for the South Pacific. Assessment is made based on Knutson's and therefore has a lot of commonalities with the global assessment in the previous slide.
3. Points to be underlined are; 1) a clear view that TC frequency will decrease, and 2) an increase of TC-related storm surge is emphasized. Sea level rise will lead to a higher impact of storm surges. It needs to be considered with the projection of more intense TC rainfalls because it could cause the combined effect of storm surge and river flooding in coastal areas.



Narrative Part

1. In AR6, WGI has introduced the term "climatic impact-drivers". A climatic impact-driver or CID refers to a long-term condition or an extreme event that directly affects society or ecosystems.
2. The table on this slide shows the regional assessment of CIDs change in the small islands of the Pacific and the Caribbean for mid-century under RCP4.5, the medium scenario. They are most relevant to small islands and will lead to "hazards" in the five primary domains, i.e., (1) "Heat and Cold", (2) "Wet and Dry", (3) "Wind", (4) "Coastal and Oceanic", and (5) "Other".
3. The table assesses each CID by representing the confidence in its projected change and thereby suggests the level of confidence which is determined by the existence of robust evidence and model agreement. So, it will help identify the drivers of greater significance to the region. The level of confidence is indicated by the orange colour for decrease, blue for increase, white for no significant trend, and grey for not applicable.
4. Regarding "Heat and Cold", "Mean air temperature", and "Extreme heat" are identified as "High confidence of increase". It suggests significant recent warming trends will continue in the 21st century with an increase in intensity and frequency of temperature extremes, particularly in the Pacific. So, a considerable increase in heat stress will be inevitable.
5. There are many white squares found in "Wet and Dry". It is mainly because of the complexity of the global water cycle, scarcity of regional datasets, and complex climate variability of the regions. Nonetheless, high confidence is solely given to the increase of "Heavy precipitation and pluvial flood" in the Pacific. It reflects the increase in frequency and intensity of extreme rainfall events in the western tropical Pacific in the 21st century, even for the Low emission scenario. Meanwhile, the increase in "Aridity" is classified with medium confidence for the southern Pacific.
6. For Wind, again, many are in white due to the scarcity of data. Regarding "Tropical cyclones", the Pacific region will generally face fewer but more intense storms, as we saw in the previous slides. However, we should note that there is a large

3. Climate Change Impact on rural water access

variance between regions.

7. Regarding the “Coastal and Oceanic”, it is notable that all the drivers are categorized as “High confidence of increase”, including acidification, heatwave, sea level, coastal flood and erosion, and sea level rise. In particular, the effect of sea-level rise is considered to continue to be a major threat to small islands and atolls, as it exacerbates the impacts, coupled with storm surges and swells. Projections indicate that shoreline retreat will occur over most of the Pacific and Caribbean small islands throughout the 21st century.
8. The chart on the right illustrates the impact of coastal inundation on small islands. It represents the potential effect of the percentage of the population that may be exposed to coastal inundation. It considers not only environmental but also political and socioeconomic factors and demonstrates the vulnerability of an island to sea level rise. As shown here, it is noteworthy that the islands in the Pacific are far more vulnerable than those of other regions, including the Caribbean.

Glossary

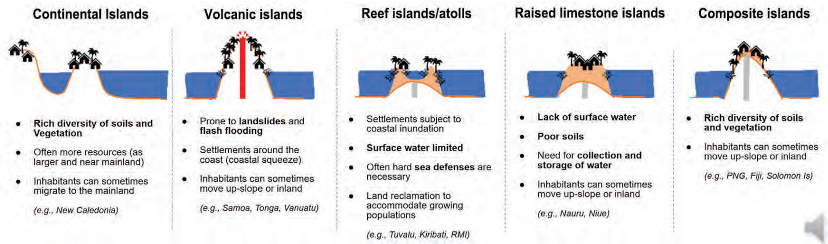
➢ **Climatic impact-driver (CID)**

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral or a mixture of each across interacting system elements and regions. See also Risk, Hazard and Impacts (consequences, outcomes).

Geological overview of PICTs and their classification

- Pacific islands can be categorized largely into **high islands and low islands**. Whereas high islands generally have **orographic rain**, low islands are relatively small and do not have orographic rain.
- Water resources on high islands (**reef/atoll**; **limestone**) are generally limited to ground water and rainwater, while surface water is abundant in high islands (**volcanic**; **composite**).

Classification of island types and human exposure to climate change impacts



Source: IPCC[38]

Narrative Part

1. Compared to larger landmasses, many climate change impacts and risks are more severe for small islands in the Pacific, and so are the impacts on water resources. In the meantime, however, there is a wide diversity between the islands regarding geological features. Such diversity is closely related to the difference in freshwater resources from country to country, hence the difference in climate change impacts.
2. Roughly, small islands in the Pacific are divided into two main types: high and low islands. Those two types of islands can be categorized further into several types based on the lithology and elevation: namely, continental, volcanic (reef or atoll), limestone, and composite islands.
3. A typical difference between high and low islands is the occurrence of orographic rainfalls induced by mountainous terrain. So, high islands such as volcanic and composite are likely to have surface water resources in the form of springs, streams and rivers. In contrast, low islands, such as atolls and limestone, generally have only groundwater and rainwater.
4. This is a quick review of the geological and hydrological characteristics of the Pacific Islands. In the next slide, let's see the climate change impacts from various perspectives.

Summary of climate change impact on water security in PICTs

- Pacific island freshwater resources are highly vulnerable to many of the impacts of climate variability and change.

Predicted change	Confidence	Impact
More frequent or intense floods	*Very likely*	· Damage to water storage infrastructure · increased water pollution · Potential relief of water scarcity in some areas · Higher operating costs for water systems · Saltwater intrusion in coastal areas
Increase in area affected by drought	*Likely*	· Reduced water availability · Reduced groundwater resources · Compromised water quality · Increased risk of water-borne disease · Increased demand for irrigation
More intense tropical cyclones	*Likely*	· Damage to water storage/supply system · Power outages causing disruption to public water supply · Increased water pollution · Increased risk of vector and water-borne diseases
High sea-level rise	*Likely*	· Damage to water storage/supply system · Saltwater intrusion in coastal areas · Salinization of groundwater and estuaries
Higher water temperatures	*High*	· Increased water pollution · Water quality problems, such as algal blooms and reduced dissolved oxygen content · Higher operating costs for water systems
Changes in river flow and discharge	*Likely*	· Changes in seasonal water availability · Increased risk of flash floods · Impacts on groundwater recharge
Increased rainfall variability	*Very likely*	· Changes in seasonal water availability · Changes in water storage · Increased demand for irrigation water

Source: UNEP

Water tanks (Tuvalu)

(SPREP)

New reservoir cover (Marshall Is)

(SPREP)

To prevent erosion (Kiribati)

(SPREP)

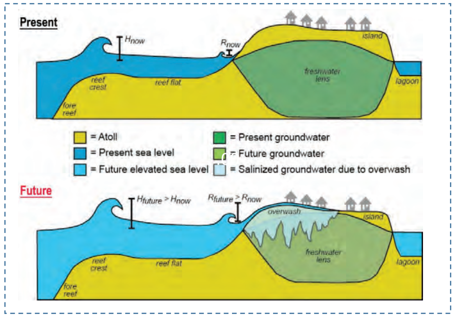
Narrative Part

1. Water security remains a critical concern in the Pacific, where water is in short supply already. Being constrained by remoteness, small size, natural vulnerability and limited human and financial resources, Pacific countries face unique challenges for water security. The major types of projected climate change impacts are outlined in this slide's table.
2. More frequent or intense floods, as a result of the water cycle intensification, will affect infrastructure and the operation of water systems. While floodwater can contaminate the wells, flooding will also cause saltwater intrusion combined with sea level rise.
3. Warmer temperatures increase evaporation, and some areas are subject to drought. It will lead to less availability of drinking water. A decrease in water flow and volume of the water source will increase its salinity. The risk of water-borne diseases will also be raised through the concentration of pathogens such as bacteria, viruses, and parasites.
4. Regarding more intense tropical cyclones, damage to the infrastructure of water systems comes first for both storage and supply. In addition, after the storm, more attention will be necessary to water-borne diseases such as Cholera and Dengue.
5. Sea-level rise. The influences of sea-level rise are brought to surface water and groundwater. In both ways, damage to water systems is serious. Seawater intrusion will contaminate surface waters and, if it reaches aquifers, will cause the salinization of groundwater.
6. Increases in water temperature will reduce dissolved oxygen and could lead to thermal pollution. Higher water temperatures will also cause an overabundance of nutrients or eutrophication, and algal blooms are likely to occur. As a result, water systems may require facility improvement.
7. Intensified water cycle will change river flow and discharge, both decrease and increase, on a seasonal or even yearly basis. So is the recharge and discharge of groundwater. Accordingly, there will be a significant change in water availability. More intense rainfall will increase the risk of flashflood.

Submergence and flooding of islands and coastal areas

- Projected changes in the wave climate superimposed on SLR will rapidly **increase flooding** in small islands. Problems of **growing exposure and vulnerability** are most clearly seen in atoll islands.

Conceptual diagram showing impact of sea-level rise and wave-driven flooding on atoll-island groundwater



Grater wave-heights (H) and wave-driven runup (R) will contaminate the freshwater lens.

Source: USGS

Narrative Part

1. As we have noted so far, coastal inundation will have deep implication for water management. Due to the geological and socio-economic reasons, small islands are becoming more vulnerable and exposed to coastal flooding and erosion.
2. Regional Sea Level will be 0.4–1.0m higher late this century relative to 1995–2014 under the high-emission scenario. Studies show, that in some Pacific atolls, freshwater resources could be significantly affected by a 0.4 m Sea Level Rise.
3. The diagram in this slide shows the atoll groundwater being affected by sea-level rise and flooding. Upper is present and lower is future.
4. Sea-level rise will result in waves with larger periods and greater heights and allow larger waves to reach the shoreline. These larger waves will increase wave runup and contaminate the atoll island's freshwater lens. We should bear in mind that; most atoll islands will be frequently affected by wave-driven overwash by the mid-21st century.

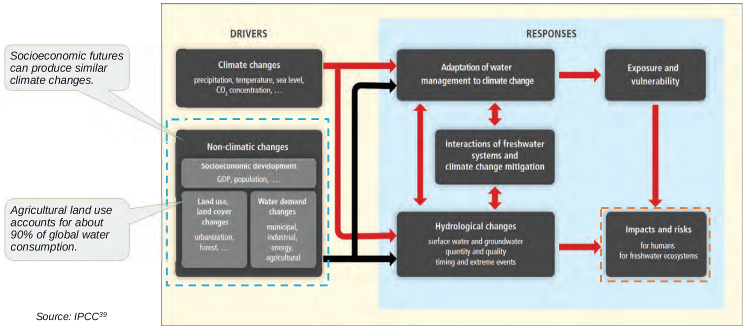
8. Warmer climate will make rainfalls more variable in time and space. Water availability will change the same as above, and water storage will be affected, particularly those of lower capacity. Irrigation could form a buffer against rainfall variability.
9. As we have examined, the vulnerability of water resources and the associated socio-economic and environmental stresses in the Pacific is closely related to the availability of water. Climate variability and change will therefore become an increasingly important driver in water resource planning and decision-making.

4. Non-climatic factors

Introduction

- In addition to impacts of climate change, the future of freshwater systems will also be impacted by non-climatic factors (or drivers) such as demographic, socioeconomic and technological changes, including lifestyle changes.

Impacts of climatic and social changes on freshwater systems.



Source: IPCC[39]

Narrative Part

1. The impact of climate change on the freshwater systems is a function of biophysical changes in water and the management of water uses. Main climatic factors (or drivers) include precipitation, temperature and sea-level rise, as we saw in the previous slide. These drivers will call for adaptation and mitigation measures while causing various changes to the hydrological cycle and leading to impact and risks.
2. Meantime, however, it is important to note that a wide range of socioeconomic futures can produce similar climate changes. It means certain projected hydrological changes can occur under a wide range of future demographic, social, economic, and ecological conditions, such as population growth, land-use change, and even geological processes.
3. For our more pragmatic approach to adaptation and mitigation measures, it is important to have a clear understanding of non-climatic drivers.

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Non-climatic factors – I

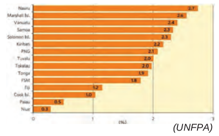
Socio-economic activities

- *Population growth*

  Growing population and economy lead to an increase in pressure on water use and physical scarcity of water. It also raises the risk of water pollution from polluting existing sources such as sewage and waste dumping.
- *Land-use change*

  Changing land use is expected to affect freshwater systems strongly in the future. Expanding urbanization will decrease groundwater recharge. Agricultural land use, especially irrigation, will severely impact freshwater availability.

Population growth rate in 2014



(UNFPA)

Urbanization

(UN HABITAT)

Waste disposal

(SPREP)

Cultivation for farming

(FAO)

Narrative Part

1. A wide range of socio-economic development, along with a growing population, is a major driver of water use and the hydrological cycle. The growth of cities and their associated infrastructure have greatly changed the historical uses of water, including increasing water abstraction from an expanding population. Water accessibility in the Pacific is highly vulnerable to these increasing threats and challenges. Actually, the largest water supply problems are found in relation to urban settlements, where population densities, growth rates and the increasing demands for water are the highest. An increase in human activities will place even greater pressure on the already strained water resources in the region, resulting in over-exploitation, increased waste and pollution, and degradation of ecosystem services which are necessary for sustainable management of water resources.
2. Changing land use is expected to affect freshwater systems strongly in the future. Of particular importance for freshwater systems is future agricultural land use, especially irrigation, which accounts for about 90% of global water consumption and severely impacts freshwater availability for humans and ecosystems. The removal of surface water and groundwater for irrigation changes the water's natural distribution and impacts ecosystems. Drainage of shallow subsurface water is also common in areas with high water tables and extensive wetlands. In the Pacific, small-scale irrigation of food crops occurs in a number of countries. Swamp taro is grown in pits dug below the groundwater table on many small coral islands. In addition, irrigation waters that return to either groundwater or surface waters can contain salts and pesticides or have elevated levels of nutrients such as nitrate and phosphorous.

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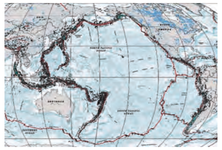
Non-climatic factors – II

Geological processes

- Although temporally, geological hazards (i.e., earthquakes, tsunamis, and volcanic eruptions) could cause devastating impacts on the water systems of PICTs. Volcanic ash can contaminate surface water, soils and groundwater with heavy metals and non-metal contaminants.
- Located along the Circum-Pacific Belt of active volcanoes (Pacific Ring of Fire), PICTs are inevitably subject to these geological hazards.

Seismicity of the Pacific for 1900-2018



(USGS)

2022 tsunami in Tonga

(UNICEF)

2022 Hunga Tonga–Hunga Ha'apai

(Tonga Geological Services)

Narrative Part

1. Finally, the factors of genuinely natural origin - geological processes.
2. The massive volcanic eruption in Tonga in January is still fresh in our minds. Located in the circum-pacific belt of active volcanoes, or Pacific Ring of Fire, Pacific islands are frequently affected by geological hazards such as volcanic eruptions, earthquakes, and tsunamis. In fact, the Ring of Fire traces boundaries between several tectonic plates. Of the 1,500 active volcanos in the world, almost 90 % are in the Ring of Fire.
3. Obviously, those geological hazards are often devastating, and, as a matter of fact, in Tonga, the drinking water crisis was the priority issue in the aftermath of the eruption. It highlighted the vulnerability of water systems not only because of the physical damage to the infrastructure but also of the contamination of drinking water by volcanic ash and saltwater intrusion by tsunamis. However, it should be noted that more than 80% of tsunamis are generated by earthquakes and 7% by volcanoes.

Glossary

- **Pacific Ring of Fire**

Most earthquakes and volcanic eruptions do not strike randomly but occur in specific areas, such as along plate boundaries. One such area is the circum-Pacific Ring of Fire, where the Pacific Plate meets many surrounding tectonic plates. The Ring of Fire is the most seismically and volcanically active zone worldwide. (USGS)

CBCRP-PCCC Virtual Training Course

Enhancing climate resilience and safe water access in rural areas in the Pacific

Government of Samoa, SPREP, and JICA

Module 2. Adaptation and mitigation options with innovative approaches

2.1 How to identify, develop and manage water resource? tools, surveys and data

Peter Sinclair | Water Resources Assessment and Monitoring Coordinator
Pacific Community, SPC
email: petes@spc.int

Pacific Community
Communauté du Pacifique

1

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   - [3]: WGI AR6; SPM-9 (A.2.1)
   - [4]: WGI AR6; SPM-9 (A.2.2)
   - [5]: WGI AR6; SPM-5 (A.1.2)
   - [6]: WGI AR6; Figure SPM.1
   - [7]: WGI AR6; Chapter 12-87, lines 27-28
   - [8]: WGI AR6; Atlas-93, lines 53-54
   - [9]: WGI AR6; Regional fact sheet - Small Islands
   - [10]: WGI AR6; Atlas-175, Figure Atlas.11
   - [11]: WGI AR6; Chapter 9-8, lines 32-33
   - [12]: WGI AR6; Chapter 9-8, lines 34-35
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   - [14]: WGI AR6; Infographic TS.1
   - [15]: WGI AR6; SPM-17 B.1
   - [16]: WGI AR6; SPM-36 D.1.1
   - [17]: WGI AR6; Figure SPM.8 a)
   - [18]: WGI AR6; Table SPM.1
   - [19]: WGI AR6; Figure SPM.10
   - [20]: WGI AR6; Chapter 12-88, lines 3-4
   - [21]: WGI Interactive Atlas; CMIP6 projections
   - [22]: WGI AR6; SPM-25, B.3.1
   - [23]: WGI AR6; SPM-20, B.2.4
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   - [26]: WGI Interactive Atlas; CMIP6 projections
   - [27]: WGI AR6; SPM-28, B.5.3
   - [28]: WGI AR6; SPM-28, B.5.4
   - [29]: WGI AR6; Figure 9.28 (d)
   - [30]: WGI AR6; Figure SPM.8 d)-middle, e)-right
   - [31]: WGI Interactive Atlas; CMIP6 projections
   - [32]: WGI AR6; SPM-28, B.5.1
   - [33]: WGI AR6; Figure 9.3 (a)-left, (d)-right
   - [34]: WGI AR6; SPM-28, B.5.1
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1. Pacific Freshwater Sources
2. Water resource assessment techniques
3. Development of freshwater resources
4. Monitoring and management of freshwater resources

Pacific freshwater resources and uses

Country	Main freshwater resources	Main freshwater uses
Cook Islands	SW, **GW**, RW, DS (tourist resorts only)	**WS**, T
Federated States of Micronesia	SW, **GW**, RW	**WS**
Fiji	SW, **GW**, RW, DS (tourist resorts only)	**WS**, T, H, IR, I
Kiribati	**GW**, RW, DS	**WS**
French Polynesia	SW,**GW**,RW,DS	**WS**
Marshall Islands	RW, **GW**, DS	**WS**
Nauru	RW,**GW**, DS	**WS**
New Caledonia	SW, DS, **GW**	**WS**, M
Niue	**GW**, RW	**WS**
Palau	SW,**GW**,RW	**WS**
Papua New Guinea	**GW**, SW, RW	**WS**, H, M
Samoa	**GW**,SW,RW	**WS**
Solomon Islands	**GW**,SW,RW	**WS**
Timor Leste	**GW**,RW,SW	**WS**
Tokelau	RW, B, **GW**	**WS**
Tonga	**GW**, RW, DS	**WS**
Tuvalu	RW,**GW**, DS	**WS**
Vanuatu	**GW**,RW, SW,DS	**WS**, T, H
Wallis and Futuna	**GW**,RW	**WS**

GW = Groundwater, SW = surface water, RW = Rainwater, DS = desalination WS =water supply, T = Tourism, H = hydroelectric, IR = irrigation, I = industrial

Groundwater is used and relied upon in every country in the Pacific
Dominant use of freshwater in the Pacific is for domestic water supply purposes, cooking, washing, drinking, limited agriculture (irrigation) and some industrial (mineral water bottling, manufacturing)
Rainwater is the preferred water source for drinking in most countries
Desalination while expensive to setup and costly to maintain is being used in some places for ensuring freshwater supplies where there is insufficient natural freshwater sources

Water Resource Assessment techniques

Understanding and collecting information on the **quantity and quality** of a water resource

Water Source	Parameters of interest
Groundwater	*Quantity:* Location and depth; estimated volume and abstraction rate; recharge/sustainability of groundwater. *Water Quality*: salinity, bacteriological, hardness
Surface water	*Quantity:* daily minimum flow abstracted *Water Quality*: turbidity, bacteriological, salinity
Rainwater	*Quantity:* roof area and guttering, rainfall availability and variability (monthly) *Water Quality*: bacteriological

Water Resource assessment for the purposes of water supply suitable for a particular purpose focuses on water quantity, - how much water is available, and water quality – is the water suitable for its intended purpose.

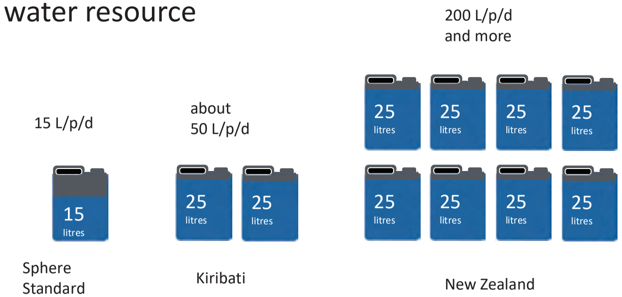
Different water sources require different techniques to determine the water quantity and to some extent water quality.

Main water quality parameters measured in the Pacific – bacteriological, salinity, turbidity, and hardness

While there are many other parameters used to determine water quality suitability, for chemistry of heavy metals, or other specific contaminants, the Pacific's lack of intensive agriculture and heavy industry suggests these water quality issues are less likely. However if there is know potential water source contamination then these parameters should be investigated for.

Water Demand

Average water use per day – important in the development of any water resource



Planning purposes: Estimate of 60-100L/p/d for development of a water supply in most rural communities of Pacific.
Where freshwater is more readily available these estimates will increase up to 200-300L/p/d

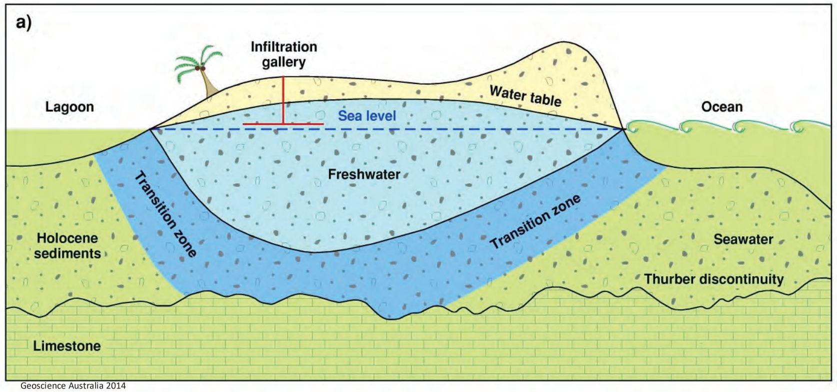
Source: Dave Hebblethwaite (SPC 2016)

Understanding the amount of water required per day for different purposes is critical in the development of water sources. Different water sources can be used conjunctively to meet the water needs of the community.

For example: High quality freshwater from rainwater tanks (boiled) can be used for drinking water purposes (15L/pers/day), and the remainder may be available from groundwater/surface water for which there is less need for high quality water (washing, cleaning, toilets)

Sphere – global movement which provides guidance on humanitarian needs (15L/p/d is for basic drinking, hygiene, cooking needs)

Groundwater in atolls settings



Schematic of the occurrence of groundwater in an atoll setting – island of carbonate sands underlain by limestone

- a thin freshwater lens which due to density differences “floats” on the underlying seawater. Recharged by rainwater from the surface. Freshest portion of the lens is at the top of the lens. Tidal mixing causes the freshwater to increase in salinity with depth
- Lens thickness of freshwater from 2m – 20m thick, and will vary depending on the amount of abstraction and the recharge to the system
- Groundwater is found in the spaces between the sands (porosity)

Water Resource Assessment techniques

- This slide shows a snap shot of the type of activities that are undertaken by Pacific Island countries in the assessment and monitoring of fresh water resources for water quality and quantity of groundwater, surface water, and rainwater
- It includes
  - Geophysics for groundwater assessment,
  - Gauging of rivers and streams,
  - Surveys of rainwater harvesting systems
  - Measurement of rain gauges
  - Monitoring of water levels (groundwater and surface water) and salinity
  - Water quality analysis for bacteriological impact
  - Identification and mapping of groundwater extents
  - Measurement of water use (water demand)

Groundwater assessment techniques

Resistivity

Geophysics – uses the responses of different materials found in the earth (water, clays, sand, hard rock) to electrical or electromagnetic pulses entered into the ground.

EM-34

Geophysics – used to help identify the extent and location of groundwater, and an indication of salinity of groundwater. Used in atolls for shallow groundwater and deeper groundwater found in volcanic islands

Geophysics – uses the responses from different materials found in the earth (water, clays, sand, hard rock) to electrical or electromagnetic pulses entered into the ground

Resistivity and EM-34 are the two techniques which are often used in the Pacific

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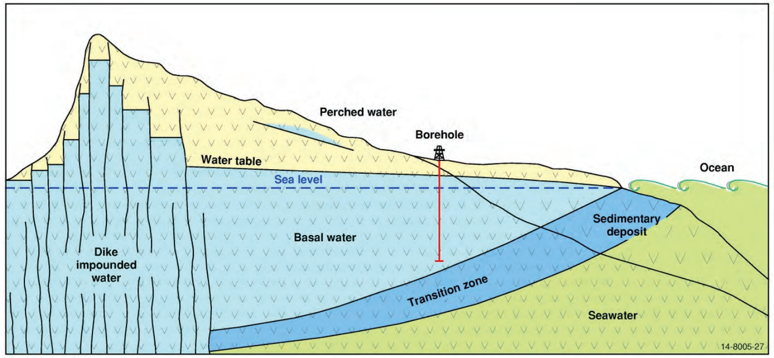
Groundwater in volcanic settings



Geoscience Australia 2014

High Volcanic islands
Often characterised by large number of springs which communities exploit for their freshwater needs
Shallow boreholes <20m found around the coast to access the basal aquifer
Deeper boreholes 30-100m required further inland and often need specialised water resource assessment techniques to locate potential drilling targets
Groundwater is found in the fractures and layers between the different rock types

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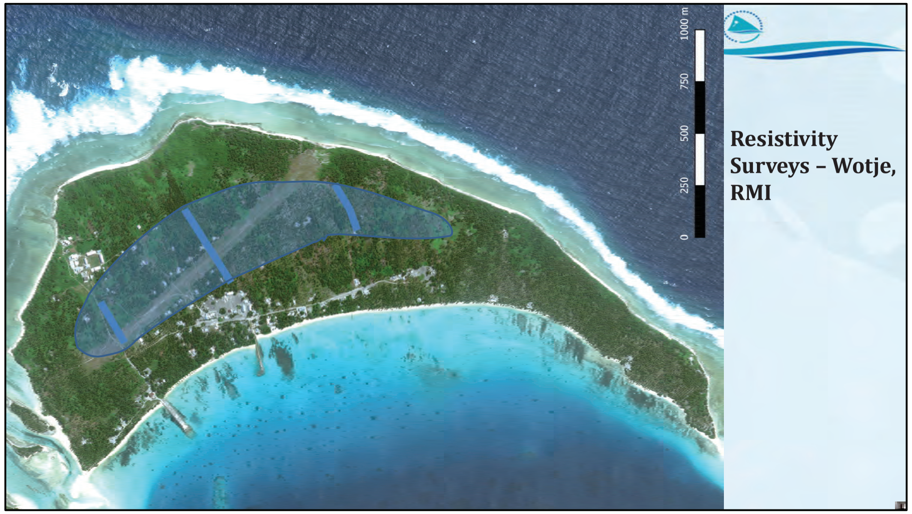
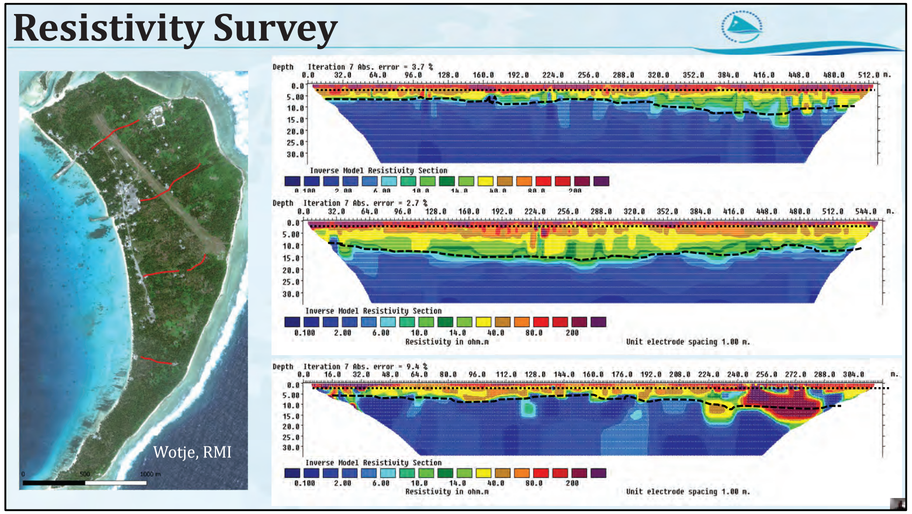


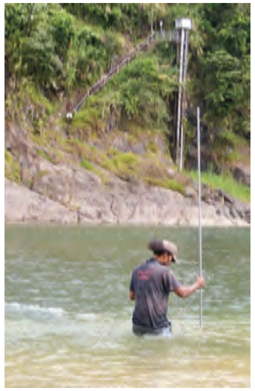
Water resource mapping is useful in identifying and quantifying the extents of useful ground water resource for future development by the community

- Provides advice on what volumes can be expected, and using rainfall data, estimates of recharge for planning purposes can be made. This information is important in developing the design for abstraction methods and also for longterm groundwater protection
- It is important that the information is provided back to the community and government following the survey – valuable exchange of information, as it allows the community to become more invested in how they would like to utilise the resource, and builds ownership



Example of a resistivity survey on an atoll (Wotje, RMI) indicating the location and depth of the fresh groundwater.

Surface water assessment



Llyod Smith (SOPAC 2010)

In larger volcanic countries, surface water is an important source of freshwater.

Measurement of flow m^3/s = area of water area m^2 x velocity m/s.

Stream flow is a combination of the rainfall falling across a catchment minus losses to infiltration and evapotranspiration, plus gains/losses from groundwater.

Baseflow is the volume of groundwater that enters into a perennial stream during a extended period of no rainfall

In larger volcanic countries, surface water is an important source of freshwater.
Measurement of flow m^3/s = area of water area m^2 x velocity m/s
Uses dedicated stations to provide an indication of water level for a known cross section of the river, coupled with velocity at a point in time to determine the volume of water passing through a section of the river. This is an estimate which is used to help determine flood impacts as well as water available for available for extraction from the river for water supply needs

Stream flow is a combination of the rainfall falling across a catchment minus losses to infiltration and evapotranspiration plus gains/losses from groundwater

During droughts and periods of low rainfall, streams and rivers are supported by the inflows from groundwater to these rivers and streams, referred to as baseflow

High flow measurements, gauging's, are important for flood estimates and flood management. Low flow measurements, gauging's, are important in determining available water for abstraction and environment
Water supply purposes (for communities, hydro electric and other purposes need to consider baseflow being the minimum flow

Rainwater Assessment techniques

Rainwater harvesting

- Effective roof area (m^2) * gutter capture coefficient * rainfall (m/month) = available rainfall collection/month (m^3/month)
- Available water/month = storage volume m^3 – usage m^3/month + available rainfall collection/month (m^3/month)

Rain water harvesting relies upon the collection of rainfall across a hard impervious clean surface, its transmission through a guttering system and its storage in a suitable tank/cistern
It relies upon frequent and sufficient rainfall to ensure adequate freshwater supplies from this water source
Guttering is often the most important component for improving efficiency in the collection of rainfall. Most pacific Island HH's can often only afford guttering on one side of the house and it is often too small or in need of repair. Guttering coefficient is an estimate as a % of the amount of rainwater that is transmitted from the roof to the storage. (100% being fully efficient and 0% for a unconnected guttering)
Most systems in the Pacific for the connected roof area are <70% for gutter coefficient, and only for 50% of effective roof area.

Calculations of average effective roof areas and gutter estimates against monthly rainfall minus estimated daily usage for a average household size gives an estimate of suitability of rainfall harvesting for each community.
Note that periods of no rainfall beyond 2-3 weeks can have a significant impact on communities that rely solely upon rainwater harvesting for their freshwater needs.
During droughts rainwater harvesting is the first water source to be impacted.

Heavy metals are often associated with the minerals/chemicals natural or introduced which the water source is in contact with (Arsenic can be naturally found in some groundwaters, while poor storage of lead batteries can expose some water sources to lead toxins.

Both field and laboratory techniques are used to determine the water quality and provide guidance to communities of the suitability of water for a specific purpose and ay treatment measures required.

Water quality assessment

Water quality parameters	Groundwater	Surface water	Rainwater
Bacteriological	√	√	√
Salinity	√	√	
Turbidity		√	
Hardness	√		
Heavy metals	√		
Other chemicals (Nitrates, Phosphate)	√	√	√
Organic contaminants (pesticides, herbicides)		√	

In general, due to the pristine environment and the specific geology of the Pacific as well as the relatively low use of pesticides and herbicides, due to lower broad acre farming and industrial practices, impact from these pollutants is lower than in other developed countries. However where it is know that they are being used it is important to investigate for their occurrence.

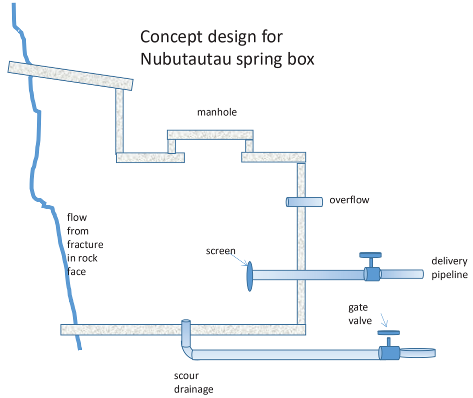
The most common and expected contamination is from bacteriological contamination including faecal matter, animal or human, which can enter into the water supply system and requires boiling, chlorination or alternate water treatment before use for drinking water purposes. Groundwater can often be protected from this type of bacteriological contamination. However in most cases all water should be treated before drinking.

Salinity of water is a field measurement that is regularly used to give an indication of its suitability for a specific purpose. Salinity as a measure of the electrical conductivity (EC) with units of μS/cm, is commonly used in the Pacific which provides an indication of the Total Dissolved Salts (TDS) that is found in the water. Rainwater has an EC <100 μS/cm, water with an EC of <2,500 μS/cm is considered fresh, while seawater is approx. 50,000 μS/cm. There is no health consideration for salinity but it is used as an indicator for taste preference

Hardness is a measure of the amount Mg and Ca carbonates and bicarbonates in the water. Hard water is often indicated by a lack of foam formation when using soap, and by the formation of limescale in kettles and water heaters. Water softening is commonly used to reduce hard water's adverse effects.

Turbidity is the suspension of fine sediment in the water which increases during floods. It is treated using chemicals such s alum to help settle the water through flocculation, and or settling ponds.

Groundwater bores and spring box construction



Groundwater in volcanic environments is collected either via drilling with a drill rig, which can be expensive but which generally provides the greatest reliance to a reliable water source.
Spring boxes, are constructed around existing springs (expression of groundwater at the surface) and designed to reduce contamination of the water supply from animals, or upstream pollution. While cheaper to construct during droughts springs can be impacted with reduced flows, making them less reliable than a borehole.
Many villages in the Pacific rely upon springs (protected and unprotected) as their main water source to the community

Rainwater harvesting systems in island communities

Community RWH in Kiribati and proposed upgrades - KIRIWATSAN

RWH systems are readily adopted by island communities, however during low rainfall require access to alternate water source

Rainwater is the preferred water source for drinking by most island communities. However during drought it is often unreliable, and needs to be supplemented by alternate water sources.
Protection of stored water is important from bacteriological sources. Advantages is that it provides good quality drinking water at the house
Can be used for a community water supply but requires management and responsibility of maintenance by community leaders

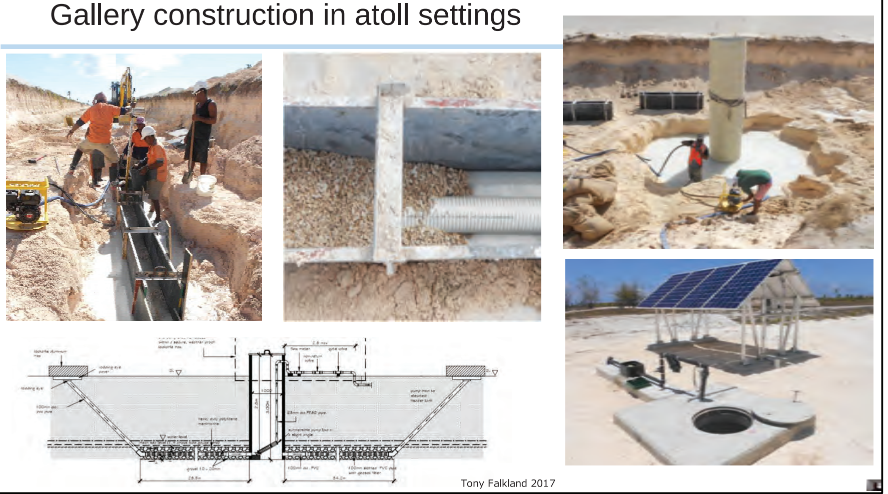
Surface water

Llyod Smith (SOPAC 2010)

Waimanu River offtake for raw water before being treated at the Waimanu treatment plant. Image taken during period of low flow impacting on water availability

Structures known as offtakes are constructed in rivers and dams to siphon water off at different levels from the river. Larger volumes of water can be accessed, suitable for public water supplies, however water requires treatment before use to remove turbidity, and chlorination to make it suitable for drinking water purposes. While offering some resilience to droughts, extended droughts can often mean that water supply can be jeopardised.

Gallery construction in atoll settings



Tony Falkland 2017

Horizontal wells or “galleries” are used to access the freshest water in shallow freshwater lenses. They are constructed just below the water table (taking tidal fluctuations into account)

The design helps to reduce the potential for salinisation of the lens from a single point abstraction as the groundwater flows across the entire length of the horizontal well. Horizontal wells have slotted PVC screens with natural gravel in place to minimise the inflow of fine sediments.

Monitoring of water resources

- Monitoring of water resources is critical to the effective management of water resources.
  - Quantity
    - Inflows, outflows, and changes in storage
  - Quality
    - Changes in relevant water quality parameters to ensure water remains suitable for purpose
- Monitoring parameters include:
  - Climate information (rainfall, evaporation)
  - Water levels (groundwater and surface water)
  - Storage volumes (RWH systems)
  - Water quality data – salinity, bacteriological data, turbidity, other
  - Volumes of water abstracted
- Monitoring should be performed on a regular basis quarterly/monthly at established localities/stations to develop long term time series data.

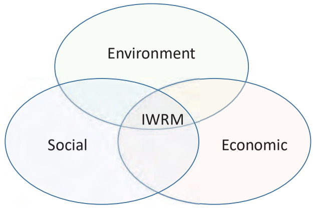
Monitoring changes of water resources over time is essential, to determine the impact of climate, and abstraction on the water source. Monitoring provides information on the behaviour of the water source under different pressures, eg drought, heavy rain, over extraction, etc

Quantity and quality parameters to be monitored should be identified prior to development of the water source and baseline information undertaken to establish water resource changes prior to abstraction from the water source, that is establish the baseline data under a natural system.

Monitoring information is important to ensure that unsustainable overextraction of the resource or unexpected and undesirable impacts does not take place.

Management of water resources

- Many existing water management approaches in the Pacific focus on ensuring adequate quantity of water, often at the expense of quality or environmental considerations.
- Shift to promote a proactive approach to management to ensure that water resource management considers quantity and quality, for long term sustainability.
- Water resource management requires balance between economic, social and environmental considerations. Integrated Water Resource Management (IWRM)



Utilising regular and reliable monitoring data improved understanding of the resource develops allowing for development of management practices that both improves water quality, and reliability of supply for the long term.

Water resource management requires sufficient consideration to environmental needs of the water, as well as the social and economic concerns. For example streams require sufficient flow to ensure that ecosystems are sustained while communities can also meet their water needs

This requires an adaptive approach to water management to ensure the principles if integrated water resource management is maintained.

Adaptive water management approach is the systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies.

CBCRP-PCCC Virtual Training Course

Enhancing climate resilience and safe water access in rural areas in the Pacific

Government of Samoa, SPREP, and JICA

Module 2. Adaptation and mitigation options with innovative approaches

2.1 Technical solutions for safe water access from water source to households

Dr Mat Francis | Director of Water Chemistry
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Hello everyone, my name is Dr Mat Francis. Firstly, a little background about me, I have been working in desalination and water treatment since 2005. The company I currently work for, Moerk Water Solutions Asia Pacific, has provided water treatment solutions to more than 50 communities in the Asia Pacific region and we have been asked to share our experiences with you, particularly in the area of delivering and monitoring clean water. In the first part of this module you learnt how to identify and manage water resources. In this part of the module, what we are going to be looking at is innovative ways to improve water delivery and monitoring particularly in remote regions like the Pacific. We will cover a few different treatment technologies and monitoring methods that are appropriate for water supply at the household or community level.

1

Summary of the presentation

- Pacific uses rainwater, surface water and groundwater for its freshwater needs. Supplemented by desalination water in some countries and some situations. Not all countries have access to surface water.
- Dominant use of freshwater is for domestic water supply purposes, cooking, washing, drinking, limited agriculture (irrigation) and some industrial (mineral water bottling, manufacturing).
- Water resource assessment techniques vary for each water source. Groundwater assessment relies on geophysics to identify the location and extent of freshwater resources. Rainwater harvesting assessment is undertaken using survey of infrastructure and climate. Surface water uses stream discharge at specific stations.
- Development of water sources requires specific infrastructure. The unique atolls of the Pacific access fresh groundwater through shallow wells and the use of horizontal galleries. Springs provide the freshwater supply for many villages in high volcanic islands, while less common is drilling and construction of deep bores due to costs, but which are more resilient to drought. Rainwater harvesting requires the installation of hard roofing materials and suitable guttering and storages to effectively transmit and store rainfall. RWH is subject to drought impacts more so than other sources.
- Monitoring of water source inflow, outflow and storage changes as well as water quality is essential to improved understanding of water resource behaviour to external impacts eg climate change and extraction.
- There is a need in the Pacific to be more proactive in the application of water resource management practices to optimise extraction while maintaining suitable water quality, and environmental and social needs for fresh water.

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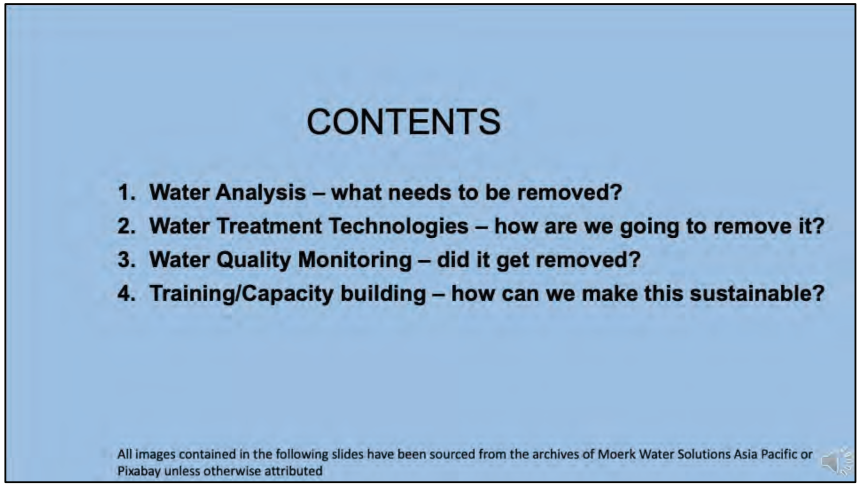
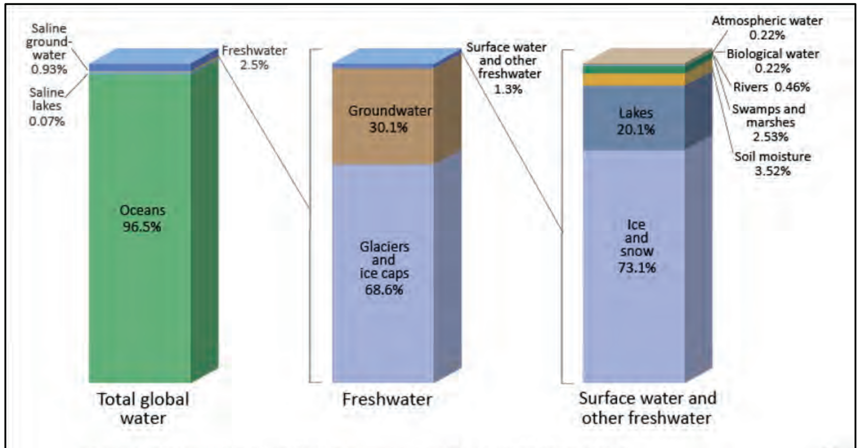
and sampling of the feed water, maintenance and operation of the water treatment system and correct monitoring of the product water only succeeds through correct training and support. This is how you can make water treatment projects truly sustainable regardless of the technology used.



As we move through this section of module 2.1, we will be following the standard method for designing water treatment solutions. The first step, once you have identified the source of water to be treated, is to get a water analysis and determine what needs to be removed. This information, combined with the desired capacity (how much water the end user needs) as well as information regarding the local water situation (which is usually sourced from interviews with locals or their representatives) is then used to design a bespoke water treatment system. This design step is step 2 – what technology or process is the best for removing the problem species identified in step 1. The treatment system chosen will depend on what needs to be removed and what combination of technologies will work best together. Once the unit has been installed and commissioned, the performance of the treatment unit needs to be monitored to determine that the species identified in step 1 did actually get removed – this is step 3. There are a range of software and hardware tools that enable accurate monitoring and I will discuss these with a view to advantages and limitations. This is not meant to be an exhaustive list but instead show some of the standard approaches to monitoring and some new developments happening in the field. The final step I wanted to discuss underpins all of the previous points but is the most important. During my career in water treatment, I have seen that training and local capacity building is the key to the success of water treatment projects, particularly in remote regions like the Pacific. Correct selection

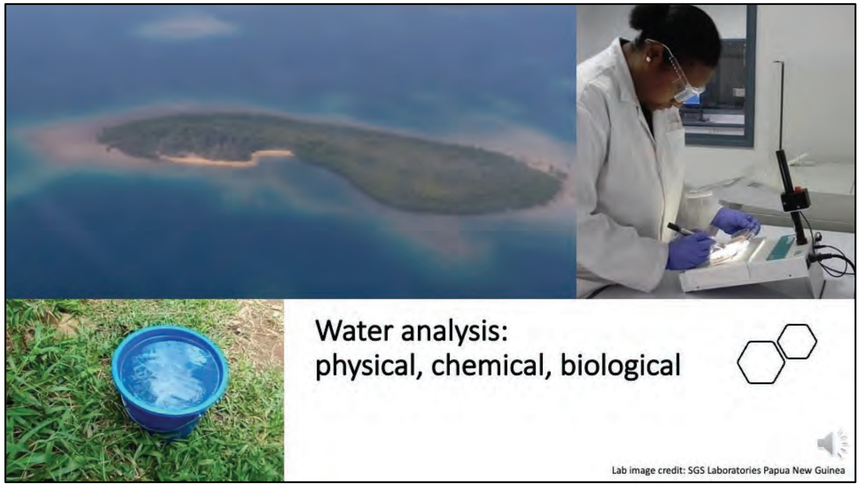


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

To start with, I wanted to give an overview of drinking water sources. Traditionally, most people sourced their drinking water locally from surface water. Lakes, rivers and creeks are all examples of surface water sources traditionally used for drinking water. As populations grew, surface water sources were either outgrown or became polluted, so people were forced to start looking for alternative sources. Collecting rainfall has long been an effective means of supplementing a water supply but it is difficult to store enough for the dry season. Dams, which are essentially a form of rainwater harvesting, are used to increase surface water supplies but require a large area of land to provide sufficient storage. Additionally, rainfall patterns are changing so rainwater harvesting and dams are becoming less reliable. So with scare clean and fresh surface water, groundwater extraction has been used. Groundwater is any water that is contained in the ground. Aquifers are an example of groundwater. There is 50 times more groundwater on this planet than there is fresh surface water. Groundwater is globally the world's most extracted resource and currently accounts for 50% of the world's drinking supply. However, groundwater extraction at current rates is unsustainable – recharge rates are less than the rate of extraction. Due to this, another source of water needed to be found. The largest source of water on the planet by far is seawater – while groundwater is less than 1% of the worlds water, seawater is around 97% of the world's water. This has meant that with surface and groundwater use at capacity, the latest push in water supply has been about

providing fresh water by removing the salt from seawater. This process is known as desalination. While desalination is the most expensive water treatment option, if all of the available surface and groundwater are being used, then it can be a reliable alternative.

Generally a water supply solution will be a combination of treatment technologies applied to surface, groundwater or seawater. The water can either be produced centrally and distributed to all the users on a specific network or it can be produced locally by treating a nearby water source. The key to an effective water treatment solution is to determine what is the most appropriate technology (be it centralised or decentralised) for a given water supply solution by getting a complete understanding of the local water situation.



So the first step after you have examined the local surface, ground and ocean water sources – is what needs to be removed from each? Given the contaminants in each source, which is going to be the best to use as our feed water? There are a range of online tools that enable you to get a good understanding of local water quality at the start of a project. Online data sets, like GEMStat, mWater and even Google Maps, can give you an indication of what the local water quality is likely to be. With these you can answer questions like is there a mining camp upstream? Is the community on a coastline so saline intrusion into the groundwater is a possibility? Has a nearby village in the same watershed uploaded a groundwater analysis to an online database? Once you have a better understanding of the location, it is always essential to get local water information – this is generally done through interviews or surveys. Locals can answer valuable water quality questions like which of the local water sources are salty? muddy? bright green? What is the capacity of the local sources? What alternatives are available? How does the water change seasonally? All of this information can then be combined with local testing either through testing kits (although these can be expensive and inaccurate) or through simple analytic testing. An example of a simple analytic test is getting locals to take a sample of muddy water, put it in a bucket and wait to see how long the mud takes to settle out. By knowing the height of the bucket and the time it takes to settle, the average particle size of the suspended solids can be determined. There are a range of other

simple tests that can be used to determine what kind of treatment a water source may require.

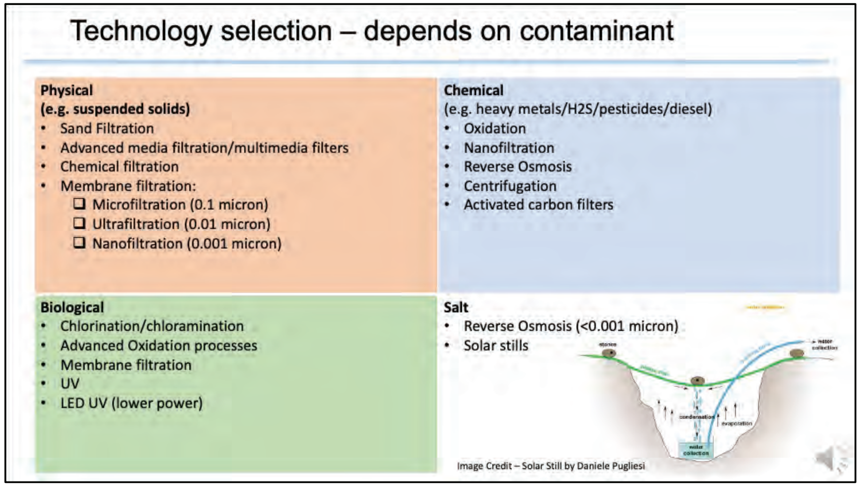
However the gold standard approach is to get a water analysis. Local private labs and universities across the Pacific have the necessary analytic equipment to perform set analyses depending on the water source that is identified as the best to treat. There are basically four main classes of contaminants that need to removed from water: physical material (e.g. dirt) – also known as suspended solids, biological material (e.g. algae), chemical contaminants (e.g. fertilizer run-off) and radiological material (e.g. potassium-40). This last class is quite rare so generally just the first three classes are analysed unless the information gathered on the location has indicated that radiological materials might be present. When looking at a water analysis, it is often useful to separate the salt concentration out from the chemical group of contaminants and essentially make it its own class. This is because salt is the most expensive contaminant to remove using current technology so it needs to be considered seperately.

Technology selection for the chemical class is determined by what species needs to be removed. Some chemicals (like iron and low boiling point solvents) are oxidized which causes them to either precipitate (and be filtered out) or evaporate out of solution. Some chemicals like chlorine are absorbed onto activated carbon filters while chemicals like heavy metals can be easily removed through even finer pored membrane filtration methods like nanofiltration and reverse osmosis.

Technology selection for biological species focuses on inactivating the biological species. This process is commonly carried out with chlorine but chlorine is increasingly being replaced by advanced chemical methods like ozonation (an example of an advanced oxidation process) or alternative chemicals to chlorine like chloramine or chlorine dioxide. There are also physical methods that can be used like membrane filtration which screen the bacteria or virus out by size exclusion or irradiation using UV light. UV irradiation is technically an advanced oxidation process but it operates chemical free. The downside of UV irradiation is that UV lamps can take up to 10 minutes to warm up and contain heavy metals. A new development in UV technology is LED based UV irradiation which uses lamps that do not contain heavy metals and have no warm up time.

The last technology selection we will examine is for the removal of salt. There are a variety of methods for removing salt from water (or extracting low salinity water from saline water). These desalination processes fall into three broad categories: membrane based, thermal based and electrical based. Given the high energy requirement to remove salt from water, the important consideration when selecting desalination technologies is what is the cheapest option. Of the current desalination technologies, Reverse Osmosis (a membrane method) is the cheapest and most adaptable. Reverse Osmosis can be used at a range of scales and can treat both brackish water and seawater. In Reverse Osmosis the feed water is pressurized (on the order of 50 bar for seawater) to allow for fresh water to be pushed through a semi-permeable membrane with pores small enough to reject salt ions. The high pressure is required to overcome the natural osmotic pressure of the seawater. Electrical methods are comparable to membrane technologies at low salinities but become too costly at higher salt levels. Thermal technologies are currently the most expensive of the three methods but are becoming cheaper as the technology advances. For small scale, household level desalination the other technology that can be cost effective is the solar still. In this process a clear plastic film is set over a pit or container of salty brackish water. Solar radiation evaporates the water from the salt water and it condenses on the plastic film then drips into a collector where it can be consumed. This is a good method for getting drinking water for a household (i.e. a few litres a day) but is impractical for larger scale requirements such as supplying water for cooking or cleaning.

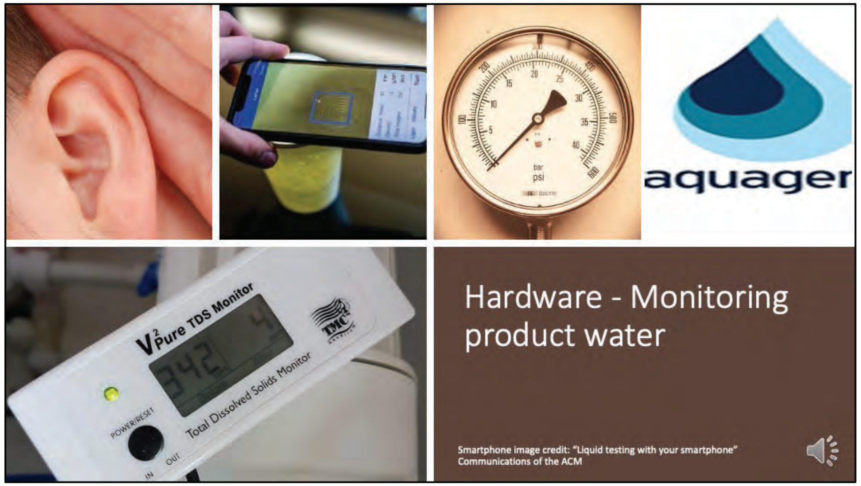
Generally the final design of a water treatment plant will consist of a series of these technologies in a treatment train so an accurate water analysis is essential to ensure the correct chain of technologies is put together to get the desired product water.



So step 2 – how are we going to remove the species of concern we have identified? Each contaminant has specific technologies or methods that are best at removing it. It is a matter of determining which technology is best for the local situation and which can work in combination with other technologies to get the desired product water. For physical matter, it all depends on the size of the suspended solids. Physical contaminants are generally screened out through a series of filters with different pore sizes. The most common filtration technology is sand filtration, which is just filtering the water through a bed of sand. Sand filtration will filter particles out which are larger than 20 micron but any colloidal material like silt and clay will pass through this filter. There are a range of different media that can be added to a filtration vessel to improve the filtration such as modified glass particles that allow filtration down to 1 micron or a combination of media like sand, garnet and coal which filter below 20 micron and add the ability to remove bacteria from the influent stream. Flocculants can be added (which can be thought of as chemical filtration). Flocculation causes fine particles to clump together by neutralizing their surface charge. These agglomerated particles are then large enough to be filtered out with standard sand filtration. Membrane technologies like microfiltration and ultrafiltration, where the water is pushed through a fine semi-permeable membrane, are increasingly becoming popular as they don’t require a chemical flocculant and can filter down to 0.1 and 0.01 micron respectively.

used to estimate the level of suspended solids, these work by measuring how much light can be shone through a sample, but these are expensive to purchase and difficult to maintain. Bacterial and heavy metal testing is more important as these constituents, if not treated, can be harmful. Bacterial testing is also important if treated water is being kept for long periods of time in tanks without chemical sterilisation. The proliferation of smartphones have changed the field of water monitoring. One company, Aquagenx, have microbiological test kits based on a simple colour change reaction that only cost $10 each. Instead of the less accurate water strip methods, the Aquagenx test kits are supported by two smartphone apps that interpret the results and share real time water quality data. So called lab on a smartphone systems have also been developed where the optical detector on a smartphone is used in conjunction with an electrowetting device to determine if e coli is present in a water sample. Given the high level of faecal contamination of drinking water around the world this is an area of research that is always evolving. Heavy metals (like lead, mercury and iron) can be routinely measured using test strips but metals like arsenic can be expensive to measure. The other issue with heavy metals is that to test at the concentrations that cause human harm you generally need to use specialist laboratory equipment.

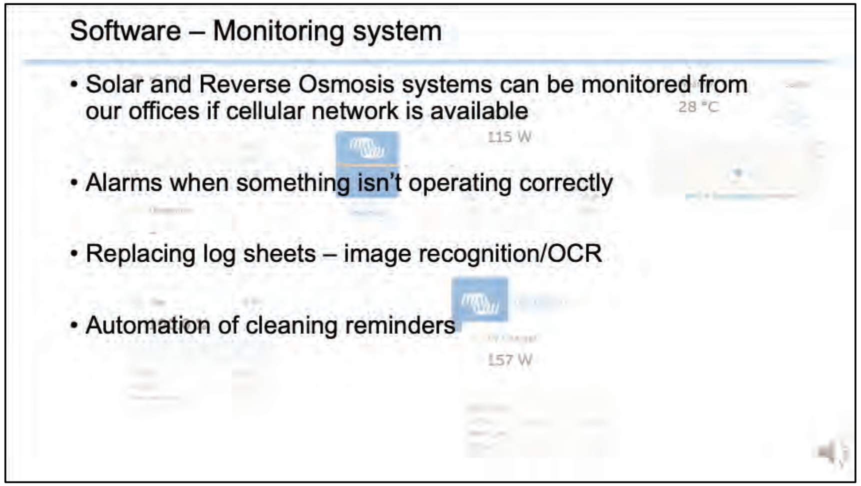
The best, and cheapest option is to understand how the treatment process is working and to ensure that it continues working properly – to notice when there are changes in the operation, to be able to diagnose what effect this will have on the product water and to rectify the system. This all comes down to daily operator training and building local servicing expertise in the regions where these treatment units are installed.



So step 3 – did we remove it? Once the treatment train has been designed and constructed it is then installed and commissioned to make sure it is operating correctly – this is the stage at which design flaws, if any, will be discovered. Once it is operational, it is essential to monitor the system to ensure it continues to perform as designed. The easiest and cheapest method is to just use your senses – do the pumps sound ok? Does the feed water smell differently than normal? Can you actually see the dirt being removed by the filtration system? Does the product water still taste salty? Daily operators will have the best understanding of what has changed with the machine from day to day. Inline sensors measuring conductivity, pressure, temperature and flow rates are installed on most water treatment units and by combining observations from the daily operators and the quantative information from the sensors it is possible to diagnose what is wrong with water treatment equipment even at a distance.

There are additional testing methods that households can use to cheaply measure the main contaminants in water: salt level, suspended solids concentration, the presence of biological material or if heavy metals are present. TDS meters and refractometers are affordable methods that can be used to estimate the salt level in the product water. These can also be used to confirm if the inline electrical conductivity sensors on the unit are performing as expected. Turbidimeters can be can be converted into a digital format – with the data digitized, the performance of the machine can then be normalized, the performance analysed and compared to the design specifications. In practice most monitoring systems are usually a combination of software and the hardware mentioned on the previous slide.

The degree of automation of a water treatment system needs to be carefully considered – if a system is fully automated then there is less for the daily operator to do and their understanding of how the system is operating might suffer – they will be unable to give you invaluable insights into what might be causing issues. On the other hand, if a system is fully manual then the system can be operated incorrectly and damaged, meaning water production stops. Working with locals to develop the most fit for purpose solution should always include a consideration of how automated the system should be for a given context.



In addition to hardware monitoring, there are a range of software programs that can be used to track system performance. Some systems are built with remote sensing and remote control capabilities (where cellular networks are available). These programs deliver real time performance information to a user's phone or computer. The remote monitoring system also uploads the information to the cloud where it can be analysed based on set values so the system goes into an alarm state when these are exceeded – for example a drop in permeate production or quality.

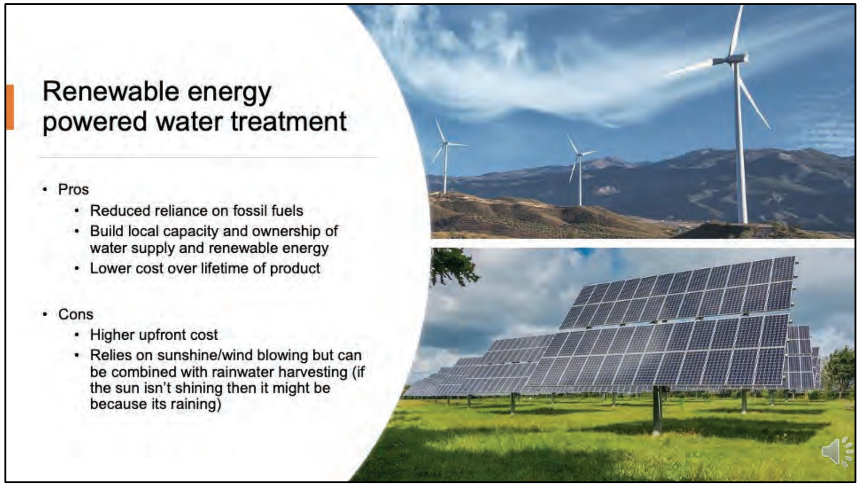
Most water treatment systems have hardwired alarms installed which indicate when something is out of standard operating conditions – these can be if there is no feedwater, if the product water tank is full, if the cartridge or media tank is clogged or if low or high pressures are being exceeded by the pumps. If these conditions are met, the system shuts down automatically to protect itself and sends a visual or audio cue to the operator that something needs rectifying before the unit can switch on again.

Log sheets are also an essential tool which allow the daily operator to record system parameters each time the machine is operational. These too can be turned into a powerful monitoring system through the use of software programs. Daily operators can upload a photo of the log sheet and then through optical character recognition it

As I have mentioned throughout this presentation, the key to the success of a water treatment project is adequate training, local capacity building and support. A lot of water treatment systems fail in the Pacific due to a lack of spare parts or due to insufficient training. We are working to rectify this by putting operator training at the centre of all water treatment projects and building up regional expertise in water treatment. Training is generally performed in person, but during the COVID-19 lockdowns, it was shown that training can be moved online for remote places that were closed to visitors. This is a model we are continuing.

In addition to training operators for specific projects, it is also important to strengthen vocational training programs across the Pacific to allow plumbers and electricians to get experience maintaining water treatment systems. I am currently involved in such a program with the Kiribati Institute of Technology. With sufficient training and support offered through either a hotline or apps like whatsapp, messenger or signal, water treatment systems can be kept operational for their design life, no matter how remote the location. By entrenching training as central to water treatment projects it ensures the sustainability of the project. It also removes the reliance on outside expertise or parts in managing one's own water supply.

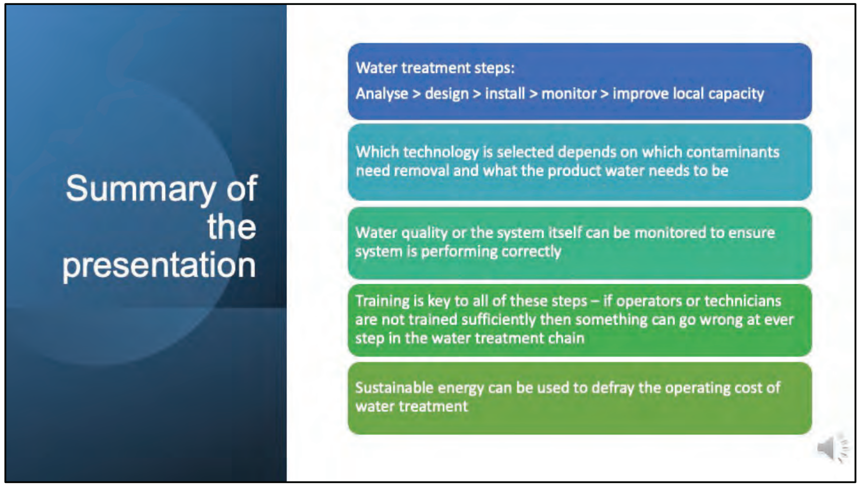
8



The last point I wanted to discuss was using renewable energy to offset the cost of desalination. Given the amount of ocean water available, if desalination can become cheaper then it will often be the best solution for coastal communities or low lying islands. This will be covered in greater detail in the next section of the module but there are some clear pros for using renewable energy (particularly in the Pacific) and very few drawbacks. The main advantage is that using renewable energy reduces the reliance on fossil fuels and ensures local ownership of projects (as imported fuel is not required) while making desalination a viable alternative. Additionally, if solar energy is used then it can be combined with traditional rainwater harvesting to have a wet and dry season treatment system. The main drawback for renewable energy is the higher upfront cost of wind turbines or solar panels and batteries compared to diesel generators. However it is easy to demonstrate that over time the upfront cost of renewable energy is recovered through the lower operating costs when compared to the ongoing cost of diesel fuel. We find it is usually 3-4 years for a community scale plant to pay back its renewable energy installation through lower ongoing operating costs.

9

treatment systems.



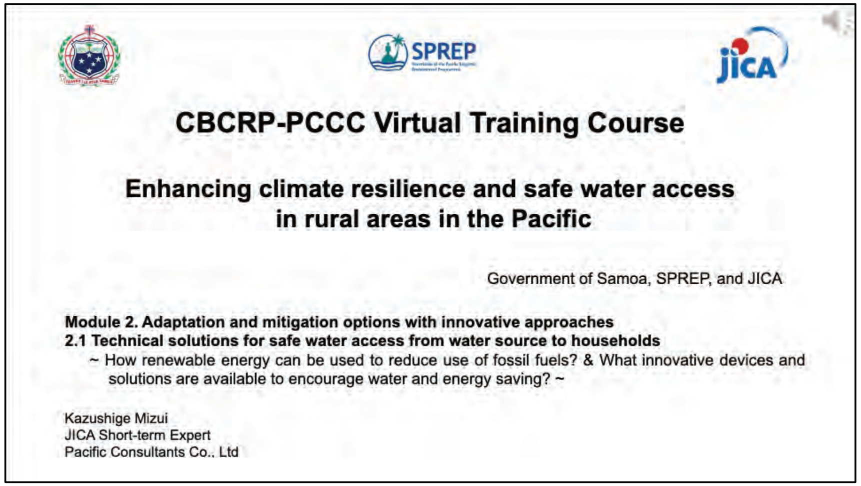
The main takeaways for this part of the module were that water treatment follows a series of sequential steps. After a water source is selected, the water is analysed, then a system is designed based on the analysis and local interviews, then the system is installed and lastly it is monitored to make sure it is performing correctly.

The water analysis step is key to a well designed system – by understanding what is in the water and what needs to be removed you can design the best system – if the water analysis is wrong then the entire design of the system can be wrong.

The monitoring system can be either hardware and/or software based but again relies on the local circumstances and the degree of automation required.

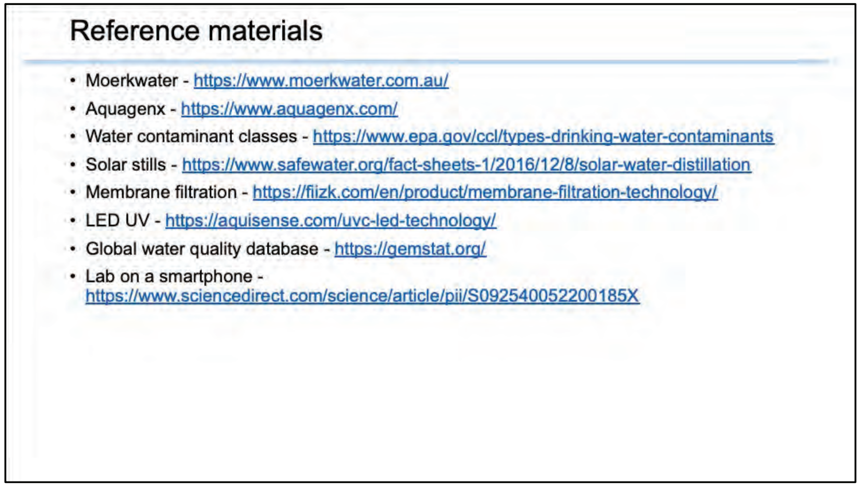
Training is the key to all of these steps, without training and support, a single problem can cause the entire treatment chain to stop working and no longer produce clean water. However, as more units are installed across the Pacific this will improve local capacity in water treatment, reducing the reliance on outside experts.

Lastly, the high energy cost of desalination and the remoteness of the Pacific means solar or wind energy are an attractive alternative to power these units. This is a trend that is being seen around the world to offset the high energy cost of water



1

In this section, I would like to introduce innovative technical solutions for adaptation and mitigation in water sector, particularly applicable to the water supply in remote regions.
My name is Kazushige Mizui, a JICA Short-term Expert, working for water supply system development and planning in Asian countries in a private consulting firm. I hope you would find some clues for upgrading your water supply to make it more safe and sustainable.



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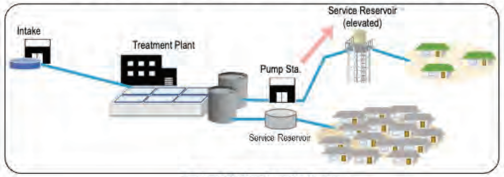
CONTENTS

I prepared 5 topics in this section, starting with an explanation on the energy use in a normal water supply system, and the difference of the system between in the urban area and remote regions in terms of energy use and emission reduction measures. I use the word “simplified water supply system” for the water supply in remote regions.

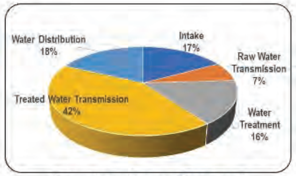
In the latter half of this section, I introduce innovative technical options for utilizing renewable energy and reducing energy in a simplified water supply system.

Energy saving effect of a simplified water supply system (WSS)

- Water supply system (WSS) consumes much energy, particularly in treated water transmission process
- In terms of equipment a pump requires a large amount of electricity



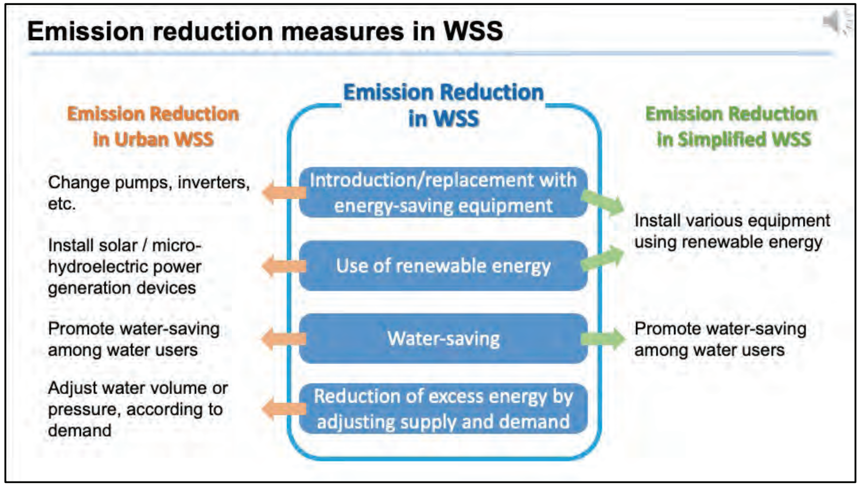
Typical Water Supply System



Proportion of Energy Consumed by water supply processes in Japan

- To reduce energy consumption, locate WSS facilities at higher and closer
- Water supply to the remote regions is relatively inefficient
- A simplified WSS, being independent from urban WSS, for remote regions is reasonable

Firstly, I would like to explain how the water supply system uses energy.
Please look at the schematic water supply system, left in the middle. The normal water supply system is designed to use gravity to transmit the water to minimize the energy consumption as much as possible, so the locations of facilities like intake, treatment plant, pumping stations are desirably at higher altitude. However, there are some residential areas situate higher than the reservoir. In such a case, water is once pumped up and then distributed to the residential area. And also, where the residential area situate far from the treatment plant, a more water pressure in the water pipe is required to be kept at a certain level, because there is an energy loss due to the friction in the water pipe in a distribution process.
The circular graph shows the proportion of the energy consumption by water supply processes. The figures are from the total sum of water utilities in Japan, but the tendency is similar more or less in other countries. The largest portion is in a water transmission process, followed by water distribution and treatment. So the most contributing factor of energy consumption in the water supply system is a pumping. Therefore, it is ideal to locate water supply facilities higher and closer, which means that a compact system is cost-effective. In other word, water supply to the remote region is relatively inefficient, so, in terms of energy consumption as a total water supply service, a simple, small-scale water supply system, independent and isolated system from the large-scale urban water supply system is ideal.



This slide shows the main measures for reducing energy consumption, emission reduction in water supply system, introduction/replacement with energy-saving equipment, use of renewable energy, water-saving, and reduction of excess energy by adjusting supply and demand.

There are some different measures between the urban water supply system and a simplified water supply system to be applied.
Relatively cost-effective urban system can change equipment to more efficient one or adjust supply and demand, relatively easily, thanks to its economies of scale.
However, a simplified water supply system in remote regions cannot apply those measures easily.

But, there are of course applicable solutions to reduce emissions as much as possible in a simplified water supply system, thanks to the modern innovative technologies.

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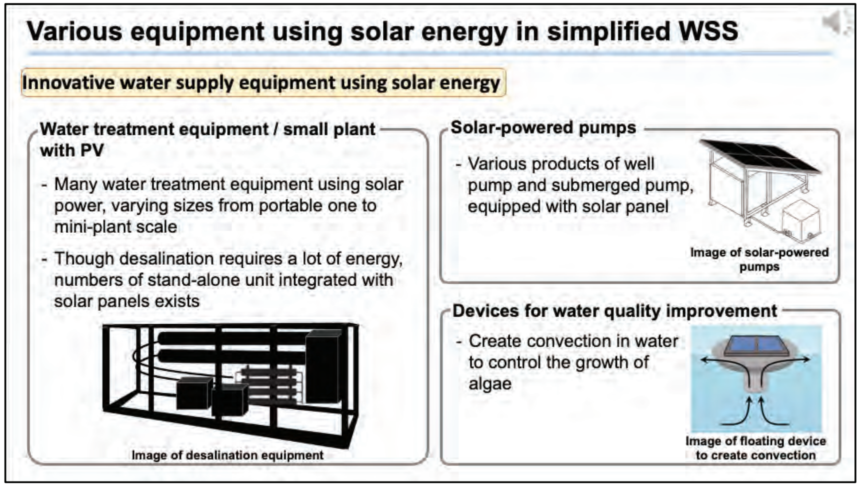
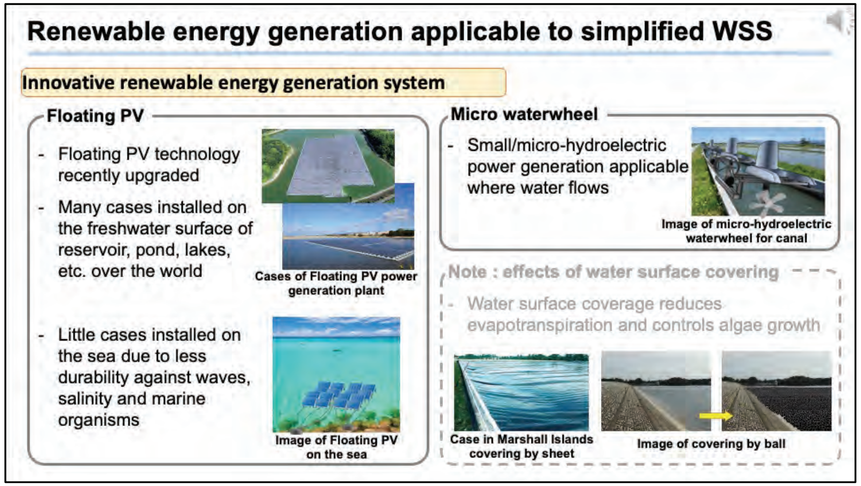


Here are the examples. Using solar energy for equipment with a smaller scale.

The left frame is a water treatment equipment. There are many equipment combined with solar power system available from the portable scale to the mini plant. Even for the desalination plant, which requires a lot of energy for permeating raw water thorough membrane, there exists some system unit using solar power.
And there are many small-scale pumps nowadays attaching solar panel.
It is noted that, because solar power is generated in the daytime, water demand in the nighttime shall be concerned when applying those equipment.

The right bottom is a device for making raw water quality better. The device create water convection, raising up the bottom water and spread to the upper surface, in order to control the growth of algae in the pond or reservoir. When the raw water quality is better, you can save the energy in the treatment process. The device can work by the solar power independently.

5



Some water supply facilities can utilize as an opportunity to generate the power. The left frame shows a floating PV system. In recent years, the application of floating PV has become a fad over the world. It can apply to water reservoir, pond, lakes, dams, wherever there is a water surface with a calm condition. Although there are very few cases yet applied in the offshore, because it is difficult to keep the structural durability under the higher waves or wind, or the lower efficiency of PV module when some salinity or marine organisms attach to the panel, there are some actual case exist like in Maldives.

I would like to mention that there is a side effect for floating PV. Because it cover the water surface, it has an effect of reducing the evapotranspiration and controlling algae, same effect as I explained before. In Marshall island, the reservoir is covered by the sheet, and the right figure shows a case in the dam in California. The Los Angeles Department of Water and Power use "shade balls“, 10cm diameter black polyethylene balls putting on the surface of the dam. The cost of one ball is 36 cent.

Not only the solar power, the water flow can utilize to generate power by using wheel as shown in the right upper frame. Small or micro scale hydroelectric power generation device is getting more familiar compared to the past.

CBCRP-PCCC Virtual Training Course

Enhancing climate resilience and safe water access in rural areas in the Pacific

Government of Samoa, SPREP, and JICA

Supplement material on
Module 2. Adaptation and mitigation options with innovative approaches
2.1 Technical solutions for safe water access from water source to households
~ How renewable energy can be used to reduce use of fossil fuels? & What innovative devices and solutions are available to encourage water and energy saving? ~

Kazushige Mizui
JICA Short-term Expert
Pacific Consultants Co., Ltd

Water-use-saving attempts in remote regions

Effects of water-use-saving

- Encouraging water users to reduce the amount of water use is expected to save energy
- A water-saving leads to a reduction in energy consumption for water intake, water purification, etc. due to a reduced water demand.

Measures for water-use-saving

Promotion / campaign

- Raising awareness among users
- Water-saving promotion or campaign by water utilities or communities

Simple and inexpensive commodities

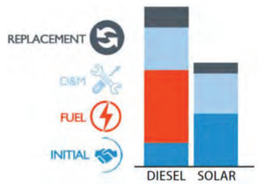
Finally, I would like to mention about the water-use-saving.
Encouraging water users such as residents and businesses to save the amount of water use is expected to save energy, because it leads to a reduction in energy consumption for water intake, water purification, etc. due to reduced water demand. Promotion or campaign for water saving by water utilities or communities can be effective in raising water conservation awareness among users. Also, there are many inexpensive, simple technology products that can save water at home usage such as changing the packing in the faucet to moderate the water flow, water-saving shower head and toilet basin. Recent technologies helps a lot for reducing water amount, and those are cost effective. The packing for faucet is about 1 USD and anybody can change by him/herself. Some utilities in Japan provide it by free to encourage uses for water-saving.

That's the end of this section. I hope would get some clue for find some solution to upgrade your water supply system and contribute to emission reduction for sustainable water supply system. Thank you so much.

Example of renewable energy utilization in water sector (1)

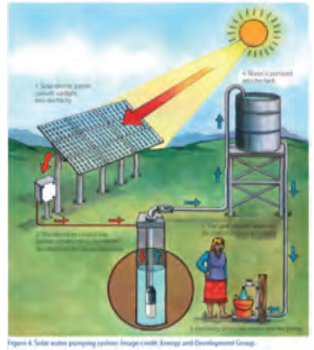
Solar photovoltaic water pumping (SWP)

Solar photovoltaic water pumping (SWP) uses energy generated by PV panels to power an electric water pump



	DIESEL	SOLAR
LCC (US$)	93,000	59,000
LCC water	40¢/m³	25¢/m³
IRR	-	34%
Payback	-	3.6y

Economic comparison of SWP with diesel pumping for the case in Tanzania



Source: World Bank. 2018. "Solar Pumping: The Basics." World Bank, Washington, DC.

Solar photovoltaic water pumping (SWP) uses energy which are generated by PV panels to power an electric water pump.
It is reported that technology of SWP has recently been improved and nowadays pumps can reach up to 500 meters depth and push water up to 1,500 m3/day.

Pros of SWP is that consuming little to no fuel, producing clean energy with zero or much reduced exhaust gases and pollutant. And PV panels have a design life of over 20 years and solar pumps have few moving parts, requiring little maintenance compared to diesel pump.

Cons of SWP is high initial capital costs, however, component prices are dropping, and investment payback is quick thanks to vast reductions in fuel usage. Although water storage tank is required for SWP due to no or less power during night and bad weather condition, a hybrid solar/diesel pumping can reduce the need for storage and hence costs.
The case study in Tanzania shows that the life-cycle cost of SWP is calculated about US$59,000, 36% decreased from US$93,000 for the diesel pumping.
This leads a price reduction of water extraction around 40%. Internal rate of return (IRR) of the case would be expected around 34% and the paid back would be within 3.6 years.

2

Example of renewable energy utilization in water sector (2)

Major system components

PV modules
Pumps and motors
Power conditioner

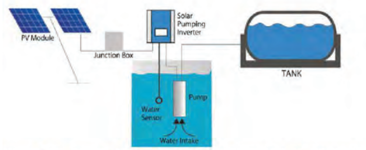


Figure 8. Basic elements of a solar pumping system, Source: Zhuhai MNE Technology Co., Ltd.

System design consideration

- Water demand
- Water source
- Design flow rate
- Water storage
- Total dynamic head
- Location of PV panels
- Solar insolation

Source: World Bank. 2018. "Solar Pumping: The Basics." World Bank, Washington, DC.

A solar pumping system consists of PV modules, a pump set, a storage tank, electronic components, and interconnection cables.

And the conceptual design of solar pumping systems is best accomplished by analyzing the following seven key parameters:
• Water demand
• Water source
• Design flow rate
• Water storage
• Total dynamic head
• Location of PV panels
• Solar insolation

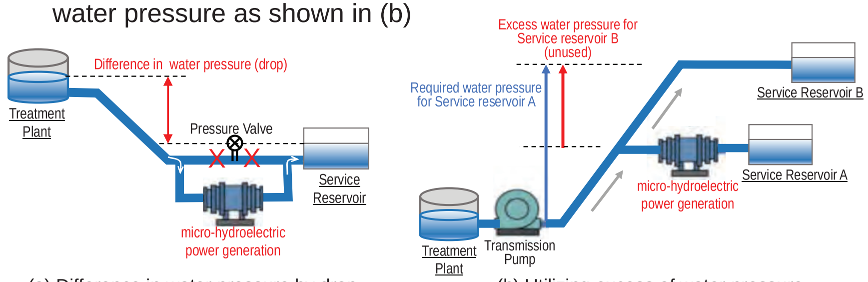
Please refer the reference document, Solar Pumping: The Basics. Published by world bank.

3

Examples of micro-hydroelectric power generation system application (1)

Application of micro-hydroelectric power generation

- There are much potential of micro-hydroelectric power generation to install to water pipe
- It utilizes difference in water pressure as shown in (a) or excess of water pressure as shown in (b)



(a) Difference in water pressure by drop (b) Utilizing excess of water pressure

Micro-hydroelectric power generation system could also be applicable if there is an enough amount of unused water pressure.
The two diagrams presents two examples of how and where to place micro-hydroelectric power generation device and which unused water pressure is utilized.

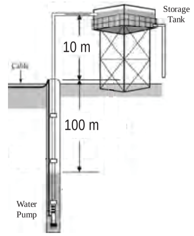
The case (a) shows the case of changing pressure valve to micro-hydroelectric power generation. When there is an elevation difference between water treatment plant and service reservoir, there is a water pressure in the pipe, and there will be a pressure valve in order to maintain the proper pressure in the pipe. However, the pressure is itself an energy. So, if the pressure is large enough, it might be cost effective to change from pressure valve to micro-hydroelectric power generation to generate electricity.

The case (b) also represent the utilization of unused water pressure under different condition with the case (a). The transmission pump at the same elevation with treatment plant needs to push the water up to the elevation of service reservoir B. However, water pressure in the same pipe is constant, the actual pressure level at the service reservoir A is over the requirement. Therefore, the excess of pressure could be converted to the energy by applying micro-hydroelectric power generation system.

Example of renewable energy utilization in water sector (3)

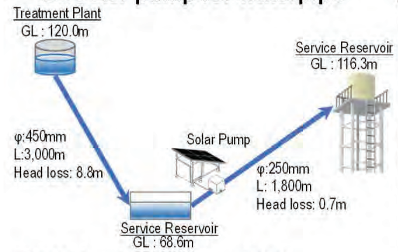
Referential calculation of solar pump application

Solar pumping for well



Total Head	118.5 m
Design Flow	60 m³/day
Pump Capacity	35.4 kWh/day
Required Array Size	10.2 kWp

Booster pump for waterpipe



Total Head	13.2 m
Design Flow	960 m³/day
Pump Capacity	17.0 kWh/day
Required Array Size	4.9 kWp

There are several types of pump applications, and here is two calculation examples for the solar pumping for well and booster pump attached to water pipe.
Cost or size of required solar photovoltaic array varies depending on the parameters regarding the system design considerations as explained.

The calculation example in the left shows the application of pump in the well with 100m depth. Assuming the design flow of 60 m^3/day, which is 2,000 users with the consumption of 30 liters/capita/day, and other assumptions for the efficiency of pump, energy losses, etc., required pump capacity is calculated as 35.4 kWh/day.

The calculation example in the right shows the application of booster pump equipped with the waterpipe. Booster pump utilize the existing water pressure that inflow already has, so as to reduce the size and power of pumping of outflow to the required elevation. The example shows the situation with a total head of 13.2m and design flow of 960 m^3/day, resulting in 17.0 kWh/day of required pump capacity, which is less than a half of the calculation example in the left. This is due to the smaller head, although the design flow is far large.

When assuming solar insolation, required array size will be calculated. Suppose if solar insolation is 4.5 kWh/m2/day, required array size for water pump in the well in the left example case is 10.2 kWp, and 4.9 kWp for booster pump in the right example case.

Examples of micro-hydroelectric power generation system application (2)

Size and cost of micro-hydroelectric power generation

- Initial cost varies depending on the amount of water pressure, size of turbine, etc.
- Generally, the average initial cost is around 13,000 USD/kW

Micro-hydroelectric power generation Installation examples in Japan			
Capacity	55 kW	35 kW	7 kW
Max. water transmitted	0.35 m^3/s	0.13 m^3/s	0.046 m^3/s
Drop	21.0m	42.8m	33.6m

The size and cost of micro-hydroelectric power generation also varies depending on the amount of water pressure, size of turbine etc. And there are many variety of devices in terms of capacity, efficiency, etc.

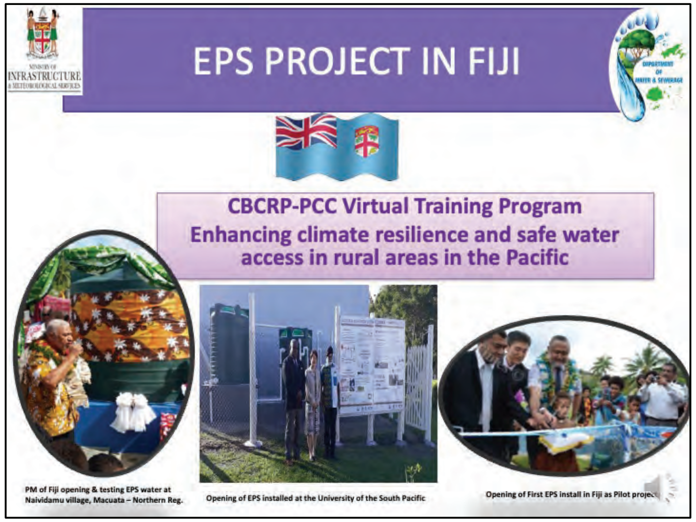
However, generally speaking, the initial cost of device has been decreasing recently, and nowadays the initial cost is around 13,000 USD/kW, according to the study result in Japan.

Reference

World Bank. 2018. “Solar Pumping: The Basics.”, https://documents1.worldbank.org/curated/en/880931517231654485/pdf/123018-WP-P159391-PUBLIC.pdf

Island Students the EPS set up, its treatment process and for students to learn and to be able to market in their own country that there is a natural water treatment facility in Fiji which is also can be adopted and implemented in the Pacific regions.

The commitment towards the EPS project in Fiji starts from the PM of Fiji towards Government & Non-Government Stakeholders and to the Beneficiary of the project.



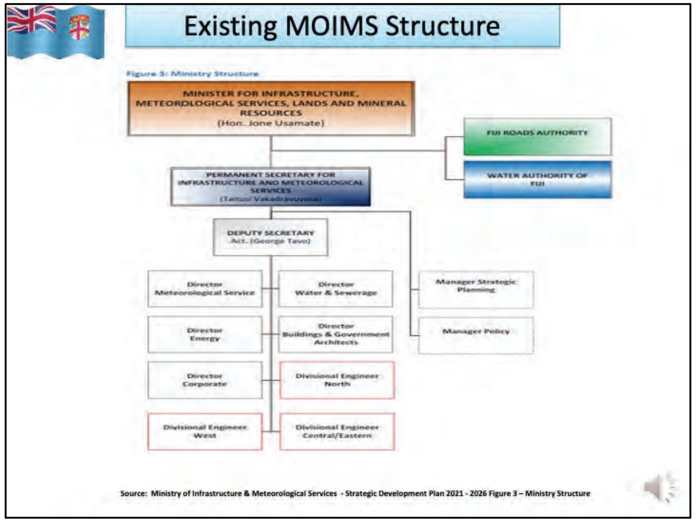
Bula Vinaka and Welcome to all participants of the CBCRP- PCC Virtual Training Program.
My name is Mr. Filipe Batiwale and I'm from Fiji and my presentation today will try to link to Enhance climate resilience and safe water access in rural areas in the Pacific.

Today I will share with the participants what Fiji had adopted from Training in Okinawa in Japan in trying to develop the best technical solution of safe water access from water source to household.

Through that collaboration training between JICA & Department of Water & Sewerage Fiji is now implementing EPS project around the rural communities in Fiji. Ecological Purification System (EPS) is a natural treatment system that will provide safe drinking water to the Fijian community.

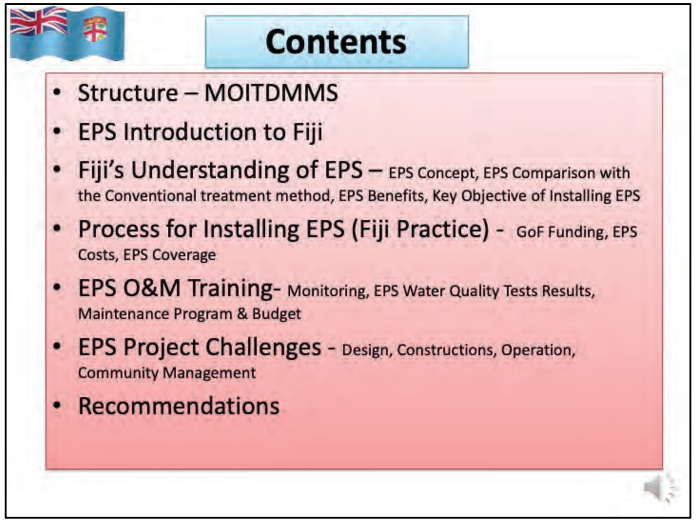
The first slide indicates that Fiji's Head of State the Honorable PM is committed and support the EPS project in Fiji where he officiate the openings and all drinks from the EPS water and similarly to the two Permanent Secretary who also officiate openings of EPS to show support towards the project.

Currently EPS is being installed at the University of the South Pacific again a collaboration between JICA & Department of W&S in trying to show Pacific



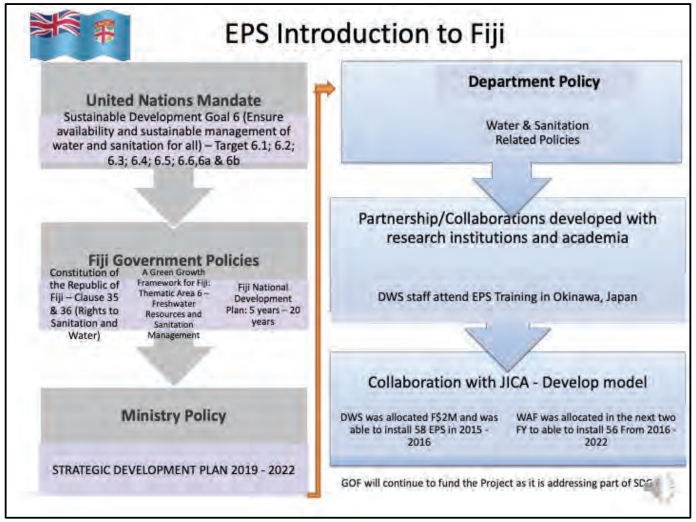
This is a current structure of the Ministry of Infrastructure & Meteorological Services where the two units responsible for Water & Sanitation in Fiji are being placed. The Water Authority of Fiji who is responsible for Operation, Maintenance and Implementation of Capital works for Water & Sewerage system in Fiji is currently operating as semi commercial while the Department of Water & Sewerage which is a Government entity who carry out regulatory, monitoring, policy, and an advisor to the Minister with regards to Water & Sanitation issues. The two units combine effort is to try to provide safe and clean Water & Sanitation to the people of Fiji.

3



The contents of my presentation this morning will display the Introduction of EPS in Fiji and the understanding of EPS after all the trainings and installing of EPS around the rural villages in Fiji. It will also display the process of installing EPS in Fiji, EPS Operation & Maintenance Training. The last part of my presentation will illustrate EPS project challenges, Recommendations for future implementation of EPS and references table.

2



SDG 6 was established by the UN General Assembly in 2015 where Fiji is a current member with the Mission statement "Ensure availability and sustainability management of Water and Sanitation for all"

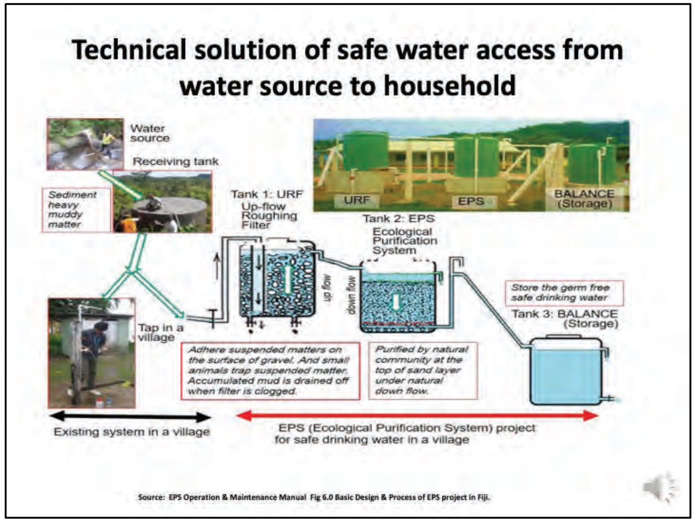
SDG 6 is all about "Clean water and Sanitation for all"

Through this mandate, Fiji Government developed Constitution, Policies and Fiji National Development Plan on 5years to 20 years with targets which needs to achieved by various government & non- government stakeholders.

The target for the Water is to provide safe, accessible and sustainable water to the community of Fiji 100% of rural population by 2031. With this target the Department was looking for the best solution that is economical, user friendly and best for the rural community of Fiji

One of the Department task is to Partnership/Collaboration with research institutions and academia which the Department had benefitted from through a Training that was held in Okinawa, Japan where Dr Nakamoto had carried out training on the Natural Water purification through Ecological Purification System (EPS)

This concept was taken seriously by Fiji where it was piloted on two sites in Fiji



The main objective of the lecture is to display to the participants the technical solution Fiji had adopted in trying to provide safe water access from the water source to households.

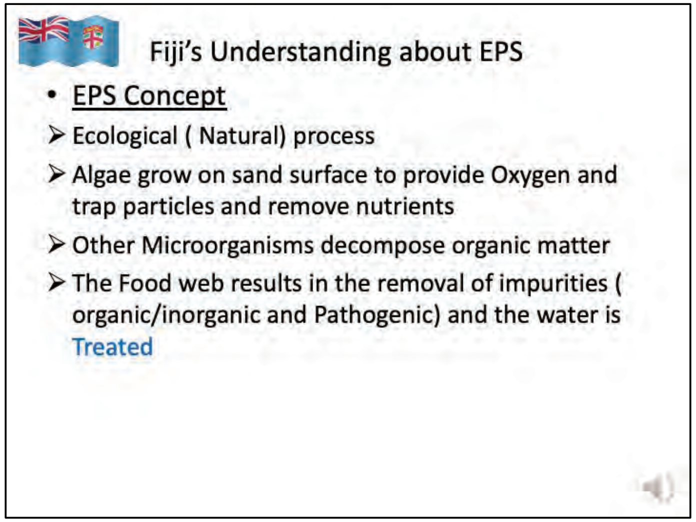
The left hand side slide shows the current existing water system that exists in most Fijian community who uses surface water as their main water source and the middle to the right hand side slide display the inclusion of water purification system (EPS) Fiji had adopted in trying to convert the water supply system to be a safe and clean water supplied to the villages rural water system.

At this stage I believe that the participants would like to know how this treatment works when no electrical or mechanical or chemical is used and yet Fiji is using and saying that it is best treatment process that suits Fiji's context.

This will explained further in the next few slides.

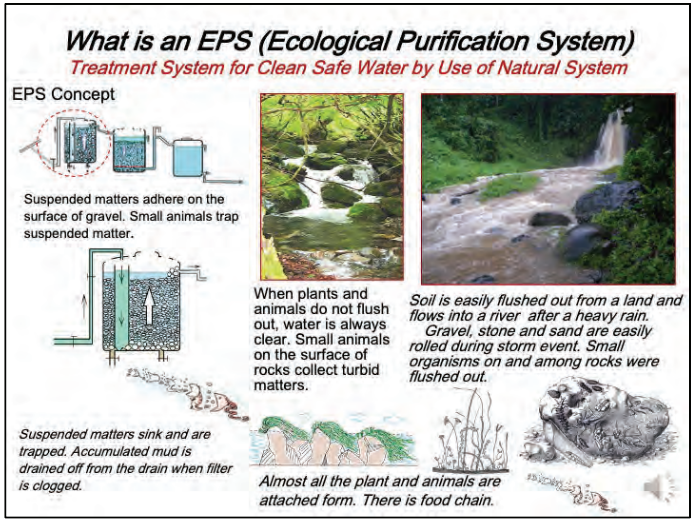
in 2012 than the Government commences with the funding for implementation by the Department of W&S from 2015 to 2016 where the Department managed to install 58 EPS sites in the rural communities.

Government of Fiji continues funding the WAF from 2017 to install EPS in Fiji where WAF had installed 72 EPS therefore currently a total of 130 rural village community had benefited from the project.



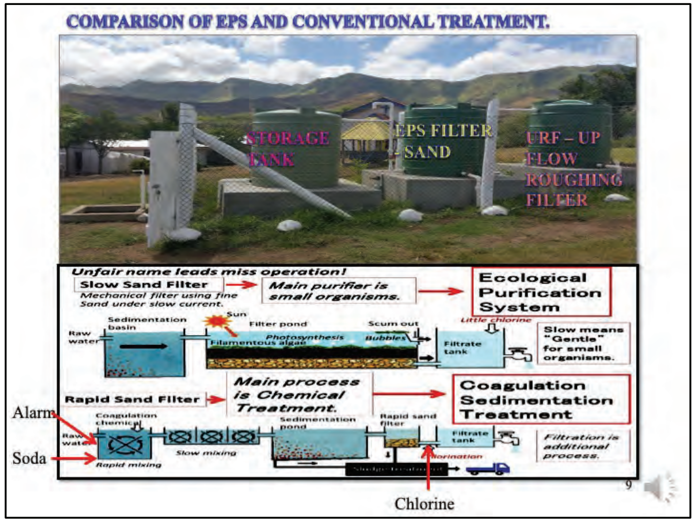
Fiji's local context on the understanding of EPS which will be further simplified on the next slide.

heavy rain situation as surface water is unsafe to drink.



From EPS Training conducted by Dr Nakamoto we have understood the concept of bacterial removal in a stream. The middle photo display water gentle flowing in a stream. From the photo we could say that the water is flowing downstream, while flowing down the water hits the stones and the splash out white water wash due to its effect of hitting the stones. Stones are covered with algae web from top to bottom of stones than it reaches to stand still pond with clear water presence. From the description above there are three process of water purification occur. 1. When water hit the stone the water turns with white wash due to effect of hitting thus **oxygen is added to the water**, 2. On the same process the **turbid matters settles at the bottom of the stream**, 3. The algae web covering the stones is where the small animals live and waiting for their food which is the bacteria. As soon as the bacteria trapped on the algae web or mat the **small organism feeds on the bacteria thus bacteria is being removed from the stream water**. The removal of bacteria is caused by **Food Chain Reaction process** happens on the surface of stones.

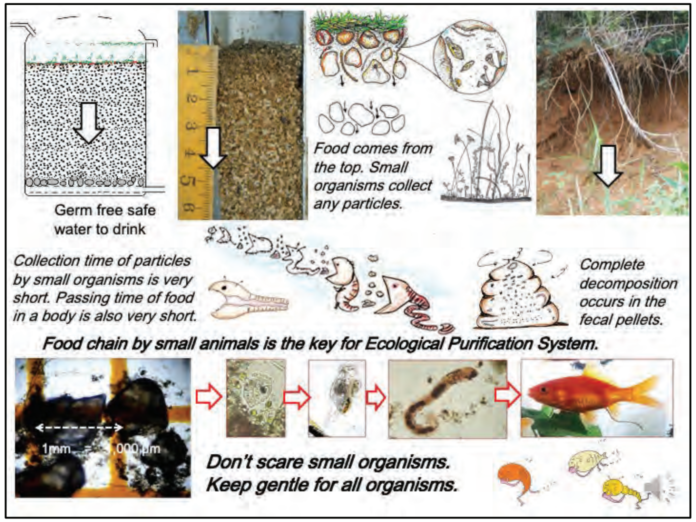
The photo on the right hand corner is the opposite process of water gentle flow displayed in the middle photo. What happens in the stream is directly the opposite of what transpired in the earlier process. We could say that the water flow is fast with excessive brown discolored water and no algae growth on the surface of the stone. There is no treatment at this stage thus there is always a message from the Health Ministry to boil drinking water during or soon after any



The Conventional Treatment Alarm & Soda is used to trap turbid matters or flock that floats after mixing of water through mechanical filters. Water is than flow into sedimentation tank where sludge is being drawn down to the take base and released to the sludge lagoon while the effluent water is directed to a sand filter for last round of filtration before water is channel to the Filtered tank for chlorine injection to remove bacteria. You could see that to improve Turbidity in water chemical, mechanical and electrical is used. For water to be from bacteria again chemical, mechanical pump and electrical is used to treat water. All these treatment needs 24 hours of operating which cost Government expenses.

The EPS through the URF tank where stone only is placed with water flow from bottom to the top through gravity thus oxygen is added, turbid matters settles at the base of the tank and algae growth on the surface of stones where Food chain reaction occurs thus bacteria have been removed. The EPS tank which is located in the middle serves as filtration as course sand material is used for filter media and algae growth on the top layer of sand is also the second source of Bacteria removal through Food Chain Reaction process.

Filtered and Treated water is than channeled to the storage tank and ready for distribution to the rural communities.



The Food Chain Reaction process can be seen through Microscopic view as the sizes of bacteria is 0.2 to 1 micron. Jica expert Dr Nakamoto had shown during EPS training in Fiji the real view from the microscopic view where the Food Chain Process occurs. An illustration of the Food Chain reaction is shown on photo above where the small fish feeds on small organism and the small organism feeds on smaller organism till the small organism feeds on the bacteria.

A video of the same that was shown to the Fijian by Dr Nakamoto is attached for your observation later where you can see the video recording of Food Chain Reaction on the algae web mat.

The removal of bacteria through this process was justified after a test that was carried by a University Student who undertake studies on the bacteria removal in which she states that the bacterial removal is 99% provided system is operated as described in the O&M Manual for EPS.

Benefits of EPS

- Biological & Natural Process
- Use local conditions
- Does not use power
- No chemical used
- Low cost
- Test done, with 99% coliform reduction
- Construction is very simple.
- Easy to operate and maintain

10

KEY OBJECTIVES OF EPS INSTALLATIONS

- Ensure that rural people have access to quality drinking water;
- Reduce and eliminate the occurrences of water-borne diseases;
- Improve standard of living within rural communities;
- Design and implement a cost-effective and environmentally-friendly water purification system for rural communities;
- Ensure that rural communities are able to operate and manage their projects
- EPS – one of the best fit!

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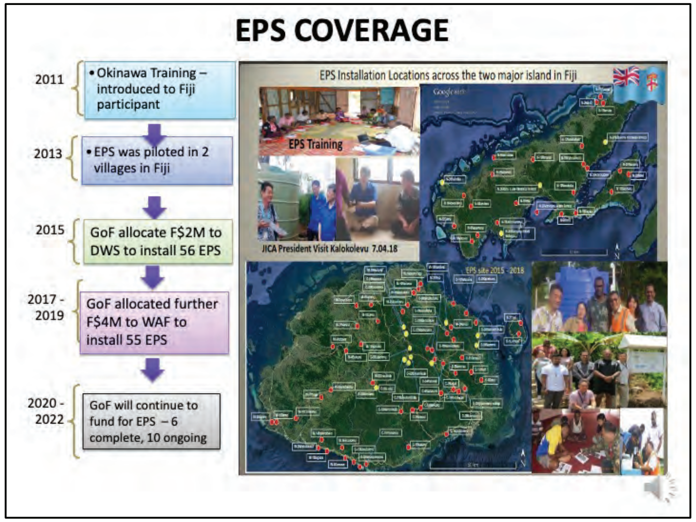
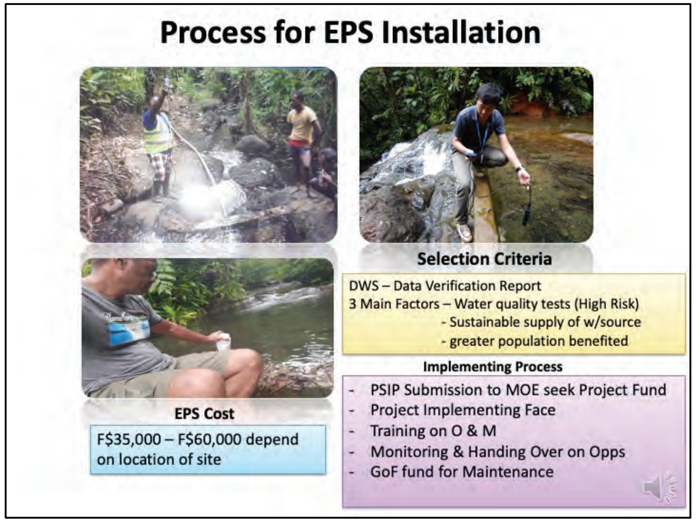


Since the Department of Water & Sewerage launch the implementation of the EPS project in Fiji the Government of Fiji funded the EPS project back in 2015 to DWS where 58 EPS project was installed in Fiji as shown on the map.

The 2017 to-date the GoF had given funding of the EPS project to WAF and WAF had managed to install 72 projects and this will continue.

Some non-government stakeholders are also planning to implement the project of EPS installation thus numbers will increase in the near future.

There are other form of water treatment in Fiji like slow sand filtration, Ultra Filtration, Nano Filtration, Filter cartridge of different sizes filters for borehole water supplies and many more.



One of the yearly activities of the Department is to carry out Data Verification or Water Point Survey for Rural communities or villages in Fiji. Through this activity the Department determines the 3 main factors for selecting village that needs to be implement the EPS project as their will be only 15 to 40 villages only selected to install EPS. 3 Main Factors is shown.

After site have been determined than a Water Safety Management Plan needs to be developed by the Implementer so that the planning of water purification process is well planned taking into consideration all relevant topics like site selection for EPS site, location stand pipes for EPS, Training of O&M, Monitoring & Hand Over process.

The cost of EPS currently installed in Fiji is around F$35,000 to F$60,000 depend on the location of site

The Department of Water & Sewerage carry out EPS Trainings for Water Authority of Fiji, Divisional Engineers Central, Western and Northern and also Non-Government stakeholders who do request the Department for the Training of EPS.

These trainings include both the classroom trainings and the field trainings. From the filed they are given chances to operate and show the trainers on how to backwash, how to draw off sludge at bottom of URF tank so that turbid matters is being removed.

The Department also takes time to monitor EPS by visiting the EPS sites and carry out water testing to check on the performance of the EPS installed.

The above works will continue as we trying to sustain the operation of EPS in Fiji.

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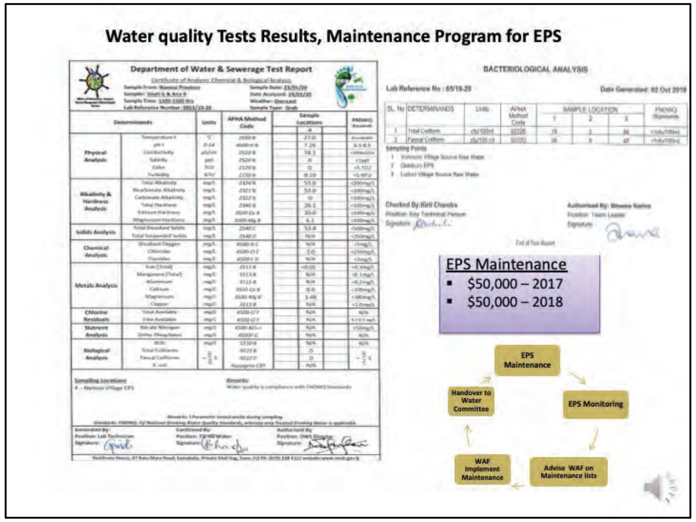

After monitoring the EPS, the Department produces lab results and always refer back to water committee if results is not meeting national water drinking standard so that the water committee or EPS operators to carry corrective measures so that the product water is safe.

The Department also carry out monitoring training of EPS and issues to EPS operators the water testing materials like H2S so that they carry out testing on a monthly period and send water quality results with their comments of their water system. This is done on a monthly basis.

EPS Maintenance is undertaken by WAF as funding by GoF is issued to WAF. Minor leakages is undertaken by WAF but DWS is currently planning on a new strategy which should be implemented in the coming years

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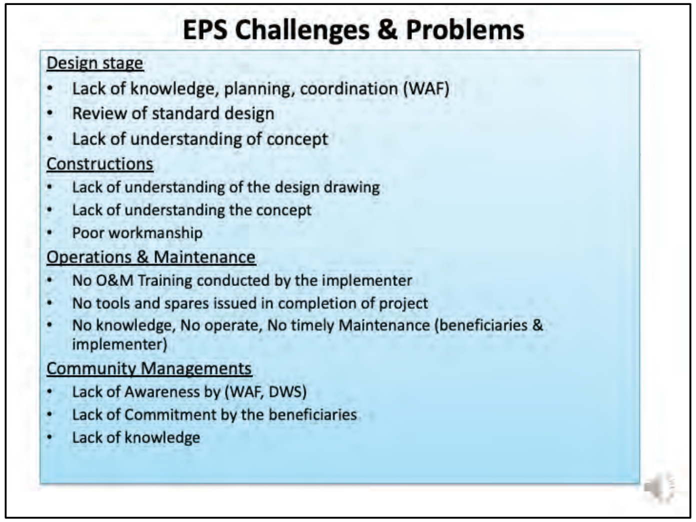

If you are planning to adopt EPS as solution to provide safe water to your rural communities than you might need to consider some of the challenges at the different level of phases of work from Design stage to Constructions to O&M and Community Awareness.

If only this is well planned and coordinated than EPS implementation should be OK

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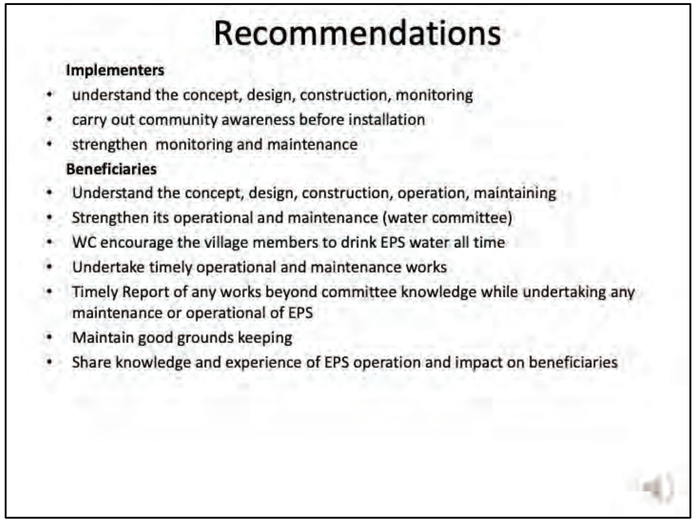


17

CBCRP-PCCC Virtual Training Course

Enhancing climate resilience and safe water access in rural areas in the Pacific

Government of Samoa, SPREP, and JICA

Module 2. Adaptation and mitigation options with innovative approaches
2.2. Community-based management for rural safe water access: Samoa case
Topic: Ownership arrangement

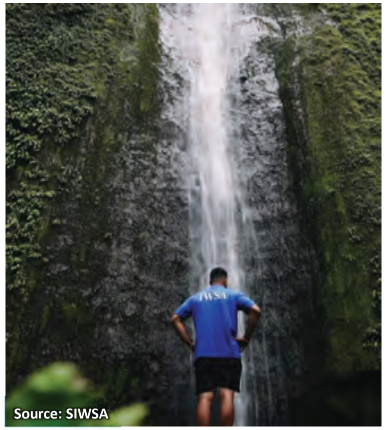
Clarissa Therese Laulala (Program Manager)
Samoa Independent Water Schemes Association
clarissal@iwsasamoa.ws

Talofa all, the topic for the first presentation is ownership arrangement.

Reference

Slide No	Photo or slide reference from
1	Photo from EPS opening – Department photo folder
3	Ministry of Infrastructure & Metrological Services – Strategic Development Plan 2021 - 2026
4	EPS – O&M Manual Fig. 6 Basic Design & Process of EPS project in Fiji
7 & 8	Department of Water & Sewerage PPP to the Divisional Engineers Training on EPS prepared by Dr Nakamoto 2017
13	Department of Water & Sewerage – Updated EPS coverage PPP for the Divisional Engineers Training on EPS.

Contents: Ownership arrangement



1. Context
2. Ownership arrangement
3. Challenges
4. Solutions
5. Summary
6. References

In this presentation, I will first provide a context for the material discussed in the five presentations. Here, a brief background of the Samoa Independent Water Schemes Association (the "Association") and the independent water schemes ("schemes") is presented. Second, the current ownership arrangement of water resources in Samoa and the water supply infrastructure are discussed. Furthermore, the associated challenges and corresponding solutions implemented by the Association are discussed in the third and fourth sections respectively. The photo shows the Sinaloa waterfall located in Sili scheme, Savaii.

2

1. Context

Samoa Independent Water Schemes Association (SIWSA)

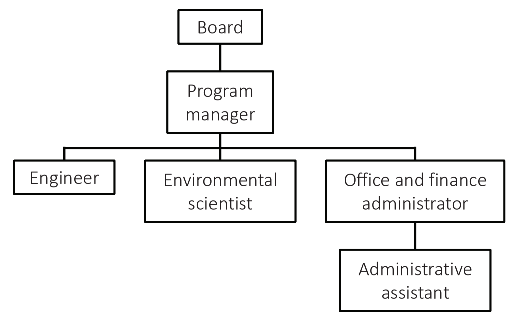
- Incorporated society
  - Formed in 2006, registered in 2008
  - Legal entity (Water Schemes Act [WSA] 2015)
- Vision: Clean, safe, and affordable water at all times.
- Mission: To support the development of the independent water schemes in Samoa through partnerships with government and non-government stakeholders.
- Implementing agency
  - Water Supply sub-sector → Water, Sanitation, and Hygiene sector

The Association was formed in 2006 and formally registered as an incorporated society in 2008. It was then established as a legal entity under the WSA 2015, providing a legal basis for assistance from the government. It's vision is clean, safe, and affordable water at all times; its mission is to support the development of the schemes in Samoa through partnerships with government and non-government stakeholders. The Association is one of two implementing agencies under the Water Supply sub-sector of the Water, Sanitation, and Hygiene sector of Samoa. The other implementing agency is the Samoa Water Authority.

3

1. Context

SIWSA organisational hierarchy



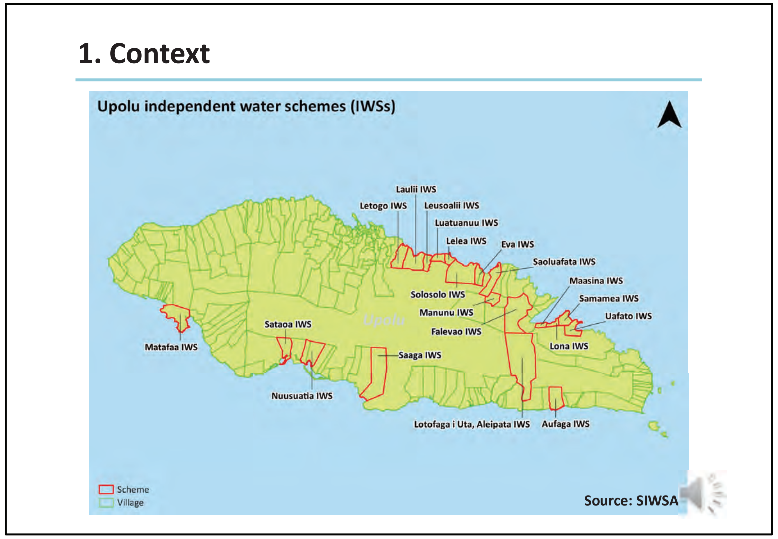
This diagram shows the organisational hierarchy of the Association. The office comprises five employees which is a relatively small number. To put this into perspective, the Samoa Water Authority has more than 300 employees.

1. Context

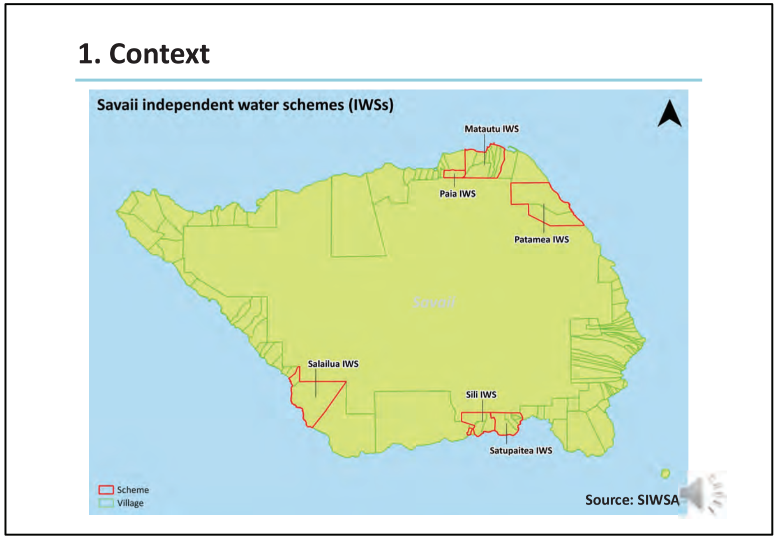
Independent water scheme (IWS)

- Water services provider (WSA 2015, s 4)
- Water committee
  - Members appointed by the village council (WSA 2015, s 7.1)
- Two types:
  1) A village community that manages a water supply system (WSS)
  2) A group of village communities that jointly manage a WSS
- Twenty six in total: six in Savaii and 20 in Upolu
  - Support 44 village communities
  - Service approximately 10% of Samoa's population

The schemes are legally recognised as water service providers under the WSA 2015. A water committee is appointed by the village council to look after the scheme's water supply system (WSS). Generally, there are two types of schemes. The first type consists of a single village community that manages a WSS. The second type consists of a group of village communities that jointly manage a WSS; in this case, the water committees are responsible for the portion of the WSS located within the bounds of their respective villages. Currently, there are 26 schemes altogether: six in Savaii and 20 in Upolu. They support 44 village communities and service approximately 10% of Samoa's population.



This map shows the 20 schemes located in Upolu.



Conversely, this map shows the six schemes located in Savaii.

1. Context

Water supply infrastructure (WSI)

- Donor-funded projects
  - Construction, upgrade, and rehabilitation

Water supply infrastructure (WSI or “infrastructure”) is provisioned through the Association by way of donor-funded projects. These include the construction of new infrastructure and the upgrade or rehabilitation of existing infrastructure. The photos, from left to right, show the water meter installation project in Aufaga scheme, Nuusuatia scheme’s ultraviolet water filtration kiosk, and Saaga scheme’s slow sand filter water facility.

2. Ownership arrangement

Water resources

- State control of use (Water Resources Management Act [WRMA] 2008, s 6.1)
- Community ownership of customary land on which water resources are located (WRMA 2008, s 6.4; WSA 2015, s 5)

WSI

- IWS ownership

The current ownership arrangement is discussed in terms of water resources and WSI. Under the Water Resources Management Act (WRMA) 2008, the government has sole rights to permit the use of water resources for essentially all purposes. Community ownership of customary land on which water resources are located is legally recognised in the WRMA 2008 and WSA 2015. The WSI is owned by the schemes.

3. Challenges

- IWSs' lack of trust towards government agencies
  - Misconception about WSI ownership
- Limited community involvement and participation
  - Lack of a sense of ownership
  - Misconception of responsibilities
  - Limited capacity of water committees
- Lack of resources for major upgrade and rehabilitation works

The current ownership arrangement has its challenges. First, the schemes show a lack of trust towards government agencies, owing to a misconception regarding WSI ownership. As clarified in the previous slide, the schemes own the WSI. However, the schemes fear that government involvement in the management of the schemes would eventually lead to a transfer of ownership. Second, there is limited community involvement and participation in the management of the schemes. This can be attributed to three things: the lack of a sense of ownership, the misconception of responsibilities, and the limited capacity of the water committees to perform their responsibilities effectively. The third challenge pertains to the lack of resources available to the schemes to carry out major upgrade and rehabilitation works; for instance, pipe replacements, excavation works etc.

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4. Solutions

- Promote community awareness
  - Current ownership arrangement, legal rights and obligations
- Promote community involvement and participation
  - Community input in projects
  - Capacity building training
- Reinforce existing/pursue other means of revenue
  - Water usage fees, rural facility fund
  - Financial assistance from government and donor agencies
    - Donor-funded projects

The Association has implemented the following solutions corresponding to the aforementioned challenges. First, community awareness of the current ownership arrangement, and the legal rights and obligations of the schemes and government is extensively promoted during community consultation programs. Second, the Association promotes community involvement and participation in the management of their schemes by working closely with the communities in all phases of a project. From our experience, community input during the design phase promotes a strong sense of ownership in the communities towards their WSSs. Third, the lack of resources for major upgrade and rehabilitation works can be resolved by reinforcing existing means of revenue and pursuing other means of revenue. Examples of reinforcing existing means of revenue include the timely and consistent collection of water usage fees, and effective utilisation of the government's rural facility fund which allows for upgrade and rehabilitation works for a small number of schemes every year. Other means of revenue that can be sought out include financial assistance from the government and donor agencies.

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5. Summary

- Water resources → State control of use
- Customary lands with water resources → Community ownership
- WSI → IWS ownership
- Challenges
  - IWSs’ lack of trust towards government agencies
  - Limited community involvement and participation
  - Lack of resources for major upgrade and rehabilitation works
- Solutions
  - Promote community awareness
  - Promote community involvement and participation
  - Reinforce existing/pursue other means of revenue

In summary, the government controls the use of water resources in Samoa for essentially all purposes. Community ownership of customary land on which water resources are located is legally recognised. The WSI is owned by the schemes. The challenges relating to the current ownership arrangement include the schemes’ lack of trust towards government agencies, limited community involvement and participation in the management of the schemes, and the lack of resources for upgrade and rehabilitation works. The corresponding solutions implemented by the Association include promoting community awareness of the current ownership arrangement and the legal rights and obligations of the schemes and government, promoting community involvement and participation in the management of the schemes, and the reinforcement of existing means of revenue and pursuit of other means of revenue. Thank you for your time.

12

6. References

- Water Resources Management Act 2008 (WS).
- Water Schemes Act 2015 (WS).

13

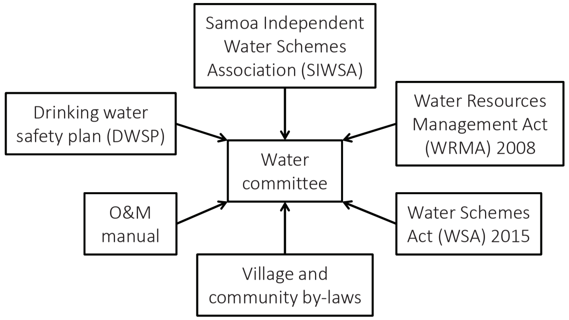
Contents: Operation and maintenance of water supply systems

1. Operation and maintenance (O&M) support mechanisms
2. SIWSA O&M support services
3. Technical considerations
4. O&M financing
5. Summary
6. References

In this presentation, I will first discuss the operation and maintenance (O&M) support mechanisms available to the water committees, who are responsible for the O&M of the water supply systems (WSSs). Second, O&M support services provided by the Samoa Independent Water Schemes Association (the "Association") are discussed. The technical considerations that affect O&M as well as O&M financing are also discussed in the third and fourth sections respectively.

2

1. O&M support mechanisms



Source: SIWSA

There are six O&M support mechanisms available to the water committees. They are the Samoa Independent Water Schemes Association, the Water Resources Management Act (WRMA) 2008, the Water Schemes Act (WSA) 2015, village and community by-laws, O&M manuals, and drinking water safety plans (DWSPs). The Association provides a number of O&M support services to the schemes which are discussed in further detail under section 2. The WRMA 2008 and WSA 2015 provide guidance to the schemes with regards to water resources management, functions, and responsibilities. Village and community by-laws help to strengthen governance, ensuring that WSSs are well looked after by the communities. O&M manuals compile all the information on the O&M of WSSs. Last, DWSPs contain, among other things, improvement and monitoring schedules for systematically addressing risks to WSSs.

3

1. O&M support mechanisms

Village and community by-laws

- All traditional villages (~200) have by-laws
  - Largely undocumented and unregistered
    - Thirty one traditional villages have registered by-laws
    - Three schemes (5 traditional villages) have registered by-laws
- Village *fono* = Assembly of the *ali'i* (high chiefs) and *faipule* (councillors) of each village in accordance with custom and usage (Village Fono Amendment Act 2016)
  - Authority to make by-laws

An important O&M support mechanism is the village and community by-laws (the "by-laws"). All traditional villages (approximately 200 in total) in Samoa have by-laws, though largely undocumented and unregistered. Thirty one traditional villages have registered by-laws. With regards to the schemes, only 3 (comprising 5 traditional villages) have registered by-laws. The village *fono* has the authority to make by-laws under the Village Fono Amendment Act (VFAA) 2017. By definition, it is the assembly of the *ali'i* (or high chiefs) and *faipule* (or councillors) of each village in accordance with custom and usage.

4

1. O&M support mechanisms

Village and community by-laws

- By-laws formulation and registration process
  1) Formulation
     - Draft by-laws
     - Optional though recommended: Community and Ministry of Women, Community, and Social Development (MWCSD) consultations
  2) Village *fono* approval of by-laws
  3) Submit original signed copy of the proposed by-laws to MWCSD chief executive officer
     - Copies sent to *sui o le nu'u* or village mayor, Registrar of the Lands and Titles Court, Attorney General, Clerk of the Legislative Assembly, and Ministry of Police

The by-laws formulation and registration process consists of 4 steps. The first step is formulation, wherein the proposed by-laws are initially discussed within the community and drafted. An optional though recommended action here is for the community to consult with the Ministry of Women, Community, and Social Development (the "Ministry"); the objective is to utilise the Ministry's expertise in order to facilitate the drafting process, and assess the proposed by-law for legal compliance. The second step is to obtain the approval of the village *fono.* The third step is to submit the original signed copy of the by-laws to the Chief Executive Officer of the MWCSD, after which, copies are circulated to the *sui o le nu'u* or village mayor, Registrar of the Lands and Titles Court, Attorney General, Clerk of the Legislative Assembly, and Ministry of Police.

5

1. O&M support mechanisms

Village and community by-laws

- By-laws formulation and registration process
  4) Registration of by-law
     – MWCSD public register
- SIWSA proposal: Formulate and register water supply management by-laws for all independent water schemes (IWSs)
  - Community awareness
  - Strengthen governance

The fourth and last step is to register the by-laws in the MWCSD's register, which is open to search and inspection by the public. Currently, the Association is working to formulate and register water supply management by-laws for all schemes, utilising the aforementioned process. This would help to promote community awareness of the by-laws (something that is not readily accessible to the community) and strengthen governance.

6

2. SIWSA O&M support services

- Technical assistance
  - Governance, project management, engineering, environmental science, and financial management
- O&M resources
  - O&M manuals, maps, plumbing toolboxes, and materials
- Capacity-building trainings
  - O&M, plumbing, governance, financial management, and communications
- Community consultation programs
  - O&M awareness

The Association provides a number of O&M support services to the schemes. These include technical assistance in the areas of governance, project management, engineering, environmental science, and financial management; supply of O&M resources such as O&M manuals, maps, plumbing toolboxes, and materials to facilitate O&M works; capacity-building trainings in O&M, plumbing, governance, financial management, and communications; and community consultation programs to promote O&M awareness.

7

3. Technical considerations

- Water supply system (WSS) design
  - Good design → good performance → Minimal O&M
  - Bad design → poor performance → Frequent O&M
  - Minimal O&M = Cost savings
- Supervision of construction works
  - Ensures WSS design specifications are met
- Material quality
  - Maximise the lifetime of the WSS
  - Minimise the risk of WSS breakdown
- Workmanship

The following technical considerations greatly influence O&M and must always be taken into account. They are WSS design, supervision of construction works, material quality, and workmanship. The design of a WSS affects its performance and level of O&M required once it is operational. For instance, a well designed WSS translates to good performance and minimal O&M, and vice versa; minimal O&M means cost savings. Proper supervision is essential in ensuring that WSS design specifications are met. Good quality or industry-standard materials help to maximise the service lifetime of a WSS while minimising the risk of breakdowns. A high standard of workmanship, like good quality materials, contributes to the optimal performance of a WSS.

The photos show the O&M manuals, maps, and materials supplied to the schemes. The schematic maps of the WSSs are printed in A1 size and laminated.

4. O&M funding

- Water usage fees
  - Collected by the water committee on a monthly basis
  - Flat rate, vary from IWS to IWS
  - Consideration: affordability vs. O&M costs
- Rural facility fund
  - Government assistance
  - Upgrade and rehabilitation works

For the schemes, the main source of O&M financing is water usage fees. These fees, collected by the water committees on a monthly basis, are largely flat rate and vary from scheme to scheme. The Association encourages the schemes to consider their monthly O&M costs when deciding a flat rate to charge. The secondary source of O&M financing is the government's rural facility fund, which a limited number of schemes can access through the Association to fund upgrade and rehabilitation works.

Summary

- O&M support systems
  - SIWSA, Water Resources Management Act 2008, Water Schemes Act 2015, village and community by-laws, drinking water safety plan, and O&M plan
- SIWSA O&M support services
  - Technical assistance, O&M resources, capacity-building trainings, and community awareness programs
- Technical considerations
  - WSS design, supervision of construction works, material quality, and workmanship
- O&M financing
  - Water usage fees and rural facility fund

In summary, there are six O&M support mechanisms available to the water committees: the Samoa Independent Water Schemes Association, WRMA 2008, WSA 2015, village and community by-laws, O&M manual, and DWSP. The Association provides four O&M support services to the schemes; namely, technical assistance, O&M resources, capacity-building trainings, and community awareness programs. The technical considerations that greatly influence O&M include WSS design, supervision of construction works, material quality, and workmanship. The two sources of O&M financing available to the schemes are water usage fees and the rural facility fund. Thank you for your time.

Contents: Social and gender inclusion

1. Water committees
2. SIWSA support of social and gender inclusion
3. Summary
4. Practical quiz
5. References

In this presentation, I will first discuss the current situation of social and gender inclusion in the water committees. Second, ways in which the Samoa Independent Water Schemes Association (the "Association") supports social and gender inclusion in the independent water schemes (the "schemes") are discussed.

References

- Village Fono Amendment Act 2016 (WS).
- Water Resources Management Act 2008 (WS).
- Water Schemes Act 2015 (WS).

1. Water committees

Situation

➢ Predominantly older men

- Cultural bias
  - Leadership roles are given to *matai* (chief)
  - In 2016: ratio of male *matai* to female *matai* **=** 9:1 (Samoa Bureau of Statistics, 2020)
- Gender stereotypes
  - Women support, men lead (cultural influences)
  - Women are weak, men are strong

At present, water committee members are mostly older men. A significant influence is cultural bias. Leadership roles in the village are typically given to *matai*—that is, men and women who hold a chief title. However, men are more likely to become *matai*. According to the 2016 national census, the ratio of male *matai* to female *matai* is 9 to 1. The age aspect can be explained with the Samoan saying: *o le ala i le pule o le tautua*, which literally translates to: the way to authority is to serve. Traditionally, men and women serve their families, congregations, and villages for a substantial amount of time, to earn the right to become a *matai*. Another influence is gender stereotyping. A prevalent gender stereotype is “women support while men lead”. Traditionally, with religious influences, the man (or the husband) is viewed as the head of the family, while the woman (or the wife) is tasked with supporting the man. Another gender stereotype is “women are weak while men are strong”. The work done by the water committee is laborious and physically demanding in nature. For this reason, men are favoured as they are presumed to be better able to carry out the work.

3

The following photos show the water committees from four different schemes. As you can see, the water committee members are entirely older men.

4

1. Water committees

- Under-represented social and gender groups
  - People with disabilities, women, youth, and *fa'afafine* (biological males that identify as either female, transgender, or non-binary)
- Growing representation of women over the years
  - In 2006 (SIWSA formed): 0% women representation
  - In 2022 (present): 31% women representation
  - At least two members must be women (Water Schemes Act 2015, s 7.2)

Some social and gender groups are under-represented in the water committees. These include people with disabilities, women, youth, and *fa'afafine*. Of these, women representation has grown significantly over the years. In 2006, there were no women in the water committees. Fast-forward to 2022, 31% of the schemes now have women. One of the main drivers for this change is the Water Schemes Act 2015, which requires at least two members of a water committee to be female.

2. SIWSA support of social and gender inclusion

- Community consultation programs
  - Formal request for women, youth, and children to attend
  - Encourage women to join the water committee
  - Encourage women participation in discussions
  - Encourage the youth to assist the water committee
  - Promote affordable water usage fees to support low-income families

The Association supports social and gender inclusion in the schemes in four ways. First, the Association encourages the participation of under-represented social and gender groups in matters pertaining to the scheme through its community consultation programs. Prior to every program, the Association formally requests the attendance of women, youth, and children through a formal written letter to the village mayor. During the programs, the Association proactively encourages women to join the water committee and participate in discussions. Also, the youth are encouraged to assist the water committee with their responsibilities. Furthermore, the Association promotes affordable water usage fees to accommodate for the low-income or poverty-stricken families.

This is a photo of one of our programs (a drinking water safety plan workshop) showing a large number of female participants.

2. SIWSA support of social and gender inclusion

- Project designs
  - Improve drinking water accessibility to women and children
    - Ultraviolet water filter kiosks constructed at safe and accessible locations
    - Ecological purification system constructed at a primary school
    - Household water filters installed in homes
- Capacity-building trainings
  - Gender inclusive
  - Encourage women participation in all trainings
- Youth mentorship

Second, community projects are designed with vulnerable social groups in mind. For the ultraviolet (UV) water filter kiosks project, the kiosks were constructed at safe and accessible locations to accommodate for the elderly and disabled. Also, the kiosks were designed so that the tap was reachable and operable by children. For the ecological purification system (EPS) project, a slow sand water filtration system was constructed at a primary school to improve the access of children to safe drinking water. Similarly, for the household water filters project, water filters were installed in homes to improve the access of women and children to safe drinking water, removing the need to travel in order to procure it. Third, the Association provides capacity-building trainings for the water committee and the wider village community. The trainings are promoted as gender inclusive and women are proactively encouraged to participate. Fourth, the Association provides mentorship for the youth with the hope of them joining the water committees in the future to support their village communities.

The pictures show project design implications towards social and gender inclusion. The kiosks are easily accessible to children and are located in a safe location near the *fale komiti* or the village communal house, as shown in the image on the right.

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This photo shows a member of our team, Mark, an Australian volunteer, mentoring the youth during the implementation of the household water filters project.

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Summary

- Water committees
  - Comprise predominantly of older men
    - Cultural bias and gender stereotypes
  - Under-represented groups in water committees
    - People with disabilities, women, youth, and *fa'afafine*
  - Growing women representation in water committees over the years
- SIWSA support of social and gender inclusion
  - Community consultation programs, project designs, capacity-building trainings, and youth mentorship

In summary, water committee members are predominantly older men, owing to cultural biases and gender stereotypes. People with disabilities, women, youth, and *fa'afafine* are under-represented in the water committees. Women representation in the water committees has grown over the years. The Association supports social and gender inclusion in the schemes through community consultation programs, project designs, capacity-building trainings, and youth mentorship. Thank you for your time.

11

References

- Samoa Bureau of Statistics. (2020). 2016 Population and Housing Census: Samoa Gender Dynamics Monograph. https://www.sbs.gov.ws/images/sbs-documents/info-graphics/SGM/SGM_FINAL_web_4oct.pdf
- Water Schemes Act 2015 (WS).

12

Contents: Disaster preparedness and post-disaster response


Source: SIWSA

1. Disaster preparedness and post-disaster response
2. Drinking water safety plan (DWSP)
3. Summary

In this presentation, I will first provide a brief overview of the disaster preparedness and post-disaster response support mechanism utilised by the independent water schemes (the “schemes”); namely, the drinking water safety plan (DWSP). Second, ways in which the DWSP contribute to disaster preparedness and post-disaster response are discussed; other support mechanisms are also discussed in this section.

1. Disaster preparedness and post-disaster response

DWSP

- Incorporates disaster preparedness and post-disaster response
- Definition: “A comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer” (World Health Organisation, 2017, p. 45).
- Contents
  - Background and history of the water supply system (WSS)
  - Water committee membership
  - Water quality results
  - Characteristics of the water catchment

  (Continued in the next slide)

The DWSP is the main disaster preparedness and post-disaster response support mechanism available to the schemes. Disaster preparedness and post-disaster response are incorporated into each scheme’s DWSP. According to the World Health Organisation, a DWSP is defined as a “comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer.” The contents of a DWSP include a background and history of the water supply system (WSS), water committee membership details, water quality results, characteristics of the water catchment…

1. Disaster preparedness and post-disaster response

DWSP

- Contents – Cont'd
  - Description of the WSS
  - Maps of the WSS
  - Water supply management
  - Risk assessment
  - Corrective actions and improvement schedule
  - Operational monitoring schedule
  - Emergency response plan

…a description of the WSS, maps of the WSS, water supply management guidance, a risk assessment of the water supply, a corrective actions and improvement schedule, an operational monitoring schedule, and an emergency response plan.

4

2. DWSP

Disaster preparedness

- Current state of the water supply system (WSS)
- Risks and vulnerabilities associated with the water supply
- Control measures in place and to be implemented
  - Tree planting, intake clean-up, and clearing of access roads to maintain accessibility to important water supply infrastructure
- Emergency response plan
- Other support mechanisms
  - Community awareness programs
  - Capacity-building trainings

For disaster preparedness, the DWSP outlines the current state of the WSS, the risks and vulnerabilities associated with the water supply, and the control measures in place and those to be implemented. Examples of control measures include tree planting, intake clean-up, and clearing of access roads to maintain accessibility to important water supply infrastructure such as the intake, storage tank etc. Also, a customised emergency response plan is developed and presented in the DWSP to provide water supply guidance during disasters and emergencies. Other disaster preparedness support mechanisms include community awareness programs and capacity building trainings conducted or coordinated by the Samoa Independent Water Schemes Association (the "Association"). An example of a community awareness program that supports disaster preparedness is the DWSP workshop. The DWSP workshop, in part, discusses the emergency response plan with the village community. It informs the community of ways it can safeguard its water supply, the extent and effects of various types of disasters on the water supply, and alternative water sources when the main source(s) is compromised. Examples of capacity building trainings include operations and maintenance trainings, and plumbing trainings. These trainings help to prepare the water committees to be able to effectively deal with most WSS-related issues during disasters and emergencies.

5

This photo shows the effects of Cyclone Gita on Letogo scheme's intake. The debris that washed into the intake was cleared away by the villagers.

This photo shows another angle of the clearance work done.

Possible Emergency situations	• Cyclone / flooding damages supply and distribution lines • Faecal contamination of water supply • Waterborne disease outbreak • Extreme weather events (High Turbidity) • Drought Events
Persons to be notified	• Water Committee Secretary: Tautai M Phone Number: 7366170 • IWSA Office Number: +(685) 842 9959 • MoH Office Number: +(685) 68 100 • (WSSCD) Office Number: +(685) 67 200 • Disaster Management Office (DMO) Office Number: +(685) 67 200 or 27307 • MNRE (WRD) Office Number: +(685) 67 200
Method of alerting the community	• Community meeting • MoH & IWSA will issue boil water notice • MNRE (WRD & DMO) Notices
Alternative water supply	• SWA and WRD water truck • Spring Source • Collect Rainwater • Buy water bottles from licensed water supplies

Source: SIWSA

This table shows an example of an emergency response plan.

2. DWSP

Post-disaster response

- Emergency response plan
  - Water committee responsible for execution
- Other support mechanism
  - Contingency budget under the Water, Sanitation, and Hygiene sector
    - Financial assistance for the independent water schemes during emergencies

For post-disaster response, the water committee executes the emergency response plan. One other post-disaster response support mechanism is the contingency budget under the Water, Sanitation, and Hygiene (WaSH) sector. The Association can access the contingency budget on behalf of the affected scheme(s) for financial assistance towards remedial works.

Summary

- Disaster preparedness and post-disaster response → DWSP
- Disaster preparedness
  - DWSP: Current state of the WSS, risks and vulnerabilities associated with the water supply, and control measures in place and to be implemented, emergency response plan
  - Other: Community awareness programs, capacity-building trainings
- Post disaster response
  - Execute emergency response plan
  - Contingency budget

In summary, the DWSP is the main disaster preparedness and post-disaster response support mechanism available to the schemes. For disaster preparedness, the DWSP outlines the current state of the WSS, risks and vulnerabilities associated with the water supply, control measures in place and to be implemented, and an emergency response plan. Other disaster preparedness support mechanisms include community awareness programs and capacity-building trainings conducted or coordinated by the Association. For post-disaster response, the water committee executes the emergency response plan. In addition, the contingency budget under the WaSH sector can be accessed for financial assistance towards remedial works. Thank you for your time.

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References

- World Health Organisation. (2017). *Guidelines for Drinking-water Quality, Fourth Edition: Incorporating the First Addendum*. https://www.who.int/publications/i/item/9789241549950

11

Contents: From short to mid-term plan and management

I will first discuss the short to mid-term plan in place for the independent water schemes (the “schemes”); that is, the drinking water safety plan (DWSP). The DWSP process and its benefits are discussed in the second and third sections respectively.

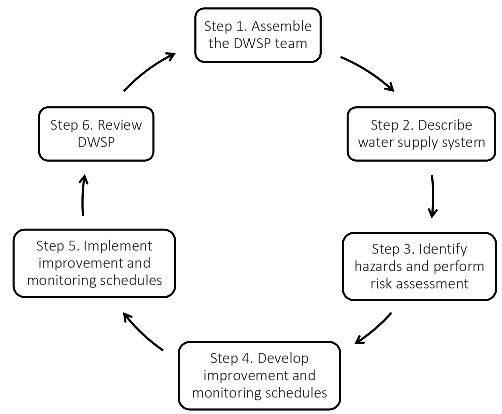
1. Short to mid-term plan

Drinking water safety plan (DWSP)

- Definition: “A comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer” (World Health Organisation, 2017, p. 45).
- Reviewed every two years
- Currently, 85% of IWSs have an endorsed DWSP

To refresh, a DWSP is a “comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer.” The DWSP is reviewed every two years. At present, 85% of the schemes have an endorsed DWSP.

2. DWSP process



Source: SIWSA

This flowchart shows the Samoa Independent Water Schemes Association’s (the “Association”) DWSP process (the “process”).

2. DWSP process

Step 1: Assemble the DWSP team

➢ Team responsibility: Develop, implement, manage, and improve DWSP

Stakeholder	Responsibilities
Water committee	Operations and maintenance
SIWSA	Support the water committee to develop and implement the DWSP
Ministry of Natural Resources and Environment	Water catchment management
Ministry of Health	Water quality compliance, water quality monitoring, and DWSP audit
Ministry of Women, Community and Social Development representatives	Community awareness and governance strengthening

Source: SIWSA

The first step of the process is to assemble a DWSP team, which is responsible for developing, implementing, managing, and improving the DWSP. The table lists the stakeholders represented in the DWSP team and their respective responsibilities.

2. DWSP process

Step 2: Describe water supply system (WSS)

- Data collection
  - Field survey
    - Conducted by SIWSA and water committee
  - DWSP workshops
    - Discussions and questionnaires
  - Water committee interviews
    - WSS history information
  - Water quality tests
    - Conducted by the Ministry of Health on a quarterly basis

The second step of the process is to describe the WSS. To facilitate this step, relevant data and information are collected through various means. A field survey is jointly conducted by the Association and the water committee to gather catchment and WSS data. More data are collected during the DWSP workshops through community discussions and questionnaires. Water committee interviews are also conducted to gather historical information on the WSS. Last, water quality data from quarterly tests conducted by the Ministry of Health are incorporated.

2. DWSP process

Step 3: Identify hazards and perform risk assessment

- Risk assessment
  - Input data: Step 2 data
  - Identifies hazards and hazard events
    - Likelihood, consequence, and priority levels
  - Identifies control measures in place
    - Control measure = An activity or process that prevents or minimises the likelihood of hazard occurrence
  - Identifies corrective actions
    - Corrective action = An action undertaken when a control measure is ineffective

The third step of the process is to identify hazards and perform a risk assessment. Data collected in step 2 are used as input data for the risk assessment. The risk assessment identifies the hazards and hazard events that may affect the water supply, control measures in place, and corrective actions. The associated risk, consequence, and priority levels of the hazards and hazard events are also determined.

2. DWSP process

Step 3: Identify hazards and undertake risk assessment

➢ Risk assessment

ID	Cause / Hazard event	Hazard type	Control measures in place	Likelihood	Consequence	Priority	Corrective Action
1.6	Animals accessing the intake area	Microbial	Small fence in place	2	3	Med	Improve fencing and develop inspection program
1.7	Contamination due to uncertainty of spring catchment boundaries	Microbial	-	2	3	Med	MNRE to undertake mapping exercise
1.8	Seasonal variations / drought conditions which reduce source flows	Insufficient Supply	Rationing of water during Jul-Oct. 8am-2pm School, 2pm-6pm everyone, 6pm-6am water off at main tank	4	4	High	Improve understanding of water demand and implement leak detection program
1.9	Intake pipe blocked by debris	Insufficient supply		1	4	Low	Install wire filter on end of pipe, protect source from debris, regular inspection

Source: SIWSA

This table shows a partial example of a risk assessment.

2. DWSP process

Step 4: Develop improvement and monitoring schedules

➢ Improvement schedule

- Implementation → DWSP endorsement by Joint Water and Sanitation Sector Steering Committee
- Addresses the findings of the risk assessment
- Priority-based plan of action for the implementation of corrective actions

➢ Monitoring schedule

- Assessment of the effectiveness of control measures and corrective actions

The fourth step of the process is to develop improvement and monitoring schedules. The improvement schedule addresses the findings of the risk assessment. It is a priority-based plan of action for the implementation of corrective actions. Conversely, the monitoring schedule allows the DWSP team to assess the effectiveness of control measures and corrective actions to ensure that the water supply is consistently safe.

2. DWSP process

Step 4: Develop improvement and monitoring schedules

➢ Improvement schedule

Component	Hazard ID	Cause / Hazardous Event	Action item ID	Action required	Lead	Support	Due date/ Timeframe	Resources	Status
Priority 1 - Extreme: Urgent Priority									
Component 2: Intake	2.2	Lack of maintenance at intake 3 (spring)	2.2.1	Clear access road & conduct regular O&M by the WC as specified in the O&M manual	WC	IWS	Every fortnight	$200 for WC	O&M Routine
Component 4: Treatment	4.1	No centralised treatment	4.1.1	Expand HWT systems project to households	Community	IWSA	Short term	$10,000 HWT systems	Planning-looking for funds
Component 6: Distribution line	6.1	Blocked/leaking pipes	6.1.1	WC to conduct regular inspection and fix all leaks on distribution pipeline	WC	IWSA	Quarterly	$1,000 for materials	Planning-looking for funds
Priority 2- High: High Priority									
Component 1: Catchment Area	1.1	Humans and animals entering source catchment	1.1.1	Fence immediate catchment area & create, register and enforce village by-laws.	MNRE-WRD	Village Council	Mid term	$8,000	Planning-looking for funds
	1.2	Heavy rainfall increasing turbidity and transportation of pathogens	1.2.1	Clear fallen/dead trees and branches upstream	WC	IWS	Every fortnight and after heavy rain or extreme weather event	$100	O&M Routine
			1.2.2	Conduct tree planting	MNRE-WRD	WC	Short term	-	M[illegible]VRD responsibility

Source: SIWSA

This table shows an example of an improvement schedule.

2. DWSP process

Step 4: Develop improvement and monitoring schedules

➢ Operational monitoring schedule

PARAMETER	OPERATIONAL LIMIT	CRITICAL LIMIT	FREQUENCY	LOCATION	RESPONSIBILITY	ACTION
Catchment	20 or more meters from intake and upstream (river)	Less than 20 meters of the intake or the Spring stream	Monthly	Laulii Catchment Area	Water Committee and MNRE	Request assistance from the MNRE to enforce protection of watershed to improve water supply
Spring/Stream/ Spring Flow	12 or more hours of continuous water supply daily	less than 12 hours of continuous water supply	Quarterly	Laulii River & Spring intakes	IWSA and Water Committee	Request flow data from MNRE WRD and ration water when needed
Turbidity	Clear	Hint of brownish color observed in the water	Daily	Laulii – Intake & Storage Tank	IWSA and Water Committee	Use the tank and/or inform the community to settle and decant drinking water
E.coli	0 CFU/100ml	1 CFU/100ml	Quarterly	Laulii Intakes, tank & customer tap	MoH	Conduct E.coli Testing and inform the scheme to boil all drinking water
Total Coliform	0 CFU/100ml	1 CFU/100ml	Quarterly	Laulii Intakes, tank & customer tap	MoH	Conduct Total Coliform Testing and inform the scheme to boil all drinking water
Structural Integrity of Infrastructure	Minor Damages to Infrastructure	Major Damages to Infrastructure	Monthly and after heavy rainfall	Laulii WSS	Laulii Community with assistance from IWSA	Inspect and repair any damage to the infrastructure
Catchment & Intake condition	Debris in intake	Blocked intake and turbid water due to debris	Monthly and after heavy rainfall	Laulii Intakes	Laulii IWS Community	Inspect and clean intake and pipelines
Signs of vandalism	Markings or writings on intake covers and storage tanks	Damaged pipelines /or storage tanks, broken fencing, door/gate locks broken	Monthly	Laulii WSS	Laulii IWS Community	Enforce village council policies
Signs of Contamination	NO sign of contamination	ANY sign of contamination	Weekly or when suspicious of water taste/smell	Laulii WSS	Laulii IWS Community	Inspect, clean intak[illegible] for serious cases inform IWS[illegible]

Source: SIWSA

Conversely, this table shows an example of an operational monitoring schedule.

2. DWSP process

Step 5: Implement improvement and monitoring schedules

- ➢ Requirement: DWSP endorsement by Joint Water and Sanitation Sector Steering Committee
- ➢ Operations and maintenance manual
  - Facilitates the implementation of improvement and monitoring schedules
  - Contains standard operating procedures

The fifth step of the process is to implement the improvement and monitoring schedules. Prior to this, the DWSP must first be endorsed by the Joint Water and Sanitation Sector Steering Committee. This step is facilitated by the operations and maintenance manual created by the Association for the schemes. The manual contains standard operating procedures which are important for the proper implementation of control measures and corrective actions outlined in the schedules.

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2. DWSP process

Step 6: Review DWSP

- ➢ Conducted every two years
- ➢ Assessment of overall performance of the DWSP
  - Based on monitoring data
- ➢ Check → Up-to-date and accurate
- ➢ Revise DWSP as necessary

The sixth and final step of the process is to review the DWSP. As aforementioned, the DWSP is reviewed every 2 years by the DWSP team. During the review, the overall performance of the DWSP is assessed based on the monitoring data collected. The DWSP and its components are also checked to ensure that they are up-to-date and accurate, and revised as necessary.

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3. DWSP benefits

- Comprehensive integrated approach to water supply management
  - Climate resilience
- Cost reduction
- Supports applications for funding

In our experience, the DWSP provides three key benefits. First, the DWSP is a comprehensive integrated approach to water supply management; it covers all facets of water supply management and ties in the various stakeholders in support of the schemes, thereby, increasing climate resilience. Second, the DWSP promotes the efficient utilisation of resources to reduce costs. Third, the DWSP highlights the need for the schemes which is useful in supporting funding applications.

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Summary

- Short to mid-term plan → DWSP
- DWSP process
  - Six steps
    1) Assemble the DWSP team
    2) Describe WSS
    3) Identify hazards and perform risk assessment
    4) Develop improvement and monitoring schedules
    5) Implement improvement and monitoring schedules
    6) Review DWSP

In summary, the short to mid-term plan implemented by the schemes for the effective management of their water supplies is the DWSP. The DWSP process has six steps, they are: assemble the DWSP, describe the WSS, identify hazards and perform risk assessment, develop improvement and monitoring schedules, implement improvement and monitoring schedules and review the DWSP.

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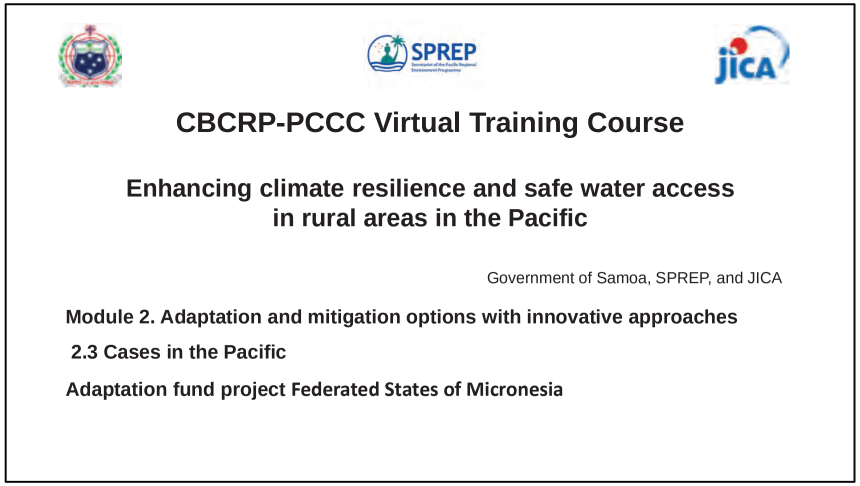
References

- World Health Organisation. (2017). *Guidelines for Drinking-water Quality, Fourth Edition: Incorporating the First Addendum*. https://www.who.int/publications/i/item/9789241549950
- Mudaliar, M. M., Bergin, C. & MacLeod, K. (2020). *Drinking Water Safety Planning: A practical Guide for Pacific Island Communities*. ReliefWeb. https://reliefweb.int/sites/reliefweb.int/files/resources/pacific_drinking_water_safety_planning_guidelines_who_spc.pdf

Summary

- Three key benefits
  - Comprehensive integrated approach to water supply management
  - Cost reduction
  - Supports applications for funding

The DWSP provides three key benefits. It is a comprehensive integrated approach to water supply management, reduces costs and supports applications for funding. Thank you for your time.



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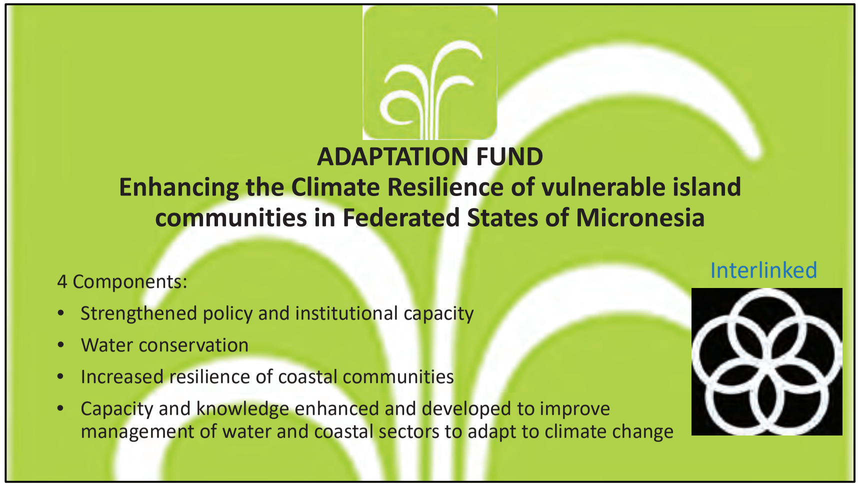

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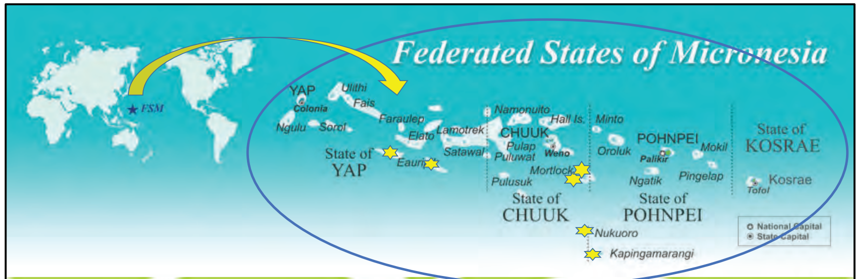
Hello, my name is Richard Moufa and I support the FSM Department of Environment, Climate Change and Emergency Management in managing the Adaptation Fund project which was awarded to the FSM by the Adaptation Fund Board to address the challenges of climate change in the Federated States of Micronesia.

The Adaptation Fund project is a five year project which was officially awarded to FSM in 2017 and implementation started in 2018. The project was co-developed by the Department of Environment, Climate Change and Emergency Management and the Secretariat of the Pacific Regional Environment Programme with the title: “Enhancing the Climate Change Resilience of Vulnerable Island Communities in the Federated States of Micronesia”.

Financially, the project is a 9 million U.S dollars projects with four primary climate change adaptation components that focus on strengthening policy and institutional capacity; water conservation; increasing resilience of coastal communities; and enhancing and developing capacity and knowledge to improve management of water and coastal sectors to adapt to climate change. The four focus areas are actually interlinked with each other.



4 States: Yap, Chuuk, Pohnpei & Kosrae
Geographical size: 607 islands (a combined land area of approximately 702 km2 or 271 sq mi)
Ocean Size: the country's waters occupy more than 2,600,000 km2 (1,003,866 sq mi) of the Pacific Ocean
Population: 104, 832 (mid-2021-estimated)
AF Water Security Project Sites: Eauripik & Woleai (Yap); Lekinioch & Satawan (Chuuk); Nukuoro & Kapingamarangi (Pohnpei)
Project Staff: 3 PMU; 4 State Operation Officer; 6 Community Coordinators

Before I continue, I would like to share geographical background on the Federated States of Micronesia for those of you who are not familiar with the FSM.
As you can see in the map, the FSM is situated just north of the equator and just north of Papua New Guinea. The FSM comprised 607 small islands grouped in four states: Yap, Chuuk, Kosrae and Pohnpei where the national capital is located. FSM population is around 104 thousand. The islands are spread across a vast area of the Pacific Ocean of approximately 1 million square miles.
Now, with the amount awarded to the project, we cannot implement its activities in all the islands. Therefore, it was decided for the project to implement its activities on six FSM islands, Eauripik, Woleai, Satawan, Lekinioch, Nukuoro and Kapingamarangi, which are indicated on the map.
These project site islands are low-lying islands which experienced frequent droughts and other impacts of climate change. To facilitate implementation of the project activities on the selected islands, the project has arranged for one project coordinator on each of the islands and one project staff at state level and management support at the national level with 3 staff.

3

Water Security Component

"Water conservation and management technology & practices adopted, responding to drought, sea level rise and early recovery from cyclones"

- Primary Water Security Activities:
  - Ground Truthing – Water Infrastructure Assessment
  - Installation of Water Infrastructure/ Technologies
  - Water Management Training/ Plan
  - Climate Change and WASH Education

Although the FSM AF Project focuses on 4 primary components, for the purpose of this presentation, I will only share the project case on the Water Security Component.
Basically, the primary focus of the Water Security Component is to present appropriate water conservation and management technology and practices with the aim that the communities will adopt in the long run as response to drought, sea level rise and early recovery from natural disaster, leading the communities to be more resilient to the impacts of climate change.
Under the Water Security Components, there are primary activities that needs to be implemented. Keep in mind that these activities themselves are appropriate practices for water conservations and management.
The primary water security activities are: Ground truthing or Water Infrastructure Assessment; Installation and repair of water infrastructures or technologies; Train the communities on water management and develop water management plan; Enhance communities understanding of climate change and its impacts; Provide awareness and education on Water, Sanitation and Hygiene (WASH).

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from a water laboratory. This project is the first project to carry out water testing on the islands. It is the first time the community actually knows the quality of their water resources and has given the project the opportunity carry out awareness and education on the important of clean water and ways to disinfect their water before consumption.

Recording the location of the water infrastructures using GPS is important for the project. The GPS dataset includes coordinates, identification tag for the infrastructures, owner's name, pictures of infrastructure, conditions and so forth. The FSM DECEM GIS program has helped the project on creating a google map for the project where the public can access and see the individual infrastructures with its datasets and updates of work. Recording the location of the infrastructure and uploading to google map for public information is also a new innovative activity for the community. The project is still continuing populating the map with data.

Information on how many people have access to the infrastructures is also recorded.

Once the data are collected, then recommendations on what work is required and list of materials are submitted to the project management unit for consideration and procurement of repair supplies.

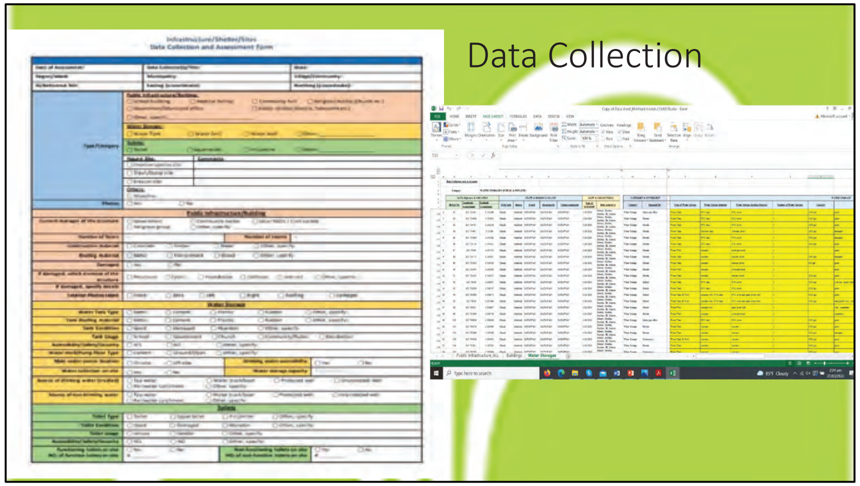
When preparing to undertake the water infrastructures assessments on the selected islands, the project had to consult the community leadership for a list of primary public and private water infrastructures that require repair work or new tanks. The reason for the list is that the project cannot financially repair or install new tanks at all the households or at public buildings. We have to be strategic on location and number of people benefiting from the improved water infrastructures.

Once the list is provided, a team of local experts or specialists from government agencies and organization partners traveled to the islands to do the assessments. The experts ranged from engineer, water quality specialist, geographic information system (GIS) trained person, water utility specialist, WASH trainer and gender advocate.

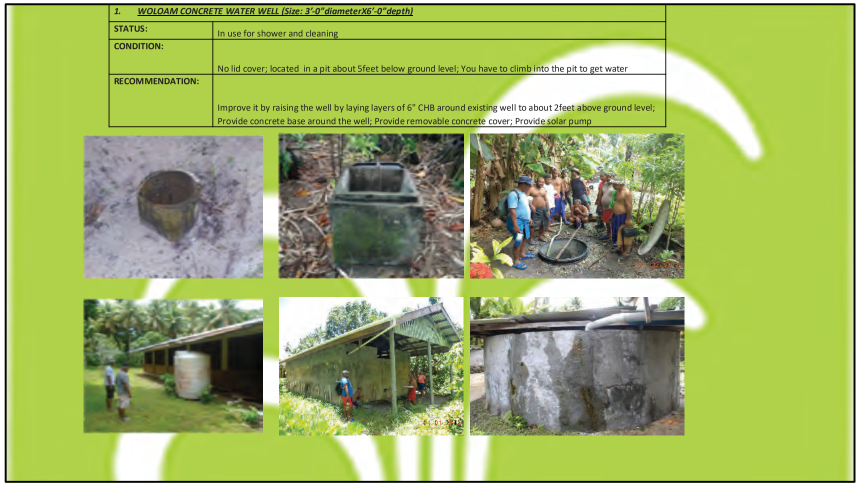
The assessment tasks are very comprehensive and simple. For example, the engineer role is to document current condition of the water well or rainwater harvesting system. The condition of the roof or catchment system, gutter, the type of tank/well structures, the size/ volume, piping and collection area. The engineer observation will not only be recorded on paper, but it is important to be supported with photos/ pictures.

At the same time, water sample was collected for water quality test for bacteriological contamination using the Hydrogen Sulfide test kits also known as H2S kits. The reason why H2S kits is because it is the most suitable and affordable water quality test kits for such islands communities that are distant

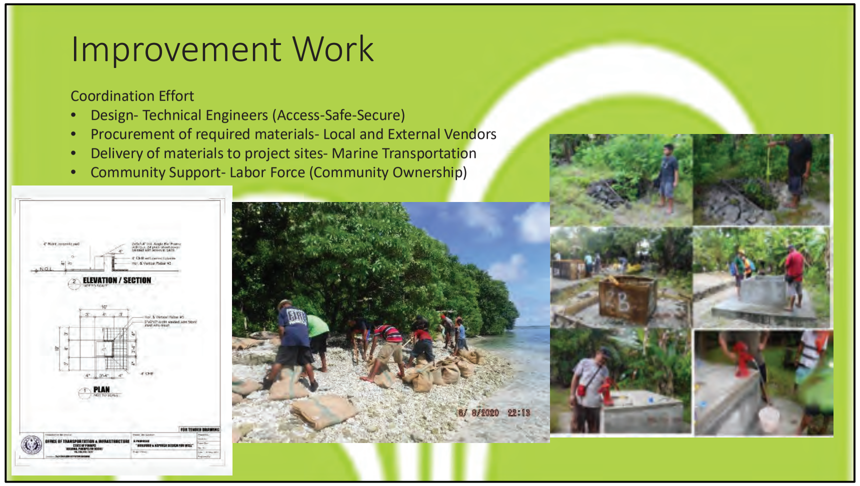
Using the GPS information, the project has mapped out the location of the selected infrastructures for sharing to the public and community information on locating where the work will be implemented. The map will also show how strategically the improvement work is done on the island in terms of accessibility to the public.



This is the assessment form or template the project uses when assessing and collecting data on the infrastructures. The collected data are then transfer into a excel sheet for the project usage and recording. One of the aim for the template is to establish a universal assessment form that the community or any communities and NGO can use for future assessment activities.



This slides just show how the recommendation on required improvement work on the individual water infrastructure is submitted to the project management unit for their consideration and planning and the needed materials. As mentioned, the project strongly required photos of infrastructures to be taken in details to help the management in their planning.



Once the recommendations are reviewed by the project management unit, a meeting will be called among the assessment expert to lay out the plan of work to be undertaken. The engineer will provide technical design of improvement work required with consideration of safe access and security, the project will seek community commitment to provide labor work arrangement, the project will initiate procurement of needed materials and work with marine transportation agencies on deliver schedules.
One innovative task that is being applied to the project is the engineering design for proper infrastructures and recommendations on the appropriate type of materials to be used to make sure the infrastructures are built to accommodate everyone's accessibility and safety needs and for the infrastructures to last long and be durable against impact of climate change.

Community trainings is one important activity that the project is implementing. With help from our technical partners, trainings are ongoing on the target islands. Training activities on building and improving water infrastructure and their maintenance, water quality testing, WASH and climate change education. And educate the community on the gender inclusion concept in decision making.
It is the project's goal and objectives that the trainings will empower the community with knowledge and enhance capability in sustaining and manage their water resources to improve their water security for the long run.

Although the project is progressing, there are still enormous challenges it encounters. As mentioned in the beginning, the project targets 6 outer islands of the FSM. Arranging project missions and delivery of materials to the islands are not always according to what is planned. Transportation and shipping services to the outer islands are irregular and very limited which poses stiff challenges for the project's activities. The photo of cargo boat in the slide is the type of boat that the project depends on for its to delivery materials and take project team to visit the sites to deliver trainings, consultations and so on. Often times, the boat is the only boat that service the whole nations. Therefore, sometimes it will service the project sites every 3 to 4 months. There are smaller fishing boats the project can use, but we have to charter which it can be very costly. So constant contact with the shipping agency is very important to seek information on when the boat will be leaving to the project sites so we can prepare.
Sometimes the boat is available, but we have nothing to deliver because there are no available supplies of required materials on the main islands. The project does have the capacity to procure the materials and hold for the next available boat, but the vendors do not have the storage capacity to keep them for a period of time. In addition, if the project procure bulk of materials, the boat will not be able to deliver all of them, because the project is not the only one servicing the boat and the project sites not have the proper storage facilities for the materials. As you can see in the picture in the slide.
The Covid-19 pandemic plays a big role in the project challenges. With the pandemic,

the FSM has closed its borders. This has a great impact to some of the project activities which required outside experts. Some of the activities are behind due to lack of outside technical expertise.

A lesson learned that stands out is the project community coordinators. It is very important for the community coordinators to have rich background in construction. Such experience has contribute to the progress of repair work on the infrastructures. What is stated in the project during the development is not always turned out exactly as it is planned. So reassessing the project activities is important to meet current situation and community needs. Thus, the project is always look out for changes and community challenges so it can modified its activity within the range of the project objectives.

The project activity on water conservation and security is still ongoing and we know we will encounter unforeseen challenges, however, we have already seen positive impact on the communities and the communities are happy the project is addressing their concerns and their need to adapt to the impact of climate change.

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References:

1. https://www.adaptation-fund.org/about/governance/board/

Contact Information: richard.moufa@gov.fm

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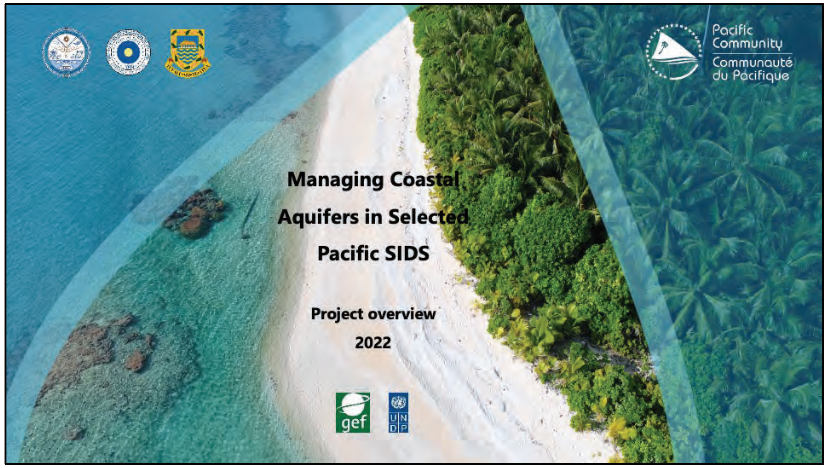

Hello, my name is Peter Sinclair. I'm the Water Resource Assessment and Monitoring Coordinator and Project Manager here at SPC in Suva, Fiji, for the Managing Coastal Aquifers Project in selected Pacific Island states.

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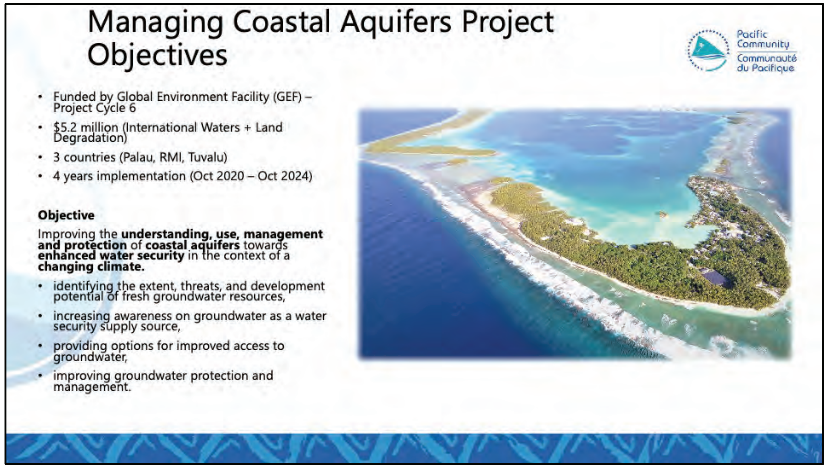

The Managing Coastal Aquifers Project, or MCAP, is a Global Environmental Facility (GEF) funded project of $5.2 million. Which is taken over four years between October 2020 and October 2024 and is implemented in three countries, Palau, Marshall Islands, and Tuvalu. The objective of the project is to improve our understanding, use, management and protection of coastal aquifers in the three target countries towards enhanced water security within the context of a changing climate. The approach that we will be taking is to identify the extent, threats and development potential of each of the fresh groundwater resources in selected islands within each of these countries to increase the awareness of groundwater as a water security supply source. Also, we look at options for improving the access and quality of groundwater that's being used in in selected localities and improving the groundwater protection and management of those aquifer systems.

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The project has four components. Component one is looking at the knowledge and use of coastal aquifers for enhanced border security. This is where we are undertaking field surveys, well surveys, socio-cultural surveys, groundwater mapping, groundwater development and groundwater treatment in terms of water quality. You can see the sorts of fieldwork that will be taken. The bottom right shows surveys of groundwater levels and water quality that's taken in wells and existing localities. We also have water supply improvements through aeration of groundwater, groundwater mappings, consultations, resistivity, and construction of galleries in this component.

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It is referred to as effectively building the capacity and the investments in human capital and tools to support resilience to climate change. We'll be looking to put in infrastructure for new monitoring networks and boreholes. There will be borehole drilling and construction of monitoring boreholes, capacity building with staff in each country to improve the way that groundwater monitoring, water quality monitoring, rainfall monitoring, all the information that's needed in order to understand the resource and to better manage the resource is undertaken during this component. You can see different monitoring techniques that have been employed for the different groundwater settings.

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Component three is local-based approaches to support the sustainable management and protection of coastal aquifers. This is really focusing back into the community to improve their approaches to how they can manage and understand the groundwater systems. We will be developing knowledge products, and introducing citizen science so that the community itself can undertake the monitoring of the groundwater systems. We'll be utilizing some groundwater modeling to better understand the impacts associated with over-abstraction or coastal inundation which causes salinization of the aquifer through overtopping. And we are looking at approaches on how to better manage those aquifers in each of those target countries.

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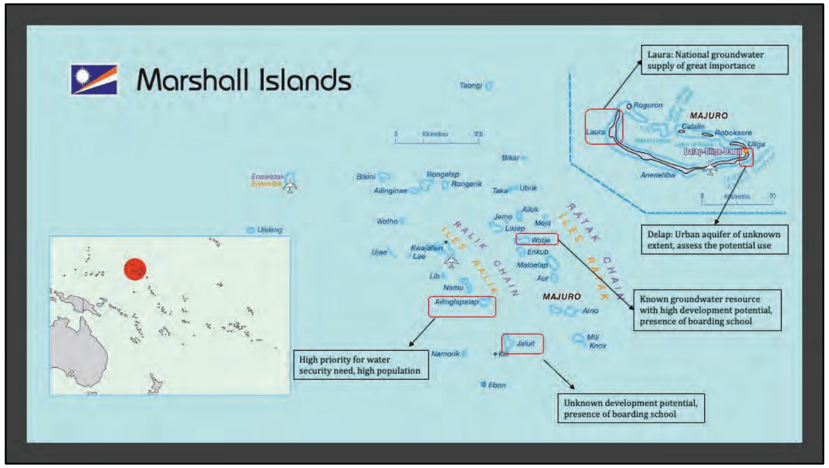

Component four of the project is in regards to the project management side of things which is common to most projects. The locality of each of these sites in which we will be working across the three countries is shown in the following maps. In the Marshall Islands, we'll be working up in the Laura site in the Majuro atoll. It is found through here and Laura has its main national groundwater supply coming through for the capital down at DUD (Dalap-Uliga-Darrit: urban town area of Majuro). We'll also be investigating some of the urban aquifer impacts down in the DUD area. In the outer islands, we'll be considering doing some installation of a new gallery system up in Wotje, and some investigation of groundwater supplies in Jaluit and Ailinglapalap, which had been identified by the government as being important islands for further development of water security options.

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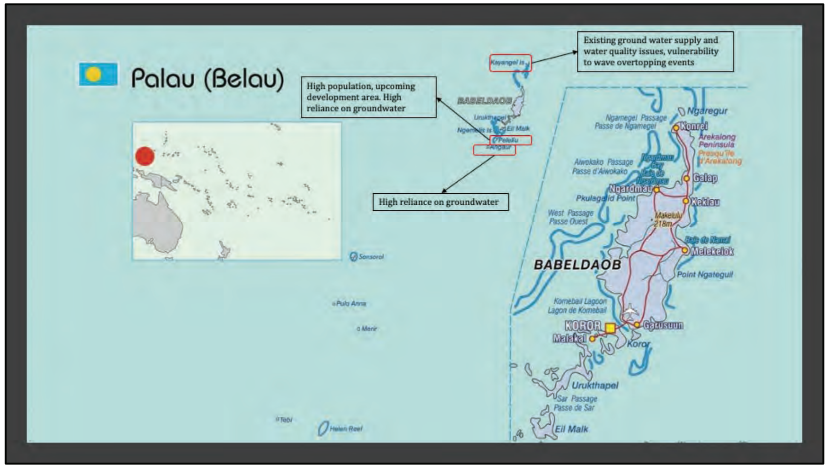
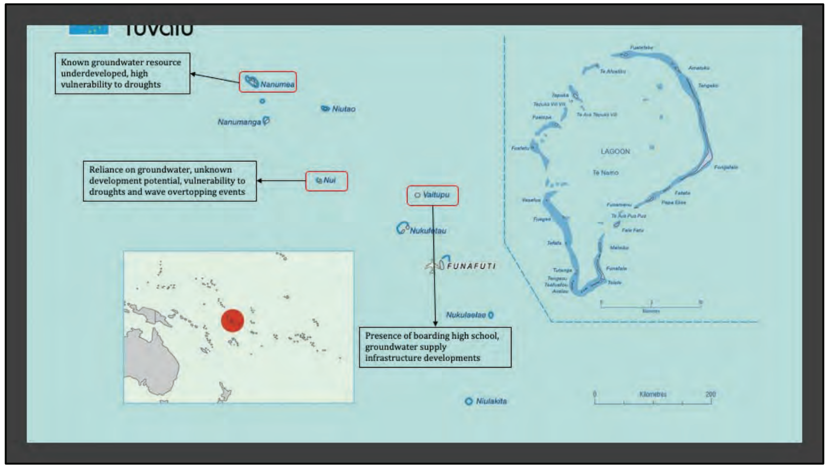
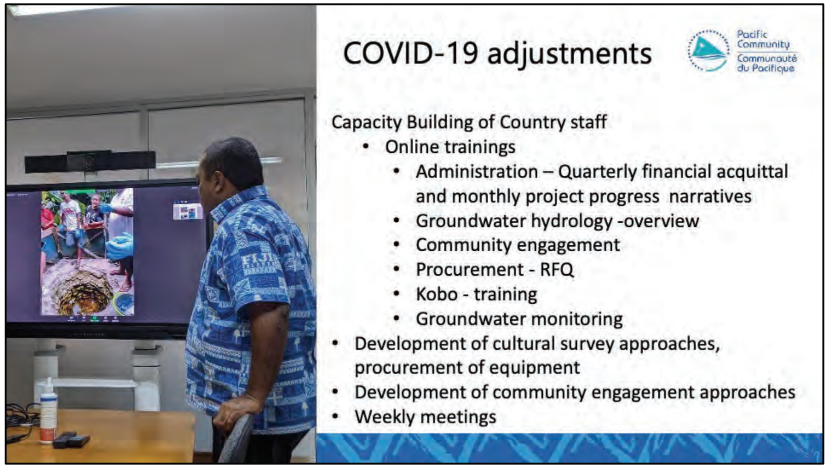


In Palau, the main focus will be on three outer islands including Kayangel up to the north, which is a low-lying carbonate sand island. It has existing groundwater supplies and water quality issues and is vulnerable to wave overtopping. Then, two raised limestone islands, both Peleliu and Angaur, have a high reliance on groundwater in those areas, and some water quality issues which will need to be investigated.



In Tuvalu, there'll be three sites. The project will focus on Nanumea to the north, where we have a known groundwater supplier in that area highly vulnerable to droughts. We'll be looking to put in some innovation in terms of a gallery system to access the thin freshwater lens which exists in that island. We investigate the groundwater potential in Nui for future development. Also, we are working in Vaitupu alongside another project which is helping to develop a water supply from groundwater there. We'll be working to support through some cultural surveys and some citizen science the development of that resource and its sustainability and in terms of its abstraction.



As with all projects over the last couple of years, they've all needed to adjust to COVID-19. This project tried some innovative approaches towards that through online trainings which whilst not necessarily innovative in their own way, allow us to guide our participants in the field through mobile phone technology. So, we were able to undertake the sampling remotely with them. The image on the left there which allowed us to do that. It was a pretty successful approach. But a lot of the focus was building the capacity of country staff who were in a position to undertake some of that work. Thus, we provided online trainings around the administration. That is the project management approaches, how they do the financial acquittals or monthly progress reports. We provided them with a background in terms of groundwater hydrology, how systems work, what they should be looking at, community engagement techniques, how to better engage with the community, how to undertake procurement which is in keeping with the principles of procurement, requests for quotations, approaches and sorting various quotations to allow for competitive approaches to procurement. The training was in regards to mobile phone technologies for data collection, using the Kobo software, undertaking groundwater monitoring remotely with the community or participants of the training course so that they were supported while they were doing their monitoring in the field. We put a lot of focus into development of cultural surveys and procurement equipment.

One of the focus areas particularly over the last year or so with limited travel due to COVID has been to develop some manuals for use by the countries and the community to assist with their monitoring. This is a small brochure or guidelines for rainwater and groundwater well assessment and monitoring. This is some examples of the step-by-step guide on how you measure the groundwater salinity, take water samples and do the analysis using compact bag technologies, which is an easy way to get bacteriological sampling. The innovation around this is for the community to be able to undertake their own monitoring. We're providing the resources, basic tools, sampling bags and the guidelines document which will help them to undertake that work.

Cultural surveys took a new approach. It's looking to see how to capture the traditional knowledge around how communities have utilized their water resources in the past, identifying sites and practices which are of cultural significance and relate to water. Surveys were then putting that information and archiving that information so that the community can make decisions about how they might look into the future for their management techniques and also to preserve those sites which are of value to them. So, traditional wells which have been relied upon for generations and have cultural significance, are cataloged, used, and protected. There is also the development of community engagement approaches and providing country staff with the tools and techniques to allow them to better access different parts of the community and to engage the community more thoroughly and in a much more sensitive approach. As a result of COVID-19 there was a need for increased communication so we undertook weekly meetings with our project managers to try and achieve that.

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These next few slides are a case study of some of the citizen science approaches, which is novel and innovative for us for community water management. It’s something which hasn't been done in the Pacific in the past, but has a great opportunity particularly with the advances in mobile phone technology. The purpose of it is to build awareness and empower remote communities to look after their own water sources they rely upon. It's about developing a working relationship and partnership to link the efforts of the national authorities and local communities to strengthen the water management system. It's using people who are based in the communities on the remote islands, and providing them with the skills and equipment that they need to monitor their groundwaters or their water supply systems, and therefore to provide that information back to the national government, who can also support them with their needs. You can see the diagram here, the intention is to use volunteers such as Red Cross Society to collect information, engage the island councils on the information that's being collected, and liaise with national governments. There is a loop arrangement where information is feeding back from national governments to volunteers and island councils and also from to volunteers through to national governments.

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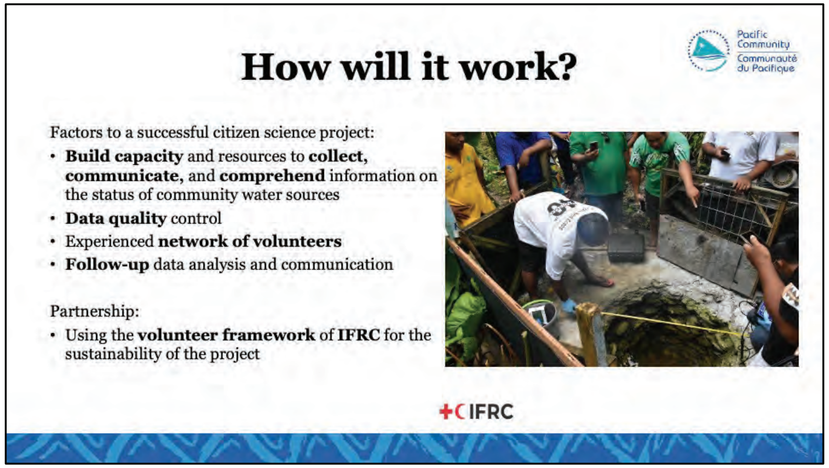

How will this community science work? What we believe the best approach is to build the capacity of our citizen or community scientists and provide them resources to better collect, communicate, and comprehend information on the status of community water sources such as the well shown on the right here. We also need to make sure that the data collected is robust and able to be replicated. We have some confidence in that data and it's archived for future use. We're going to link into existing networks of volunteers or officers who are assigned to do this work in outer islands. It's important to also provide follow up on the data which has been provided in terms of analysis and communicate that back to both the island councils and to the citizen scientists. So, there's a feedback loop in it and it is not just a one-way process. That partnership seeks to use the existing volunteer framework and in this case of the Red Cross Society, to achieve the longer-term sustainability of the project by engaging them with the skills and knowledge through trainings so that they're able to address some of the needs that the community's in outer island have during droughts or emergency situations. They're in a position to help with the monitoring and provide that information back to the national government and to island councils.

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Some of the equipment which the citizen science teams will use include salinity meters, which are robust equipment and relatively easy to use. They can be calibrated. We can maintain the quality control and that gives an indication of the salinity of the groundwater and its suitability for use. There are builders tapes to measure storages, to measure the depth to groundwater, to measure how much water is in rain tanks, and so on. For bacteriological sampling, we use accredited compact bag technology, which is gaining a lot of application across the Pacific as it's an easy way to collect samples, determine and quantify the bacteriological contamination of a particular sample be it from a well, rain tank or another water supply. The community citizen science teams are provided with GPS enabled mobile phones with good cameras. They'll be uploaded with the Kobo Toolbox. We will be able to install survey questions to guide the team. The intention is that citizen science will go to their community and will fill out the online forms, take images, and enter all the information on salinity, depth, water, and storage levels. They can install that in an offline process on the phone. Then when they get back to an Internet connection, they can upload that to the Kobo database which is then easily accessible by others to review and interpret that data and have a speedy return of information. We can check it for errors and archive that data in a consistent fashion. It's a really good application and approach to collect information and to be more timely with its

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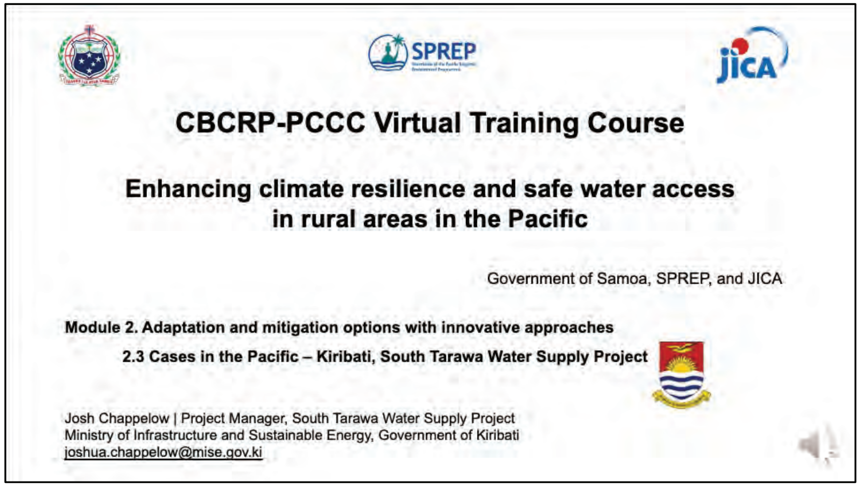
delivery back to the national government and project teams.

To give you the lessons learned from a recent training that took place in Tuvalu over a three-day process and 20 participants involved. The Red Cross was there who have access to an enthusiastic base of volunteers for this sort of community science. Some of the interesting points is that we needed to make sure that whilst they're volunteers, there was funding available to cover expenses such as transport, meals, and water when they were undertaking the survey work to help support them and ensure their wellbeing during the project. We also recognize that it's really important to engage with our partners with the Red Cross Society to empower them to take ownership, work with them and identify what their needs are. We needed to do a follow-up training and we are undertaking that training this coming week. These were the main lessons learned by building these partnerships with our key stakeholders who are involved or potentially involved including Ministry of Health, Public Works, Red Cross Society, and Home Affairs. We were able to strengthen the results in the National Disaster Management Office. We're able to strengthen the uptake, understanding and build on existing initiatives that were already in place. We strengthened the approach to collecting relevant information to be used by a variety of people and different situations as well as having a coordinated approach to monitoring which can be used at different times such as droughts and emergencies, or general quarterly monitoring which you would do to ensure the health of the water resources.



This country case study is about the South Tarawa Water Supply Project in Kiribati. My name is Josh Chappelow and I am the project manager responsible for implementation working for the Ministry of Infrastructure and Sustainable Energy, Government of Kiribati.

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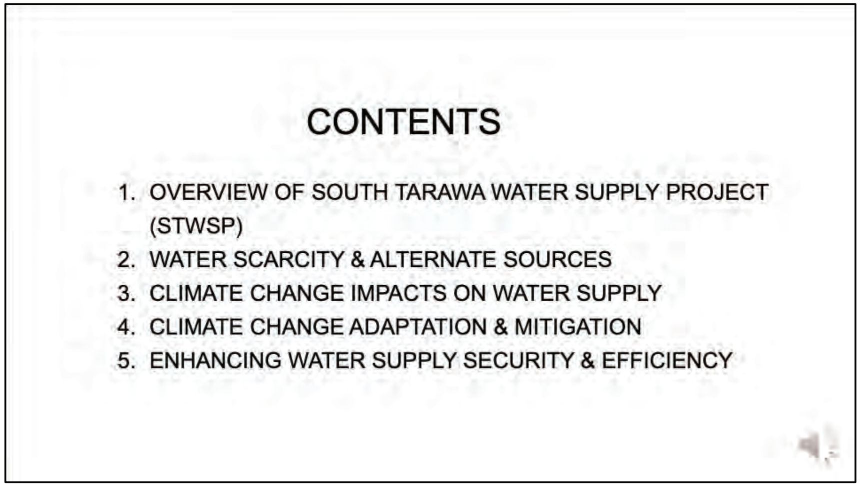

The presentation is divided into five main topics.
1. OVERVIEW OF THE SOUTH TARAWA WATER SUPPLY PROJECT (or STWSP for short)
2. WATER SCARCITY & ALTERNATE SOURCES
3. CLIMATE CHANGE IMPACTS ON WATER SUPPLY
4. CLIMATE CHANGE ADAPTATION & MITIGATION
5. ENHANCING WATER SUPPLY SECURITY & EFFICIENCY

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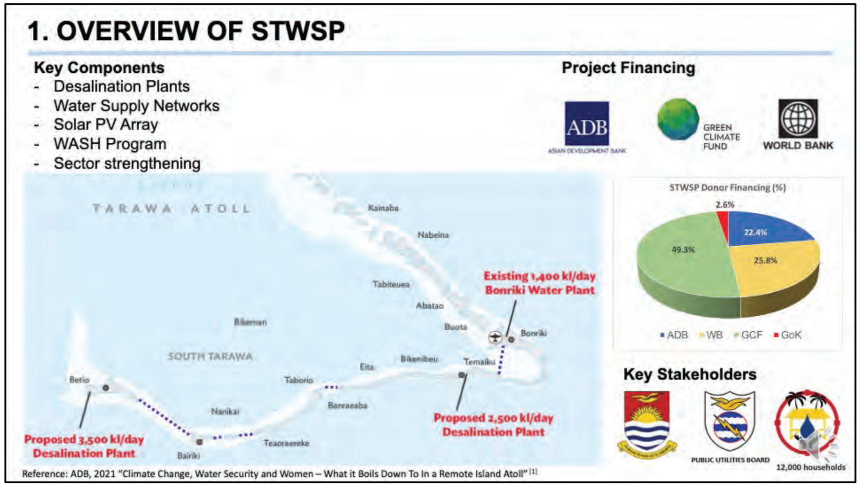

Overview of the South Tarawa Water Supply Project.

The project has an estimated total budget of approximately US$63.87 million and is co-financed by the Green Climate Fund (GCF), the Asian Development Bank (ADB), the World Bank (WB) and Government of Kiribati (GoK). The pie chart provides a high level breakdown of STWSP donor financing by % contribution. Additional financing from the Global Environment Fund (GEF) is also being processed to support climate change resilience outcomes.

The Public Utilities Board (PUB) is a key stakeholder with responsibility for long-term operation and maintenance of the new water and energy infrastructure that will provide improved services to around 12,000 households.

The impact of the project is aligned with the *improved health* and *climate change resilience* of South Tarawa's population.

The main outcome of the project will be *increased access to safe, climate-resilient water supplies*.

The main outputs of the ensuing project are:

Output 1: Climate resilient and low carbon water supply infrastructure. This will be achieved through construction of two Sea Water Reverse Osmosis (SWRO) desalination plants with energy consumption offset by solar PV, and rehabilitation of the water supply network to address leakages, and 100% metered household

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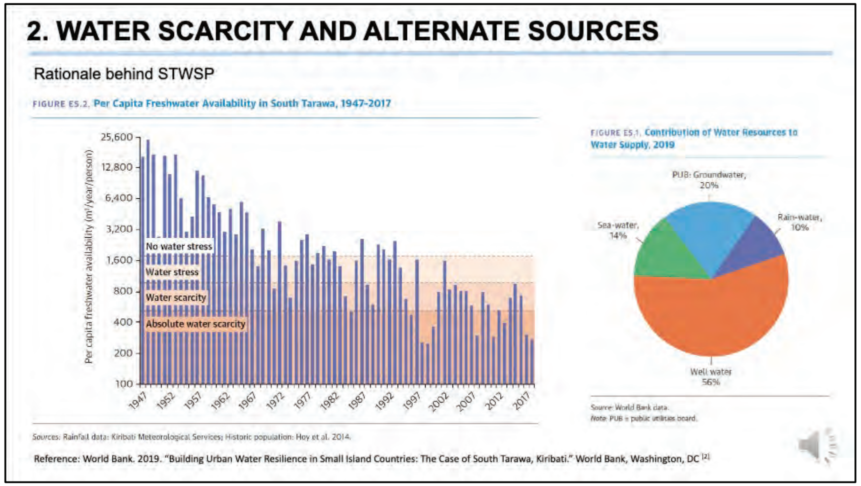


Kiribati is one of the most remote and least developed countries in the world. It faces significant challenges due to its vulnerability to climate change. The capital, South Tarawa, has uniquely fragile water resources due to its small size, lack of natural capacity for water storage, and competing land use. [2]

The main chart shows per capita freshwater availability in South Tarawa for the period 1947 – 2017. It indicates a declining trend toward a future of absolute water scarcity, which is the key driver for the urgent interventions under STWSP.

The pie chart shows the contribution of various water resources to current water supply in South Tarawa. PUB's groundwater from the Bonriki Water Reserve is treated and supplied intermittently to households for only 2 hours every 2 days. Access to the PUB water network is low and leakages are very high with losses estimated to exceed 60%. The water quality in PUB's piped networks is also compromised by low system pressures, a consequence of intermittent supply.

The population relies on a mix of water sources including private wells, which are almost always contaminated, and harvested rainwater. Seawater is also utilised for toilet flushing in the urbanised areas which have access to PUB's sewerage system. All sources of freshwater rely on regular rainfall. However, climate change is expected to increase the variability of rainfall, including the severity of drought events. Clearly, a new climate resilient source of drinking water is required to meet the basic needs of South Tarawa and to sustain its growing population.

connections to piped water supplies.

Output 2: Capacity of MISE and PUB to effectively manage water supply infrastructure increased. This will be delivered through 5-year operation and maintenance contracts for the desalination plant and water supply network, as well as specialist support to PUB in key result areas and vocational training.

Output 3: Awareness on WASH and climate change issues is raised. This will be achieved through the implementation of a comprehensive and intensive 5-year WASH and climate change awareness program.

Output 4: Project implementation is managed efficiently and effectively. This will be achieved through support to the government's Project Management Unit (PMU).

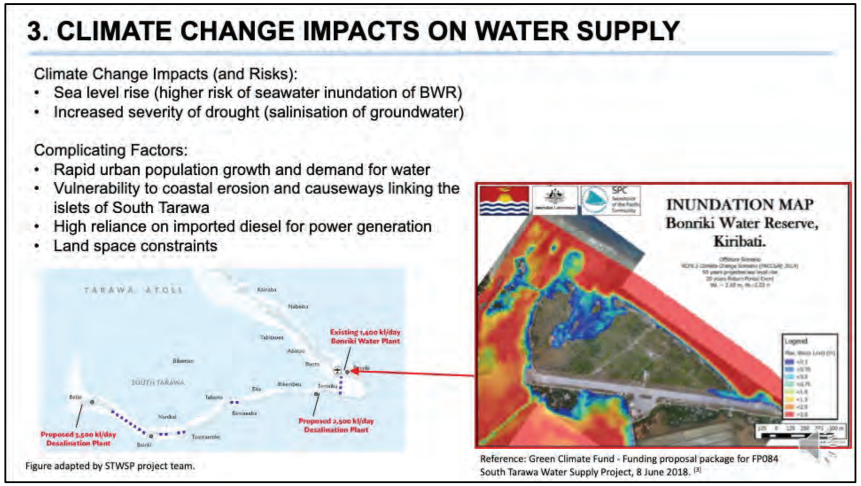
There are also some **Supplementary Outputs** financed by the World Bank including:

(i) Sustainable management of the Bonriki Water Reserve and sector strengthening, and
(ii) Sanitation pilot

The map shows key features including the location of Bonriki Water Reserve and Treatment Plant at the eastern end next to the international airport and, proposed new Desalination Plants located near Bikenibeu and at Betio. The unique geography of South Tarawa is also illustrated and it can be seen that it comprises of several low-lying coral sand islets linked by Causeways (blue dashed lines).

coastal erosion events. Loss of just one causeway has potential to cut water supply to the western end.

- Desalination processes are energy intensive and Kiribati currently has a high reliance on imported diesel fuel for electrical power generation. STWSP proposes to install a 2,500 kWp Solar PV array to offset the additional power requirements of the Desalination Plants and water distribution system.
- Land availability is highly constrained in South Tarawa due to over population. There is limited available space for installation of utility scale Solar PV arrays. Co-location of Solar PV arrays within the Bonriki Water Reserve maximises use of this available area whilst enhancing water catchment protection.



Climate Change Impacts (and Risks):
South Tarawa’s water supply is heavily dependent on underground freshwater lenses at Bonriki Water Reserve (BWR). The quality and quantity of these groundwater sources are seriously threatened by climate change induced seawater inundation and prolonged drought. Should such events occur simultaneously or in quick succession, they may reduce the groundwater lenses yield to zero for periods up to five years.
Seawater Reverse Osmosis (SWRO) Desalination was selected as the preferred technology for augmenting South Tarawa’s drinking water supplies as it is a climate resilient technology that is completely independent of rainfall.

Complicating Factors:

- Rapid urban population growth is likely to compound climate change risks. Population projections suggest that the population of South Tarawa may grow from approximately 60,000 in 2021 to 95,000 in 2041. Coupled with an increased per capita demand and population growth, the demand for water on South Tarawa is projected to grow significantly in coming years. [1]
- South Tarawa comprises of a string of mostly low-lying islets which are susceptible to inundation and coastal erosion. The causeways linking the islets carry the water supply transmission mains and are particularly vulnerable to wave attack and

- Allowance for Sea Level Rise (SLR) in design of all water infrastructure. For design beyond year 2050, this involves setting building/infrastructure floor levels at least 1.0m above existing ground level and no less than 4.5m above SEAFRAME GAUGE 0 datum.

Climate Change Mitigation

GHG emissions will be avoided through:
- Reduction / elimination of boiling for household water treatment
- Reduction of leakages and increased efficiency of transmission and distribution pumping systems
- Installation of 2,500kWp Solar Photovoltaic (PV) array to offset over 90% of power requirements for production and distribution of water with renewable energy.

4. CLIMATE CHANGE ADAPTATION & MITIGATION

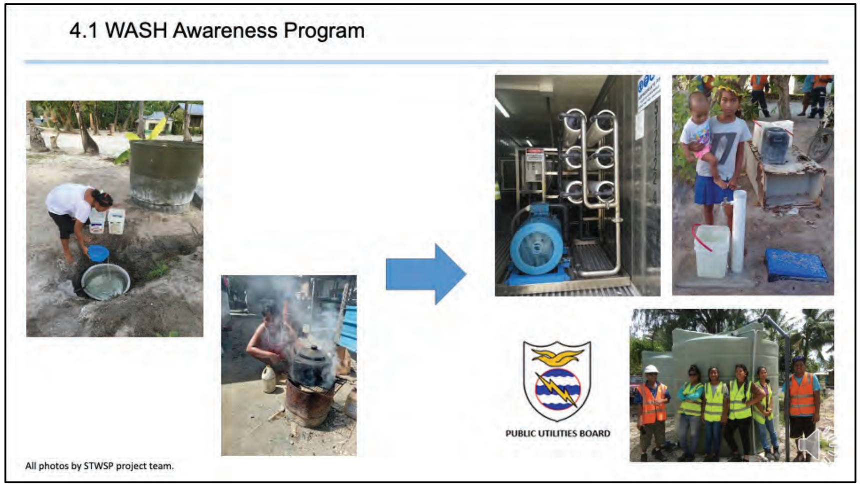
CC Adaptation	CC Mitigation
Water demand projections include + 2 litres per capita per day allowance for climate change	GHG avoidance - reduced need for water boiling
Seawater Reverse Osmosis (SWRO) Desalination plant for production of water independent of rainfall (also increases diversity of water sources)	GHG avoidance – reduction of water network leakages and increased efficiency of pumping systems
Allowance for SLR and 20m setback in design of water infrastructure	GHG avoidance - 2,500kWp Solar Photovoltaic (PV) array to offset over 90% of power requirements for production and distribution of water

All photos by STWSP project team. Figure from "A Different Pathway – Developing a Long-Term Coastal Security Strategy for Kiribati" [3]

Climate change adaptation and mitigation interact with South Tarawa's water sector in many ways, at many points:
1. Climate change will affect both the supply of and the demand for water.
2. The sector's infrastructure – pumps, reservoirs, treatment plants, pipes, electricity supply, etc. - is physically exposed to climate variability and climate change.
3. The production and distribution of clean water requires energy – hence the sector can be a significant contributor to greenhouse gas (GHG) emissions.

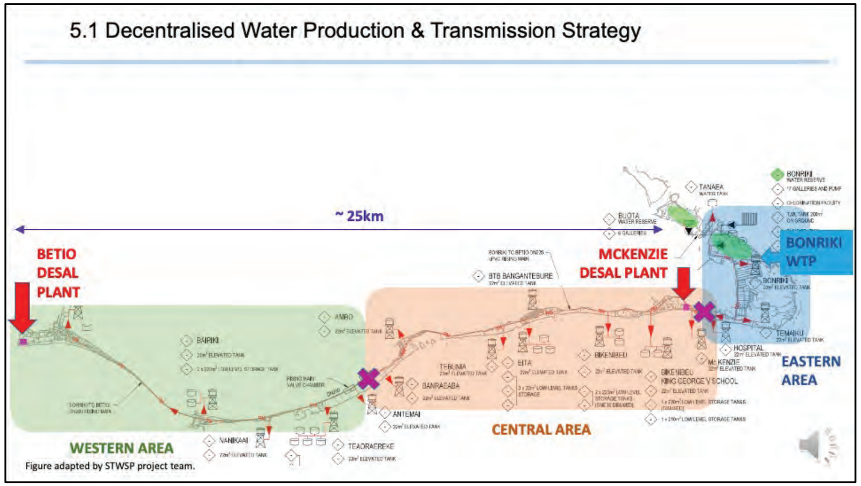
The GCF financing will support adaptation of South Tarawa's water sector for climate change, whilst also mitigating climate change through avoidance of GHG emissions. The table lists the key climate change adaptation and mitigation measures incorporated in the design of the South Tarawa Water Supply Project.

Climate Change Adaptation
- Allowance of 2 litres/capita/day from 2020 based on the assumption that daily demand will increase in response to increased temperature through climate change
- Introduction of SWRO desalination technology for water production which is independent of rainfall. Diversification of water sources also increases resilience against climate change impacts.



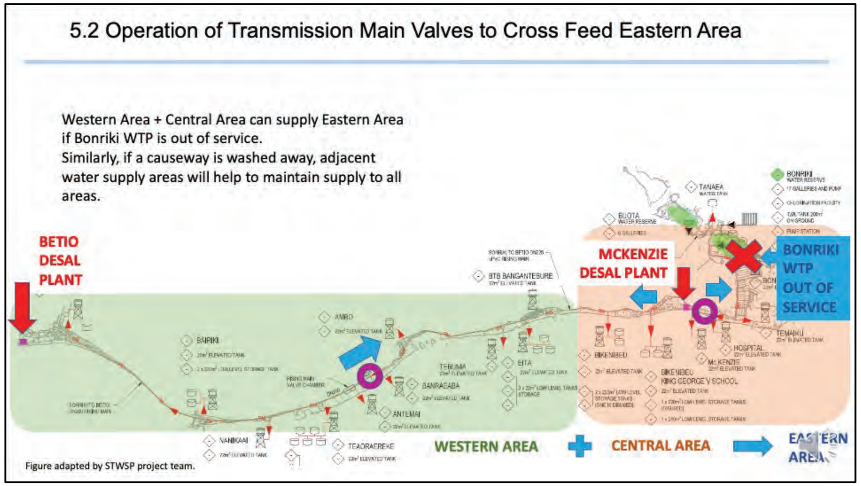
A 5-year WASH and climate change awareness program will be implemented as part of STWSP. The WASH program is critical to support significant transformations in the population's water use and behaviours which are key to project success, such as:
a) restoring confidence towards PUB and the quality of its supplied water;
b) deterring further use of unsafe water sources for consumptive use;
c) raising awareness of the volumetric tariff and stimulating payment for water according to metered consumption;
d) conserving water despite its apparent abundance at the tap; and
e) changing behaviours linked to sanitation, hygiene, menstrual hygiene management, and solid waste management.

Coastal erosion hazards are expected to increase through climate change driven Sea Level Rise and higher frequency of damaging storm events. The causeways linking the islets of South Tarawa are highly vulnerable as they contain crucial water supply and power transmission mains.



Originally, just one Desalination plant was planned for Betio. However, pumping the water from Betio to, say Bikenibeu (~25km), requires a large amount of energy. A water source should be located as close as possible to the demand it is meeting to minimise capital and operational costs. The energy requirement can be reduced by shifting some of the source of water closer to the demand.

One of the innovative elements of this project was the development of an alternative water production and transmission strategy aimed at improving energy efficiency, whilst also increasing the resilience of the water supply system to the impacts of climate change. This strategy involves *decentralization* of SWRO desalination production, essentially constructing two separate desalination plants with 3,500 kl/day produced at Betio and 2,500 kl/day produced at McKenzie (see Red Arrows). Both desalination plants are adjacent to densely populated urban areas with high demand for water. Having two separate desalination plants combined with the existing Bonriki Water Reserve groundwater production (Blue Arrow) enables division of the South Tarawa water supply system into three distinct Water Supply Areas: Western, Central and Eastern as shown by the colored areas on the figure. New isolation valves will be installed in the Transmission Main at the locations marked by the pink X's.



A key advantage of having three water supply areas is, that Western Area and Central Area can cross feed the Eastern Area if Bonriki Water Reserve is inundated with seawater or, out of service.

Similarly, in the event of loss of a causeway or other catastrophic failure (e.g. fire at one of the Desalination Plants), continuity of water supply can be maintained to all areas by operating isolation valves. This greatly increases the resilience of the project to potential climate change impacts.

Summary of the presentation

- Without intervention, South Tarawa is facing a future of absolute water scarcity aggravated by climate change and high population growth.
- Expected climate change impacts include sea level rise with higher risk of seawater inundation of Bonriki Water Reserve and, increased severity of drought which will lead to salinisation of groundwater.
- The STWSP, co-financed by the GCF, ADB, World Bank and Government of Kiribati will increase access to safe, climate-resilient water supply for around 12,000 households by 2027.
- Seawater Reverse Osmosis Desalination technology will be utilised for production of drinking water independent of rainfall. New water supply networks will be constructed to minimise leakage and to improve efficiency. Power requirements for operation of the desalination plants and new networks will be offset by renewable energy generated by a new Solar PV system.
- A 5-year WASH awareness program will be implemented as part of STWSP to smooth transition to the new water supply services and maximise health and social benefits.
- Water supply security and energy efficiency outcomes will be enhanced through implementation of a Decentralised Water Production and Transmission Strategy.

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A 5-year WASH awareness program will be implemented as part of STWSP to smooth transition to the new water supply services and maximise health and social benefits.
Water supply security and energy efficiency have been enhanced through implementation of a Decentralised Water Production and Transmission Strategy.

5.3 Water Supply Security and Efficiency Outcomes

CC Adaptation	CC Mitigation
Decentralisation - 2 separate desalination plants increased resilience to climate change impacts	GHG avoidance – approx. 50% decrease in energy requirement for water transmission.

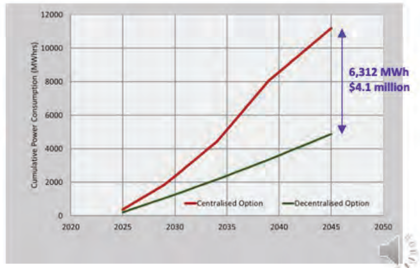

Figure adapted by STWSP project team.

Computer modelling of the alternative decentralized strategy confirmed that by locating a second desalination plant at McKenzie, closer to the major population center of Bikenibeu, lower pumping energy is required overall. The estimated energy savings of 6,312 MWh, or around 4.1 million dollars over 20 years of operation are significant for PUB in terms of minimizing its operation costs. The energy savings also translate directly to avoided GHG emissions (Climate Change mitigation).

CBCRP-PCCC Virtual Training Course

Enhancing climate resilience and safe water access in rural areas in the Pacific

Government of Samoa, SPREP, and JICA

Module 2. Adaptation and mitigation options with innovative approaches

2.3 Cases in the Pacific

Koji Kumamaru Ph.D. | Project Manager
UNDP Marshall Islands
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In this session, I'd like to share with you one of the examples of GCF funded water security project in the Pacific Region.
Project name is "Addressing Vulnerability in the Water Sector in the Marshall Islands" and in short, we called ACWA project.

Reference materials

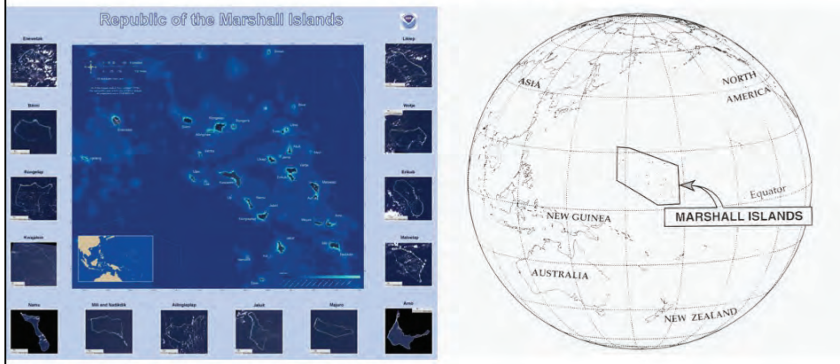
1. Climate Change, Water Security and Women – What it Boils Down To In a Remote Island Atoll, June 2021
2. World Bank. 2019. "Building Urban Water Resilience in Small Island Countries: The Case of South Tarawa, Kiribati." World Bank, Washington, DC
3. Green Climate Fund - Funding proposal package for FP084 South Tarawa Water Supply Project, 8 June 2018.
4. Betio Maternity Ward Photo - Vila Times
5. A Different Pathway – Developing a Long-Term Coastal Security Strategy for Kiribati, Government of Kiribati
6. All other photos and charts by STWSP project team

CONTENTS

1. General Background of Marshall Islands
2. About ACWA project

This is the contents of this session.

Central-NW Pacific: 29 Atolls, 5 Islands



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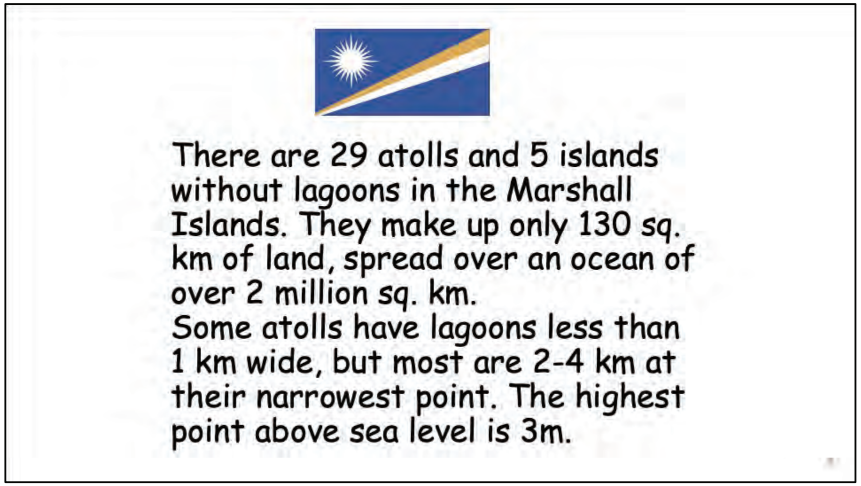
The Republic of the Marshall Islands (RMI) is a small island developing state (SIDS) consisting of 29 coral atolls and 5 single islands.



The nation is a large-ocean state, with a total land area of only 182 km2, spread across over 2 million km2 of ocean. There are 24 inhabited atolls and islands, which are mostly remote and lie merely 2m above sea level on average.

4

Nearly 75% of this population lives in the two urban centers of Majuro and Ebeye. RMI is a high human development and a lower middle-income country with a 2016 per capita income of USD 3,665, yet the country fails in indicators such as under-5 mortality and infant mortality rates compared to other countries of similar income. Approximately 20% of population of RMI has been reported to be living on less than USD 1 a day.

5

Freshwater Sources and Availability

- For the outer Atolls, the main source of potable water is from rainwater from household and community Rainwater Harvesting (RWH) systems; the latter are attached to public, commercial and community buildings
- Generally adequate but when the number of consecutive days with little or no rain exceeds a threshold, the harvesting and/or storage capacity is insufficient to meet even basic needs
- Surveys in 11 atolls in 2013 showed that household and community RWH are inadequate and in poor condition
- Improving household and community RWH through provision of new gutters, downpipes, etc. and provision of new community RWH and storage could meet water requirements even for prolonged droughts
- Groundwater from the freshwater lenses underlying the atolls and islands provides a secondary source of water, however, with increasing sea-level, tidal heights and storm surges, groundwater quality is compromised, especially during droughts.

This slide presents the freshwater situation in the RMI.
The type of freshwater resources available in the rural communities of RMI are, Rainwater, Groundwater and desalination using Reverse Osmosis (RO) unit.
Among those, dependance on rainwater as the primary source for drinking water is high; it was estimated at 98%.

During the Feasibility Study (FS) of GCF project done between 2015-2018, Rainwater Harvesting System (RWHS) is the most commonly available system in the rural communities, but found that existing facility requires improvement in terms of increasing efficiency of water catchment and strengthen storage capacity to address prolonged drought season.

There are few installed stationary desalination systems powered by renewable energy, but the communities are facing financial difficulties in supporting operations and maintenance costs of the desalination systems and are dependent on grant funding from external donors.

To assess the most cost-effective sequence of water supply augmentation measures and to ensure water security by 2045, a cost curve methodology was used in the feasibility study.

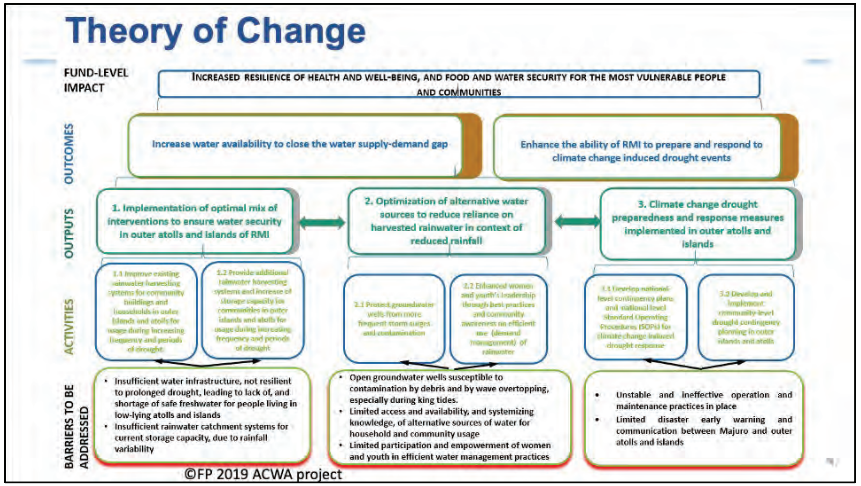
The Climate Context of RMI

- Particularly vulnerable to CC; its climate is influenced by large ocean-atmosphere interactions such as trade winds, El Nino, monsoons
- Hydro-geophysical features contribute to high vulnerability with droughts and storms as the main extreme events
- Increasing sea-level rise and decreasing rainfalls are the main challenges related to freshwater supply; these are expected to exacerbate over time
- Small and sparsely distributed land and population – economy is small and fragile
- Limited land and significant distances between islands and atolls make the cost of economic activity high and economies-of-scale difficult to achieve
- Given the context: a cost-effective and practical investment will be required to promote increased capacity for water harvesting and storage, along with promotion of efficient use of water in RMI during times of severe drought

These bullet points describes the climate context of Marshall Islands.
Despite the minimal contributions to global greenhouse gas emissions, RMI is disproportionately burdened with the significant impacts from climate change risks.
The root cause of this adverse condition is its high exposure and vulnerability to climate hazards, combined with limited adaptive capacity.
RMI is highly exposed to, and threatened by sea level rise, extreme tidal events, as well as higher rainfall episodes with longer and more intense dry periods. A number of environmental, economic, and socio-political factors contribute to its vulnerabilities, and lead to increased risks of climate change impacts in RMI as indicated in the slide.

rainwater.

Output 3 will implement climate change induced drought preparedness and response measures in outer atolls and islands. This output will be supported through two activities. The first activity is to update national-level contingency plans and national-level water safety plans, and develop Standard Operating Procedures (SOPs) for climate change induced drought response. The second activity is to develop and implement community-level drought contingency planning in outer islands and atolls. As described in the barrier section, there are unsustainable and ineffective operation and maintenance practices in place throughout the outer atolls and islands, and indeed this is also prevalent in the urban center of Majuro. This barrier will be addressed through community-level drought contingency planning with a focus on operation and maintenance of water infrastructure.



This slide present the Theory of Change of the project.

Output 1 will improve existing rainwater harvesting systems through installing new guttering systems at community buildings and households so that all of the available roof area is connected to storage tanks and the overall rainwater harvesting capture efficiency meets best practice. Output 1 will also build new storage tanks at existing suitable community buildings and at new roof catchment systems. Long life, high quality materials will be used at all sites to ensure the sustainability of the project. First flush devices will be included with the guttering systems to protect drinking water quality. The project design incorporates good practices and lessons learned from similar projects including the International Organization for Migration (IOM) “Rainwater Harvesting Improvement Project” supported by the New Zealand Government that piloted the improvement of rainwater harvesting systems at the household level in four of the outer atolls.

Output 2 will optimize alternative water sources to reduce reliance on harvested rainwater in the context of reduced rainfall. To achieve this output, there are two supporting activities. The first is to protect groundwater wells from more frequent storm surges and contamination. The second is to enhance women and youth’s leadership through best practices and community awareness on efficient use of

RMI ACWA Project

Objective:

to support the Government of the Republic of the Marshall Islands (GoRMI) in adapting to increasing climate risks, particularly more frequent and extreme droughts, which impacts the country's drinking water supply, which will be implemented in the 24 islands of the RMI. This goal will be addressed through:

1) **Water Security**- Improving household and community rainwater harvesting and storage structures in 86 communities at 24 outer islands and atolls
2) **Water Resilience**- Protecting groundwater (GW) wells from contamination
3) **Water Governance**- Strengthening the technical capacities of national and local institutions and key stakeholders by developing drought contingency plans

This slide is the summary of ACWA project objective and main three pillars of Outputs, namely Water Security, Water Resilience and Water Governance.

The uniqueness of ACWA project is considering future climate-induced droughts. General Water Security and/or WASH project address the current water shortage, however, ACWA project horizon in 25 years, i.e. up to 2045 considering the population growth rate, change of climate induced drought length etc in the computation of water gap analysis and water investment plan.

Also, the compatibility of family size, catchment area and storage volume has been very critical in the analysis and determining the type of Water Investment to implement in a certain community with varying rain intensity and drought length in RMI.

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SUMMARY

- The ACWA project implements the most cost-effective mix of interventions to bridge the gap between current water supply capacity and the capacity needed to supply at least 20 liters per capita per day year-round, including during drought events aggravated in frequency and duration by climate change.
- Coverage: 24 outer islands and atolls; 86 communities; 2,606 households; 14,144 direct beneficiaries (28% of population in 2017 and 49% female)
- Duration: 7 years for GCF project (Feb. 2020-Feb 2027); 25 years for assets to be operational
- GCF (Green Climate Fund) Grant: USD 18.63 million
- GoRMI Co-finance: USD 6.12 million in cash (years 1-7) ; USD 13.97 million (years 8-25)
- The project is being implemented by following UNDP Direct Implementation Modality (DIM) with RMIEPA as the lead executive for the project while CCD serve as GCF National Designated Authority (NDA)


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This is the summary of project target population and financial background information for your reference.

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THEORY OF CHANGE IN DEVELOPING BANKABLE PROJECT PROPOSALS

DR. PETER KING
SENIOR POLICY ADVISOR
INSTITUTE FOR GLOBAL ENVIRONMENTAL STRATEGIES
BANGKOK REGIONAL CENTRE

A Theory of Change in developing bankable project proposals.

Reference

1) GCF Funding Proposal FP112: Addressing Climate Vulnerability in the Water Sector (ACWA) in the Marshall Islands (July 2019)

2) Government of RMI. 2007, Republic of the Marshall Islands National Action Plan for Disaster Risk Management

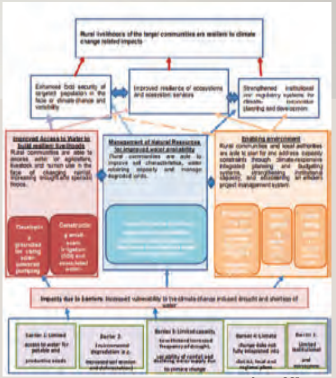
GCF GUIDANCE ON THEORY OF CHANGE

- The project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address. This determination will form the starting point and basis for the theory of change diagram, which articulates how the project will address the identified problem.
- The theory of change, despite being called a "theory", is a methodological approach that allows AEs and project developers to design and plan a project by first setting up the long-term project goals and objectives then mapping backwards to identify the necessary preconditions to meeting those goals, the project outcomes and outputs, as well as the assumptions under which the theory of change is developed. In this way, the theory of change clearly articulates how the results chain will cascade from the theory of change statement to the project activities.
- The innovation of the theory of change lies in making the distinction between desired and actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on forms of intervention to achieve those outcomes.

GCF has provided guidance on a theory of change, and this presentation will help to understand exactly what GCF is looking for in relation to theory of change.
Firstly, the project scoping exercise should start with the identification of the climate change problem that the proposed project is aiming to address.
Generally, that's done through a problem tree.
This determination will form the starting point and the basis for your theory of change diagram or narrative, which articulates how the project will address the identified problem.
The theory of change, despite being called a theory. is actually a methodological approach that allows accredited entities and project developers to design and plan a project by first setting up the long-term project goals and objectives and then mapping backwards to identify the necessary preconditions and inputs to meeting those goals.
The project outcomes and outputs as well as the assumptions under which the theory of change is developed.
In this way, a theory of change clearly articulates how the results chain will cascade from a theory of change statement to the project activities.
The innovation of the theory of change lies in making the distinction between what is a desired outcome and the actual outcomes, as well as in requiring stakeholders to model their desired outcomes before they decide on the forms of intervention to achieve those outcomes.

THEORY OF CHANGE

- **SOME COMMON QUESTIONS**
- **What is the difference between a "theory of change" and the "logical framework"?**
- **What are the implementation implications of the theory of change?**
- **Why aren't the climate predictions a required element of the theory of change?**
- **Why is a theory of change best presented as a diagram instead of narrative text?**
- **Who should be involved in developing the theory of change?**



Source: GCF

Now some common questions that are often asked in relation to the theory of change.
Firstly, what is the difference between a theory of change and the logical framework? Often, they appear to be used interchangeably.

What are the implementation implications of a theory of change? Why are climate predictions a required element of the theory of change? And why is the theory of change often best presented as a diagram instead of a narrative text?
And who should be involved in developing the theory of change? Well, we'll try and answer some of those questions as we go through the presentation.

The **climate context** provides the scientific underpinning for evidence-based climate action decision-making and the theory of change for all activities funded by GCF. It ensures that the set of causal linkages between the climate and climate impacts/hazards and action and societal benefits is fully grounded in the best available climate data and science. It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and/or adaptation in terms of reducing GHG emissions or improving the resilience of people and communities and should meet at least one of the eight GCF results areas.

The **theory of change** explains to the funder (GCF) why you think your project will work, and why the funder should expect the project to bring about the results you envision for the project. A good theory of change is like the backbone of a well-designed and fundable project proposal. Many proposals are rejected because they don't include a theory of change, or because the theory of change doesn't adequately show how the project moves from problem to solution.

The climate context provides the scientific underpinning for evidence-based climate action, decision making and the theory of change for all activities funded by the GCF. It ensures that the set of causal linkages between the climate and climate impacts or hazards, and action and societal benefits is fully grounded in the best available and most up to date climate data and science.
It demonstrates that the proposed interventions advance a national priority related to climate change mitigation and or adaptation in terms of reducing greenhouse gas emissions or improving the resilience of people and communities and should meet at least one of the eight GCF resolve areas.

The Theory of Change explains to the funder, that is the GCF, why you think your project will work and why the funder should expect the project to bring about the results you envision for the project.

A good theory of change, therefore, is like the backbone of a well designed and fundable project proposal. Many proposals, in fact, are rejected because they don't include a theory of change or because the theory of change doesn't adequately show how the project moves from problem to solution.

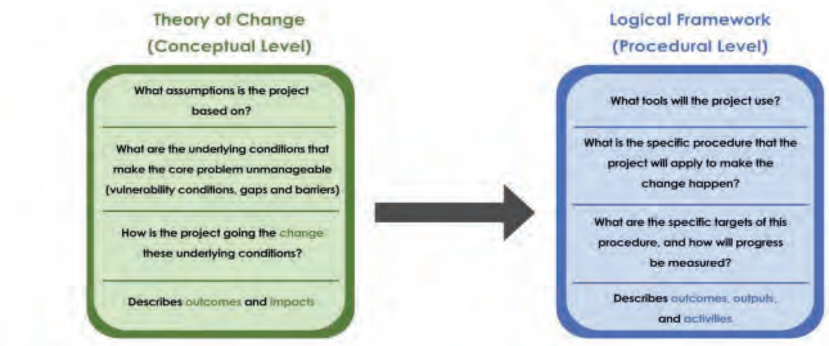


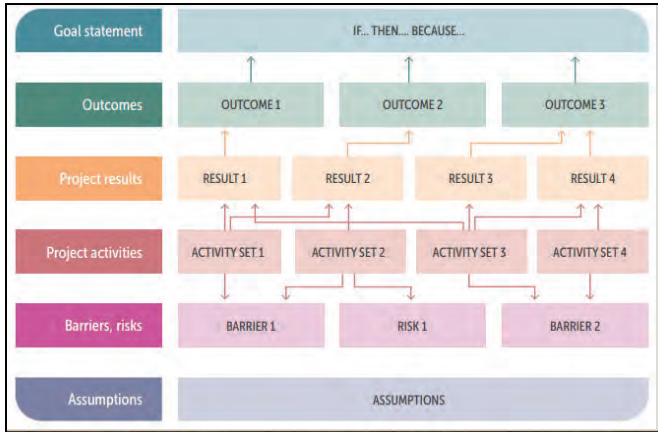
Figure 1: Relationship between project theory of change and logical framework

Source: Regional resource centre for Asia and the Pacific

A good way to think about the difference between a theory of change and the logical framework is that the theory of change is essentially at a conceptual level.

So what assumptions is a project based on? What are the underlying conditions that make the core problem currently unmanageable, often through vulnerability assessments or identification of gaps and barriers?

And how is the project going to change these underlying conditions?
It will describe the outcomes and impacts at a high level of the logic chain.
The logical framework, however, is a more procedural arrangement where we look at what tools will a project use, what are the specific procedures that the project will apply to make the change that's desired actually happen?
And what are the specific targets of this procedure and how will progress be measured? And it describes the outcomes, the outputs and activities, as well as the input supports to achieve those activities.



GCF Model Theory of Change

Ref: https://www.greenclimate.fund/sites/default/files/document/gcf-programming-manual_0.pdf

Inputs allow activities to be carried out that will deliver project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

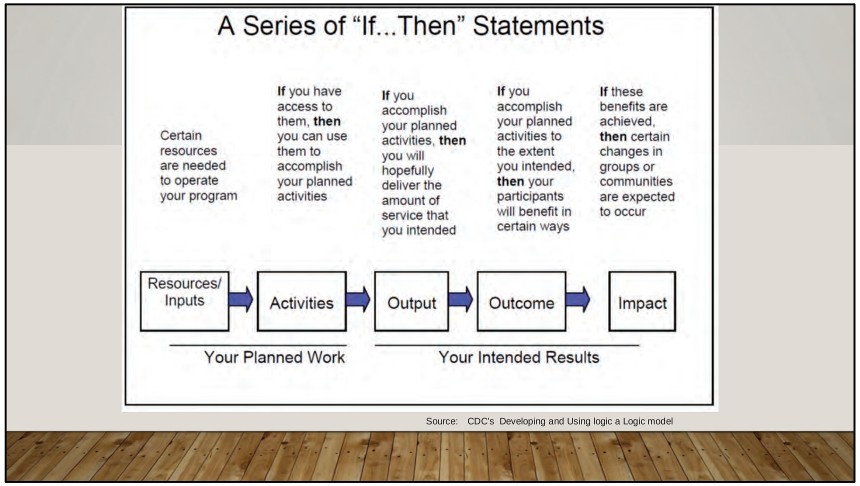
The GCF has provided a standard diagram that is relatively easy to fill in and it basically moves from the understanding of that inputs will allow activities to be carried out that will deliver project outputs which in turn will meet the immediate purpose of the project and contribute to the longer term goal that GCF is trying to achieve through its overarching paradigm shift.
Importantly, the goal statement also operates on a logical basis and says if we carry out activity X then we achieve output Y because we have undertaken a series of inputs.

LEVELS OF THE LOGIC MODEL

Impact level	Societal change?	Aggregate changes achieved in the GCF key strategic results areas
Outcome level	What changes?	Aggregate changes achieved in the country or region, as well as in the relevant policies and policy documents
Output/project result	What deliverables?	Changes achieved as a result of project or programme activities
Activity	How to deliver results?	Direct services provided through GCF investments
Input	What is needed?	GCF grants, concessional loans, guarantees or other financial instruments, as well as human effort

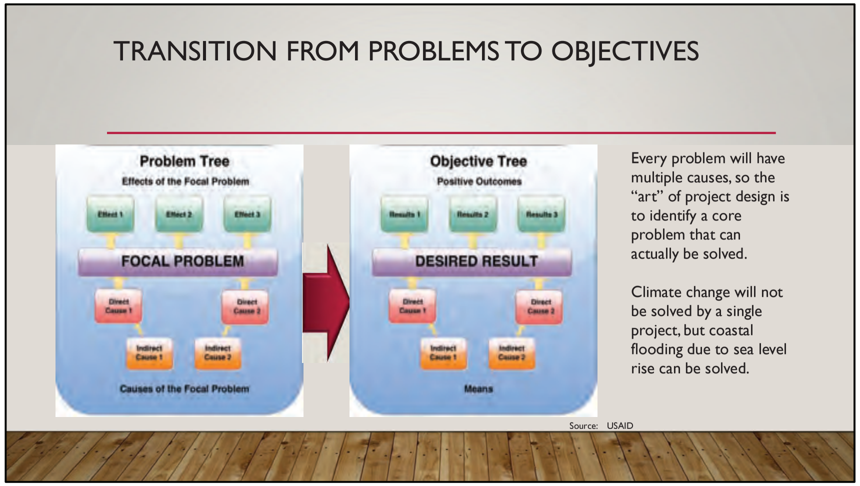
And there are different levels of the logic model that apply in the theory of change. At the impact level, which is the highest level, we're actually looking for societal change. What are the aggregate changes achieved in the GCF key strategic result areas?

At the outcome level, we're asking what changes? What changes are achieved in the country or region or project area, as well as in the relevant policies and policy documents at the national level? At the output or project result level we're really asking what are the tangible deliverables that the project will provide?
What are the changes achieved as a result of a project or programme activities?
At the activity level we're asking the question how do we deliver the results? And these are the direct services provided through GCF investments. And at the input level we ask what is needed to deliver the results?
These can be the GCF grants, concessional loans, guarantees or other financial instruments as well as the human effort that goes into project implementation.



And the logic that underpins the theory of change is that you need certain resources to operate your programme or your project.
These are the inputs and if you have access to these inputs then you can use them to accomplish your planned activities. And if you accomplish your planned activities, then you will hopefully deliver the amount of products and or services that you intended as part of your project design.
And these are the outputs. And if you accomplish your outputs and planned activities to the extent you intended, then your participants or beneficiaries will benefit in certain ways. These are your outcomes.

And if these benefits to the participants and outcomes are achieved, then certain changes in organisations, communities or systems might be expected to occur and contribute to the impact that the GCF is looking for.



Now every problem will have multiple of course.

So the art of project design is to automatically identify a core problem that can actually be solved. Climate change is so enormous and so all encompassing it cannot be solved by a single project. But coastal flooding in a specific area due to sea level rise is something that can be solved through an adaptation project.
So it's really important then to identify a problem which is solvable and then the desired result is something which is actually achievable.

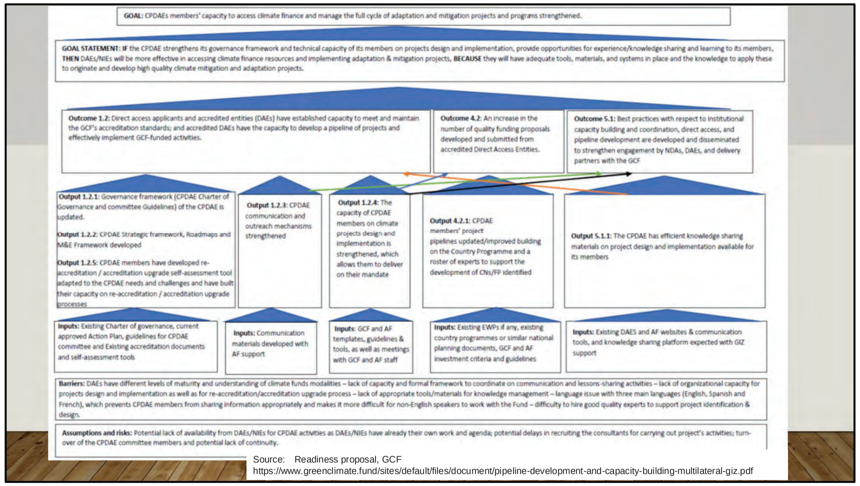
GOAL	Sustaining community resilience to climate change risks
GOAL STATEMENT	IF communities have access to safe shelter, water and food supplies all year-round and adopt climate resilient practices in their daily lives THEN community resilience can be sustained BECAUSE they are better prepared for climate change risks
RESULTS (Fund level) – defined by GCF	• A1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions • A2.0 Increased resilience of health and well-being, and food and water security • A3.0 Increased resilience of infrastructure and the built environment to climate change
OUTCOMES (Fund level) – defined by GCF	• A5.0 Strengthened institutional and regulatory systems for climate-responsive planning and development • A6.0 Increased generation and use of climate information in decision-making • A7.0 Strengthened adaptive capacity and reduced exposure to climate risks • A8.0 Strengthened awareness of climate threats and risk-reduction processes
RESULTS (Project level) – defined by the project	• An effective island /district and community development and CCDRR plans • Community-driven climate resilient interventions are implemented and sustained • Strengthened capacity of the Local Government and NGOs /CSOs to support community-based adaptation measures • Strengthened leadership in climate change and disaster risk reduction within the Local Government, NGOs /CSOs and the Community • An operational and effective community-based small grants programme

Here is a fairly typical narrative type approach for a theory of change. It starts with an overarching goal which is sustaining community resilience to climate change risks. It has this if then because goal statement if communities have access to safe shelter, water and food supplies all year round and adopt climate resilient practices in their daily lives, then community resilience can be sustained because they're better prepared for any future climate change risks.

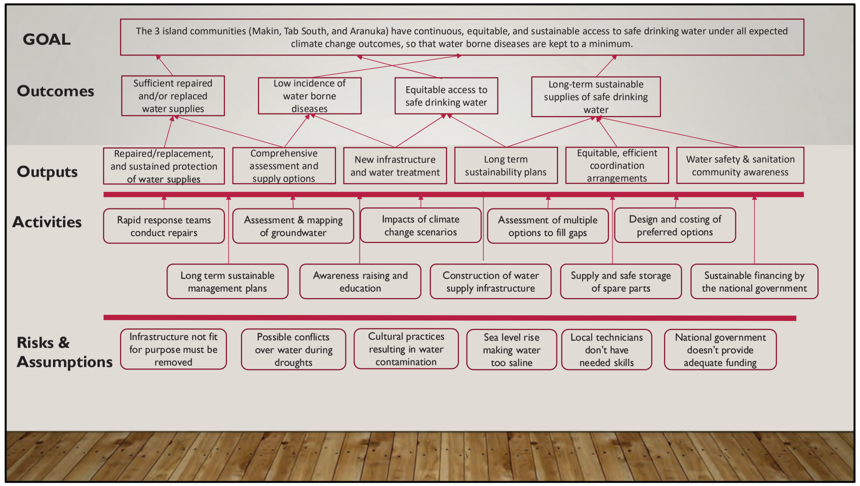
And the results which are at the fund level and defined by the GCF are increased resilience and enhanced livelihoods, increased resilience of health and wellbeing, food and water security, increased resilience of infrastructure and the built environment to climate change and these are defined by the GCF and must be reflected in the project design.

Similarly, at the outcome level these are also defined by the GCF and in this case would be a 5.0 through to a 8.0 relating to strengthened institutional and regulatory systems, increased generation and use of climate information, strengthen adaptive capacity and reduced exposure to climate risks and strengthen awareness of climate threats and risk reduction processes.

And the results are actually defined at the project level and are defined by the project proponent and these may be things like an effective island or district and community development with climate change and disaster risk reduction plans. Community driven climate impact interventions are implemented and sustained.
Strengthen capacity of local government and NGOs, strengthen leadership in climate change and DRR within the local government, and an operational and effective community based small grants programme to provide the funding to carry out these interventions.



I won't go through the detail of this particular slide is simply to show the kind of diagrammatic format that the GCF is looking for.
In addition to the narrative type approach for the theory of change.



Here is another version, a simpler version of that rather complicated theory of change.
And here you can see that there is a logical connection between the various activities, the intended outputs, the outcomes and the ultimate goal of the project. And below the line there are the risks and assumptions that underpin the project design.

So I'll leave it there and thank you for your attention. I hope this has given you some insight into what is a theory of change and how important it is in designing a bankable project, particularly for the GCF.

CBCRP-PCCC Training Course

“Enhancing climate resilience and safe water access in rural areas in the Pacific”

Government of Samoa, SPREP and JICA

Module 3. Problem and Objective trees and logical framework

3.2 Project objectives

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1. Introduction
2. Problem tree
3. Objective tree
4. Logical framework
5. Summary

2

Introduction

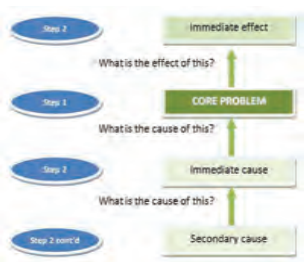
- In formulating *a climate change adaptation/ mitigation project*, the theory of change and the **logical framework** are key elements.
- They are described as tools of logic that connect cause and effect.
- All projects are designed to overcome a problem, but problems may have multiple causes.
- How do we know if we have identified the **core problem** and the **main causes**?
- All projects are intended to achieve a purpose or a goal and if it fails to achieve that end point (or ultimate effect) then the project is regarded as a failure. In the case of climate change adaptation projects, failure may also result in maladaptation.
- This session is intended to help you come to the right decisions that will lead to a convincing logical framework that will guide successful implementation.

In formulating any climate change adaptation project, the theory of change in the logical framework are key elements but what do they really mean? They're described as tools of logic that connect cause and effect but how do we uncover those connections? Now all projects are designed to overcome a specific problem, but problems may have maltiple causes so how do we know if we have identified the core problem and the main causes? Again all projects are intended to achieve a purpose or a goal and if the project fails to achieve that in point or ultimate effect.
Then, the project is regarded as a failure. In the case of adaptation projects, failure may also result in what's called maladaptation or the opposite to what is expected. So, this session is intended to help you come to the right decisions that would lead to a convincing theory of change and a logical framework that will ultimately guide successful implementation.

Brainstorming a "Problem Tree"

Starting point: construct a **problem tree** that links causes and effects

1. Define "**core problem**"
   - Displacement due to flooding
   - Water/sanitation deficiencies
2. Identify **direct causes** and **direct effects**
   - Cause- Heavy rains
   - Cause- Overburdened infrastructure
   - Cause- Settlement in flood prone areas
   - Cause- Obstructed drains
   - Effect - Increased vulnerability
   - Effect - Damage to infrastructure
3. Identify **secondary (indirect) causes**
   - Rural-urban migration
   - Lack of planning
   - No responsible lead agency
   - Inadequate urban finance



Source: USAID

We start off with brainstorming a problem tree. A problem tree is something that links causes and effects. It basically has 3 steps. The first step is to define what is a core problem you're trying to solve. It could be something like displacement due to flooding or it could be water or sanitation deficiencies. Then, you identify the direct causes and the direct effects. The cause of flooding could be heavy rains or could be overburdened infrastructure or it could be settlements in flood-prone areas or obstructed drains. The effect could be an increase of vulnerability of communities or could be damage to roads and other infrastructure.
Then, the third step is to identify the secondary or underlying driving causes. These could be issues like so many people are moving from rural areas to urban areas, could be a lack of urban planning, could be that there is no responsible lead agency driving the process, or it could be that there is inadequate urban finance. The secondary cause leads to the immediate cause. The immediate cause leads to the core problem, and the core problem leads to the immediate effect. That's the logical chain of events that underpins a problem tree.

Brainstorming

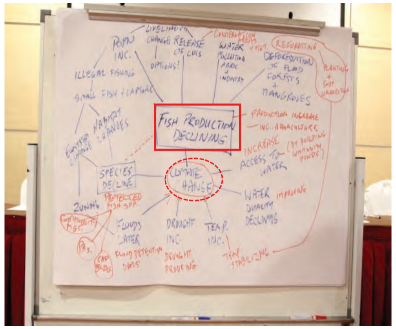
- Break participants into small groups.
- Prepare flipcharts, post-it notes, marker pens, and a table to spread out.

- Step 1. Consider what you think **the main problem** is.
- Step 2. Analyse what is **the main cause** of that main problem.
- Step 3. Check if there is **any other cause** of that direct cause.
- Step 4. Re-arrange all the answers in a tree.
- Step 5. Do the same for the effects, identify the **direct effects** and **indirect effects** of that main problem.

- You will be asked to do the same in an exercise in this training course**.**

Now to get to the problem tree. The best way of doing this is through brainstorming.
With breaking participants into relatively small groups so that every voice is heard making sure that they're all well equipped with flip charts, post-it notes, marker pens and a table to spread out on. And you start by asking each person what they think the main problem is and write down their answers on a post-it note. In a second-round ask each person what they think is the main cause of that core problem, and in the third round ask if there is any other cause of that direct cause. You rearrange all the answers in the form of a tree with roots and a trunk and some branches, starting off with a consensus on what you believe to be the main or the core problem. Step back from that and check if any key cause has been missed. Now do the same for the effects starting with the direct effects and then possibly secondary or indirect effects.
Now take note of these directions because later on in the course you'll actually be asked to do this in an exercise.

The problem tree is the "engine" of the project design



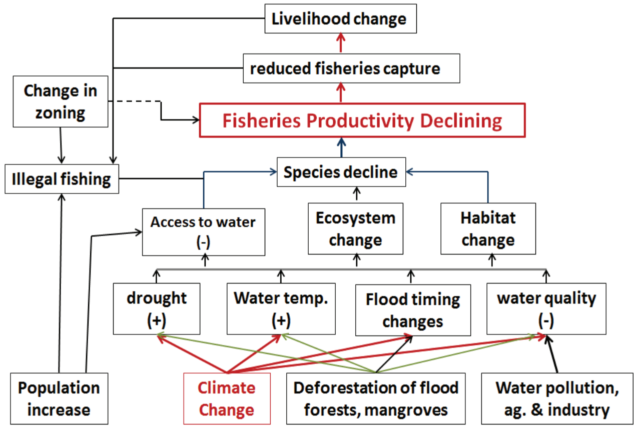
Source: USAID

- Involve the project beneficiaries and ask them to brainstorm about what they think the problem is.
- Do not assume you know what the real problem is.
- Do not start from an assumption that climate change is the problem.

Useful tips:
- It is critical to identify the core problem right in formulating a project.
- Avoid including contributing causes in the core problem statement.
- Identify one most important issue as the core problem, and avoid including multiple elements in the core problem (e.g. property damage due to severe floods).

Now the problem tree is really the engine of the project design and it's always advisable to involve the project beneficiaries and ask them to brainstorm about what they think the problem is. As an expert don't assume you know what the real problem is. You may not have sufficient local knowledge. And don't start from an assumption that climate change is a problem simply because you're preparing a concept note for the GCF. In this particular case that I've shown here where the brainstorming is very messy, the participant started with an assumption that
climate change was the core problem but as the brainstorming progressed it was realized that actually the core problem was a decline in fish productivity and climate change was really just one of multiple causes.

Reorganise the messy brainstorming



Source: USAID

Once you've done that then it's always good to try and reorganize the messy brainstorming approach into something which ultimately could go into a project document and demonstrate some clear thinking in terms of what are the causes, what is the core problem and what are the effects.

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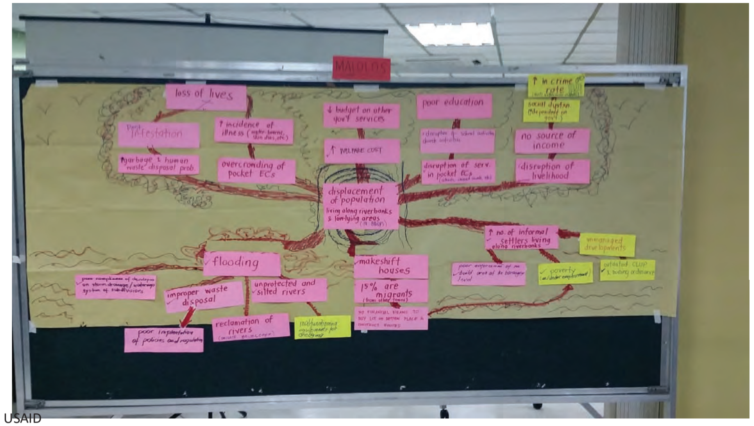
Use post-it notes to move things around



Source: USAID

Now the reason we suggest to use post-it notes is so that you can move things around on the roots and branches of the tree that enables you to organize your thoughts in a more logical fashion.

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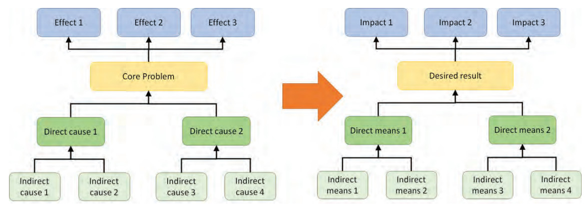
Transition from Problem tree to Objectives tree



- Every problem will have multiple causes.
- The "art" of project design is to identify a Core Problem that can actually be solved.
- Climate change will not be solved by a single project, but an eroding coastline due to sea level rise can be solved.
- Solving the Core Problem will provide the desired result at the end of the project. This result will contribute to other positive outcomes and long-term impacts.

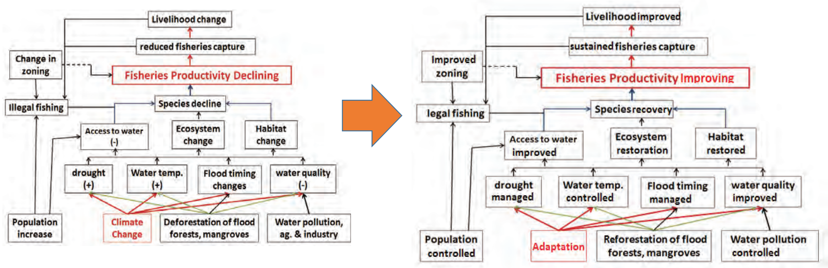
Tips:
- Problem tree and objectives tree are mirror images of each other – one negative, the other positive.
- The Means you identify in the Objectives Tree will be the basis of Project Activity in your Logical Framework.

Source: USAID

Once we have a problem tree worked out, it's relatively simple to transition from a problem tree to an objectives tree. Every problem will have multiple causes so the art of project design is to firstly identify your core or focal problem that can actually be solved. Climate change is a global problem, it is not going to be solved by a single project but an eroding coastline in a specific location due to the sea level rise can be solved. Now solving the core problem will provide the desired result at the end of the project, but that result in turn will contribute to other positive outcomes and long-term impact beyond the scope of the specific project.

An Objectives Tree

- Objectives trees transform all problems from your Problem Tree into an objective – Each negative problem will become a positive objective.
- Each cause can be transformed into a possible project activity or component. For example, water pollution control or reforestation could be key activities.



Source: USAID

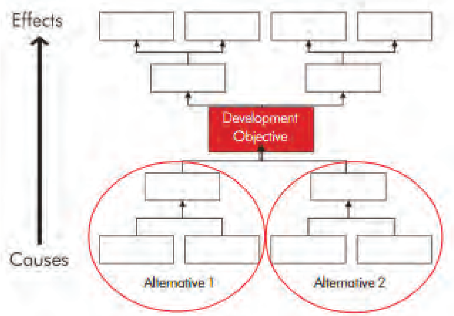
We come up with an objectives tree by basically transforming all of your problems from your problem tree into an objective. So each negative problem is then turned around to become a positive objective. And note again that climate change might not be the core problem but it could be one of the contributing objectives. Below the core result or project output, each cause can be transformed into a possible project activity or component. For example, in this objectives tree, water pollution control, reforestation or ecosystem restoration could be key activities that ultimately contribute to species recovery and the improvement in fisheries productivity.

Check that no critical cause or effect has been missed

- Once your problem tree and objectives tree have been completed, stand back and discuss if anything has been missed or if a specific cause or effect is too minor to include.
- In the fisheries productivity example, one of the key elements that the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries.
- If this capacity issue was not addressed, then the whole project could fail. Later on we will see why the logical framework would have included this as a potential risk or assumption.

Once your problem tree and your objectives tree have been completed, stand back, have them side by side and discuss if anything is being missed or if a specific cause or effect is too minor to include. In the fisheries productivity example, one of the key elements with the brainstorming missed was the lack of capacity in the local compliance and enforcement agency, which was a contributing cause of the water pollution problem, the deforestation problem, and inadequate control of the illegal fishing. This omission could have been because the brainstorming group did not include people outside the government or potential beneficiaries. Now if this capacity issue was not addressed, then the whole project could fail and later on we'll see why the logical framework would have included this as a potential risk or an assumption.

Use the objectives tree to decide on project alternatives



- There may be several alternative ways that a project can contribute to the development objective.
- The objectives tree can help to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective.
- In some cases, the objectives tree might highlight the possibility of complementary projects that will combine to reach the central development objective.

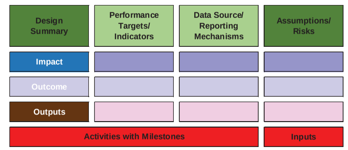
Useful tips:
- Direct Causes and Indirect Causes you identified in the Objectives Tree can be the basis of your Logical Framework (transformed as Project Activity and Inputs).
- You can put only the selected Causes in your Logical Framework which are relevant to your project objectives.

Source: ADB

Now we can also use the objectives tree to decide on project alternatives. There are often several alternative ways that a project can contribute to the development objectives. The objectives tree can help you to illustrate these alternative pathways and lead to a consensus on which one shows the most promise for reaching the central development objective. In some cases, the objectives tree might also highlight the possibility of complementary projects that will each combine to reach the central development objective.

Logical Framework

- A logical Framework is also called:
  - Project Framework
  - Logframe
  - Project Decision Matrix
  - Results Framework
  - Design and Monitoring Framework



Source: ADB

- Standard sections:
  - **Four Columns** – Design Summary (Description), Performance Targets, Monitoring Mechanisms, and Assumptions and Risks;
  - **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Note hierarchical "logical" relationships vertically and horizontally, link all 20 frames.
- **Inputs** allow **activities** to be carried out that will deliver project **outputs**, which in turn will meet the immediate purpose (**outcome**) of the project and contribute to the longer-term **goal**.

Now turning to the logical framework, sometimes is also called the project framework or shortened to logframe. Sometimes it's called a project decision matrix, a results framework or a design and monitoring framework. These are essentially different terms for the same matrix. There are standard sections. There are four columns: a design summary or description, performance targets, monitoring mechanisms and assumptions and risks. And there are 5 rows: the goal, the purpose sometimes called an outcome, outputs, activities and inputs. So note that there is a hierarchical logical relationship both vertically and horizontally that links together all 20 frames of the logical framework. A way to understand this is that the inputs allow activities to be carried out that will deliver the project outputs, which in turn will meet the immediate purpose of the project and contribute to the longer-term goal.

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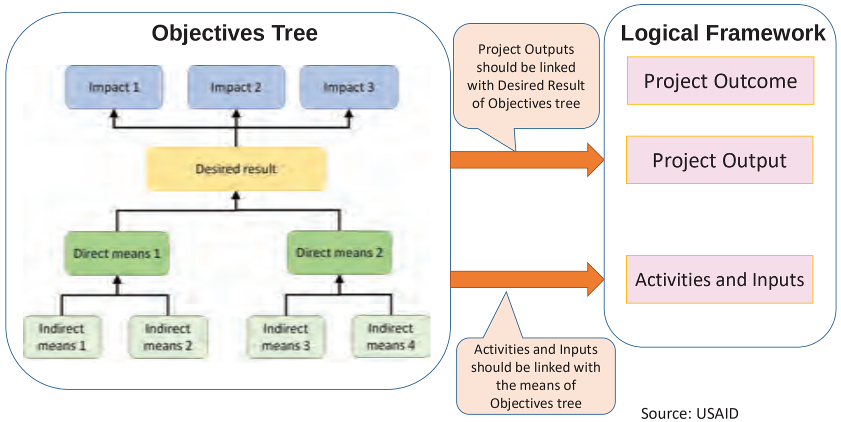
Develop the Logical Framework from the Objectives Tree



Source: USAID

Going from the objectives tree to the logical framework is a simple process where the means in the objectives tree are basically what becomes the inputs and activities that lead to the end of project outputs, which is the same as the desired result of the objectives tree. The purpose or outcome and the goals or impacts of the extension beyond the project boundary is equivalent to the results both direct and indirect that come from the objectives tree.

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Logical framework approach of Green Climate Fund (GCF)

H.1.1. Paradigm Shift Objectives and Impacts at the Fund level[1]							
Paradigm shift objectives							
Increased climate resilient sustainable development	Please elaborate on the paradigm shift objectives to which the project/programme contributes.						
Expected Result	Indicator	Means of Verification (MoV)	Baseline	Target Mid-term (if applicable)	Target Final	Assumptions	
Fund-level impacts							
Choose appropriate expected results	Please select relevant GCF indicators from the Fund's performance measurement framework. More than one indicator may be selected per expected impact result.						

In this Logframe template (version 2.0), GCF specifies the ultimate goal (paradigm shift), fund-level impacts, and core indicators.
In addition to the core indicators, GCF also suggests additional indicators at:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
https://www.greenclimate.fund/document/integrated-results-management-framework

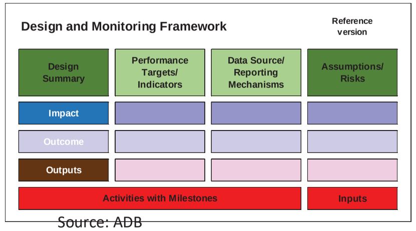
Paradigm shift objective: Increased climate resilient sustainable development
Fund-level impacts (adaptation):

- ✓ 1.0 Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions
- ✓ 2.0 Increased resilience of health and wellbeing, and food and water security
- ✓ 3.0 Increased resilience of infrastructure and the built environment to climate change threats
- ✓ 4.0 Improved resilience of ecosystems and ecosystem services

Core indicators (for adaptation): e.g. Total Number of direct and indirect beneficiaries; Number of beneficiaries relative to total population; Number and value of physical assets made more resilient to climate variability and change, considering human benefits (reported where applicable)

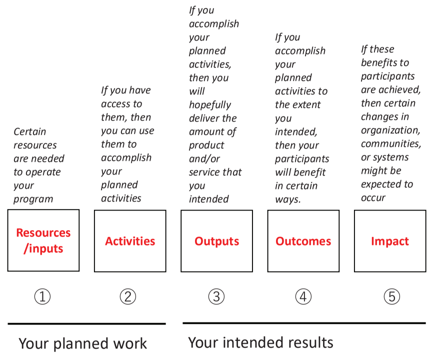
The way the Green Climate Fund approaches the logical framework is worthwhile getting a better understanding as you will often be involved in looking at this framework. The first thing to note is that the ultimate objective or the impact that is intended is specified as a paradigm shift objective of the GCF. Given that the overall mandate for the GCF is a paradigm shift. In the case of an adaptation project, this is increased climate-resilient sustainable development. The GCF also defines fund level impacts and in the case of an adaptation project, there are basically four of these:
increased resilience and enhanced livelihood with the most vulnerable people, communities and regions, increased resilience of health and well-being and food and water security, increased resilience of infrastructure and the built environment to climate change threats, or improved resilience of ecosystems and ecosystem services. Now for each of these impacts GCF has also indicated a number of core indicators. In the case of an adaptation project, it is the total number of direct and indirect beneficiaries plus the number of beneficiaries relative to the total population.
It could also be the number in value of physical assets made more resilient to climate variability and change considering human benefits where applicable. Note that GCF specifies the ultimate goal, the fund level impacts and the core indicators. In addition to these core indicators, the GCF also suggests

Performance targets



Source: ADB

- ➢ To ensure that each design "element" is implemented as planned, performance **targets** are specified, as are the mechanisms for **measuring** these targets – plus the **risks** that could upset achievement are explicitly recognized and assumed to be mitigated (by another project, by the government agency, or by other means).
- ➢ Unmitigated or unforeseen risks could torpedo an otherwise well-developed project.



In relation to performance targets, it's important to ensure that each design element is implemented as planned. So, performance targets are specified as well as the mechanisms for measuring those targets. Then in turn, the risks that could upset achievement are explicitly recognized and assumed to be mitigated either by another project, by the government agency or by other means. Unmitigated or unforeseen risks could actually torpedo an otherwise well-developed project. Another way to think about the logic of the logical framework is that your planned work will consist of the resources and inputs that you have available to operate your program. These contribute to a certain number of activities, so if you have those inputs, you can use them to accomplish your planned activities. These in turn lead to your intended results. Firstly, if you accomplish your planned activities, then you will hopefully deliver the amount of product or service that you intended at the end of the project. If you achieve those outputs, then you may benefit wider outcomes at your national level, at the regional level, or at the global level and if you achieve those outcomes
then you may be able to contribute in some way to much broader impact, such as the Paris agreement for example.

additional indicators and there is a website where you can see those additional indicators that you may use in your own project designs.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 7 and 8 of the document “Mitigation and adaptation performance measurement frameworks” for details.

Logical framework approach of GCF (cont.)

H.1.2. Outcomes, Outputs, Activities and Inputs at Project/Programme level

Expected Result	Indicator	Means of Verification (MoV)	Baseline	Target: Mid-term (if applicable)	Target: Final	Assumptions
Project/programme outcomes	Outcomes that contribute to Fund-level impacts					
Choose expected outcome	*Please select relevant GCF indicators from the Fund's performance measurement framework. More than one indicator may be selected per expected impact result.*					
Specify other expected results						
Specify other expected results						
Project/programme outputs	Outputs that contribute to outcomes					
1.						
2.						
3.						
Activities	Description		Inputs		Description	
1.1.			1.1.1.			
1.2.			1.1.2.			
2.1.			1.1.3.			
…			…			

Outcomes (for adaptation)**:**

- 5.0 Strengthened institutional and regulatory systems for climate responsive planning and development
- 6.0 Increased generation and use of climate information in decision-making
- 7.0 Strengthened adaptive capacity and reduced exposure to climate risks
- 8.0 Strengthened awareness of climate threats and risk reduction processes

Outputs, Activities, Inputs:
to be uniquely designed by the project

The latest template of GCF funding proposal and results management framework can be found at:
https://www.greenclimate.fund/document/funding-proposal-template
https://www.greenclimate.fund/document/integrated-results-management-framework

Moving further down in the logical framework to the outcomes. The GCF also specifies the outcomes. In the case of adaptation projects, these are again four: strength and institutional and regulatory systems for climate responsive planning and development, increased generation and use of climate information in decision-making, strengthened adaptive capacity and reduced exposure to climate risks, and strengthened awareness of climate threats and risk reduction processes. Then to go one step further down to the project or program outputs. These are left up to the program designer or the project designer to specify. Then you come down to the activities and a description of those and the inputs required to achieve each of those activities and again a description of those and that information then goes into your budget proposal.

Note:
https://www.greenclimate.fund/sites/default/files/document/mitigation-adaptation-performance-measurement.pdf
Please refer to page 9 and 10 of the document “Mitigation and adaptation performance measurement frameworks” for outputs examples of GCF.

addition to the core indicators, GCF also suggests additional indicators for the outcome level while leaving the project output targets and indicators to the project designers.

Summary of this presentation

- All projects are designed to overcome a problem, but problems may have multiple causes, so a **"problem tree"** helps to sort out cause and effect.
- Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that end point (or ultimate effect) then the project is regarded as a failure. An **"objectives tree"** helps to identify the means of achieving a desired result or **output** at the end of a project, as well as indicating the longer-term **outcomes** and impacts that the project can contribute to.
- The **objectives tree** is simply the mirror image of the problem tree, where all negatives are turned into positives. The objectives tree may also highlight alternative pathways to achieve the desired result as well as indicating the possibility of multiple, complementary projects.
- The objectives tree contributes the "bones" of the **logical framework**, which consists of **Four Columns** – Design Summary, Performance Targets, Monitoring Mechanisms, and Assumptions and Risks; and **Five Rows** – Goal, Purpose (Outcome), Outputs, Activities, Inputs.
- Most funding sources require a logical framework (or equivalent) as a crucial part of any project proposal. The Green Climate Fund (GCF) specifies the ultimate goal (paradigm shift), fund-level **impacts**, and core **indicators**. In addition to the core indicators, GCF also suggests additional indicators for the **outcome** level, while leaving the project **output** targets and indicators to the project designers.

To summarize, all projects are designed to overcome a specific problem but problems may have multiple causes, so a problem tree helps to sort out cause and effect.
Similarly, all projects are intended to achieve a purpose or a goal and if we fail to achieve that endpoint or ultimate effect then the project is regarded as a failure. An objectives tree helps to identify the means of achieving a desired result or output at the end of a project as well as indicating the longer-term outcomes and impacts that the project can contribute to in some small way.
The objectives tree is simply the mirror image of the problem tree where all of the negatives of the problem tree are turned into positives. The objectives tree also highlights alternative pathways to achieve the desired result of the project as well as indicating the possibility of multiple complementary projects to achieve the core objective. The objectives tree contributes
the bones of the logical framework which consists of 4 columns: a design summary, performance targets, monitoring mechanisms and assumptions and risks, and 5 rows: goal purpose, output activities and inputs giving a total of 20 elements that need to be filled in. Now most funding sources require a logical framework or its equivalent as a crucial part of any project proposal.
The Green Climate Fund specifies the ultimate goal, that is a paradigm shift, the fund level impacts, which they have pre-defined and the core indicators. In