REPORT ON COMPONENT 1 (ANNEX)

This Annex has been prepared by JICA in relationship to the Component 1 of the Project.

Climate Change Impact Assessment Summary for River Runoff

(1) Summary in Brantas River Basin

1) Impact on Water Resources

i. There is a relatively high degree of agreement among GCMs about the future direction of drought conditions over the entire basin. The ensemble mean change of low flows is around -15% by the 2050s, indicating severe drought conditions in the future climate.

ii. There is a relatively high degree of agreement among GCMs about the future direction of flood conditions over the entire basin. The ensemble mean change of top 2% of duration curve is around 10% by the 2050s, indicating severe flooding conditions in the future climate.

2) Impact on Flood Regime

i. The change in flood peak discharge is more significant than that of rainfall when the magnitude of the flood discharge is large, because water generally flows faster as its volume increases. The results indicate severe flooding conditions in the future climate.

ii. Projected land-use changes proved to have a negligible impact on the basin, because the change area is too small (less than 10%) to have an effect on flood discharge.

(2) Summary in Musi River Basin

1) Impact on Water Resources:

i. Annual rainfall will decrease very likely.

ii. Monthly averaged discharge will decrease in the first-half rainy season and the second-half dry season, whereas will increase in the second-half rainy season and the first-half dry season.

iii. Low flow discharge will likely decrease, whereas high flow discharge will likely increase.

iv. It is very likely that the drought period will become longer in future

v. The changes in ET and soil moisture, which are closely related with rice production, are very small.

2) Impact on Flood Regime

i. The range of projected flood changes is very wide. A scenario approach is effective for adaptation planning.

Long-term runoff analysis including a land use change scenario

1) Changes in the methodologies for the bias correction and downscaling of GCM output rainfall and the recalibration of WEB-DHM

In "The Project for Assessment and Integrating Climate Change Impacts into the Water Resources Management Plans for Brantas and Musi River Basins (Climate Change Impact Assessment and Hydrological Simulation)," [1] bias correction and downscaling methods have been used for river runoff simulations. However, when those methods are used for long-term river runoff simulations needed to develop climate change adaptation measures, the river runoff tends to be overestimated because localized intense rainfall events are assumed to be coinciding at different locations over the river basin. Overestimation of this sort causes negative impacts on designs for water resources infrastructure. To solve this problem, we used bias corrected rainfall obtained by applying the Gamma Distribution Function to GCM outputs and basin-averaged rainfall (BAR) derived from observed rainfall using the Thiessen method. The BAR was also used to re-calibrate WEB-DHM.

2) Impact assessment of land use change associated with the future expansion of plantations

Large-scale expansions of plantations mainly for rubber, palm oil and coffee are predicted in the Musi River basin, as shown in Figure 1. The impact of commercial crops on rainfall runoff depends on crop types and growth stages. Studies have reported that rubber plants consume a larger amount of water than natural vegetation[2] and that higher infiltration rates[3] are observed in coffee plantations. In palm-oil plantations, both saturated volumetric soil moisture and infiltration rate fall in the early growth stage and rise back up gradually as the plants near the maturity stage[4].

The vegetation type and soil parameter of each commercial crop are given in Table 1. The current and future vegetation type distributions are shown in Figure 1 and 1b, respectively. Figure 2 compares the results of the simulated hydrographs under the current and future land use. The flood analysis indicates that the land use change has some impact on the river runoff during the low flow period although its overall impact is negligible. Considering this result, we decided to include the impact of the land use change only in water-use simulations, but not in flood simulations.

Reference

1. JICA, the University of Tokyo and Nippon Koei Co., Ltd.: Final Report on "The Project for Assessment and Integrating Climate Change Impacts into the Water Resources Management Plans for Brantas and Musi River Basins (Climate Change Impact Assessment and Hydrological Simulation)", 2017
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3. P. de Gier, 2015, The impact of coffee-based agroforestry on the hydrology of the upper Genale River basin, Sidama Zone, Ethiopia, 31p. Utrecht University.
4. I. Comte, et al. 2012, Agricultural Practices in Oil Palm Plantations and Their Impact on Hydrological Changes, Nutrient Fluxes and Water Quality in Indonesia: A Review, Chapter 3, Advances in Agronomy, Vol. 116, Elsevier

	Growing Stage.	Vegetation Parameter(LAI)	Soil Parameter	
			theta_s	Ks_1
Rubber	All stage	Sib2 Type 1	Original value	Original value
Palm oil	Matured stage	Sib2 Type 4	Original value	Original value
	2nd stage		½ value	½ value
	Initial stage		¼ value	¼ value
Coffee	All stage	Sib2 Type 6	Original value	Double value
Other Crops	All stage	Sib2 Type 4	¼ value	¼ value
Temporary fallow	All stage	Sib2 Type 7	Original value	Original value

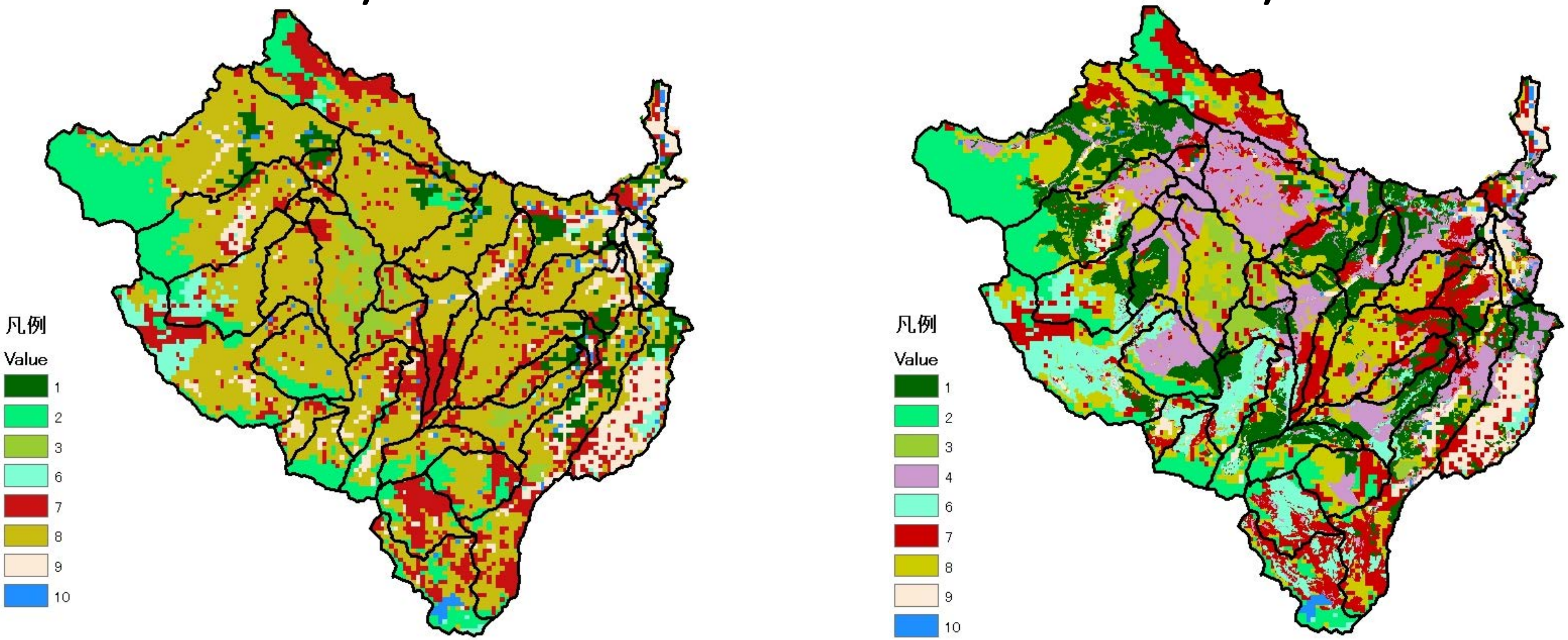
Sib2 Type:

Broadleaf Evergreen Trees	1	Short Vegetation/C4 Grassland	6
Broadleaf Deciduous Trees	2	Shrubs with Bare Soil	7
Broadleaf and Needleleaf Trees	3	Dwarf Trees and Shrubs	8
Needleleaf Evergreen Trees	4	Agriculture or C3 Grassland	9
Needleleaf Deciduous Trees	5	Water, Wetlands	10

Table 1 Vegetation type and soil parameters of each commercial crop

a) Current Land use

b) Future Land use



Sib2 Type:

Broadleaf Evergreen Trees	1	Short Vegetation/C4 Grassland	6
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Needleleaf Evergreen Trees	4	Agriculture or C3 Grassland	9
Needleleaf Deciduous Trees	5	Water, Wetlands	10

Figure 2 Current and Future Vegetation Type Distributions

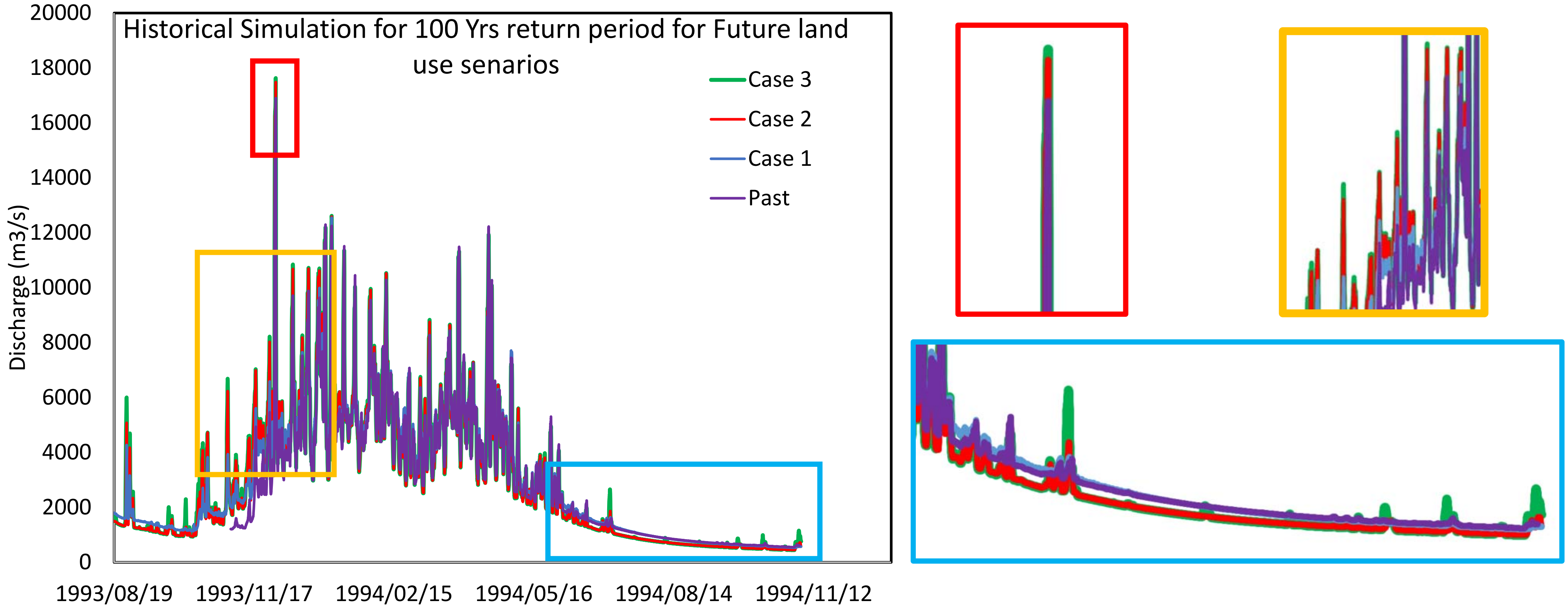


Figure 2 Inter-comparison among the simulated hydrographs under the current and future land uses. With regard to the changes of the soil parameters of palm oil: original values(case 1), ½ values (case 2), and ¼ values (case3).

Re-calculation of floods

As shown in Table 1, the Gumbel distribution function was selected as the best fitness function for the probability estimation of basin-averaged five-month rainfall by applying the standard least squares criteria (SLSC) to the bias-corrected GCM rainfall in the current (1985-2000) and future (2050-2065) climate. Considering the consistent order of the median and the 1st and 3rd quartiles shown in Figure 1, the following three GCMs were selected to represent High, Medium, and Low scenarios concerning future floods:

- GISS_AOM as High scenario (the most hazardous scenario)
- CCCMA_CGCM as Medium scenario (scenario of highest probability)
- GFDL_2_1 as Low scenario (the safest scenario)

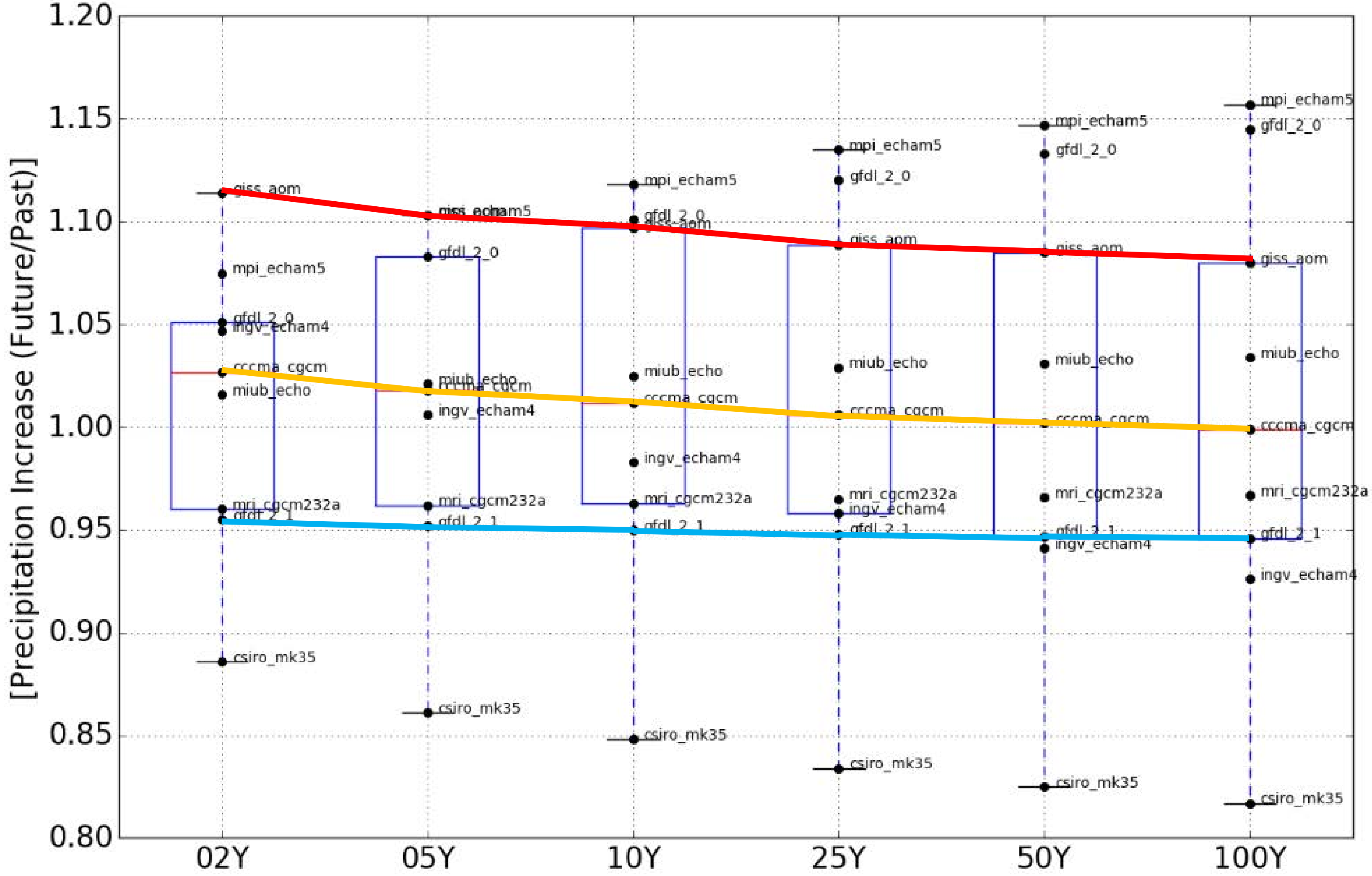
The stretch/shorten ratios for 2-, 5-, 10-, 25-, 50- and 100-year return periods (hereafter referred to as the T-year return period) for the present flood condition was calculated as a ratio of the five-month basin-averaged rainfall intensity for the T-year return period to the rainfall intensity of the actual maximum flood event from November 1993 to March 1994. By multiplying the above-mentioned ratio for each return period to the change ratio from present rainfall to future one derived from the selected GCMs, the stretch/shorten ratio for the T-year return period for the future flood conditions was evaluated. The calculated stretch/shorten ratios for the selected GCMs are summarized in Table 2. To get the T-year design rainfall, each value of Table 2 was multiplied by the rainfall record from November 1993 to March 1994. The T-year design flood for each selected GCM was simulated by inputting the T-year design rainfall into WEB-DHM. Figure 2 shows 100-year design flood hydrographs at the most downstream city, Palembang.

			Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM	Lexp	Gp	GpExp
SLSC(99%)	Past	CCCMA	0.073	0.058	0.061	0.058	—	0.056	0.055	0.052	0.054	0.052	—	—	—	—	—	—
		CSIRO	0.079	0.051	0.058	0.035	—	0.031	—	—	—	—	—	—	—	—	—	—
		GFDL_20	0.047	0.032	0.038	0.032	—	0.035	0.039	0.039	0.040	0.039	—	—	—	—	—	—
		GFDL_21	0.061	0.043	0.045	0.041	—	0.042	0.043	0.043	0.045	0.043	0.042	0.044	—	—	—	—
		GISS	0.077	0.055	0.058	0.052	—	0.050	—	0.050	0.053	0.050	0.051	0.051	—	—	—	—
		INGV	0.093	0.065	0.073	0.095	—	0.038	—	—	—	—	—	—	—	—	—	—
		MIUB	0.035	0.033	0.036	0.03	—	0.034	0.039	0.038	0.039	0.041	—	—	—	—	—	—
		MPI	0.105	0.077	0.079	0.049	—	0.042	—	—	—	—	—	—	—	—	—	—
		MRI	0.106	0.079	0.083	—	—	—	—	—	—	—	—	—	—	—	—	—
SLSC(99%)	Future	CCCMA	0.105	0.078	0.078	0.051	—	0.051	—	—	—	—	—	—	—	—	—	—
		CSIRO	0.087	0.060	0.075	0.039	—	—	—	—	—	—	—	—	—	—	—	—
		GFDL_20	0.083	0.053	0.061	0.034	—	0.026	0.030	—	—	—	—	—	—	—	—	—
		GFDL_21	0.110	0.081	0.089	0.048	—	0.040	—	—	—	—	—	—	—	—	—	—
		GISS	0.044	0.022	0.026	0.021	—	0.025	0.028	0.028	0.032	0.028	—	—	—	—	—	—
		INGV	0.073	0.050	0.052	0.045	—	—	—	—	—	—	—	—	—	—	—	—
		MIUB	0.056	0.043	0.042	0.042	—	0.048	0.050	—	0.054	—	—	—	—	—	—	—
		MPI	0.072	0.045	0.049	0.031	—	0.032	0.033	0.032	0.035	0.032	0.032	0.033	—	—	—	—
		MRI	0.130	0.106	0.107	0.056	—	—	—	—	—	—	—	—	—	—	—	—
SLSC(99%)	Past Average		0.075	0.055	0.059	0.049												
	Future Average		0.084	0.060	0.064	0.041												

Table 1 Selection of probability density function for the probability estimation of basin-averaged five month rainfall.

T-year return period	Large	Medium	Small
	GISS	CCCMA	GFDL_21
2	0.79	0.73	0.68
5	0.91	0.84	0.78
10	0.97	0.89	0.84
25	1.03	0.95	0.89
50	1.06	0.98	0.93
100	1.10	1.01	0.96

Table 2 Stretch/shorten ratio for T-year return period for the future flood conditions



High ：[giss_aom]　Medium ：[cccma_cgcm]　Low ：[gfdl_2_1]

Figure 1 Selection of three GCMs

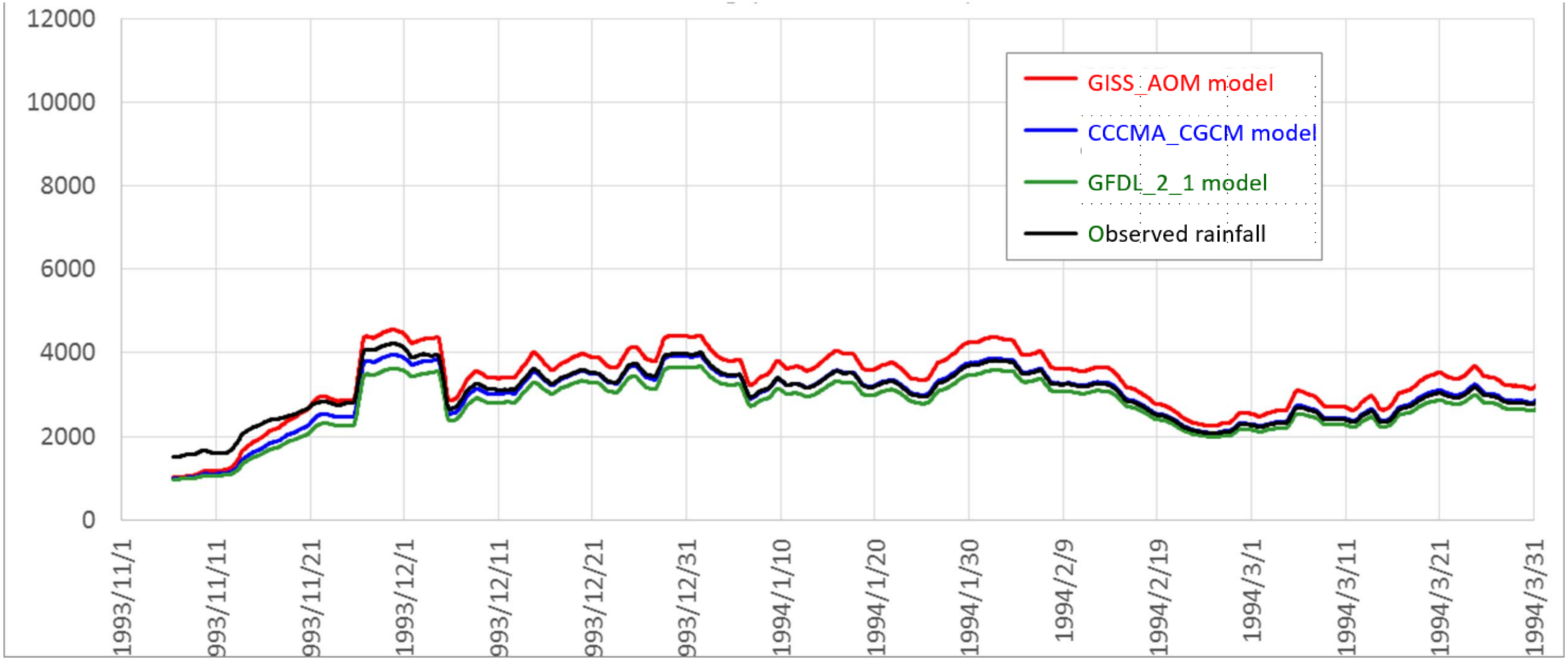


Figure 2 100-year design flood hydrographs at the most down-stream city, Palembang

Revised part on the “The Project for Assessment and Integrating Climate Change Impacts into the Water Resources Management Plans for Brantas and Musi River Basins (Climate Change Impact Assessment and Hydrological Simulation),” on Implementation of Impact Assessment for Rice Production by the Coupling Model

4.4.3 Implementation of Impact Assessment for Rice Production by the Coupling Model

(1) Simulation conditions

Three GCM scenarios, gfdl_2_0, gfdl_2_1, and ingv_enham4, were selected to predict future climate as mentioned in the previous section (Section 4.3.4). The scenarios consisted of predicted weather data for present and future, from January 1st 1985 to December 31st 2000, and from January 1st 2050 to December 31st 2065, respectively. Planted dates were set at November 1st (Days of Year <DOY> = 305) for rainfed, irrigated, and tidal swamp ecotypes in the rainy season and May 1st (DOY = 121) for all ecotypes in the dry season. These are the same as validations for the present climate. The technological coefficients were set as the values determined under the present climate, namely 1.065, 1.181, 0.821, and 1.130 for irrigated, rainfed, fresh water swamp, and tidal swamp ecotypes, respectively. The climate impacts for the future were assessed against the present both were generated by the GCM scenarios.

(2) Impact assessment

Simulated yields under present and future climates were shown in Figure 4.4.3-1 and 4.4.3-2 as examples, which were simulated under the GCM scenario gfdl_2_1. The simulation results were summarized in Figure 4.4.3-3. The yields under future climates decreased slightly in irrigated, fresh water swamp, and tidal swamp ecotypes due to higher temperature.

The effects of climate change were obvious in rainfed ecotypes in which yield was affected by precipitation through soil moisture. The yield simulated under GCM scenario gfdl_2_0 showed less standard deviation (yearly variation) in rainy season than that under the present climate. Larger yearly variation were predicted in dry season production under GCM scenario gfdl_2_1 and in rainy season under GCM scenario ingv_echam 4. The reduction was derived from lower average and larger standard deviation in soil moisture in the middle of rainy season, February and March (Figure 4.4.3-4). On the other hand, soil moisture remained high and stable at the beginning of dry season, May and June. If GCM scenarios gfdl_2_1 or ingv_echam 4 are true, adjustments to planting dates and growth duration are necessary.

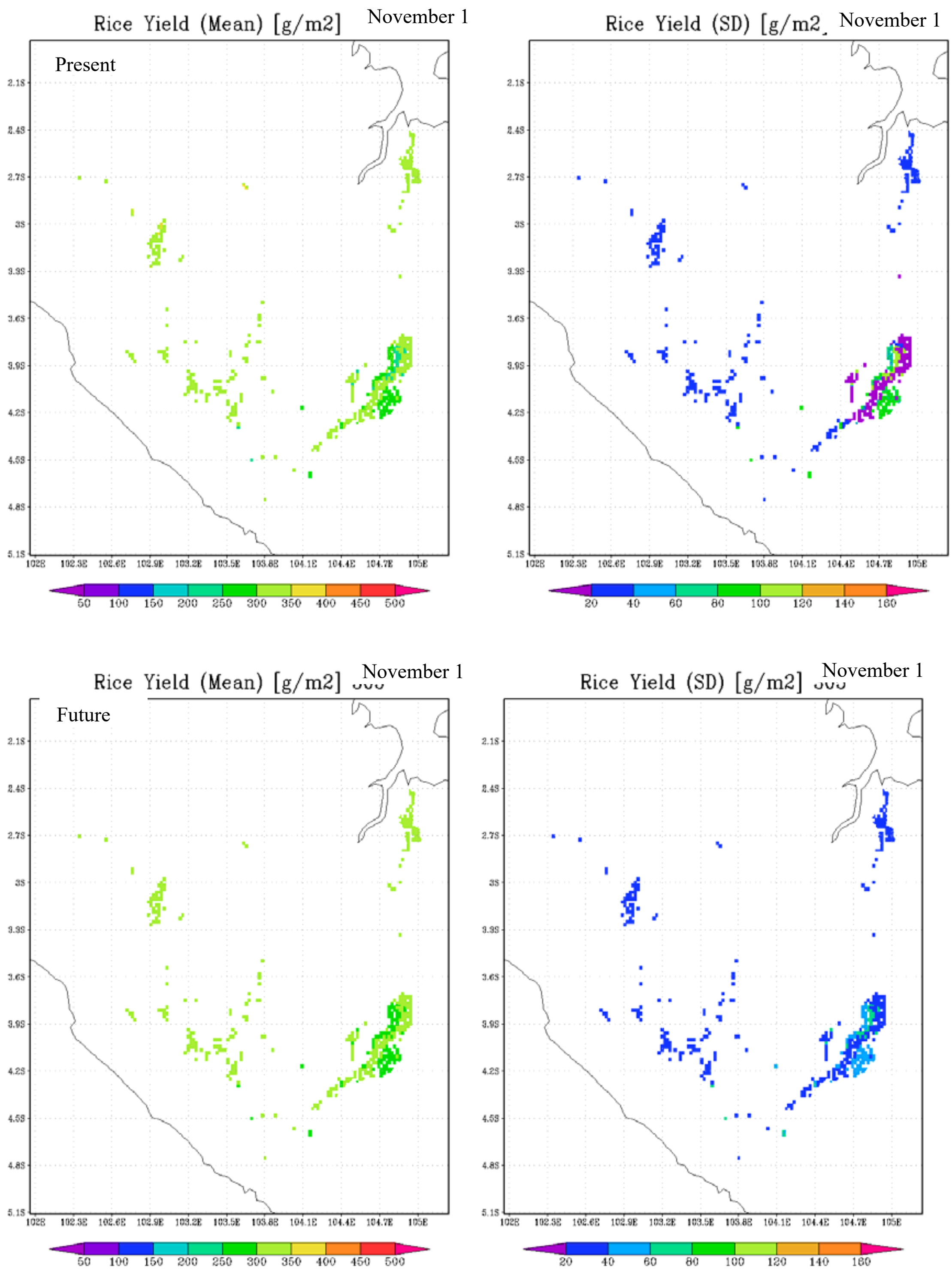


Figure 4.4.3-1 Distribution of simulated yields under the present (above) and future climate (below) in GCM scenario gfdl 2_1. Simulations were conducted for the period from January 1st, 1985 to December 31st, 2000 under the present climate conditions; and the period from January 1st, 2050 to December 31st, 2065 under the future climate conditions. Planting dates were set at November 1st

(DOY = 305, rainy season). The yields (left) and the standard deviation (right) were calculated for the period.

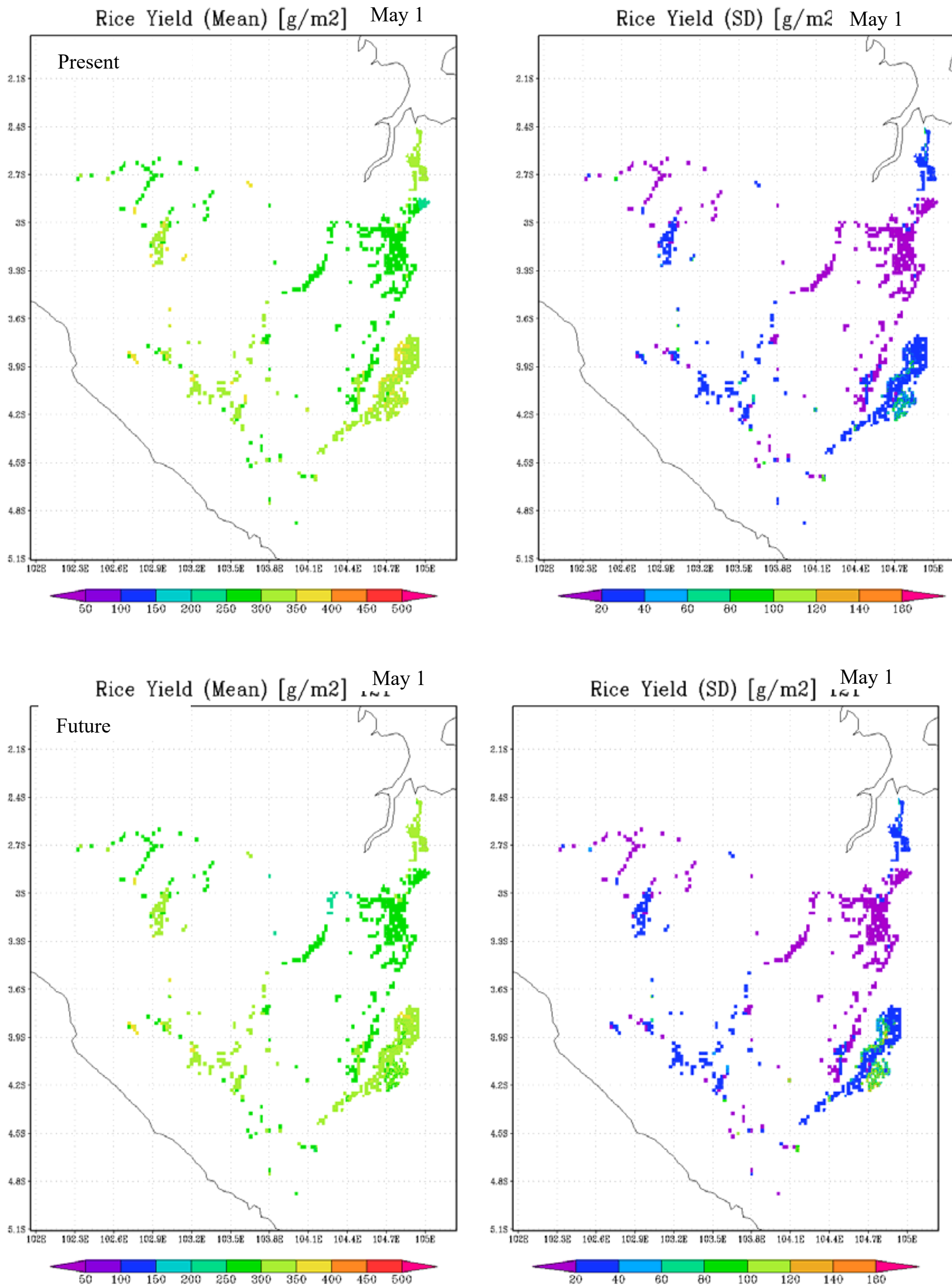


Figure 4.4.3-2 Distribution of simulated yields under the present (above) and future climate (below) in GCM scenario gfdl 2_1. Simulations were conducted for the period from January 1st, 1985 to

December 31st, 2000 under the present climate conditions; and the period from January 1st, 2050 to December 31st, 2065 under the future climate conditions. Planting dates were set at Mayr 1st (DOY = 121, dry season). The yields (left) and the standard deviation (right) were calculated for the period.

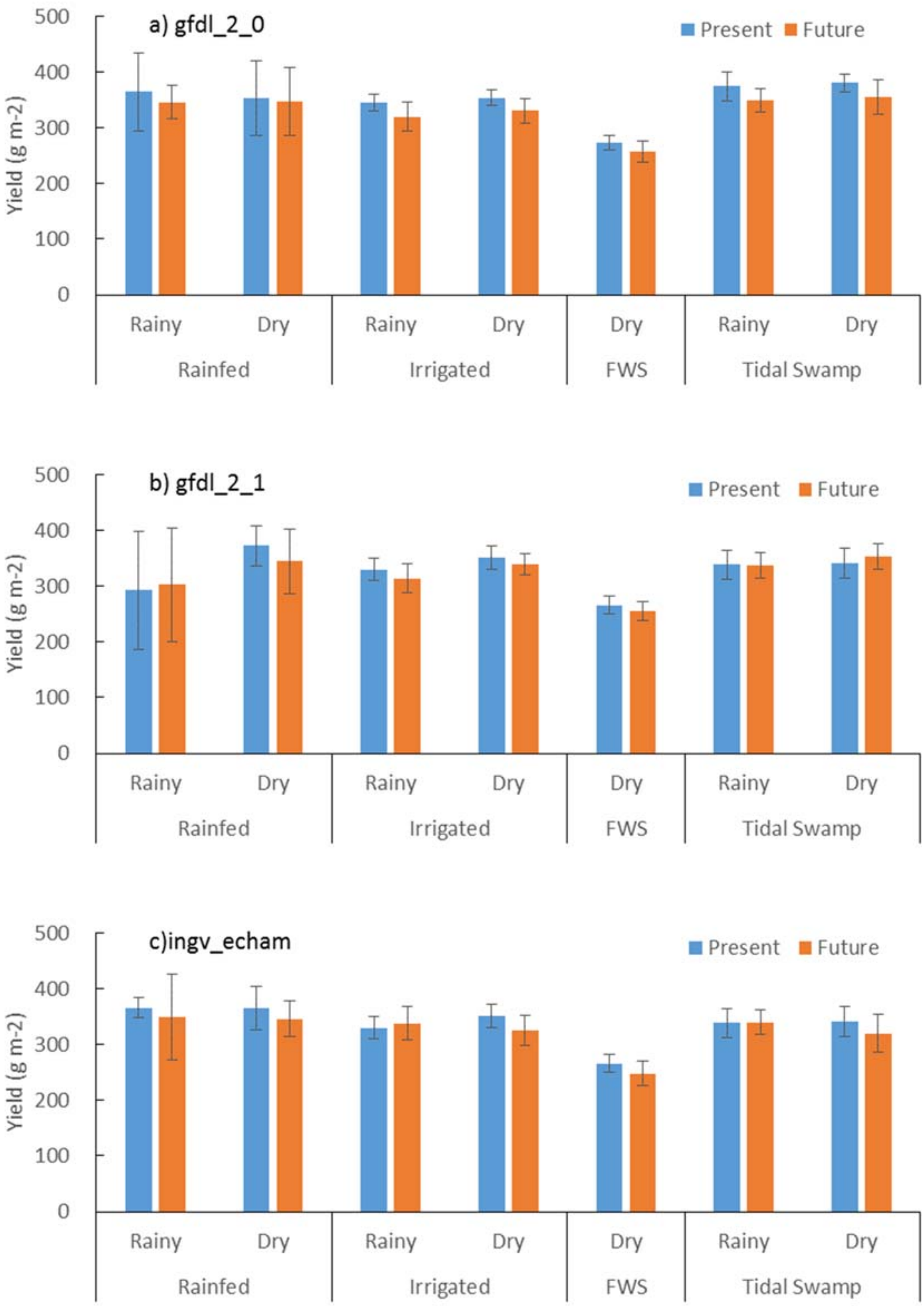


Figure 4.4.3-3. Simulated yields under future climates against those under the present climate by GCM scenarios, (a) gfdl_2_0, (b) gfdl_2_1 and (c) ingv_echam. Simulations were conducted for the period from January 1st, 1985 to December 31st, 2000 under the present climate conditions; and the period from January 1st, 2050 to December 31st, 2065 under the future climate conditions. Planting dates were set at November 1st (rainy season) and May 1st (dry season).

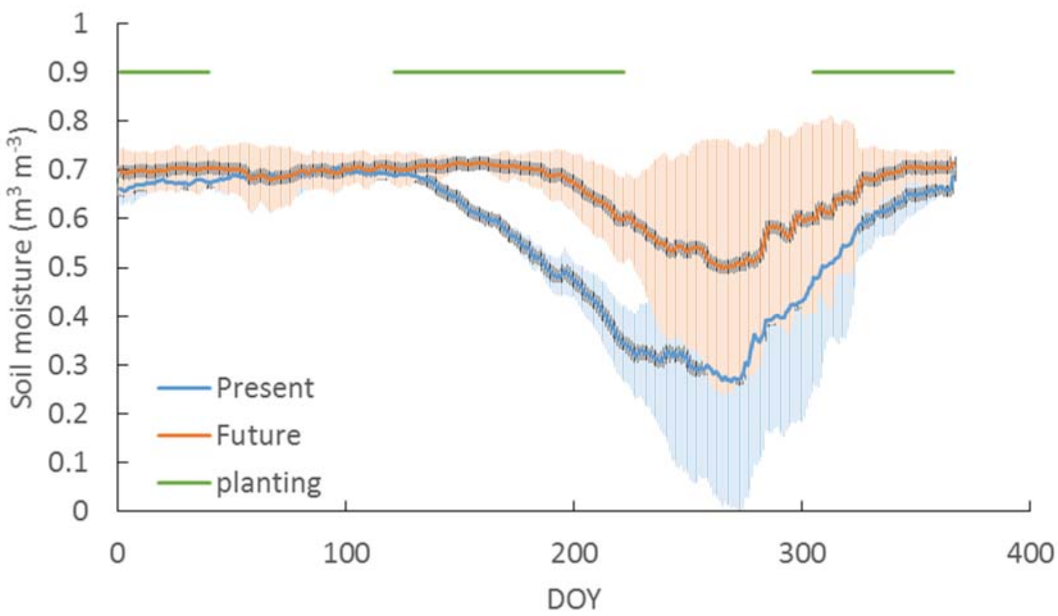


Figure 4.4.3-4 Comparison of soil moisture under present and future climates at Leumping (Rainfed ecotype). GCM scenario gfdl_2_1 was used. DOY: Days of year.

(3) Effect of planting management

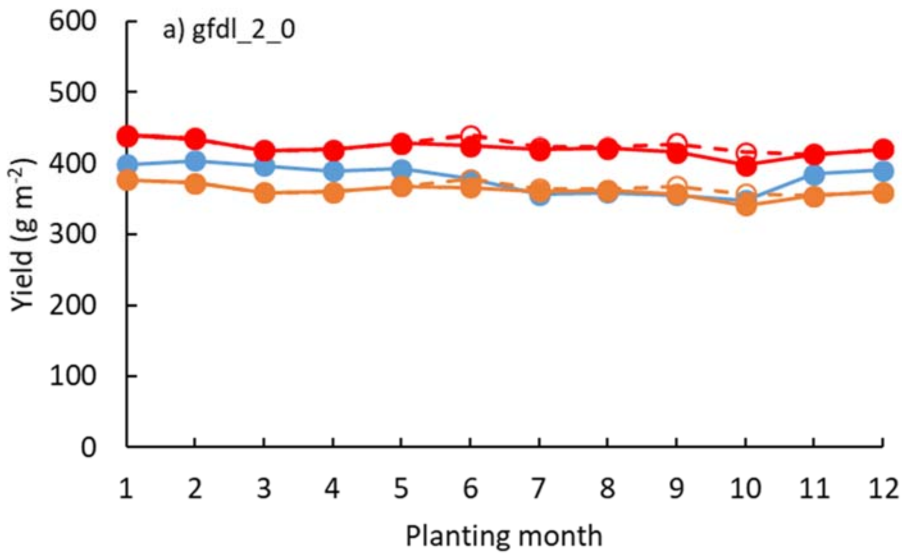
The effect of planting management was simulated for Leumping (Rainfed ecotype), where the largest climate change impact was predicted. Effect of planting month, increase of fertilizer and drought tolerant cultivar were simulated as the improvement of planting management. 20% increase of deeper root was assumed for drought tolerant cultivar.

Under gfdl_2_0 scenario, rice yield is almost constant whole a year. Although slightly lower yield was predicted for rainy season under future climate, the difference was almost derived from lower solar radiation and higher temperature. Since drought was not severe in this scenario, the effect of drought tolerant cultivar was also small.

Under gfdl_2_1 scenario, rice yield under future climate obviously decreased from that under present climate. The reduction could be compensated by 50% increase of fertilizer application in rainy season but could not in dry season due to severe drought. The present climate provides possibility of rice production even for planting in mid dry season (July to October), but the future climate may provide severe possibility of it. The simulation results shows any rice grain con not be obtained in 9 years for 15 years for the planting in mid dry season. The yield decrease by drought can be partly mitigated by the introduction of drought tolerant cultivar which increases rate of deeper root by 20%, but the effect of drought is still remains.

Under ingv_echam scenario, the results were similar to those under gfdl_2_1 scenario. However, yield difference in the rainy season was not clear. The yield reduction by drought was predicted under future climate but the reduction could be compensated by increase of fertilizer with introduction of drought tolerant cultivar.

Because rice yield is quite sensitive to solar radiation, the accuracy of prediction for solar radiation is quite important. However, change of solar radiation in future climate is not confident for GCM scenarios. Accordingly the yield difference in rainy season between under present and future climates is carefully considered. On the other hand, 2 of 3 GCM scenarios showed yield reduction in dry season under future climate due to severer drought problem. The reduction could be mitigated by selection of planting month or increase of fertilizer with introduction of drought tolerant cultivar. Since breeding of drought tolerant cultivar is time consuming work, the preparation is necessary based on the simulating results in this study.



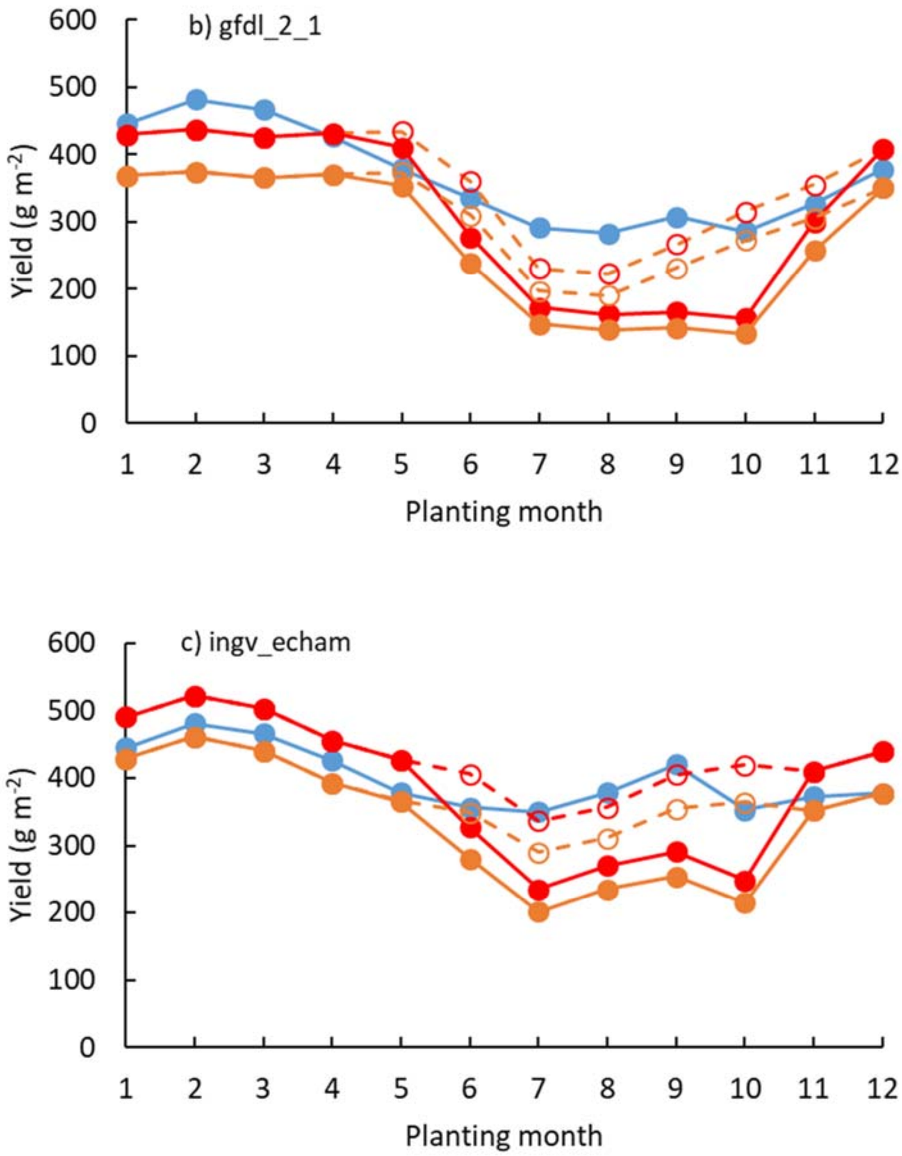


Figure 4.4.3-5 Effect of planting month on rice yield at Leumping (Rainfed ecotype) under GCM scenarios, (a) gfdl_2_0, (b) gfdl_2_1 and (c) ingv_echam. Simulations were conducted for the period from January 1st, 1985 to December 31st, 2000 under the present climate conditions; and the period from January 1st, 2050 to December 31st, 2065 under the future climate conditions. Planting date was set for the beginning of each month. ● Present management under present climate; ● Present management under future climate; ●+ 50% increase of fertilizer under future climate. ○Drought tolerant cultivar under future climate; ○Drought tolerant cultivar + 50% increase of fertilizer under future climate.

THE REPUBLIC OF INDONESIA
DIRECTORATE GENERAL OF
WATER RESOURCES
MINISTRY OF PUBLIC WORKS AND HOUSING

THE REPUBLIC OF INDONESIA

THE PROJECT FOR ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO THE WATER RESOURCES MANAGEMENT PLANS FOR BRANTAS AND MUSI RIVER BASINS

（Water Resources Management Plan）

HANDBOOK

December 2019

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.
THE UNIVERSITY OF TOKYO

Handbook
For
Assessing and Integrating Climate Change Impacts into
Water Resources Management Plans

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CHAPTER 1 Introduction

1.1 General

In Indonesia, the Water Resources Management Strategic Plan (POLA) and the Water Resources Management Implementation Plan (RENCANA) are being developed to properly manage water resources, based on Law No. 17/2019 on Water Resources and the Ministerial Regulation of "NOMOR 10/PRT/M/2015 TENTANG RENCANA DAN RENCANA TEKNIS TATA PENGATURAN AIR DAN TATA PENGAIRAN[1] (hereinafter referred to as "the Law" and "the Ministerial Regulation", respectively)". The Law and the Ministerial Regulation require to formulate POLA and RENCANA (hereinafter referred to as "the Water Resources Management Plans") corresponding to the impacts of future climate change.

In such a situation, " **The Project for Assessing and Integrating Climate Change Impacts into the Water Resources Management Plans for Brantas and Musi River Basins (**hereinafter referred to as "the Project"**)**" has assessed climate change impacts in 2050 in terms of vulnerability/risk and resilience of water resources and formulated proposals for reflecting climate change impacts in the Water Resources Management Plans, selecting the Brantas and the Musi River basins as pilot areas. In addition, the Project has prepared a handbook to be applicable to the Water Resources Management Plans for other river basins in Indonesia, taking climate change issues into account. The handbook is prepared, incorporating the knowledge and lessons accumulated in the course of the Project, as well as the approaches employed to project the future climate conditions and formulate the climate change adaptation measures for both river basins with a chief concept of formulating adaptation measures which aim to materialize less rework and less disaster risk and also place importance to spatial harmonization of their safety levels, for instance, between the areas along upper and lower river reaches, the areas on the left and right sides of a river and adjoining river basins among others.

1.2 Function of Handbook and its Relationship with the Ministerial Regulation

(1) Function

The handbook shall explain data/information, field survey/observation, assessment items, analysis methods, etc. which need not necessarily be used in the formulation of the Water Resources Management Plans under the present climate and were used in the Project in order to project the future climate conditions and formulate the climate change adaptation measures for both pilot river basins. Therefore, the handbook shall function as a practical guide in formulating climate change adaptation measures for other river basins in Indonesia.

(2) Relationship with the Law and the Ministerial Regulation

It is required in the Law and the Ministerial Regulation that the Water Resources Management Plans be formulated in consideration of climate change. Thus, to substantiate this, the handbook shall be referred to.

[1] No. 10/PRT/M/2015 REGARDING PLAN AND TECHNICAL PLAN OF WATER ARRANGEMENTS AND IRRIGATION SYSTEM

1.3 Items to be Treated in Handbook

(1) Applied river basins

It is proposed that the handbook be applied to the river basins, which have been managed under the jurisdiction of the Balai Beasr Wilayah Suengai (BBWS; Large River Basin Organization) organized in Directorate General of Water Resources (DGWR), Ministry of Public Works and Housing (MPWH), as the first phase and that those in the next phase be dependent on the policy of the Indonesian side, since the Japanese side is not necessarily familiar with all the river basins in Indonesia.

(2) Target year for future climate projection

This handbook is calculated based on the study by Japan International Cooperation Agency (JICA) on the Brantas-Musi River basins. There must be some discrepancies if it is used for other river basins and this handbook is calculated for impacts of climate change up to 2050. It is not necessarily to be applied in other river basins.

(3) Other items to be treated in the handbook

The handbook shall treat data/information, field survey/observation, assessment items, analysis methods, etc. which need not necessarily be used in the formulation of the Water Resources Management Plans under the present climate conditions and have been used in the Project in order to formulate the climate change adaptation measures for both river basins, as explained hereunder.

(4) Others

(a) To help clarify the linkage between the handbook and the Ministerial Regulation, each description in the handbook shall be provided at its end, as appropriate, with number(s) of relevant provision(s) between angle brackets to be referred to in the Ministerial Regulation.

(b) The work flow for assessing and integrating climate change impacts into the Water Resources Management Plans is referred to in the next page.

(c) The Project, which commenced in 2013, has been conducted in reference to the IPCC Fourth Assessment Report, so called “AR4”. Hence, it is important that the assessment reports to be issued in the future by IPCC shall be referred to as the need arises for the application of the handbook to the Water Resources Management Plans.

JICA
THE PROJECT FOR ASSESSING AND INTEGRATING CLIMATE CHANGE IMPACTS INTO THE WATER RESOURCES MANAGEMENT PLANS FOR BRANTAS AND MUSI RIVER BASINS

WORK FLOW OF STUDY ON CLIMATE CHANGE ADAPTATION MEASURES FOR WATER RESOURCES MANAGEMENT PLANS*

A. Data Collection and Compilation

B. Climate Change Impact Assessment

B-1 **GCM** Selection

B-2 **Bias Correction** and **Downscaling**

B-3 Climate Change Impact Assessment

C. Future Climate Scenario Selection and Probabilistic Analysis for Water Resources Management Plans*

C-1 **Future Climate Scenario** Selection (High, Medium & Low Scenarios)

C-2 Probabilistic Analysis of Rainfall and Discharge under Future Climate Scenarios

D. Integration of Climate Change Impacts into Water Resources Management Plans*

D-1 Assessment of **Safety Level** against Droughts and Floods under Climate Change Conditions

D-2 **Water Balance Analysis** and **Flood Inundation Analysis**

D-3 Assessment of **Risk** and **Resilience** for Droughts, Floods, Seawater Intrusion and Sediment Disasters in Water Resources Management under Climate Change Conditions

D-4 Reflection of Climate Change Impacts in Water Resources Management Plans*

D-4-1 **Optimization** of Existing Water Resources Management Facilities to Mitigate Climate Change Impacts on Rainstorms/Floods, Droughts, Seawater Intrusion and Sediment Disasters

D-4-2 **Identification** of Other Adaptation Measures against Climate Change Impacts on Rainstorms/Floods, Droughts, Seawater Intrusion and Sediment Disasters

D-4-3 **Formulation**** of Adaptation Measures (Priority Actions, Preliminary Cost Estimation and Implementation Schedule) against Climate Change Impacts on Rainstorms/Floods, Droughts, Seawater Intrusion and Sediment Disasters

E. Incorporation of Adaptation Measures into POLA and RENCANA to Reflect Climate Change Impacts i

Notes: *** POLA and RENCANA**

**** by using Multiple Scenario Approach (MSA) and Strategic Environmental Assessment (SEA)**

Chapter 2 Data Collection and Compilation

2.1 Meteoro-hydrological Data

Basically, the meteoro-hydrological data for the Water Resources Management Plans under the present climate shall be collected, which are referred to in the Ministerial Regulation. In addition, peculiar data to climate change are also essential, which are explained in respective descriptions hereinafter.

2.2 Other Data

2.2.1 Previous Reports

All reports related to water resources management and climate change impacts shall be collected. Especially, the following reports are important to study resilience and adaptation measures.

(1) Existing Dam(s) <Appendix I, Chapter 2, Table 2.1 IV E>

If existing dams are located in target river basin, such as Wilayah Sungai, the following information shall be collected and compiled. Time series data shall be collected for about 20 years.

- Time series data of reservoir water level, outflow from water utilization purpose and spill out from spillway and inflow;
- Gate operation record during flood;
- Deterioration of reservoir volume (Bathymetric survey results);
- As-built drawings; and
- Other information.

<u>Supplementary explanation</u>

These data are mainly applied to study resilience.

(2) New Storage Structure(s) <Appendix I, Chapter 2, Table 2.1 IV E>

If BBWS or other relevant agencies planned and/or designed new storage structures, the following reports shall be collected:

- Dam;
- Barrage;
- Pond (Embung); and
- Heightening of existing dam.

<u>Supplementary explanation</u>

These data are mainly applied to study new water storage structures considering drought condition.

(3) Water Saving Plan and Structure <Appendix I, Chapter 2, Table 2.1 IV E>

The water saving under the future climate condition shall be considered. Therefore, the following information shall be collected:

- PDAMs: Pipeline replacement plan to reduce non-revenue water, planned future connection ratio and area and other information;
- Industry: Plan of recycling plant and other information; and

- Irrigation: Plan of rehabilitation of canal improvement, capability of SRI and other information.

<u>Supplementary explanation</u>

These data are mainly applied to study demand calculation for water balance.

(4) Flood Management <Appendix I, Chapter 2, Table 2.3 3. >

The following study results shall be collected:

- Flood management (control) plan; and
- Design report of dike, retarding basin and dam that has flood control space.

<u>Supplementary explanation</u>

These data are mainly applied to study target flood discharge under the future climate condition.

After collection of the above data, these shall be sorted out to study resilience and adaptation measures.

<u>Structures</u>

1) Preparation of location map of above structures
2) Preparation of list of above structures including major information

<u>Existing Dams</u>

1) Preparation of figure of reservoir water level, inflow, outflow from beginning of the operation up to now
2) Preparation of water level and reservoir volume curve based on the bathymetric survey results

<u>Flood Management (Control) Plan</u>

1) Preparation of list of protection level and discharge to each river

(5) Sea Level Rise <Appendix I, Chapter 2, Table 2.1 IV H>

Sea level rise is one of the impacts of climate change. Coastal low-lying areas are vulnerable to flood inundation and sea water intrusion caused by sea level rise.

The future sea level rise of the concerned area should be assumed based on sea level projection results of previous studies.

2.2.2 Field Observation <Appendix II, Chapter 2, 3.6)>

If there is (are) existing dam(s), the field observation shall be carried out to study the renovation of dam(s).

Firstly, the Balai studies the possibility of renovation of existing dam(s). The possibility of renovation of existing dams are studied from topographical, geological and hydrological conditions based on completion report, as-built drawing, reservoir operation record and other information before field observation. A preliminary environmental impact study by renovation works shall also be carried out.

If three conditions are acceptable to dam renovation, the Balai shall carry out field observation to confirm actual site condition and social issues.

In addition, if it is possible to convey water from adjacent river basin, intake and outlet locations are to be examined.

Chapter 3 Climate Change Impact Assessment

3.1 General Circulation Models (GCMs) Selection < Article 4 (5) b. >

Coupled general circulation models (GCMs) are usually most widely applied to climate change impact assessments. However, there are large uncertainties associated with the outputs of these models. To reduce such uncertainties, it is necessary to conduct more analyses based on multi-model and multi-projection ensembles instead of single-model analyses. Selection of appropriate GCMs is crucial for multi-model analysis. It is important to select appropriate GCMs before applying the model output to evaluate climate change impacts on a target area. Such selection is done based on the performance of GCMs participating in the Coupled Model Intercomparison Projects 3 and 5 (CMIP3/5).

3.1.1 Methodology

Appropriate GCMs are selected based on the reproducibility of present climate conditions in a targeted area by comparing with the reference global data sets. Spatial correlation (Scorr) and root mean square error (RMSE) are used for identifying similarities and differences of seasonal and regional patterns and absolute values of climate variables including precipitation, air temperature at the ground surface, sea surface temperature, air pressure at sea level, outgoing radiation, meridional wind and zonal wind.

Targeting Tropical Asia and Islands, spatial patterns of the climate variables should be examined at a regional scale, which includes the effects on the characteristic climate systems, including the Intertropical Convergence Zone (ITCZ), the Asian monsoon, the El Nino-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). In the area, both the wet and dry seasons are very important for water management, so Scorr and RMSE for each month should be considered while prioritizing the GCMs that show high Scorr and low RMSE during the wet and dry seasons. The average values of Scorr and RMSE for each climate variable among all GCMs, Scorr_ave and RMSE_ave, are considered as thresholds of the model selection. A simple scoring rule is applied; 1-point up when Scorr and RMSE of a GCM are higher and lower than Scorr_ave and RMSE_ave, respectively; 1-point down when Scorr and RMSE of a GCM are lower equal and higher equal than Scorr_ave and RMSE_ave, respectively; elsewhere 0-point. The total score of each GCM is used as a selecting criterion.

To evaluate the ability of GCM to represent small-scale precipitation, additional screening should be done to eliminate the worst performing GCMs. Three additional criteria should be used to achieve this:

i. Long-term basin observed rainfall averages (climatology) should be compared with GCM data. If a GCM cannot represent seasonal variability, it should be eliminated.
ii. If a GCM produces too little rainfall such that unreasonably dry days persist after a no rain correction, then that model should also be eliminated.
iii. Lastly, if observed rainfall within a basin is not uniformly distributed, basin subdivision climatological averages (based on areas of high, medium and low rainfall usually related to elevation and land use) should be considered for the model selection comparison.

3.1.2 System

The Data Integration and Analysis System (DIAS) of the University of Tokyo has archived all the CMIP3/5 data sets. The DIAS is also comprised of a set of tools that provide the easy display and analysis of the CMIP3/5 data, which has wide-ranging spatiotemporal resolution, and the reference global data sets, including the Global Precipitation Climatology Project (GPCP) dataset for comparing similarities of average monthly precipitation; whereas, the Japanese 55-year Reanalysis (JRA55) outputs for the other climate variables.

Users are requested to contact the DIAS Office <dias-office@diasjp.net> for system registration. Then, CMIP3/5 data analysis tools are available through the following sites:

http://www.dias.nii.ac.jp/modelvis/cmip3/

http://apps.diasjp.net/modelvis/cmip5/

3.1.3 How to Use the System

DIAS USER GUIDE is available at the following address:

https://diasjp.net/en/wp/wp-content/uploads/2016/04/DIAS_guidebook_v.1.06_en.pdf

To implement the GCM selection system, please refer to pp.38-40 of DIAS USER GUIDE.

3.2 Bias Correction and Downscaling < Article 4 (5) b. >

Most of the variables in the present climate GCM simulations include bias errors compared with the observational datasets and such biases are also included in the future climate simulations. The statistical techniques to remove such biases from the climate GCM simulations using the observation as a reference dataset are generally called as the statistical bias correction.

There is a large gap in the grid resolution between GCMs and catchment-scale hydrology models. Horizontal resolutions of most of GCMs used for long-term climate projections are courser than 100 km and more, while those of hydrological models are much finer than 10 km or less. To address this mismatch, downscaling of GCM data is essential for regional and local impact studies. There are two main types of downscaling: dynamic and statistical. Dynamic downscaling refers to nesting of fine-scale resolution within a large-scale resolution while preserving some spatial correlation. However, this method is computationally expensive and impossible for multi-decade simulations by different GCMs. Statistical downscaling based on the relationship between large-scale circulation and local-scale phenomena can be implemented within a reasonable range of computational costs.

3.2.1 Methodology

(1) Rainfall

There are large uncertainties associated with GCM outputs. In particular, the GCM rainfall bias is too large. Most rainfall outputs from the GCMs show three main problems. These are too many rainy days with very weak rainfall (referred to as drizzle), underestimation of heavy rainfall intensity and poor seasonal representation. To alleviate these problems, the biases of the GCM rainfall should be corrected after selecting appropriate GCMs as follows:

1) Number of no-rain days

A common characteristic of all GCMs is the unrealistically high number of wet days. Most of these are represented by drizzle and can be attributed to the lack of parameterization in GCMs. To correct this, the following method is used.

(a) Both observations and present GCM-extracted values are ranked in descending order.

(b) A threshold of 0 mm/day was established for no-rain days in the observations. The rank of this threshold is then used to determine the corresponding value of no-rain days in the GCMs.

(c) All values equal to or below this rank in the GCM are set to zero.

(d) No-rain day correction for the future GCM is based on the threshold for present GCMs.

2) Extremely heavy rainfall

Most of the GCMs underestimate extreme rainfall compared with observations. To account for this, there should be appropriate correction for adjusting these values to match the distribution of the observations.

(a) Annual maximum rainfall is selected for each year in the observation dataset. Then, the smallest value of the annual maxima is identified as a threshold for the extreme events of observed rainfall. Values above this threshold are defined as extreme events. The number of such events is determined from observation stations and set to the same number of extreme events in present GCMs by ranking.

(b) Above this threshold, the Generalized Pareto Distribution (GPD) is fit to the data. GPD fitting parameters are determined by using the method of moments (MOM) .

(c) The threshold for GPD is defined in each in-situ station and simultaneously the same frequency is accounted in corresponding GCM gridded series by ranking. Here, the assumption is GCM uncorrected extreme series follow the GPD distribution same as the ground station data.

(d) The lowest root mean square error (RMSE) between corrected GCM extremes and observed data is tuned by changing in the threshold for the extreme events trial and error.

(e) The best-fit GPD of GCM extreme events is determined by the minimum RMSE between an inverse GPD of extreme events and those of observation stations (checked using trial and error with different thresholds). The same checking (present GCMs) and fitting procedure is applied to all extremes.

(f) GCM extremes for future projections are extracted and the transfer function of the present GCM extreme correction is applied.

(g) Recurrences of extreme events for different return periods in the future are calculated.

3) Normal rainfall

The range of normal rainfall is defined as less than the minimum annual maximum daily rainfall during the targeted period and greater than the threshold of the no-rain days. A correction factor for each month is calculated based on the difference between monthly average normal rainfall of the GCM and observed values.

Once statistically bias-corrected GCM rainfall data is obtained at each rain gauge station, various interpolation and extrapolation methodologies can be used to make finer grid rainfall data sets for hydrological assessment. This methodology is categorized as a joint statistical bias-correction and downscaling technique.

(2) Air Temperature

The GCM air temperature bias can be corrected by using the ratio of the monthly averages of daily mean, maximum and minimum air temperatures obtained by observations and present climate simulations by GCMs. The bias corrections of daily mean, minimum and maximum temperature data should be conducted after adjusting the observed values at mean seal level using the elevation at each station and a lapse rate of 0.649 K/100 m. Using the same lapse rate, temperature data of selected GCMs should be also adjusted at mean sea level.

3.2.2 System

DIAS provides a series of functions for implementing the joint statistical bias-correction and downscaling technique for rainfall as introduced in Subsection 3.2.1.

The DIAS data archiving function enables a series of processes including uploading data, performing quality control and adding meta-data online to be performed in a dialogue style. Each component is available through the following sites:

1) In-situ Data Upload System:
   https://diasjp.net/en/service/data-upload/
2) In-situ Data Quality Control System:
   https://diasjp.net/en/service/data-qc/
3) DIAS Metadata Management System:
   https://diasjp.net/en/service/dias-metadata-management/

Once observed data is archived in DIAS, the joint statistical bias-correction and downscaling technique for rainfall is implemented by coupling with the outputs of the GCM selected by 3.1.2. In addition to observed rainfall data, the Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) data set can be used in the system for data-sparse areas.

The CMIP3/5 data analysis tools, which are introduced in Snbsection 3.1.2, include the functions for implementing the joint statistical bias-correction and downscaling technique for rainfall.

3.2.3 How to use the system

DIAS USER GUIDE is available at the following address:

https://diasjp.net/en/wp/wp-content/uploads/2016/04/DIAS_guidebook_v.1.06_en.pdf

To archive observed data in DIAS, please refer to pp.27-37 of DIAS USER GUIDE.

To implement the joint statistical bias-correction and downscaling technique for rainfall, please refer to pp. 38-41 of DIAS USER GUIDE.

3.3 Climate Change Impact Assessment < Article 4 (5) b. >

To enable consistent descriptions of water and energy at a river basin scale under climate change, a Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) is developed by fully coupling a biosphere scheme (SiB2) with a geomorphology-based hydrological model (GBHM) (Wang et al., 2009a, 2009b). The characteristics of the model are summarized as follows:

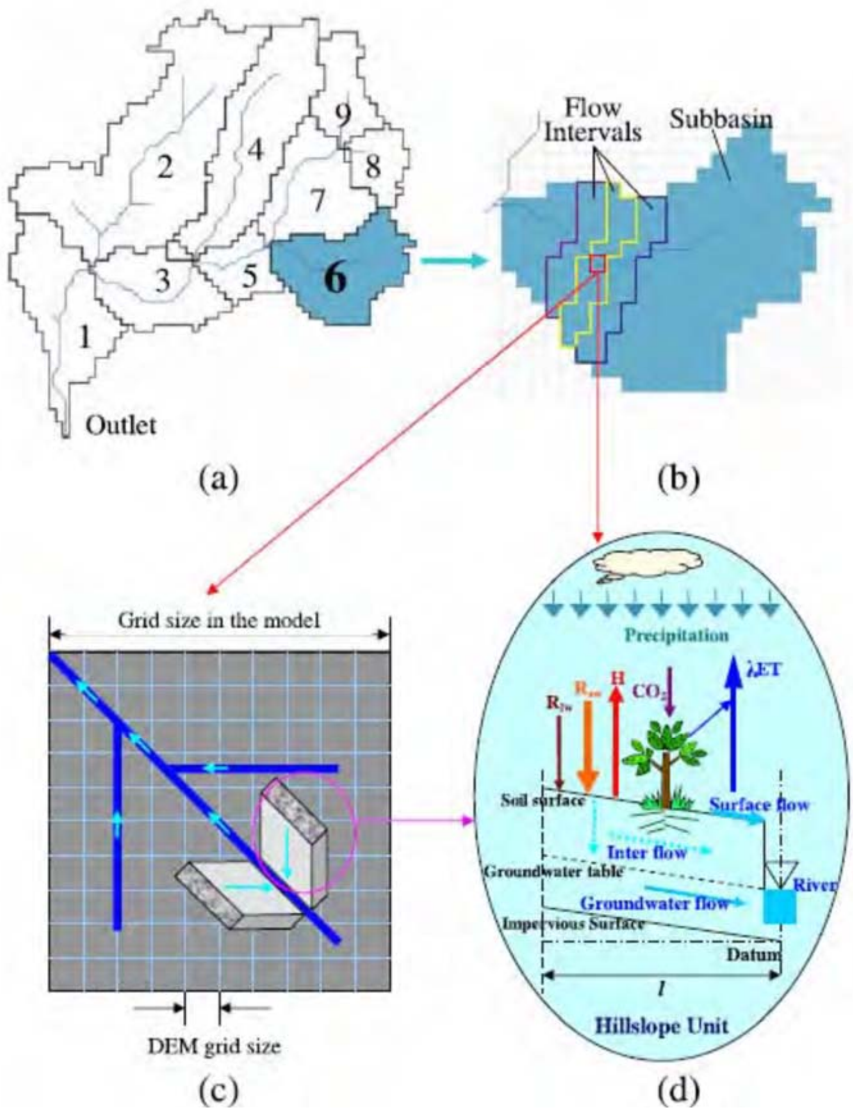
- The model physically describes evapotranspiration (ET) using a biophysical land surface scheme for simultaneously simulating heat, moisture and CO^2 fluxes in soil-vegetation-atmosphere transfer (SVAT) processes.
- The hydrologic sub-model describes overland, lateral subsurface and groundwater flows using grid-hill slope discretization followed by flow routing in the river network.
- The model has high efficiency for simulations of large-scale river basins and incorporates sub-grid topography and effects of water resource management facilities.

Model Structure

Improvements over lumped hydrologic models have been made by spatial heterogeneity, which can be represented by distributed hydrological models (DHMs). However, DHMs have large uncertainties in simulating water exchanges at the soil-atmosphere interface and the temporal evolution of surface soil moisture, owing to the conceptual treatment of the land surface. In most current LSMs (e.g., SiB2), lateral soil moisture redistributions by topographically driven runoff are usually not well formulated since they were originally developed for application in general circulation models (GCMs). The coupling of LSMs and DHMs has the potential to improve land surface representation, benefiting streamflow prediction capabilities of hydrologic models and providing improved estimates of water and energy fluxes into the atmosphere. The WEB-DHM is a distributed biosphere hydrological model via the SiB2/GBHM coupling described above. SiB2 describes the transfer of turbulent fluxes (energy, water and carbon fluxes) between the atmosphere and land surface at each model grid. The GBHM redistributes water moisture laterally through simulation of both surface and subsurface runoff, using grid-hill slope discretization and subsequent flow routing in the river network.

Overall model structure is shown in Figure 3.3-1 and is described as follows:

- A digital elevation map (DEM) is used to define the target area, after which the target basin is divided into sub-basins (Figure 3.3-1 (a)).
- Within a given sub-basin, a number of flow intervals are specified to represent time lag and accumulation processes in the river network according to distance to the outlet of the sub-basin. Each flow interval includes several model grids (Figure 3.3-1 (b)).
- For each model grid with one combination of land-use type and soil type, the SiB2 is used to calculate turbulent fluxes between the atmosphere and land surface independently (Figures 3.3-1 (b) and 3.3-1 (d)).



Source: JICA Project Team 1

Figure 3.3.1 The WEB-DHM: (a) division from a basin to sub-basins; (b) subdivision from a sub-basin to flow intervals comprising several model grids; (c) discretization from a model grid to a number of geometrically symmetric hillslopes; (d) process descriptions of water moisture transfer from the atmosphere to river (Wang et al., 2009a, 2009b).

The GBHM is used to calculate runoff from a model grid with a sub-grid parameterization. Each model grid is subdivided into a number of geometrically symmetric hill slopes (Figure 3.3-1 (c)), which are the basic hydrological units (BHUs) of the WEB-DHM. For each BHU, the GBHM is used to simulate lateral water redistributions and calculate runoff (Figure 3.3-1 (c) and 3.3-1 (d)). Runoff in a model grid is the total response of all BHUs within it. For simplicity, streams within one flow interval are lumped into a single virtual channel in a trapezoidal shape. All flow intervals are linked by the river network generated from the DEM. All runoffs from model grids in a given flow interval are accumulated in the virtual channel and led to the river basin outlet.

Forcing Data

Meteorological atmospheric forcing data required by the WEB-DHM model are listed in Table 3.3-1. For rainfall alone, observed daily records are used. For other parameters such as temperature, surface pressure, wind speed, and specific humidity, data from the Japanese 55-year Reanalysis (JRA-55) and Japan Meteorological Agency (JMA) Climate Data Assimilation System (JCDAS) are used instead of real observations. For surface solar radiation parameters such as downward longwave and downward shortwave radiation, values were estimated using sunshine duration, air temperature and relative humidity from JRA55. Equations for parameter estimations were based on Yang et al. (2006), Yang et al. (2001) and Todd and Claude (1998).

Table 3.3.1 Atmospheric Forcing Data

Name	Data Source	Time Resolution
Rainfall	In-situ observation	Daily
Temperature	JRA55 reanalysis with altitude correction	6-hourly
Surface Pressure	JRA55 reanalysis with altitude correction	6-hourly
Specific Humidity	JRA55 reanalysis	6-hourly
Surface Wind	JRA55 reanalysis	6-hourly
Downward Longwave Radiation	Estimated using JRA55 reanalysis	6-hourly
Downward Shortwave Radiation	Estimated using JRA55 reanalysis	Hourly

Source: JICA Project Team 1

In the case of the critically limited availability of rainfall data with enough accuracy in a basin, we need to identify reasonable data sets by checking data missing period and frequency.

To produce a gridded hourly rainfall product which is used as an input into the WEB-DHM, we also need to apply the following interpolation and extrapolation methods:

i. Thiessen Method by using a weighted average of the selected measurements based on the size of each one's polygon.
ii. Inverse Distance Weighting (IDW) by using a weighted average of the values available at the known twenty points for calculation of values of unknown points.
iii. Satellite-based rainfall products.
iv. Reanalysis products after bias correction by using the observed data. After making the gridded rainfall product.

An hourly version is generated by dividing it by twenty-four, and thus it is difficult to fit the peak flows well in small sub-basins.

The outputs of the joint statistical bias-correction and downscaling technique for rainfall are used to assess the impacts of climate change. Even the methodology is well verified for the reproducibility of statistical property (annual or monthly mean values and frequency distributions) for each point, there is a limitation in representing rainfall spacetime distributions at a river basin scale. If the subjected basin scale is adequately larger than the GCM grid size or the rainfall distribution over the basin is generally homogeneous, impact would be small. In the case of the reverse, impact would be large, and care must be taken, because many observation sites are located inside the same single GCM grid and heavy rainfall occurs simultaneously at all sites. If actual rainfall in the basin is characterized by the active convective rainfall of the tropical climate, there must be a big difference in rainfall distribution between downscaled GCM data with observed data. Basin average rainfall of GCM data becomes much larger than the observed one. To remove the gap, the areal average rainfall adjustment should be applied as follows:

i. Areal average rainfall over the catchment is calculated using the outputs of the joint statistical bias-correction and downscaling technique for rainfall.
ii. Methodology based on the same principle of GCM bias correction is applied to the areal average rainfall. Then, an adjustment factor for each rank of the rainfall is evaluated.
iii. Original bias-corrected GCM grid data is adjusted by scaling it with the adjustment factor, resulting in the adjusted GCM grid data.

(1) Model Calibration and Validation

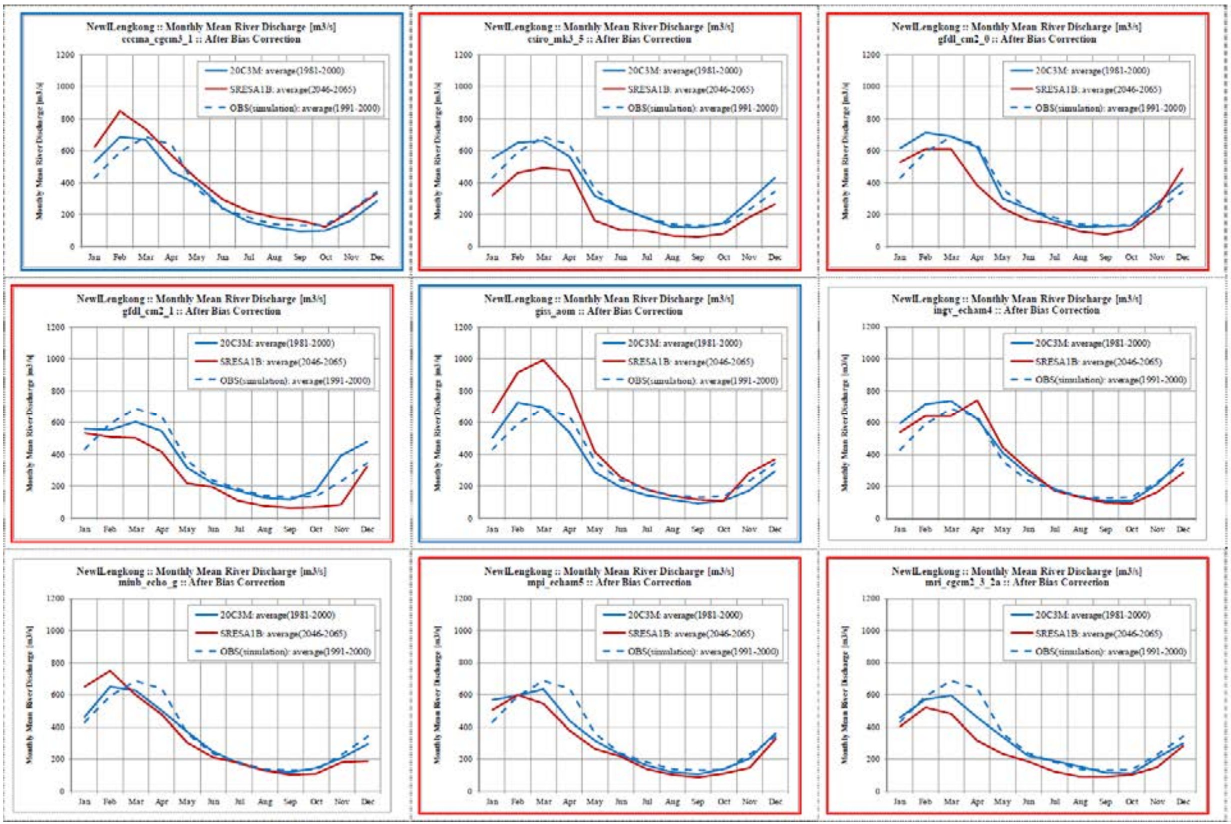
The WEB-DHM is calibrated by comparing the simulated daily discharges with natural flow derived from observed streamflow records. After careful surveying the existence of diversion channels and checking the possibility of data fabrication and abnormal runoff ratio as well as data continuity, reasonable station data should be identified to be used for model calibration. Under a critical situation concerning effective data availability, a simplified model and qualitative model calibration and validation should be applied.

3.3.1 River Runoff

River runoff is simulated by feeding bias-corrected GCM data into the developed WEB-DHM. Three types of simulations are run, namely: “simQobs”, “simQgcmp” and “simQgcmf”. The simQobs and simQgcmp represent simulated flows under the current climate, driven by observed meteorological data and bias-corrected present meteorological conditions reproduced by GCMs, respectively. The simQgcmf represents simulated flows.

(1) Changes in Seasonal Flow and Annual Flow Duration Curve

After checking the correspondence of the seasonal variability of monthly mean discharges between simQgcmp and simQobs derived from the selected GCMs, impacts of climate change on seasonal flow can be assessed by comparing simQgcmp and simQgcmf in each GCM case as shown in Figure 3.3-2. In these cases, five of nine GCMs show decreasing trends of monthly discharge in almost all seasons; whereas, two of nine GCMs show increasing trends. The remaining two GCMs show little change and a sign of changes varying with the seasons.



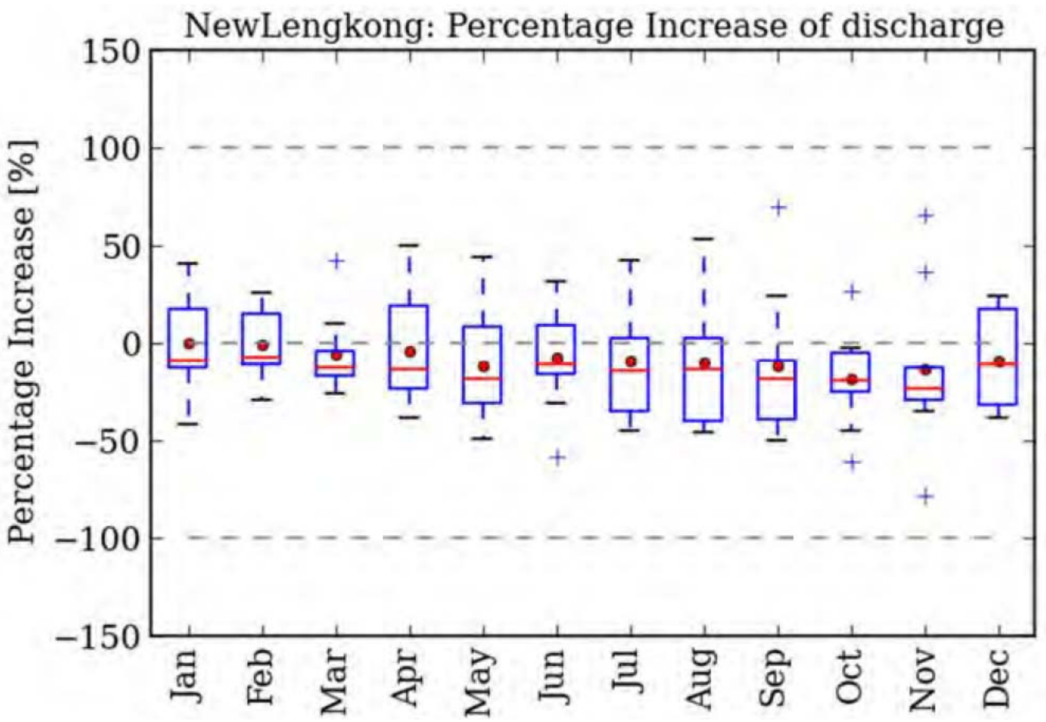
Source: JICA Project Team 1

Figure 3.3.2 20-year Mean Monthly Discharge at New Lengkong in Indonesia. Blue dashed line: simQobs; Blue solid line: simQgcmp; Red solid line: simQgcmf.

To evaluate the magnitude of predicted change and its uncertainty quantitatively, percentage increases for monthly mean discharges were calculated using projected present and future discharges. Figure 3.3-3 shows percentage increases of the monthly mean river discharge from different climate models. According to the figure, the multi-model ensemble median/mean discharge shows a decreasing trend. The median discharge decreases around 5%-20%, and the third quartile discharge decreases around 10%-40%.

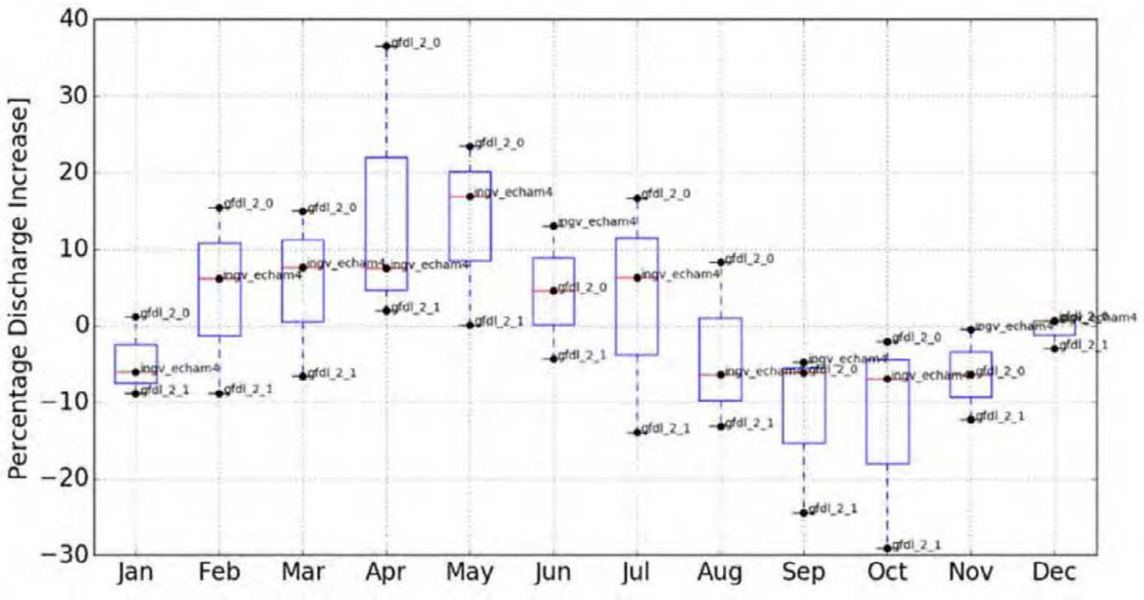
A seasonal dependency of changes in river flow is shown in Figure 3.3-4. In this case, the multi-model ensemble median/mean discharge shows an increasing trend in the average from December through May, whereas a decreasing trend from June through November. Therefore, we expect that the total discharge in this river basin in the future will likely increase in the second-half rainy season and the first-half dry season and decrease in the first-half rainy season and the second-half dry season. We also recognize that the uncertainty of monthly discharge trends among the GCMs are very large based on such widely spread results.

Figure 3.3-5 shows the annual mean duration curves for the present and future. According to the figure, simQgcmp (blue solid line) matches reasonably with simQobs (green dashed line). When compared with simQgcmp and simQgcmf (red solid line), seven of nine GCMs showed decreasing trends while others with increasing trends. In order to evaluate the magnitude of predicted change and its uncertainty quantitatively, the percentage increase of discharge at each rank is calculated using the present and future discharges. As shown in Figure 3.3-6, the multi-model ensemble mean drawn by the black thick line shows a slight increase of the flood discharges with less than 5% exceedance probability and around 15% decrease of the normal and low flows (upper 20% of exceedance probability). A similar tendency is found in Figure 3.3-7. Slight positive and negative increases (black thick line) can be identified in case the exceedance probability is less and larger than 50%, respectively. Therefore, we expect that the dry season discharge will likely decrease; whereas, flood discharge will likely increase in the future in these areas.



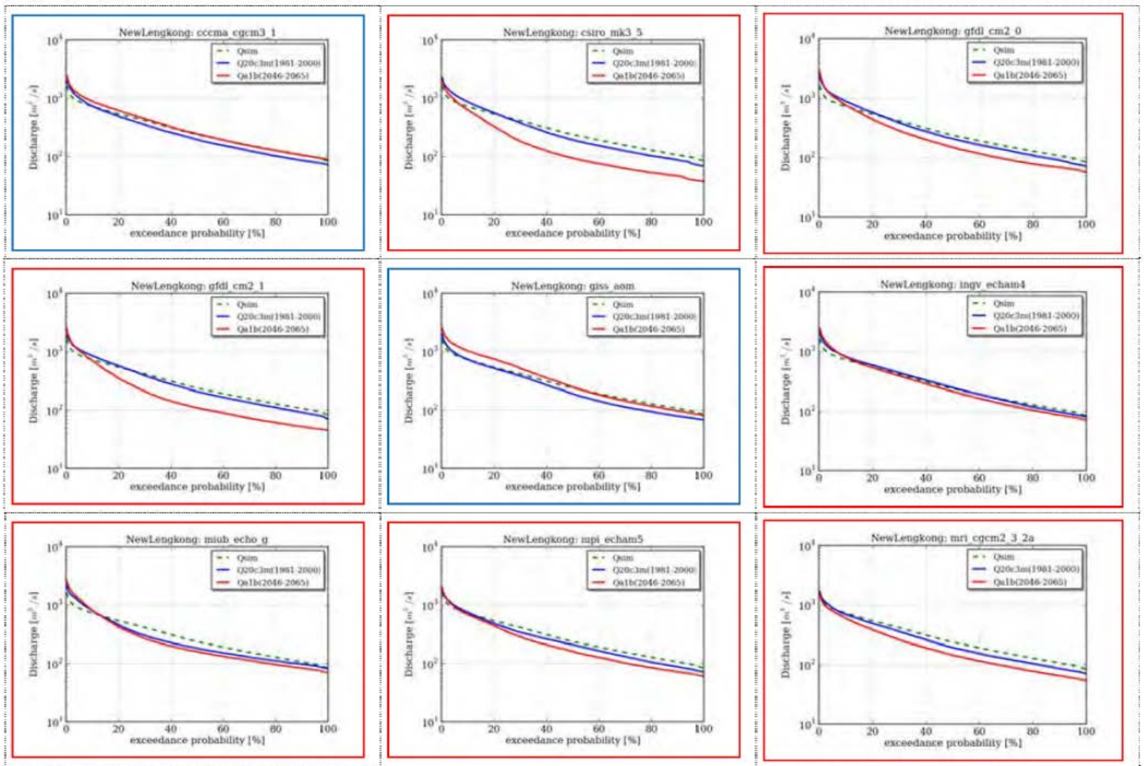
Source: JICA Project Team 1

Figure 3.3.3 Percentage Increase of 20-year Mean Monthly Discharge at New Lengkong in Indonesia. Red line: median values; Red dots: mean values. Lower and upper blue-color box edges: first and third quartiles; Upper and lower black lines: highest and lowest values within the 1.5-times inter-quartile range from the third and first quartiles. Blue crosses: outliers



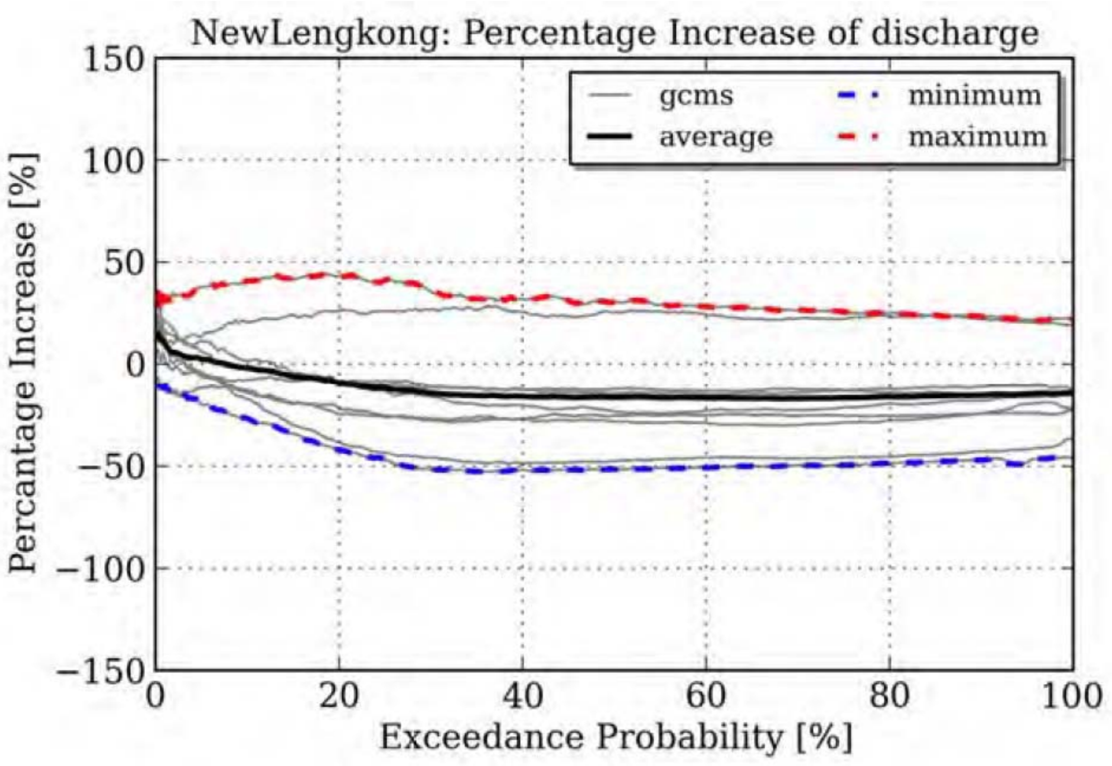
Source: JICA Project Team 1

Figure 3.3.4 Percentage Increases of 16-year Mean Monthly Discharges nearby Palembang in Indonesia. Red line: median values; Lower and upper black box edges: first and third quartiles; Upper and lower black lines: highest and lowest values within the 1.5-times inter-quartile range from the third and first quartiles



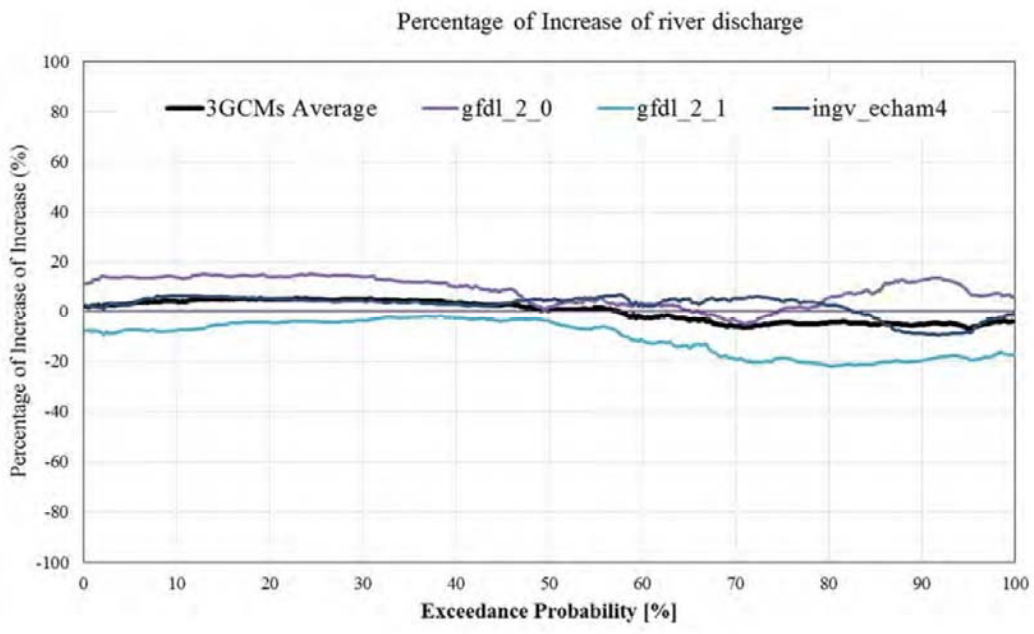
Source: JICA Project Team 1

Figure 3.3.5 Flow Duration Curve at New Lengkong in Indonesia. Blue dashed line: simQobs; Blue solid line: simQgcmp; Red solid line: simQgcmf



Source: JICA Project Team 1

Figure 3.3.6 Percentage Increase of River Discharge at New Lengkong in Indonesia. Black thick line: multi-model ensemble mean of probability of increase; Red and blue dashed line: maximum and minimum values



Source: JICA Project Team 1

Figure 3.3.7 Percentage Increases of River Discharge nearby Palembang in Indonesia from the Past, 1985-2000, to the Future, 2050-2065. Black solid line: average the three GCMs

(2) Changes in Droughts

To assess the climate change impacts on drought discharge, the following indices are used:

- Annual drought discharge (average of 355th rank of daily discharge),
- Number of days in a year in which river discharge was less than the present drought discharge,
- The 10% non-exceedance probability of present annual drought discharge,
- Number of days in a year in which the river discharge was below the 10% non-exceedance probability of present annual drought discharge, and
- Longest number of days in a year in which the river discharge was less than the present annual drought discharge.

The drought indices calculated from nine selected GCMs in Table 3.3-2 shows that seven models have increasing trends of drought conditions in the future climate and two decreasing trends. Because more than 78% of the models predict severe drought conditions in the future, it is vital to include effective countermeasures against water scarcity in the future water resource management plans.

Table 3.3.2 Drought Indices at New Lengkong Barrage in Indonesia

GCM Model	Annual Drought Discharge (m3/s) *(average 355th rank)*		# of days/year that baseflow < present drought discharge		10% Non Exceedance Probability of Annual Drought Discharge(m^3/s) *(10th percentile of 355th rank)*		# of days/year that baseflow < present 1/10 drought discharge		Longest # of days for each year below average drought discharge	
	Present	Future	Present	Future	Present	Future	Present	Future	Present	Future
cccma_cgcm3_1	77.38	94.16	26	13	46.91	65.68	2	0	125	63
csiro_mk3_5	72.94	39.22	55	165	44.58	21.15	2	68	207	304
gfdl_cm2_0	76.44	62.09	48	90	44.39	40.47	6	9	204	183
gfdl_cm2_1	80.37	47.42	82	143	37.35	27.36	4	20	202	324
giss_aom	71.70	86.11	31	1	54.82	74.46	2	0	79	13
ingv_echam4	85.68	76.81	30	53	61.64	48.51	3	14	91	168
miub_echo_g	87.70	75.71	37	60	59.77	51.47	3	7	120	151
mpi_echam5	77.50	65.18	42	66	48.92	48.10	3	5	170	149
mri_cgcm2_3_2a	76.70	58.12	36	80	51.29	41.87	3	18	117	191

Red = drier in the future; greater frequency of drought conditions

Blue = wetter in the future; less frequency of drought conditions

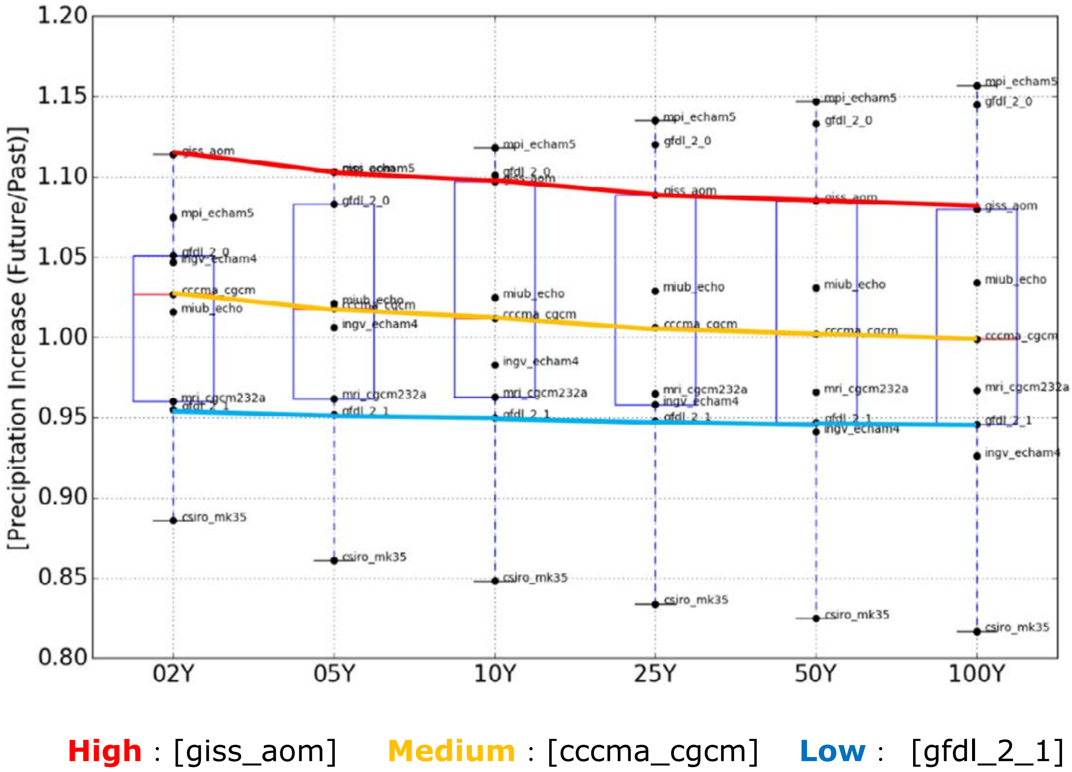
Source: JICA Project Team 1

(3) Changes in Floods

Basin-averaged rainfall intensity for 2-, 5-, 10-, 25-, 50- and 100-year return periods (hereafter referred to as T-year return period) is estimated from observed daily rainfall records after defining a rainfall duration, which affects floods in a targeted river basin. By referring the actual rainfall event, which caused a serious flood in the past, we calculated the stretch/shorten ratio for the total rainfall of the identified duration of each T-year return period.

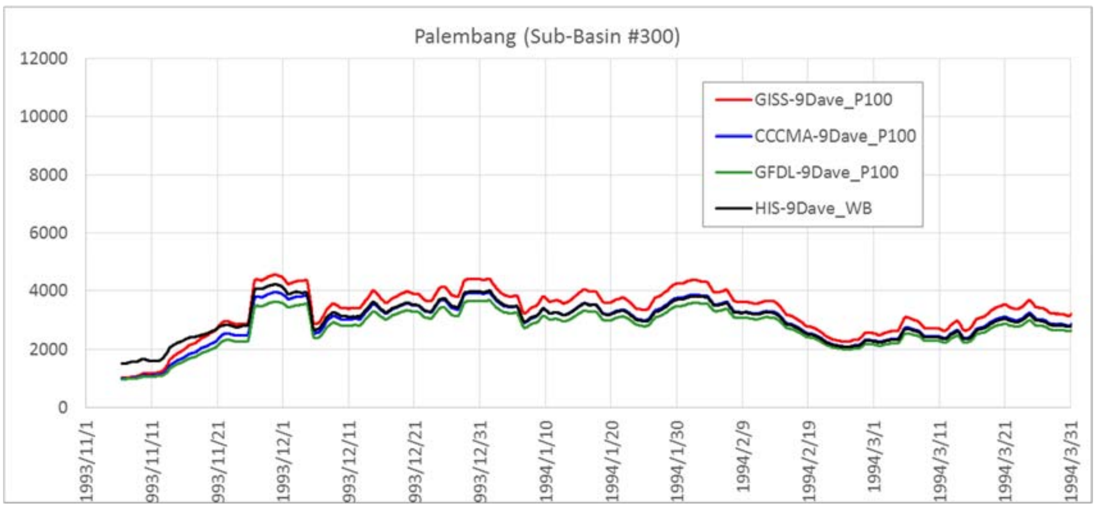
As shown in Figure 3.3-8, we identify three GCMs which represent High, Medium and Low scenarios of future floods based on the consistent order of the median and 1st and 3rd quartiles of T-year heavy rainfall increase ratios of the selected GCMs.

Then, design floods for each T-year return period are proposed by using the hyetograph of the actual flood event; the stretch/shorten ratios; the heavy rainfall increase ratios corresponding to the High, Medium and Low scenarios; and the WEB-DHM. Figure 3.3-9 shows 100-year design floods according to the three scenarios.



Source: JICA Project Team 1

Figure 3.3.8 Selected Three GCMs which Represent High, Medium and Low Increase Scenarios of Future Heavy Rainfall in the Musi River Basin in Indonesia



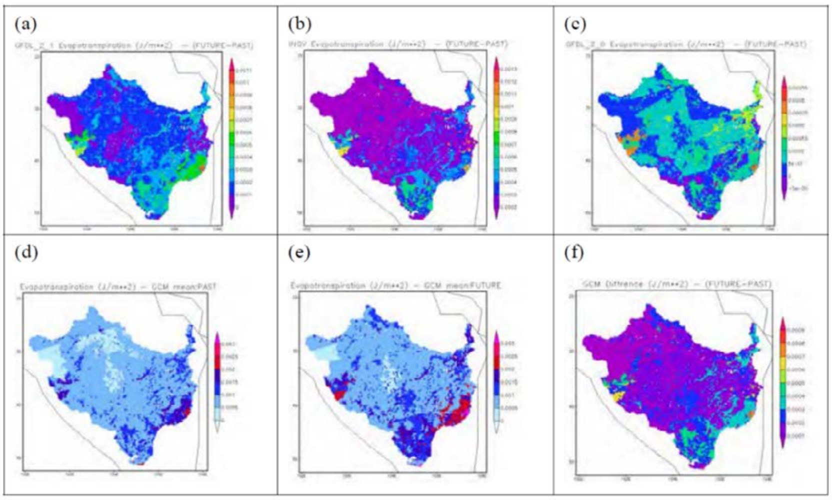
Source: JICA Project Team 1

Figure 3.3.9 Selected Three GCMs which Represent High, Medium, and Low Increase Scenarios of Future Heavy Rainfall

3.3.2 Evapotranspiration and Soil Moisture

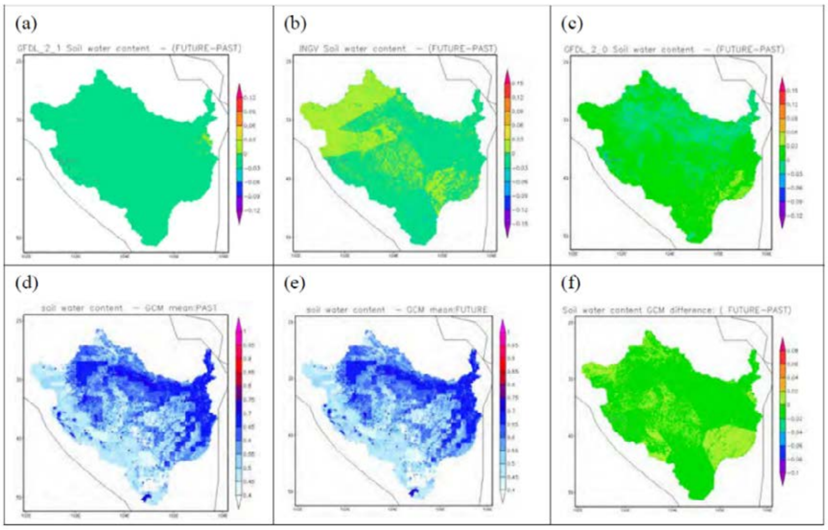
The climate change impacts on evapotranspiration (ET) and soil moisture can be assessed by inputting the products of the joint statistical bias-correction and downscaling technique for rainfall to WEB-DHM. The multi-model approach can inform a range of uncertainty as well as increase or decrease trends.

Figure 3.3-10 and Figure 3.3-11 show changes in ET and soil moisture, respectively. The former expresses a clear increase of ET; whereas, the latter indicates a slight change of annual mean soil moisture. The ranges of uncertainty are small in both cases.



Source: JICA Project Team 1

Figure 3.3.10 Changes in evapotranspiration (ET) in Musi River basin in Indonesia: (a)-(c) annual average differences for future (2050-2065) minus past (1985-2000) by using three selected GCMs; (d) three-model mean of annual average for past (1985-2000); (e) three-model mean of annual average for future (2050-2065); (f) difference between (e) and (d).



Source: JICA Project Team 1

Figure 3.3.11 Changes in soil moisture in Musi River basin in Indonesia: (a)-(c) annual average differences for future(2050-2065) minus past (1985-2000) by using three selected GCMs; (d) three-model mean of annual average for past (1985-2000); (e) three-model mean of annual average for future (2050-2065); (f) difference between (e) and (d).

Chapter 4 Future Climate Scenario Selection and Probabilistic Analysis for Water Resources Management Plan

4.1 Future Climate Scenario Selection < Article 4 (5) b. >

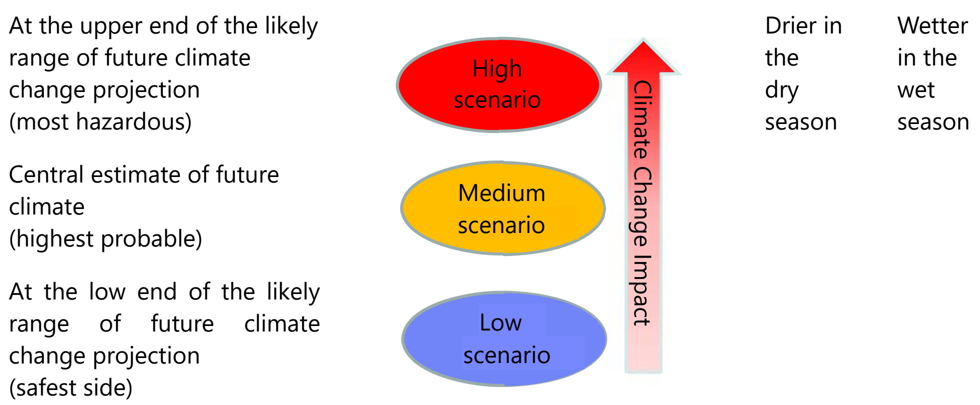
In the previous chapter, it produced multiple climate scenarios (multiple ensemble projections) statistically bias-corrected for a target river basin. In the succeeding planning stage, non-climatic social scenarios such as land-use changes and population changes are introduced to assess climate change risks in various sectors. Therefore, if we use all of the said multiple climate scenarios together with possible social scenarios, the number of total combinations is large. In the light of practical purpose of planning, to consider all the combinations is not feasible because of time, costs, and technical constraints. On the other hand, it is also not realistic to select one climate scenario as climate predictions include uncertainty and the range of uncertainty would lead to a large variation in the future water resources management planning. Plans should be based on the most likely range of change and should be flexible and adaptable to uncertain future. Therefore, selected are a set of three scenarios as listed below:

- High Scenario (at the upper end of the likely range of future climate predictions),
- Medium Scenario (central estimate of future climate predictions), and
- Low Scenario (at the low end of the likely range of future climate predictions).

The Medium Scenario describes the central estimate of the future, while the High and the Low Scenarios describe the upper and the lower boundaries of possible futures, respectively (see Figure 4.1.1).

The set of three scenarios are to be selected separately depending on the purpose of planning. For water resources management, the following two planning purposes are usually considered:

- Drought risk management planning, and
- Flood risk management planning.



Source: JICA Project Team 1

Figure 4.1.1 Set of Three Future Scenarios

4.1.1 Indicators for Scenario Selection

An indicator is to be identified for selection of future climate scenarios as a factor that is deeply related to the water resources management in the target river basin and makes a decisive influence on climate change adaptation measures against droughts and floods in the future (see Table 4.1.1).

(1) Indicators to Select Future Climate Scenarios for Drought Risk Management

In the stage of developing a drought risk management plan, the most important indicator is the change of basin's low flow conditions. Therefore, a total discharge in a dry season, an annual flow duration curve, future water supply deficit, etc. are to be selected as the indicators for drought risk management.

(2) Indicators to Select Future Climate Scenarios for Flood Risk Management

In the stage of developing a flood risk management plan, the most important indicator is the change of flood magnitude and its frequency. Therefore, changes of flood peaks with several return periods can be used as indicators of change in flood magnitude. Usually, however, there are limitations in the simulated river discharge extremes based on GCM outputs: in other words, there are considerable differences between observed and modeled flood peaks and it is difficult to apply frequency analysis to simulated river discharges directly. Therefore, the frequency analysis is to be applied to annual maximum rainfalls instead of the river discharges.

Through the frequency analysis of annual maximum rainfalls, determined are the indicators to select future climate scenarios for flood risk management, which are change ratios (future/present) of annual maximum rainfall amounts of 2-, 5-, 10-, 30-, 50- and 100-year return period events, among others.

Table 4.1.1 Indicators for Scenario Selection

Indicators	Explanation	Considerations
Rainfall	Average annual/seasonal rainfall over target river basin	• Easy to understand • Normally used for flood control plan as external force
Discharge	Average discharge at target point computed through run-off analysis	• Discharge reflects rainfall spatial and temporal characteristics and run-off characteristics in target river basin.
Water Deficit	Total water deficit computed through water balance analysis	• Both surface/groundwater and water demands are considered. • Work load is heavy.

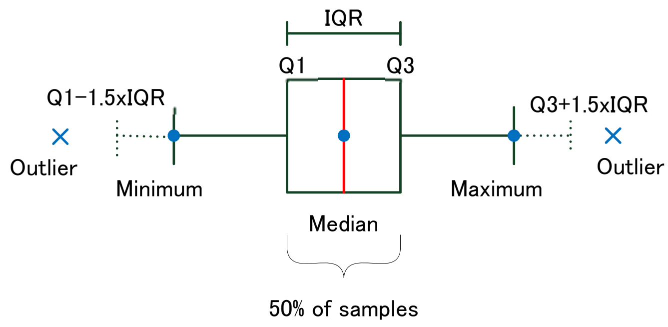
Source: JICA Project Team 2

4.1.2 Selection of Future High, Medium and Low Climate Scenarios

A box plot method is to be used to select the High, Medium, and Low Scenarios. This method is one of several useful ways of graphically depicting ranges of distributions and identifying outliers. It is a nonparametric method. That means a box plot diagram displays variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. Therefore, it is suitable when the number of samples is too small to apply a statistical distribution.

The schematic image of the box plot method is shown in Figure 4.1.2. The red line shows the median value. The width of the box shows the spread of the models and the range of the 1st and 3rd quartiles. The upper and lower black lines show the highest and lowest values and the blue crosses (x) represent the outliers, which are very different from all the other models. The box includes 50% of the samples.

The median value can be regarded as the Medium Scenario, and the 1st and 3rd quartiles can be regarded as High and Low Scenarios, respectively.



Source: JICA Project Team 1

Figure 4.1.2 Schematic Image of Box Plot

4.1.3 Uncertainty in Future Climate Scenario

Synthesis Report of the IPCC's Fifth Assessment Report (AR5, 2014) describes as follows:

Effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments, and diverse perceptions and responses to risk and uncertainty.

The main uncertainties regarding climate change exist in i) observation of changes in the climate system; ii) the main drivers of climate change; iii) understanding the recent changes in the climate system; and iv) projections of global and regional climate change.

Technical Summary of the Climate Change 2013: The Physical Science Basis identifies the sources of uncertainty related to water cycle as follows:

i. *Changes in the water cycle remain less reliably modelled in both their changes and internal variability, limiting confidence in attribution assessments. Observational uncertainties and the large effect of internal variability on observed precipitation also precludes a more confident assessment of the causes of precipitation changes.*

ii. *Modelling uncertainties related to model resolution and incorporation of relevant processes become more important at the regional scales and the effects of internal variability become more significant. Therefore, challenges persist in attributing observed change to external forcing at the regional scales.*

iii. *The ability to simulate changes in frequency and intensity of extreme events is limited by the ability of models to reliably simulate mean changes in key features.*

iv. *Projected changes in soil moisture and surface run off are not robust in many regions.*

To reduce the uncertainties within the projections by the GCMs, this Handbook firstly recommends selecting GCMs, which can express the regional climate characteristics by focusing on the spatial and seasonal distributions of several climate variables in comparison with the global observation and reanalysis products as introduced in Section 3.1. The joint statistical bias-correction and downscaling technique for rainfall is proposed in Section 3.2 to improve the uncertainties in extreme hydrological events as well as normal condition at a river basin scale. Section 3.3 recommends applying WEB-DHM to assess the climate change impacts on hydrological parameters, including river runoff, evapotranspiration and soil moisture, and proposes to use the three GCMs which represent High, Medium and Low scenarios on a consistent order of the median and 1st and 3rd quartiles among the selected GCMs.

Through the abovementioned approaches, some of the uncertainties are visualized qualitatively and numerically quantified. The information obtained as a whole can contribute to an effective decision-making under the main uncertainties regarding climate change.

4.2 Probabilistic Analysis of Rainfall and Discharge under Future Climate Scenario < Article 4 (5) b. >

In the succeeding planning stage, (i) Water Balance Analysis and (ii) Flood Inundation Analysis in the target river basin are to be conducted under the selected future climate scenarios. Both analyses are required to acquire the basic data and information to:

- Assess the risk and resilience of water resources management plans, which have been prevailing in the target basin, and
- Formulate climate change adaptation measures against droughts and floods.

In both analyses, design rainfall hyetographs and design flood hydrographs in the target river basin are essential as input data. The description on basic approaches to derive the said hyetographs and hydrographs is excluded hereinafter, except for the following explanation, since the basic approaches are the same as those to be used for study under the present climate conditions.

(1) Rainfall hyetographs for flood inundation analysis are to be obtained through multiplying the observed ones by the change ratios of probable rainfall events.

(2) Design discharge hydrographs for water balance analysis

  (a) Case 1: To use the hydrographs of discharge series in selected future climate scenarios, and

  (b) Case 2: To use the hydrographs of discharge series to obtain through multiplying the discharge series in selected future climate scenarios by a certain coefficient so that the obtained discharge series may give the future water supply deficits equivalent to those in selected future climate scenarios.

Chapter 5 Integration of Climate Change Impacts into Water Resources Management Plans

5.1 Assessment of Safety Level against Drought and Flood, Water Resources Management Risk and Resilience under Climate Change Conditions

5.1.1 Water Use

Generally, water uses in the river basin are 1) domestic water, 2) industrial water, and 3) irrigation water. These water demands are considered for land use plan, climate condition, and other parameter at the target year.

(1) Domestic Water <Appendix II, Chapter 2, 4 2) Table 2.9 No.5>

The domestic water is categorized as the Perusahaan Daerah Air Minum (PDAM: Indonesian Regional Water Utility Company) water and non-PDAM water. PDAM water shall be estimated from population, per capita, connection ratio, non-revenue water ratio, and other parameters. While, non-PDAM water is estimated to have the same method under present climate condition.

Supplementary Explanation

- The population prediction data is used for the published data prepared by the Statistics Bureau or donor agencies. If the population data is not available until the target year, it shall be decided through discussion with related agencies.
- The target connection ratio and ratio of the unaccounted water were set by Cipta Karya. However, it is difficult to catch up until the target year set by Cipta Karya because these ratios have large variations at each PDAM.

(2) Industrial Water <Appendix II, Chapter 2, 4 2) Table 2.9 No.5>

The industrial water is estimated to have the same method under present climate condition.

(3) Irrigation Water <Appendix II, Chapter 2, 4 2) Table 2.9 No.6>

The irrigation water demand is estimated from the unit water requirement and cropped area. The unit water requirement is estimated from the "Irrigation Planning Standard, Design Criteria for Irrigation Networks (KP-1)" of DGWR as shown below.

KP-1 Formula

$$KAI = (Etc + IR + WLR + P - Re)/IE \times A$$

Where:

Etc:	consumptive water needs (mm/day)
IR:	irrigation water needs at paddy field level (mm/day)
WLR:	water needs to replace the water layer (mm/day)
P:	percolation (mm/day)
Re:	effective rainfall (mm/day)
IE:	irrigation efficiency (%)
A:	irrigation area (ha)

The cropped area is estimated to be from the same method under the present climate condition.

Supplementary Explanation

- It is necessary to confirm the calculation period of the estimation of the irrigation water demand. For example, the irrigation water demand is estimated to be at a 10-day average in East Java Province and at a 15-day average in Central Java Province.

5.1.2 Surface Water Estimation <Appendix II, Chapter 2, 4 2) Table 2.9 No.4>

Generally, the surface water uses in the river basin are 1) domestic water, 2) industrial water, and 3) irrigation water. These water demands are considered for land use plan, climate condition, and other parameters at the target year.

The natural run-off shall be estimated from rainfall data, land use, and other parameters under the future climate condition. (ref. Section 4.2)

5.1.3 Groundwater Development Potential <Appendix II, Chapter 2, 4 2) Table 2.9 No.9>

The groundwater development potential is estimated from the groundwater recharge that is estimated from the rainfall and evapotranspiration under future climate condition and topographical and geological condition.

(1) Groundwater data is available

The groundwater recharge is estimated by using the calculation model. The groundwater potential is estimated from the results of the model calculation.

The future groundwater potential is estimated from the calculated groundwater potential and the groundwater demand.

(2) Groundwater data is unavailable

It is assumed that a part of the rainfall or effective rainfall is penetrated to the underground. The groundwater potential is estimated from the above assumption and the future groundwater demand.

5.1.4 Flood Discharge <Appendix II, Chapter 2, 4 3) Table 2.10 No.1>

The flood discharge is estimated by using the hydrograph under present climate condition and magnification of the peak discharge between the present and future climate condition. The magnification is explained in Section 4.1.

5.1.5 Flood Damage <Appendix II, Chapter 2, 4 3) Table 2.10 No.3>

The following flood damage shall be estimated:

- House
- Household goods
- Crops (rice, maize, and millet.)
- Infrastructure (road and irrigation)
- Indirect damage

The flood damage is evaluated to determine the annualized damage as shown below.

Return Period	Flood Damage			Interval Average of Damage Reduction	Interval Probability	Average Annual Damage Reduction
	Without Project (a)	With Project (b)	Averted Damage by Project (a) – (b)			
one year			D0=0			
				(D0+D1)/2	1-(1/2)= 0.500	d1=(D0+D1)/2 x 0.500
two years	L1	L2	D1=L1-L2			
				(D1+D2)/2	(1/2)-(1/5)= 0.300	d2=(D1+D2)/2 x 0.300
five years	L3	L4	D2=L3-L4			
				(D2+D3)/2	(1/5)-(1/10)=	d3=(D2+D3)/2 x

Return Period	Flood Damage			Interval Average of Damage Reduction	Interval Probability	Average Annual Damage Reduction
	Without Project (a)	With Project (b)	Averted Damage by Project (a) – (b)			
ten years	L5	L6	D3=L5-L6		0.100	0.100
				(D3+D4)/2	(1/10)-(1/20)= 0.050	d4=(D3+D4)/2 x 0.050
20 years	L7	L8	D4=L7-L8			
				(D4+D5)/2	(1/20)-(1/30)= 0.017	d5=(D4+D5)/2 x 0.017
30 years	L9	L10	D5=L9-L10			
				(D5+D6)/2	(1/30)- (1/50)= 0.013	d6=(D5+D6)/2 x 0.013
50 years	L11	L12	D6=L11-L12			
				(D6+D7)/2	(1/50)-(1/100)=0.010	d7=(D6+D7)/2 x 0.010
100 years	L13	L14	D7=L13-L14			
Expected Annual Average of Damage Reduction			d1+d2+d3+d4+d5+d6+d7			

Source: JICA Project Team 2

Supplementary Explanation

In Japan, the economic evaluation of flood management is conducted based on the "Manual of Economical Investigation of Flood Disaster" developed by the Ministry of Land, Infrastructure and Transportation, and Tourism (MILT). The flood damage in the Brantas River basin was estimated by applying the above manual.

The manual of the flood damage estimation shall be prepared by DGWR.

Based on this manual, the flood damages are broadly divided into categories of direct damages and indirect damages. The direct damages are physical damage on assets and crops caused by flood, while indirect damages are other economic losses such as the suspension of economic activities. The categorization of damage items by the manual and the quantified economic damages in this study are shown in Table 5.1.1 and formulation of the damages is shown in

Table 5.1.2.

Table 5.1.1 Major Direct and Indirect Damage

<table>
<tr><th>Categorization of Damage</th><th>Damage Item</th><th>Calculation in this Analysis</th></tr>
<tr><td rowspan="8">Direct Damage</td><td>House</td><td>Done</td></tr>
<tr><td>Household asset</td><td>Done</td></tr>
<tr><td>Fixed asset for business use</td><td>-</td></tr>
<tr><td>Stock asset for business use</td><td>-</td></tr>
<tr><td>Fixed asset for agricultural and fishery household use</td><td>-</td></tr>
<tr><td>Stock asset for agricultural and fishery household use</td><td>-</td></tr>
<tr><td>Agricultural crops</td><td>Done</td></tr>
<tr><td>Infrastructure</td><td>Done</td></tr>
<tr><td rowspan="5">Indirect Damage</td><td>Operation loss of enterprise due to business suspension</td><td rowspan="5">Done, assumed at ten percent of House and Household Asset Damage</td></tr>
<tr><td>Income loss of the household due to the expense from the flood</td></tr>
<tr><td>Suspension of transportation</td></tr>
<tr><td>Economic loss by suspension of lifeline</td></tr>
<tr><td>Mental damage by flood</td></tr>
</table>

Source: JICA Project Team 2

Table 5.1.2 Major Direct and Indirect Damage

Damage Item	Formula for Estimating Damage Calculation
Economic Damage to Houses	"Number of Affected Household"x"Average Value of House"x"Damage Rate"
Economic Damage to Household Asset	"Economic Damage to House" x 10%
Economic Damage to Agricultural Crops	"Affected Area of Agricultural Field(hectare)" x "Crop Yield per Hectare" x "Economic Value of Paddy" x "Damage Rate"
Economic Damage of Infrastructure	"Direct Damage of House and Household Asset" x 131.1%
Indirect Damage	"Direct Damages" x 10%

Source: JICA Project Team 2

Even the Balai uses the above method; the Balai shall study the unit price of house, house asset, agricultural crop, and other damages.

5.1.6 Assessment of Safety Level against Droughts

(1) Surface Water <Appendix II, Chapter 2, 4 2) Table 2.9 No.11 to 14>

<u>Zero Option</u>

The water balance study is carried out by considering water demands at a target year, the natural run-off and new water supply structures under the present climate condition. The available water of the domestic and industrial water and the cropping area at each irrigation scheme are estimated.

<u>Safety Level</u>

The water balance study is carried out by changing the water demands and natural run-off from present climate condition to future climate condition. The deficit of each demand and safety level is checked.

The safety level under the future climate condition may be worse than the present climate condition.

<u>Supplementary Explanation</u>

The safety level of the zero option shall be kept at the ten-year dependability of domestic and industrial water and the five-year dependability of irrigation water. The summary table is shown below.

Item	Zero option	To check safety level
Natural run-off	Present climate	Future climate[*1]
Demand estimation	➢ Target year for future climate ➢ Irrigation water is estimated under present climate condition	➢ Target year for future climate ➢ Irrigation water is estimated under future climate condition
Structure	To satisfy safety level to zero option	
Safety level	10-year (D&I water) 5-year (Irrigation water)	To estimate safety level through water balance calculation.

*1: Natural run-off is estimated based on Section 4.2.

(2) Groundwater <Appendix II, Chapter 2, 6 Table 2.16 No.3 to 6>

The safety level is not estimated to the groundwater. The groundwater is evaluated from the groundwater potential. The risk is estimated from the reduced groundwater potential under future climate condition.

5.1.7 Assessment of Safety Level against Floods <Appendix I, Chapter 3, Table 3.1 No.3>

There are two kinds of approach to assess the safety level as explained below.

(1) There are present protection level, design rainfall, and design discharge.

Step 1: Confirmation of protection level, design rainfall, and design discharge under present climate condition

Step 2: To estimate the annual maximum rainfall for design rainfall under future climate condition

Step 3: To carry out statistical analysis for estimation of probable rainfall under future climate condition

Step 4: To carry out run-off analysis to each probable rainfall under future climate condition

Step 5: To estimate the protection level under future climate condition of design discharge under present climate condition

(2) No design discharge and no protection level under present climate condition

If there is no design discharge and no protection level, the following procedures shall be carried out:

<u>Present Climate Condition</u>

Step 1: To decide the protection level based on the government policy considering the socioeconomic condition and natural condition in the river basin.

Step 2: To estimate the design rainfall and hyetograph

Step 3: To estimate the peak discharge and hydrograph by using the run-off analysis model

<u>Present Climate Condition</u>

Same calculation procedure of Step 2 to 5 of Section 5.1.7(1).

5.1.8 Drought Risk <Appendix II, Chapter 2, 4 2) Table 2.9 No.11 to 14>

The following drought risks are considered:

- Decreasing of domestic and industrial (D&I) water supply
- Decreasing of crop production

The deficits of each water demand are estimated through the water balance study. The calculation conditions are as follows:

- Natural run-off: under future climate condition (ref. Section 4.1)
- Water demand: reducing water demand to satisfy safety level
- Structure: same structures under present condition

The risk is evaluated from the water balance calculation results under present and future climate condition and is estimated for the water supply volume and crop production.

Table 5.1.3 Risk of Droughts

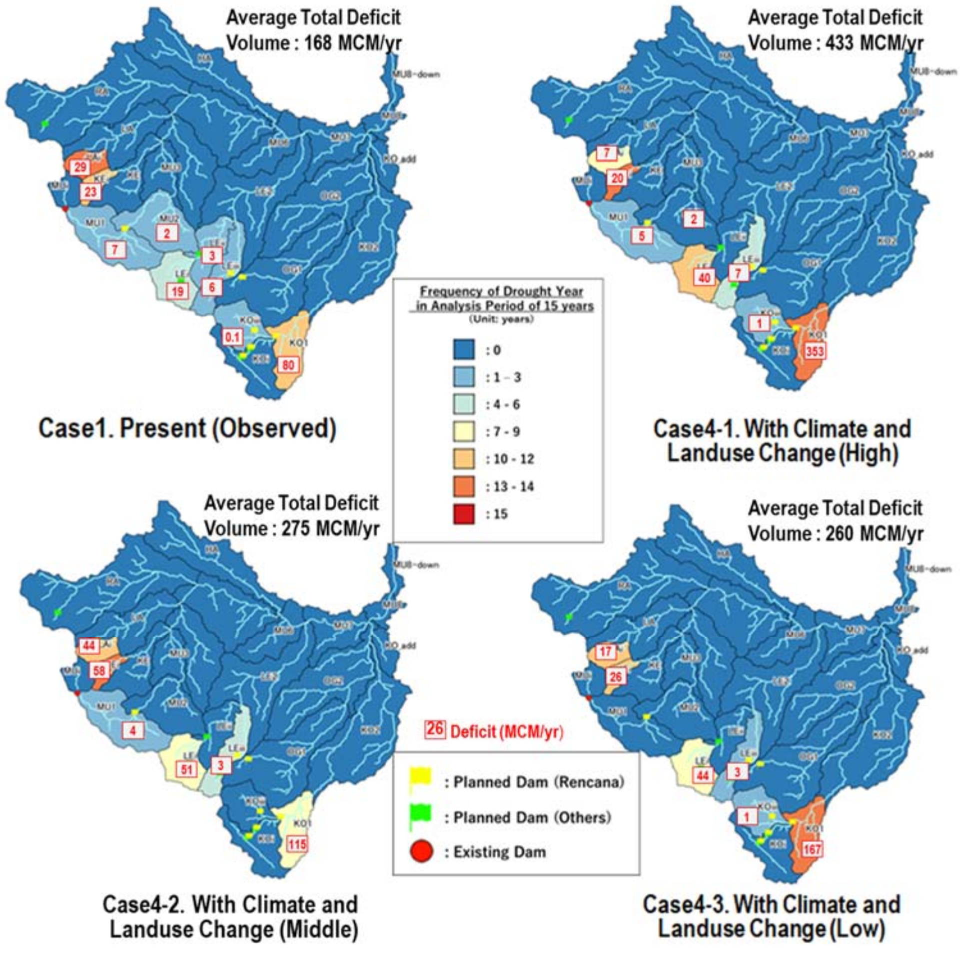
Climate	Present	Future	Risk
Safety level	ten-year: D&I water five-year: Irrigation water		
Available supply water			
Domestic	Dp	Df	Di-Df
Industry	Inp	Inf	Inp-Inf
Crop production*1	Cpp	Cpf	Cpp-Cpf

Note: *1, Crop production is estimated from cropped area and crop production

Source: JICA Project Team 2

5.1.9 Assessment of Drought Risk by Sub-basin

In a large river basin, the drought risk is different by sub-basin, depending upon the availability of the water resources and the water demands in the sub-basin. To identify the water-short sub-basins and their drought magnitudes, the results of water balance analysis are arranged/compiled in a map showing the water deficit volumes and frequency of drought years by sub-basin. A sample map is presented in Figure 5.1.1.



Source: JICA Project Team 2

Figure 5.1.1 Example of the Map of Drought Risk by Sub-basin

5.1.10 Flood Risk <Appendix II, Chapter 2, 2 3) a>

The flood risk under future climate condition is estimated from inundation area, depth of irrigation area, and residential area comparing present climate condition result. As shown in Table 5.1.4.

Table 5.1.4 Risk of Floods

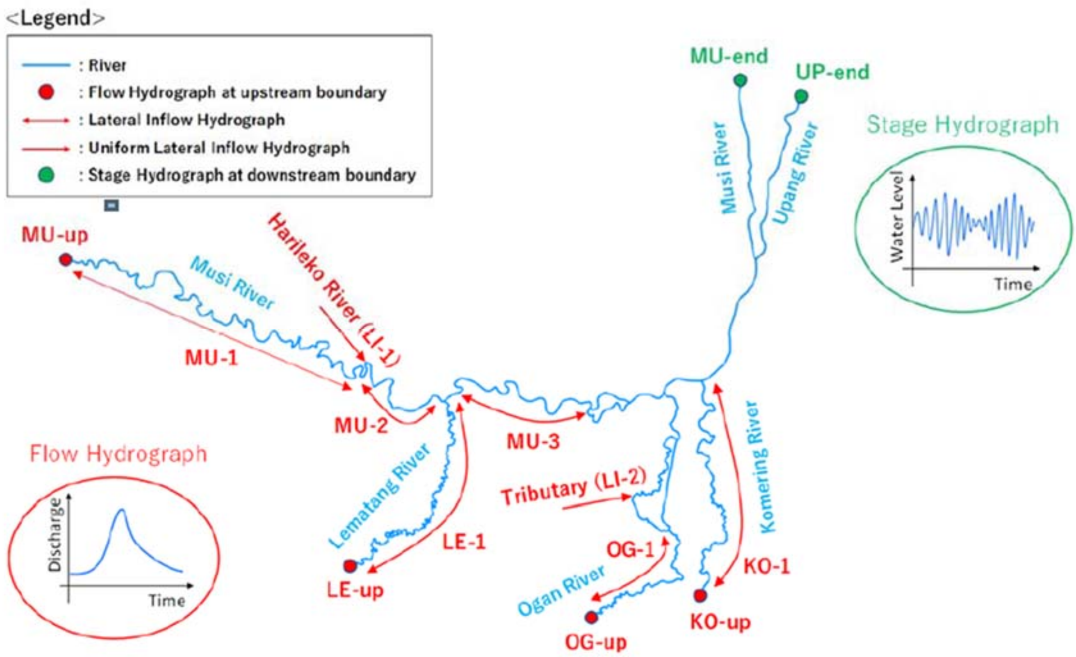
Climate	Present	Future	Risk
Safety level	Same protection level*1		
Inundation area			
Irrigation area	Airp	Airf	Airp-Airf
Residential area	Arp	Arf	Arp-Arf

Note: *1 Even though both protection levels are same ones, flood discharges are different.
Source: JICA Project Team 2

The above risks are estimated through the flood damage calculation as shown in Section 5.1.5.

5.1.11 Flood Inundation Simulation under Climate Change and Sea Level Rise <Appendix I, Chapter 3, Table 3.1 No.3>

The coastal low-lying areas are vulnerable to flood inundation caused by sea level rise as well as an increase of rainfall both of which are impacts of climate change. These two impacts should be incorporated into the flood inundation simulation. Namely, in the flood simulation model run-off discharges of future climate change scenarios and raised tide data should be given as the boundary conditions of the upstream and downstream ends respectively as shown in Figure 5.1.2.

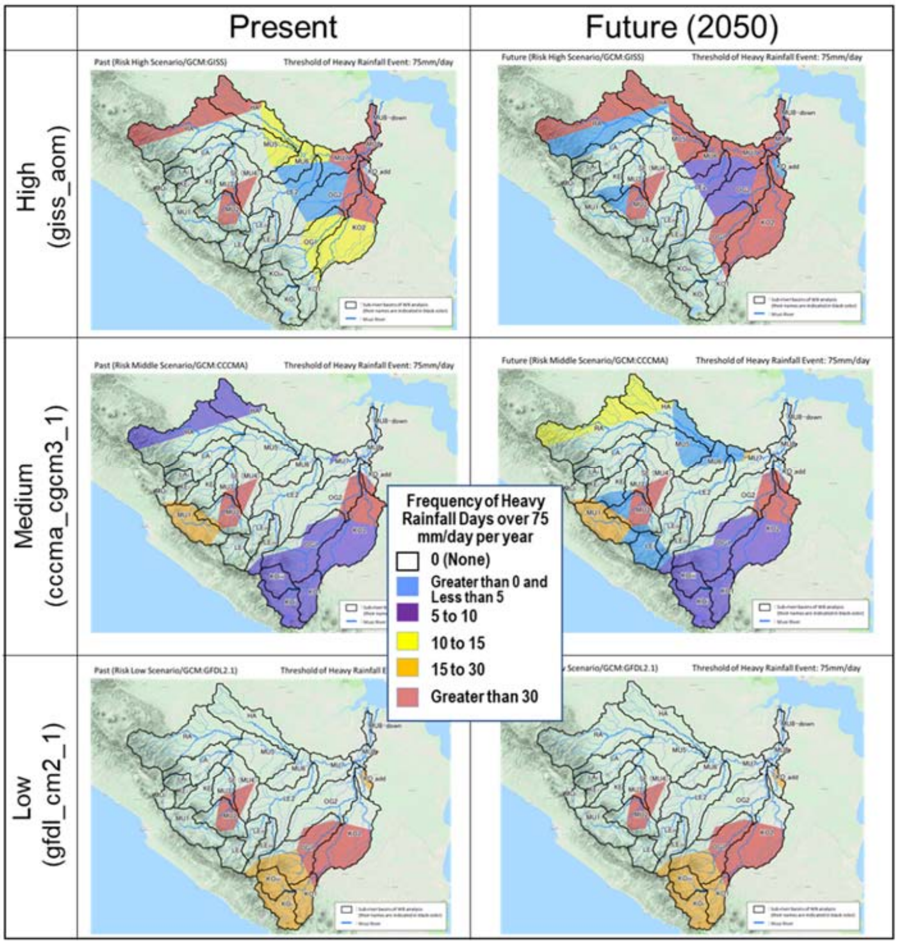


Source: JICA Project Team 2

Figure 5.1.2 Example of Boundary Conditions of Hydraulic Flood Simulation Model

5.1.12 Assessment of Change in Frequency of Heavy Daily Rainfalls

It is concerned that climate change might worsen the inland flood in urban areas. In order to grasp how much heavy rainfall events will increase as an impact of climate change, a frequency analysis should be used by using bias-corrected daily rainfall data. Figure 5.1.3 shows a case of threshold of 75 mm/day, for the Musi River basin. Namely, it shows the change of the number of rainfall days over 75 mm/day before and after the climate change.



Source: JICA project Team 2

Figure 5.1.3 Example of Map of Drought Risk by Sub-basin

5.1.13 Assessment of Risk of Seawater Intrusion < Appendix II, Chapter 2, 2 2) d. >

The coastal low-lying areas are vulnerable to sea water intrusion caused by sea level rise. To assess the risk of sea water intrusion, the following surveys should be made:

- Data collection (tide, river discharge, river cross section, water quality, water use, land use, ecology, and salt damage)
- Assumption of the future tide level based on literature survey on tide level projection
- Salinity/ Electric Conductivity (EC) monitoring

5.1.14 Assessment of Risk of Sediment Disaster <Appendix II, Chap. 2, 4 1) Table 2.8 No.5 >

The sediment disasters including landslide, debris flow, river bank erosion, and river sedimentation might be increased as impact of climate change. To assess the risk of sediment disasters, the following surveys should be made:

- Data collection (topography, geology, land use, vegetation, structures, sand mining activities, river cross section, and sediment disasters)
- Field reconnaissance
- Estimation of future sediment discharge under climate change by Universal Soil Loss Equation (USLE)

5.1.15 Assessment of Resilience for Drought <Appendix II, Chapter 2, 2 2) a. d)>

The following methods to existing dams can be considered for resilience:

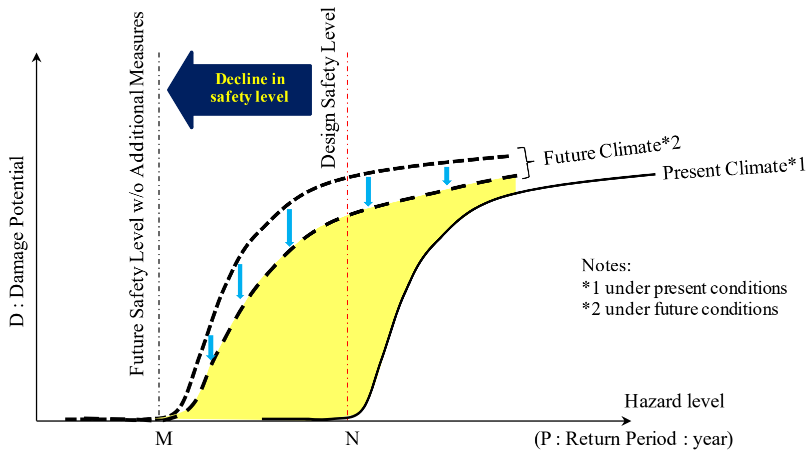
- To set the control water level during dry season (Existing dams)
- To allow over-year storage to each dam (Existing dams)
- To optimize the water supply rule and area considering cooperation of each dam (It is required to have more than two dams at the same target river basin.)

An additional water supply volume is estimated through the water balance calculation.

In addition, the improvement of existing non-structural is also considered.

<u>Supplementary Explanation</u>

The Project deals with the assessment of risk and resilience for water resources management under future climate change conditions on the basis of the concept presented in Figure 5.1.4.



- **Risk = $\sum$ D x Δ(1/P) : Expected Value (Eq. 1)**

Legend:
-------- Before exercise of resilience
----- After exercise of resilience
→ Decrease of Risk by Exercising Resilience
For Structural and Non-structural Measures
N, M Years (M < N)

Source: JICA Project Team 2

Figure 5.1.4 Concept of Risk and Resilience for Water Resources Management (Hazard: Flood and Drought)

The risk is estimated with Eq. 1, and the term of "Resilience" is defined below according to the United Nations International Strategy for Disaster Reduction (UNISDR) Terminology on Disaster Risk Reduction (2009).

Resilience = The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
<u>Comment</u>: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Source: UNISDR (United Nations International Strategy for Disaster Reduction) Terminology on Disaster Risk Reduction (2009)

5.1.16 Assessment of Resilience for Floods <Appendix II, Chapter 2, 2 3) a. >

The resilience of the existing dam shall be considered to apply the control water level method. The control water level during rainy season is studied against flood discharge under future climate condition (Existing dams with flood space). In addition, the improvement of existing non-structural is also considered.

5.1.17 Resilience Measures against Sea Water Intrusion and Sediment Disasters

Careful operation of gate/pump structures based on salinity/EC monitoring might be one of the most practical conceivable measures against sea water intrusion. Conceivable resilience measures against sediment disasters include preparation of sediment disaster risk maps, monitoring of change of river channel (regular river cross section survey) and channel maintenance dredging against sedimentation. Controlling and monitoring of sand mining are also conceivable resilience measures to protect the river bank erosion.

5.2 Reflection of Climate Change Impacts in Water Resources Management Plans

5.2.1 Planning Methodology on Water Resources Management Plan Reflecting Climate Change Impacts

Generally, the water resources management plan under future climate condition is studied based on the current technology.

(1) Drought <Appendix I, Chapter 2, 2.7.1 Table 2.3 No.2>

The planning of the methodology is same as the present climate condition.

(2) Flood <Appendix I, Chapter 2, 2.7.1 Table 2.3 No.3>

The selection of target (design) discharge for flood protection and structures under future climate condition is applied through the use of the Multiple Scenario Approach (MSA), that is one of the selection methods of the structural measures. Non-structural measures are considered to be the same as the present climate condition.

<u>Supplementary Explanation</u>

(1) Multiple Scenario Approach (MSA)

To comprehensively cope with the occurrence of different levels of hazards in changing conditions of vulnerable areas by socioeconomic factors such as increasing wealth, population growth, urbanization, and industry agglomeration as well as uncertainty such as climate change, a methodology to formulate a Disaster Risk Reduction (DRR) strategy is required.

Currently, most countries have been adapting the approaches which set a target protection (safety) level based on a preset particular hazard in a fixed scenario, which is the “Deterministic Approach” (see Figure 5.2.1). However, the capacity of this approach for adaptation to the uncertainty is not necessarily sufficient and further flexibility of disaster management plans and resilience of countermeasures are also required even for a wide range of projected risks. Therefore, a concept of “Multiple Scenario Approach” is created to minimize the damage and losses under the multiple scenarios by comprehensive combination of structural and non-structural measures.

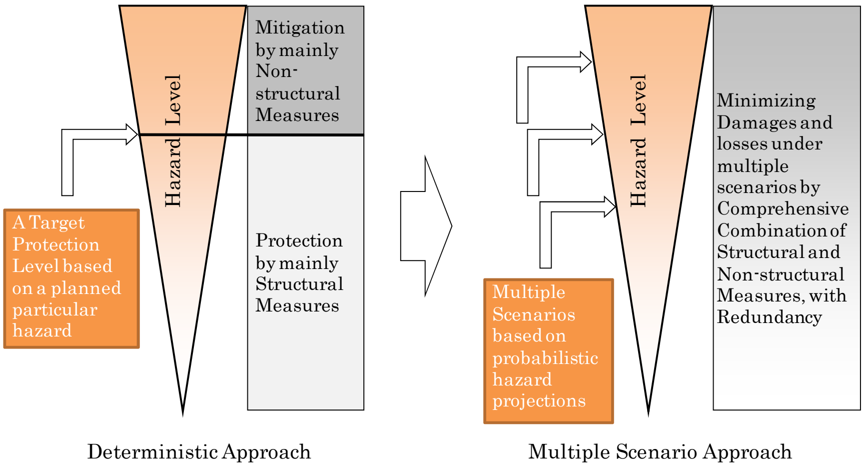
In this approach, multiple disaster scenarios from multiple hazard scales are to be considered to assign the target safety levels differently to various options and coordinate the appropriate options (see Figure 5.2.1). It is expected that most of the countermeasures planned by different target protection levels can contribute to the damage mitigation through synergetic effects and redundancy by the combination of measures.

Using the tool in Figure 5.2.2, several options of the DRR measures which should be conducted annually can be selected.

The position on the total cost curve in Figure 5.2.2 approaches to the **Point of Cost Optimum (PCO*)** as the DRR measures are conducted annually.

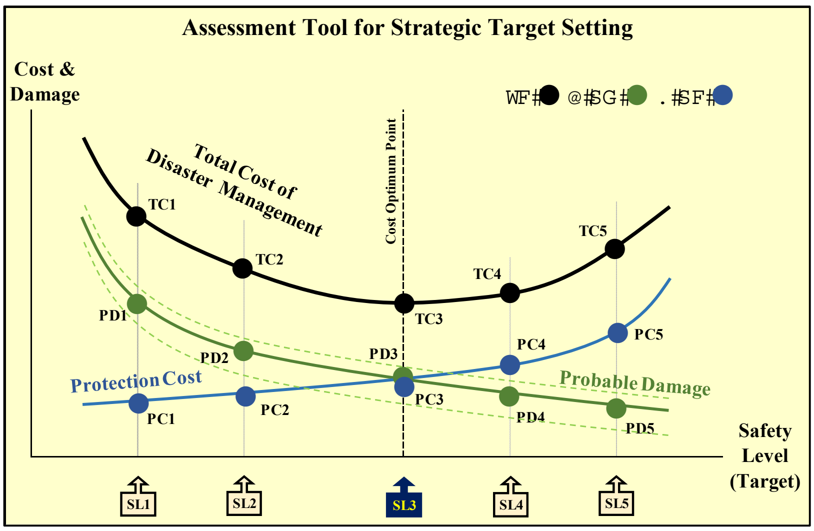
Note: * located at the intersection between probable damage and protection cost curves

- The total cost of the disaster management (= probable damage + protection cost) decreases to and increases from **PCO** through taking DRR measures.



Source: Adapted from the presentation for the second seminar in the Project by Dr. Hitoshi BABA, JICA

Figure 5.2.1 Approaches to Target Safety Level Setting in DRR Strategy



Source: Adapted from the presentation for the second seminar in the Project by Dr. Hitoshi BABA, JICA

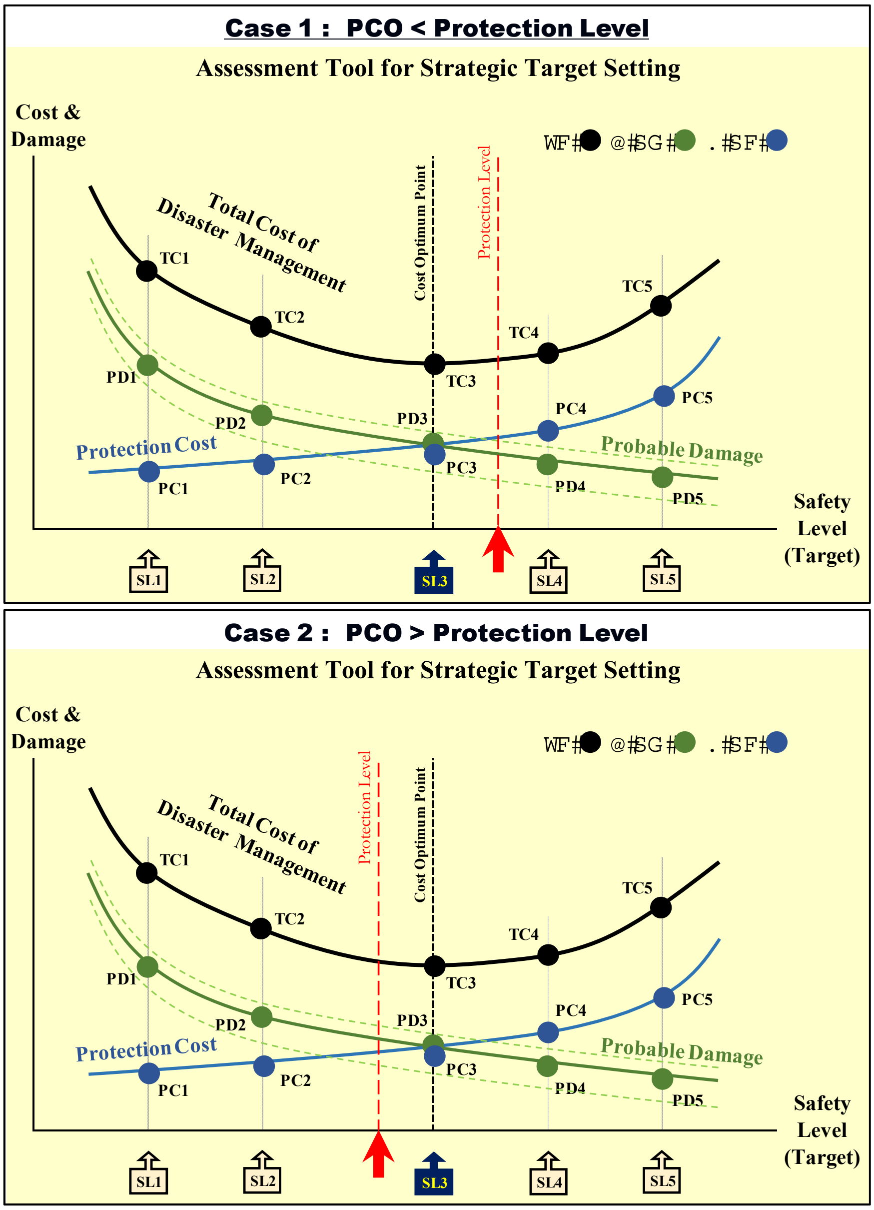
Figure 5.2.2 Assessment Tool for Strategic "Target Setting" in MSA

Most of the countries suffering from natural disasters might be on the left side position in Figure 5.2.2. Such a situation is to be shifted to the right by investing protection and reducing a damage cost with the aim of reducing the total cost of disaster management.

The goal of the "Basin-wide Water Resources Management Strategy" is supposed to stay in the position of PCO in the situation with uncertainty and the PCO is the best condition for sustainable execution of the management. In this approach, respective options of measures are assessed in terms of (i) strategic policies, (ii) investment costs/financial availability, and (iii) damage mitigation value.

(2) Target Safety Level of Climate Chane Adaptation Measures

Regarding the "**Point of Cost Optimum (PCO)**" in MSA for an object area, there are two cases of relationship with criteria for "Flood Protection Level (FPL)", which are (a) Case 1: **PCO < FPL** and (b) Case 2: **PCO > FPL**.



Source: JICA Project Team 2

Figure 5.2.3 Criteria for Protection Level

- In the case of (a), the safety level corresponding to the FPL shall be adopted for the climate change adaptation measures of the object area; and
- In the case of (b), the safety level corresponding to the PCO shall be adopted for the climate change adaptation measures of the object area.

5.2.2 Strategic Environmental Assessment < Appendix I, Chapter 2, 2.3>

POLA and RENCANA of each river basin are examined through the adaptation measures for the forecasted climate change conditions in the target year. In this examination, the Strategic Environmental Assessment (SEA) was applied to consider the environmental and social impacts from the early stage of formulating plan under future climate condition. Then, the adaption measures selected in the process of SEA are examined at the Initial Environmental Evaluation (IEE) level. SEA shall be carried out based on the Indonesian Regulation.

The following steps shall be carried out to the future climate condition (see Figure 5.2.4). However, the POLA and RENCANA under the present climate condition are also explained in the Tim Koordinasi Pengelolaan Sumber Daya Air (TKPSDA: Water Resources Management Coordination Team) meeting. Balai shall explain POLA and RENCANA under the present and future climate condition at the same time.

i) First of all, the first stakeholder meeting was held to explain the project outline, the study method, and the concept of SEA,

ii) The current conditions were confirmed by collecting secondary data and several scenarios of the future climate change conditions in the target year (For example, low, medium, and high scenarios),

iii) With and without adaptation measures are examined,

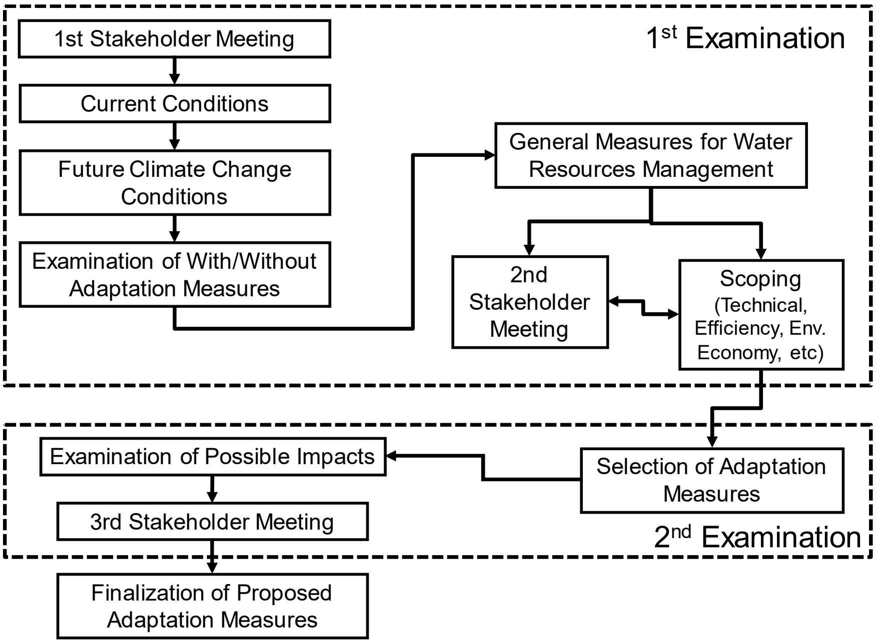
iv) Alternatives under climate change in the target year are examined,

v) The second stakeholder meeting is held to refresh the outline of adaptation measures, to explain the method of scoping, and to have an opinion exchange on the alternatives,

vi) Applicable adaptation measures are selected from the alternatives referring to the comments from the second stakeholder meeting, specific measures at each category of adaptation measure under each scenario are examined and possible environmental impact to specific adaptation measures are examined,

vii) The third stakeholder meeting is held to explain the scoping results and to have an opinion exchange on the adaption measures to be applied, and

viii) The final adaptation measures are examined referring to the comments raised at the second stakeholder meeting.



Source: JICA Project Team 2

Figure 5.2.4 SEA Study Flow for the Project

Supplementary Explanation

The PP No. 46/2016 stipulates to conduct the SEA for the policy, plan, or program which may cause environmental impact. Table 5.2.1 shows the requirement of environmental study for the structures.

Table 5.2.1 Major Ministerial Decrees on SEA

	AMDAL (Permen LH No.5/2012)	UKL-UPL* (Permen PU No.10/2008)	SPPL
(1) Constructing new dams	➢ Height: More than 15 m ➢ Inundate area: More than 200 ha ➢ Water storage: More than 500,000 m^3	➢ Height: 6-15 m ➢ Inundate area: 50 – 200 ha ➢ Water storage: 300,000 - 500,000 m^3	Small-scale project not classified as AMDAL or UKL-UPL
(2) Rehabilitating irrigation canal and distribution pipelines of PDAMs	None	Not mentioned, but UKL-UPL is necessary	Ditto
(3) Changing the water source from surface to groundwater by constructing new wells	Intake groundwater more than 50 L/s	- Community use: 2.5 -50 L/s - Commercial use: 1.0 to 50 L/s	Ditto
(4) Constructing dike	[Large City] - Length: More than 5 km - Dredging: More than 500,000 m^3 [Medium City] - Length: 10 km - Dredging: More than 500,000 m^3	[Large City] - Length: 1-5 km - Dredging: 50,000-500,000 m^3 [Medium City] - Length: 3-10km - Dredging: More than 100,000-500,000 m^3	Small-scale project is not classified as AMDAL or UKL-UPL

	AMDAL (Permen LH No.5/2012)	UKL-UPL* (Permen PU No.10/2008)	SPPL
	[Rural Area] - Length: 15 km - Dredging: More than 500,000 m^3	[Rural Area] - Length: 5–15 km - Dredging: 150,000 - 500,000 m^3	

Note: *More detailed criteria to conduct UKL-UPL are defined by the governor.
Source: JICA Project Team 2

5.2.3 Adaptation Measures to Mitigate Climate Change Impacts on Droughts and Floods

(1) Optimization of Existing Water Resources Management Facilities < Appendix II, Chapter 2, 2 2) d. and 3) b.>

1) Existing Dam (Drought/Flood)

The optimization of reservoir operation is carried out by considering the resilience. However, the optimum dam size (possibility of dam heightening) under future climate condition shall be considered. The possibility of dam heightening is studied from topographical, geological, hydrological, and environmental conditions.

2) Existing Flood Dike

The target (design) flood water level under future climate condition may be higher than the crest elevation or not enough freeboard between water level and crest elevation. Based on MSA, the combination of the new structure and/or heightening of existing flood dike are studied. The following measures can be considered:

1) Heightening of the existing flood dike,
2) New dam construction (considering flood space),
3) New retarding basin construction,
4) Combination of a new dam construction (flood space is different compared with 2) and the heightening of flood dike (embankment height is different compared with 1),
5) Combination of a new retarding basin (storage capacity is different compared with 3) and the heightening of flood dike (embankment height is different compared with 1),
6) Combination of a new dam construction (flood space is different compared with 2), the new retarding basin (storage capacity is different compared with 3) and the heightening of flood dike (embankment height is different compared with 1), and
7) Others.

The optimum heightening height is decided from MSA.

(2) Identification of Other Adaptation Measures < Appendix II, Chapter 2, 2 2) d. and 3) b.>

The possible adaptation measures are listed based on the current integrated water resources management approach. For example, the following adaptation measures are listed and the Balai should study the possibility to apply the target river basin.

1) Drought

(a) Structural measures

Saving demand side:

- ➢ Improvement of pipeline to reduce non-revenue water (leakage water)
- ➢ Rehabilitation of irrigation canal

- Reduction of non-revenue water, and
- Construction of recycling plant of industrial companies

<u>Increasing supply side:</u>

- New dam(s) construction
- Rehabilitation of existing dam
- Construction of the long storage structure (several barrages are constructed along the river)
- New embung(s) construction
- Rain harvesting

(b) Non-structure measures

- Changing of water source (if groundwater potential is remained)
- Land leveling and readjustment of paddy field
- Intermittent and shallow depth irrigation practice
- Introducing the system rice intensification (SRI)
- Optimization of cropping calender
- Public relations of the reservoir water level of each dam
- Domestic water supply support system among adjacent river basin
- Preparation of advanced drought action plan
- Watershed conservation

2) Flood

(a) Structural measures

- Dike (New/ Heightening)
- Retarding basin
- Dam (Flood control space)
- Floodway
- Comprehensive inland flood prevention measures for urban areas (river normalization retention ponds, drainage system surface water infiltration, and flood proofing building)

(b) Non-structural measures

- Flood management (For example, land use control) of frequently inundated area
- Flood forecasting and warning system
- Community-based early warning system
- Preparation of hazard map (under future climate condition)
- Designation of evacuation center
- Strengthening of Flood Prevention Organization
- Preparation of Business Continuity Plan/ Management (BCP/BCM) by private company and local governments
- Preparation of flood action plan

- Others

<u>Supplemental Explanation</u>

i) Consideration of continuity of planning

When the adaptation measures are studied, hydrological condition under long-term climate change situation shall be considered. An example of the adaptation measure study is shown below.

Present Climate Condition: Dike H = 2 m

Future Climate Condition: Dike H=3 m (heightening H = 1 m) or retarding basin A=20 ha

Future Climate Condition (long term): Dike H=5 m or Dike H=2 m and retarding basin A=50 ha

In this case, adaptation measure of future climate condition shall be considered such as a combination of existing dike with retarding basin. If the long-term condition is not considered, heightening of dike may be selected. However, if long-term condition is considered, the combination of existing dike and retarding basin shall be considered.

ii) Consideration project with less rework

MLIT in Japan is considering the selection of project with less rework under future climate condition. For example,

- Dike design considering an increase of external force by climate change impact
- Selection of the project menu with less rework
- Design image of barrage considering sea water rising

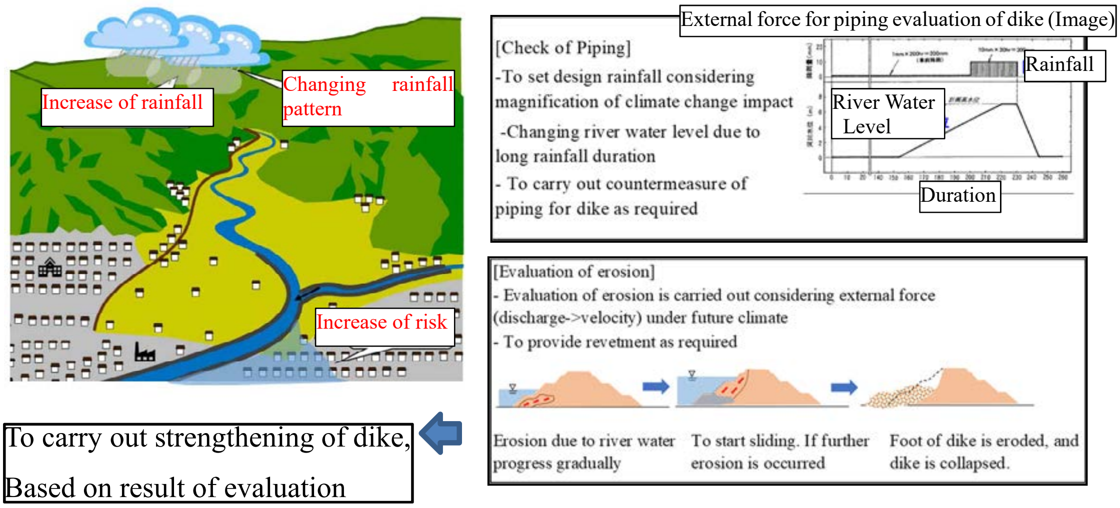
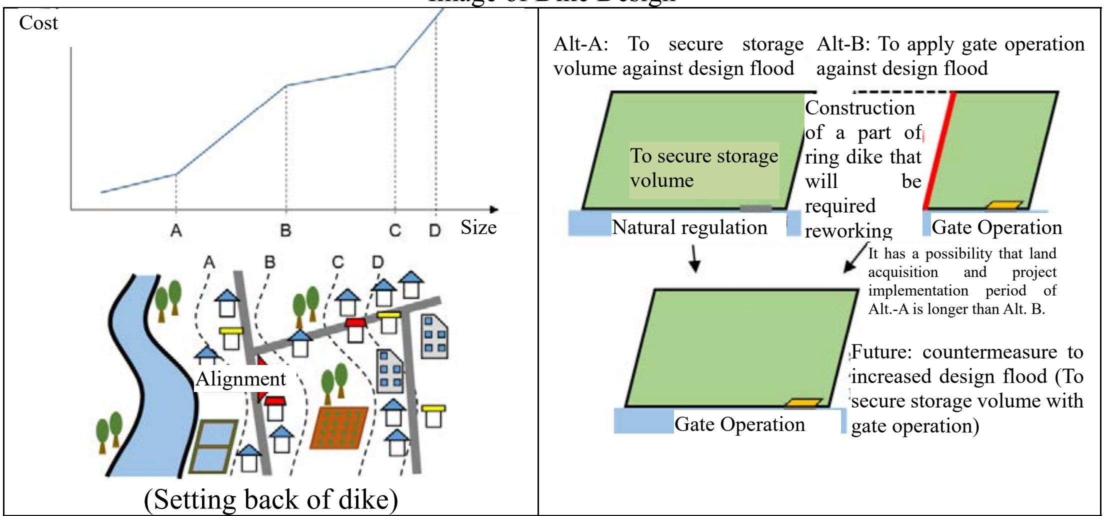
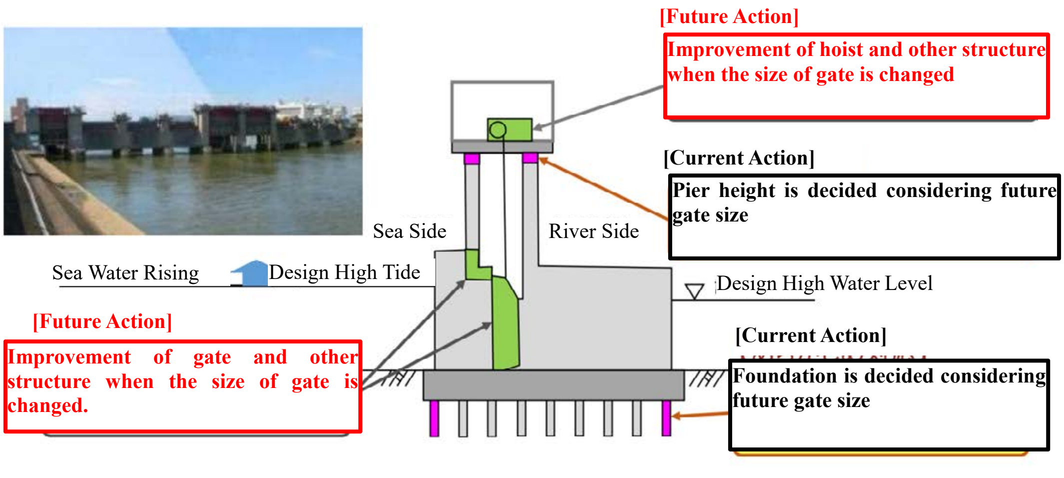


Image of Dike Design



When the size exceeds a certain one, there is a low possibility to carry out setting back of dike. Therefore, it is considered that A and C have lower possibility for rework of dike.	If a provisional countermeasure is applied to expected external force of future projection, the improvement procedure of structure with less rework is studied and applied.
Project menu with rework	Project menu with less rework

Image of Selection for Menu of Project with Less Rework



Design Image of Barrage considering Sea Water Rising

Source: Fifth Technical Review Meeting on Flood Control Plan Based on Climate Change, handout material: Draft Proposal Flood Control Plan based on Climate Change

(3) Formulation of Adaptation Measures

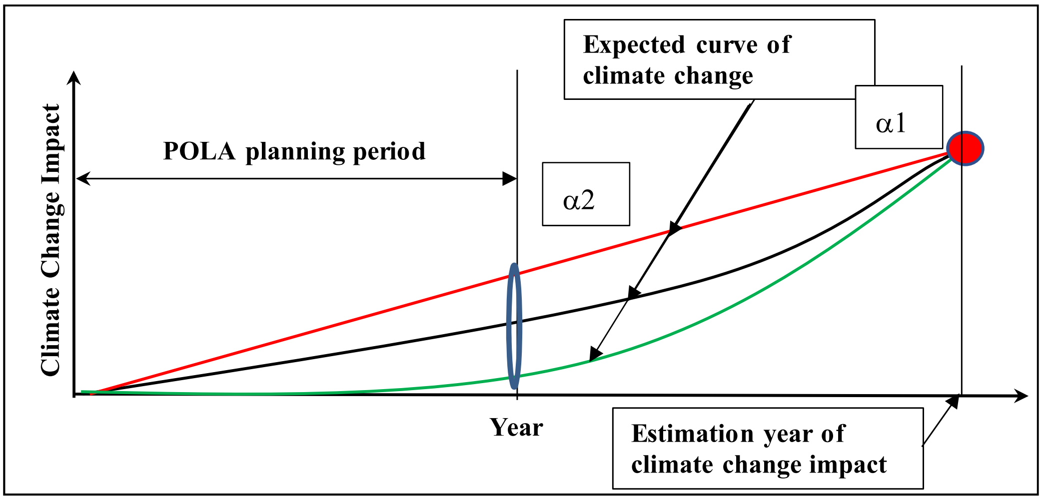
The adaptation measures under future climate condition in POLA shall be proposed until the target year.

Target year <Ministerial Regulation Article 4>

There are two kinds of selection of target year for POLA and RENCANA.

1) Twenty years from the starting year of POLA
2) More than 20 years from the starting year of POLA (In this case, PU shall decide the target year)

Even though PU selects the above 1), they shall consider the long-term climate change situation. Therefore, GCM selection shall consider the long-term climate change situation as illustrated in Figure 5.2.5.



Note: Estimation year of climate change impact and expected curve are decided by the Balai.

Source: JICA Project Team 2

Figure 5.2.5 Illustration of Target Year between Climate Change Impact Estimation and POLA

Hydrological data are estimated from the estimation year of climate change impact. The adaptation measures shall be studied based on the adjusted hydrological data.

Formulation of Adaptation Measures < Appendix II, Chapter 2, 2 2) d. and 3) b.>

The adaptation measures as explained above can be applied under present condition. The Balai shall study a possibility to apply the above adaptation measures and input timing under future climate condition.

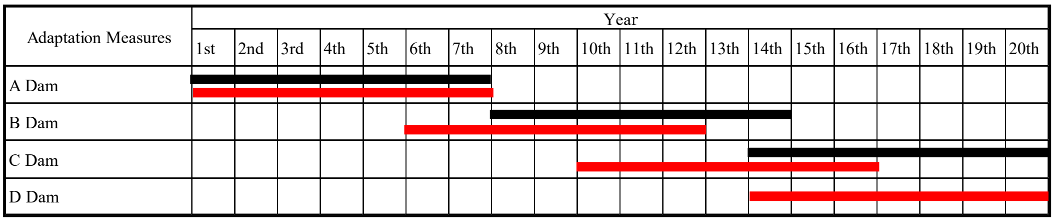
Supplementary Explanation

The formulation procedure of drought

1) To decide the adaptation measures under present climate condition considering water demand,
2) To study the input timing of selected adaptation measures under present climate condition,
3) To decide the adaptation measures under future climate condition considering water demand, and
4) To study the input timing of selected adaptation measures under future climate condition.

Table 5.2.2 shows an example of the adaptation structures and input timing.

Table 5.2.2 Adaptation Measures and Input Timing for Both Climate Condition



Note: black line; schedule for present climate condition, red color; schedule for future climate condition.

Source: JICA Project Team 2

The formulation of structural measures under future climate condition is decided from the MSA results. And the new non-structural measures shall be considered not only for the future climate condition but also for the present climate condition. The existing non-structural measures shall consider the updated timing for future climate condition.

5.2.4 Adaptation Measures to Other Impacts

(1) Sea Water Intrusion < Appendix II, Chapter 2, 2 2) d.>

The following structural and non-structural measures are conceived as adaptation measures against sea water intrusion:

1) Structural measures

- Tidal barrage
- Installation of gates on irrigation canals
- Desalination for domestic, municipal and industrial (DMI) water

2) Non-structural measures

- Capacity development of farmers on gate operation
- Monitoring of salinity/EC

(2) Peatland Management

Under the Paris Agreement, Indonesia has been committed to reduce its greenhouse gas emissions unconditionally by 29% and conditionally by 41% by 2030.

A research result* shows that among the total CO_2 emissions in Indonesia (464.18 MT**), those from peatland fires occupy 90% or more. Thus, the fire management in peatland fire is one of the essential activities for the central government. In January 2016, the Peatland Reconstruction Agency (*Badan Restorasi Gambut*: BRG) was established and placed directly under the President's Office. Accordingly, Reginal Peatland Restoration Teams (*Tim Restorasi Gambut Daerah*) were founded in the provinces of Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan, and Papua. The office in the South Sumatra Province (*Tim Restorasi Gambut Daerah*: TRGD) was founded and given authority to plan and manage all peatland reconstruction-related activities in the provinces.

*: Levine et al., 1999, Geophys. Res. Lett.; Page et al., 2002, Nature
* *: World Bank Data Indicators (2014)

The effort is to halt the lowering of the groundwater levels that will eventually dry the land and to prevent the concession contractors from setting fire on the dried-up forest. The water resources management sector headed by DGWR can contribute to the suppressing peatland fire by reducing poverty in the delta area by the development of the delta areas by constructing effective irrigation systems in which farmers can grow products even in the dry season.

There is a small-scale good practice in the delta areas enhancing the local agriculture and raising the standard of living. Propagating and supporting this type of agriculture may eventually eliminate illegal logging and peatland fire triggered by poor farmers.

Coordination between TRGD and BBWS/BWS should be enhanced especially for the most appropriate water resources management in the delta area. BBWS/BWS should participate in the TRGD coordination meetings at least as the river and channel manager.

(3) Strengthening of Hydrological Monitoring

The hydrological data are indispensable for water resources management. Without sufficient and reliable hydrological data in quantity and quality, any appropriate water resources management is never realized. In addition, poor data makes it very difficult to conduct the precise climate change impact assessment including downscaling and run-off analysis.

Therefore, strengthening of hydrological monitoring should be done as prioritized actions for water resources management.

5.3 Incorporation of Adaptation Measures into POLA and RENCANA Reflecting Climate Change Impacts < Appendix I, Chapter 2, 2 2.6>

The formulated adaptation measures incorporate into POLA and RENCANA. In that time, these adaptation measures shall be classified to five pillars. If the detailed explanation under future climate condition is required, it is mentioned in each item, such as surface water management, groundwater management, watershed conservation, and sabo management.

<u>Supplemental Explanation</u>

In POLA and RENCANA, the following table is useful to explain the adaptation measures.

Issues	Present Climate	Future Climate
Drought		
Run off volume during dry Season		
Water demand at target year		
Domestic water (m^3/yr)		
Industrial water (m^3/yr)		
Irrigation water (m^3/yr)		
Existing dams volume (m^3)		(To consider sedimentation)
Structural adaptation measures		
Non-structural adaptation measures		
Flood		
Target River Basin 1		
Design discharge		
Existing structure		-
Structural measures		
Target River Basin 2		
Design discharge		
Existing structure		-
Structural measures		
Non-structural Measures		

ANNEXES
<< Illustrative Cases in the Project >>

ANNEX A MULTIPLE SCENARIO APPROACH (BRANTAS CASE: NGOTOK RIVER)

1. Inundation Analysis Results

To collect information on the inundation depth and area.

(Medium Scenario)

Average Return Period (year)	Maximum Inundation Area (ha)	Housing Area		Irrigation Area	
		Inundation Depth (m)	Inundation Area (ha)	Inundation Depth (m)	Inundation Area (ha)
2	214	0.51	102	0.71	8
5	781	0.60	303	0.88	25
10	1,185	0.70	500	0.98	41
30	1,969	1.04	926	1.09	76
50	2,564	1.06	1,239	1.14	103
100	3,666	1.07	1,755	1.22	150

(Low Scenario)

Average Return Period (year)	Maximum Inundation Area (ha)	Housing Area		Irrigation Area	
		Inundation Depth (m)	Inundation Area (ha)	Inundation Depth (m)	Inundation Area (ha)
2	215	0.51	102	0.71	8
5	781	0.60	303	0.88	25
10	1,019	0.66	415	0.94	34
30	1,827	1.04	849	1.07	70
50	2,052	1.05	971	1.10	80
100	2,301	1.05	1,104	1.12	91

(High Scenario)

Average Return Period (year)	Maximum Inundation Area (ha)	Housing Area		Irrigation Area	
		Inundation Depth (m)	Inundation Area (ha)	Inundation Depth (m)	Inundation Area (ha)
2	485	0.54	186	0.80	15
5	1,040	0.66	425	0.95	35
10	1,678	1.04	767	1.05	63
30	3,115	1.06	1,507	1.18	127
50	4,492	1.08	2,097	1.28	182
100	6,408	1.09	2,788	1.42	250

2. Structure

If the flood control facility is a dike structure, a non-uniform flow calculation shall be carried out to make the wall for both alignments of the dike. The required dike height and length are estimated from the calculation thereafter.

The construction cost is estimated by using the unit price of a similar project.

Calculation method is the same as the current estimation method.

(Medium Scenario)

Dike Dimensions and Cost

Hazard Scale	2-year	5-year	10-year	30-year	50-year	100-year
Discharge (m^3/s)	600	759	910	1,228	1,457	1,832
Total Length (m)	9,600	16,500	22,300	34,900	43,100	55,500
Average height (m)	0.6	0.7	0.8	1.0	1.3	1.7
Cost (IDR in Mil.)	12,025	18,158	19,929	43,118	49,786	72,852

(Low Scenario)

Hazard Scale	2-year	5-year	10-year	30-year	50-year	100-year
Discharge (m^3/s)	600	759	845	1,171	1,261	1,358
Total Length (m)	9,600	16,500	20,100	32,800	36,000	39,700
Average height (m)	0.6	0.7	0.7	1.0	1.1	1.2
Cost (IDR in Mil.)	11,483	17,261	21,073	39,658	44,634	49,189

(High Scenario)

Hazard Scale	2-year	5-year	10-year	30-year	50-year	100-year
Discharge (m^3/s)	668	853	1,110	1,652	2,079	2,575
Total Length (m)	12,500	20,100	30,700	49,700	62,900	76,000
Average height (m)	0.6	0.7	0.9	1.5	2.1	2.9
Cost (IDR in Mil.)	13,637	21,268	35,613	64,629	92,294	130,646

3. Damage

The damage estimation applied is a Japanese method developed by MILT. The following damages are considered:

Categorization of Damage	Damage Item	Calculation in this Analysis
Direct Damage	House	Done
	Household asset	Done
	Fixed asset for business use	-
	Stock asset for business use	-
	Fixed asset for agricultural and fishery household use	-
	Stock asset for agricultural and fishery household use	-
	Agricultural crops	Done
	Infrastructure	Done
Indirect Damage	Operation loss of enterprise due to business suspension	Done, assumed at 10% of house and household asset damage
	Income loss of the household due to the expense from the flood	
	Suspension of transportation	
	Economic loss by suspension of lifeline	

Damage Item	Formula for Estimating Damage Calculation
Damage to houses	"Number of affected household" x "Average value of house" x "Damage rate"
Damage to household asset	"Damage to house" x 10%
Damage to agricultural crops	"Affected area of agricultural field (hectare)" x "Crop yield per hectare" x "Economic value of paddy" x "Damage rate"
Damage of infrastructure	"Direct damage of house and household asset" x 131.1%
Indirect damage	"Direct damages" x 10%

For MSA, the flood damage is estimated to annualized damage. The calculation sheet is as follows:

Return Period	Flood Damage			Interval Average of Damage Reduction	Interval Probability	Annual Average Damage Reduction
	Without Project (a)	With Project (b)	Averted Damage by Project (a) – (b)			
1 year			D0=0			
				(D0+D1)/2	1-(1/2)= 0.500	d1=(D0+D1)/2 x 0.500
2 years	L1	L2	D1=L1-L2			
				(D1+D2)/2	(1/2)-(1/5)= 0.300	d2=(D1+D2)/2 x 0.300
5 years	L3	L4	D2=L3-L4			
				(D2+D3)/2	(1/5)-(1/10)= 0.100	d3=(D2+D3)/2 x 0.100
10 years	L5	L6	D3=L5-L6			
				(D3+D4)/2	(1/10)-(1/20)= 0.050	d4=(D3+D4)/2 x 0.050
20 years	L7	L8	D4=L7-L8			
				(D4+D5)/2	(1/20)-(1/30)= 0.017	d5=(D4+D5)/2 x 0.017
30 years	L9	L10	D5=L9-L10			
				(D5+D6)/2	(1/30)- (1/50)= 0.013	d6=(D5+D6)/2 x 0.013
50 years	L11	L12	D6=L11-L12			
				(D6+D7)/2	(1/50)-(1/100)=0.010	d7=(D6+D7)/2 x 0.010
100 years	L13	L14	D7=L13-L14			
Expected Annual Average of Damage Reduction			d1+d2+d3+d4+d5+d6+d7			

(For estimation of annualized damage, the value of with project is applied zero.)

(Medium Scenario)

Return Period	H (m)	Area (ha)	Coeff.	Crop damage (ton)
2	0.707	8	0.5	26
5	0.882	25	0.5	80
10	0.975	41	0.5	131
30	1.088	76	0.64	313
50	1.143	103	0.64	424
100	1.223	150	0.64	614

(Coefficient is decided from inundation depth.)

Return Period	H(m)	Area(ha)	House	Coeff.	Nos. of Houses
2	0.506	102	495.6	0.176	87
5	0.600	303	1,473.3	0.176	259
10	0.702	500	2,427.8	0.176	427
30	1.043	926	4,502.3	0.343	1,544
50	1.056	1,239	6,020.8	0.343	2,065
100	1.070	1,755	8,529.4	0.343	2,926

(Coefficient is decided from inundation depth.)

Return Period: 2-year

RP (yr)	Probability	Crop Damage	Average	Prob		Acc.
1.01	0.990	0				
2	0.500	0	0	0.490	0.0	0.0
5	0.200	80	40	0.300	12.0	12.0
10	0.100	131	105.5	0.100	10.6	22.6
30	0.033	313	222	0.067	14.8	37.4
50	0.020	424	368.5	0.013	4.9	42.3
100	0.010	614	519	0.010	5.2	47.5

Return Period: 5-year

RP (yr)	Probability	Crop Damage	Average	Prob	Annualized	Acc.
1.01	0.990	0				
2	0.500	0	0	0.490	0.0	0.0
5	0.200	0	0	0.300	0.0	0.0
10	0.100	131	65.5	0.100	6.6	6.6
30	0.033	313	222	0.067	14.8	21.4
50	0.020	424	368.5	0.013	4.9	26.3
100	0.010	614	519	0.010	5.2	31.5

Return Period: 10-year

RP (yr)	Probability	Crop Damage	Average	Prob	Annualized	Acc.
1.01	0.990	0				
2	0.500	0	0	0.490	0.0	0.0
5	0.200	0	0	0.300	0.0	0.0
10	0.100	0	0	0.100	0.0	0.0
30	0.033	313	156.5	0.067	10.4	10.4
50	0.020	424	368.5	0.013	4.9	15.3
100	0.010	614	519	0.010	5.2	20.5

Return Period: 30-year

RP (yr)	Probability	Crop Damage	Average	Prob	Annualized	Acc.
1.01	0.990	0				
2	0.500	0	0	0.490	0.0	0.0
5	0.200	0	0	0.300	0.0	0.0
10	0.100	0	0	0.100	0.0	0.0
30	0.033	0	0	0.067	0.0	0.0
50	0.020	424	212	0.013	2.8	2.8
100	0.010	614	519	0.010	5.2	8.0

Return Period: 50-year

RP (yr)	Probability	Crop Damage	Average	Prob	Annualized	Acc.
1.01	0.990	0				
2	0.500	0	0	0.490	0.0	0.0
5	0.200	0	0	0.300	0.0	0.0
10	0.100	0	0	0.100	0.0	0.0
30	0.033	0	0	0.067	0.0	0.0
50	0.020	0	0	0.013	0	0.0
100	0.010	614	307	0.010	3.1	3.1

Return Period: 100-year
Annualized damage=0.0
Annualized damage of houses (Nos.)
The calculation method is the same as above.

Annualized Damage:

RP	Paddy (ton)	House (nos.)	Annualized Damage (IDR in Million)					
			Paddy	House	House Asset	Infra	Indirect	Total
2	47.5	187.9	135	10,333	337	13,988	1081	25,874
5	31.5	136.1	89	7,484	244	10,131	782	18,730
10	20.5	100.5	58	5,526	180	7,481	576	13,821
30	8.0	38.7	23	2,130	108	2,934	226	5,421
50	3.1	14.6	9	805	41	1,109	86	2,050
100	0.0	0.0	0	0	0	0	0	0

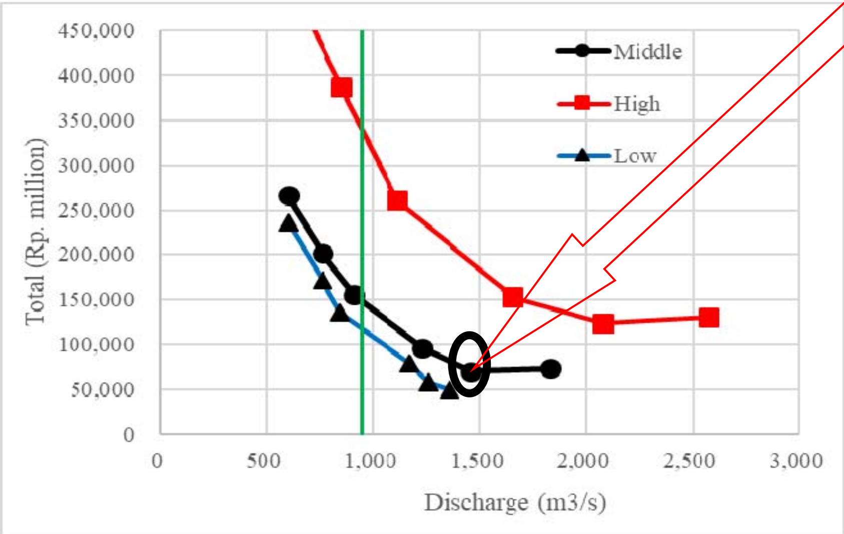
Net present value of damage is considered in the 50-year period. If discount rate is x%, calculation of the net present value is as follows;
N-year: NPV(Damage)=Damage x 1/(1+x/100)^(N-1)
If X=10%, Coefficient is 10.906. (Sum(1/(1+10/100)^(N-1)),N=1 to 50)

RP	Damage (IDR in Mil.)
2	254,117
5	183,946
10	135,729
30	53,234
50	20,133
100	0

4. Total Cost

Total cost is calculated from the damage and cost as shown below.

Return Period (yr)	Discharge with Structural Measures (m^3/s)	Cost (1) (IDR 10^6)	Damage (2) (IDR 10^6)	(1)+(2) (IDR 10^6)
2	600	12,025	254,117	266,142
5	759	18,158	183,946	202,104
10	910	19,929	135,729	155,658
30	1,228	43,118	53,234	96,352
50	1,457	49,786	20,133	69,919
100	1,832	72,852	0	72,852



ANNEX B SELECTION OF FUTURE CLIMATESCENARIOS (MUSI CASE)

(1) Selection of Representative GCMs for Flood in Musi River Basin

The Musi River basin, which has the fourth largest catchment area of some 60,000 km^2, is topographically characterized as very flat in the middle and downstream areas. In the rainy seasons, extensive flood inundation that continues for more than a few months takes place in the low-lying swampy areas. A 5-month rainfall from November to March was regarded through regression analysis between rainfall and the assumed inundation volume, as the most influential rainfall that controls the extensive inundation.

Change of the magnitude of the 5-month rainfall is used as the indicator for the selection of the future climate scenarios (GCMs). The following procedure was performed to select the representative three GCMs (High, Medium and Low) from the nine GCMs that were selected from 62 GCMs through a pre-screening:

i) Probable 5-month rainfalls (2-, 5-, 10-, 25-, 50 and 100-year return periods) of the nine GCMs for both the current (1985-2000) and future (2050-2060) climates were estimated through frequency analysis.

Increased rates from the current climate to the future climate of the estimated probable 5-month rainfalls are box-plotted as illustrated in **Figure 3.3-8***.

Considering the consistent order of the median and the 1st and 3rd quartiles shown in **Figure .3.3-8***, the following three GCMs were selected to represent High, Medium and Low scenarios concerning future floods:

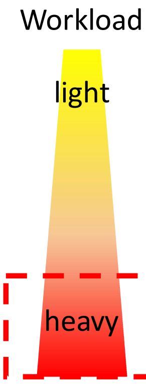
- GISS_AOM as High scenario (the most hazardous scenario)
- CCCMA_CGCM as Medium scenario (scenario of highest probability)
- GFDL_2_1 as Low scenario (the safest scenario)

*(Note) * in Chapter 3*

(2) Selection of Representative GCMs for Drought in the Musi River Basin

Table B1 shows the conceivable indicators for selecting the representative three GCMs for drought. Rainfall and discharge can express drought risk from the water supply point of view, while water deficit can express drought risk from both water supply and water demand point of view. “Water Deficit” was selected as the indicator for selecting the three GCMs for the huge and complex Musi River basin.

Table B1 Conceivable Indicators for Selecting Representative GCMs



Indicator	Explanation	Consideration
Rainfall	Average annual rainfall over Musi river basin	✓ Easy to understand ✓ Normally used for flood control plan as external force
Discharge	Average discharge at Musi river mouse computed by run-off analysis	✓ Discharge reflects rainfall spatial and chronological characteristics and run-off characteristics of river basin ✓ The effect of water use is not considered
Water Deficit	Total water deficit computed by water balance analysis	✓ Both surface flow and water demand are considered ✓ Workload is heavy

The water deficits were estimated through water balance analysis, and the increase rates of the deficit volumes from the current climate to the future climate are box-plotted to select the three representative GCMs in the same way as those for flood. The following procedure was used for the Musi River basin:

Water balance analysis was made for the current and future climates of the nine GCMs to estimate the deficit volumes. The estimated water deficits for the nine GCMs are summarized in **Table B2**, where Case 2 and Case 3 are the cases of the current and future climates under the current land use. “Case 3/Case 2” denotes increase rates of water deficits from the current climate to the future climate.

Table B2 Results of Water Balance Analysis

(Unit: MCM / Year)

GCM		Case 2		Case 3		Case 4		Case 3/Case 2		Case 4/Case 2	
		Deficit	RANK	Deficit	RANK	Deficit	RANK	Rate	RANK	Rate	RANK
GCM1	CCCMA_CGCM	1546.2	2	1498.6	4	1696.4	3	0.97	9	1.10	8
GCM2	CSIRO_MK35	1384.0	3	2442.9	1	2681.5	1	1.77	2	1.94	2
GCM3	GFDL_2_0	842.9	8	866.7	9	996.0	9	1.03	7	1.18	7
GCM4	GFDL_2_1	1074.1	4	1247.2	5	1415.3	5	1.16	6	1.32	6
GCM5	GISS_AOM	1570.9	1	1593.7	3	1685.6	4	1.01	8	1.07	9
GCM6	INGV_ECHAM4	611.2	9	935.7	8	1063.9	8	1.53	3	1.74	3
GCM7	MIUB_ECHO	890.6	6	1099.0	7	1281.1	7	1.23	4	1.44	4
GCM8	MIUB_MPI_ECHAM5	992.1	5	1205.7	6	1347.0	6	1.22	5	1.36	5
GCM9	MIUB_MRI_CGCM232A	845.7	7	1634.7	2	1743.3	2	1.93	1	2.06	1
Max		1570.9	-	2442.9	-	2681.5	-	1.93	-	2.06	-
75%		1384.0	-	1593.7	-	1696.4	-	1.53	-	1.74	-
50%		992.1	-	1247.2	-	1415.3	-	1.22	-	1.36	-
25%		845.7	-	1099.0	-	1281.1	-	1.03	-	1.18	-
Min		611.2	-	866.7	-	996.0	-	0.97	-	1.07	-

Note:
Case 2: Current climate under current land use
Case 3: Future climate under current land use
Case 4: Future climate under current land use

The increase rates ("Case 3/Case 2") were box-plotted as shown in **Figure B1**.

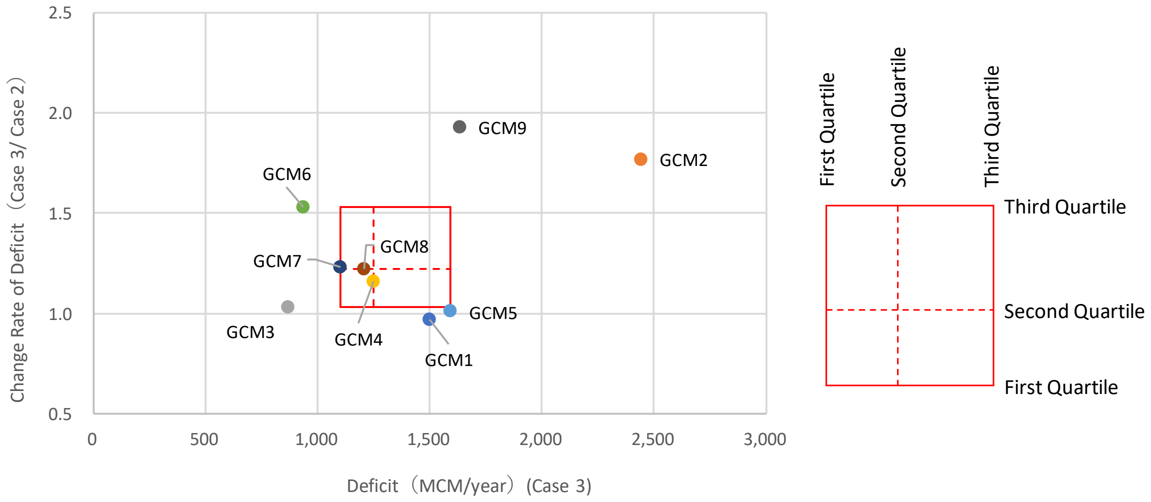


Figure B1 Box Plot in Scatter Plot of the Deficit Increase Rates and Deficit

Considering the consistent order of the median and the 1st and 3rd quartiles shown in **Table B2** and **Figure B1**, the following three GCMs were selected to represent High, Medium and Low scenarios concerning future drought:

- INGV_ECHAM4 as High scenario (the most hazardous scenario)
- MIUB_MPI_ECHAM5 as Medium scenario (scenario of highest probability)
- GFDL_2_0 as Low scenario (the safest scenario)

ANNEX C HYDROGRAPHS FOR CLIMATE CHANGE IMPACT ASSESSMENT AND PLANNING（MUSI CASE）

It is necessary to recognize the uncertainty associated with climate change projections. Even the reproduction of the current climate by GCMs includes considerable errors due to uncertainty. Accordingly, the projection of the future climate by GCMs adds a factor of climate change to the reproduction results of the current climate and will contain more errors. Therefore, it is not recommended to directly use the projection data by GCMs. Rates or amounts of change between the current and future climates should be used in order to correctly utilize the characteristics of GCMs instead.

Based on the above understanding, the time series discharge data of the three scenarios for impact assessment and planning for the Musi River basin were prepared as follows:

i) First, the deficit volumes of the future scenarios were estimated by multiplying the deficit volume of the current climate by the increasing rates in **Table B2*,** as shown in **Table C1**. For example, the deficit volume of the current climate that was obtained from the water balance analysis based on the observed climate data is 816 MCM/year. The deficit volume of the High Scenario with the current land use was estimated to be 1,248 MCM/year by multiplying 816 MCM/year by the increase rate of 1.53.

*(Note) * in Annex B*

Table C1 Estimation of Future Water Deficit Volumes of the Three Scenarios

Scenario	Current Deficit* (MCM/year)	Future Climate + Current Land Use		Future Climate + Future Land Use	
		Increase Rate from Current to Case 3	Deficit Volume（MCM/year）	Increase Rate from Present to Case 4	Deficit Volume MCM/year）
High (INGV_ECHAM4)	816	1.53	1,248	1.74	1,420
Medium (MIUB_MPI_ECHAM5)		1.22	996	1.36	1,110
Low (GFDL_2_0)		1.03	840	1.18	963

*: The current deficit volume was estimated through water balance analysis based on the observed climate data.

ii) The time series discharge data obtained through runoff analysis based on the GCM data are not directly used for impact assessment and planning from the above reason. The GCM-based discharge data was adjusted using the following formula for impact assessment and planning:

$Q_f = a \times Q_g$

Where,

Q_f: Time series discharge data to be used for impact assessment and planning

a: Adjustment constant

Q_g: Time series discharge data obtained through runoff analysis based on the GCM data

The adjustment constant “a” was determined through trial water balance analyses using Q_f and the water demand based on the GCM data. This constant was used so that the calculated deficit volume would be equal to the future deficit in **Table C1.**