Japan International Cooperation Agency (JICA)

Study on Mainstreaming Climate Change Considerations into JICA Operation (National and Regional Climate Impacts)

Final Report

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This document, “National and Regional Climate Impacts” has been prepared under the scope of “Study on Mainstreaming Climate Change Considerations into JICA Operation”.

List of Countries Prepared for “National and Regional Climate Impacts”

ASIA	(ASIA)
	Afghanistan
	India
	Indonesia
	Uzbekistan
	Cambodia
	Kyrgyz Republic
	Sri Lanka
	Thailand
	Tajikistan
	China
	Nepal
	Pakistan
	Bangladesh
	East Timor
	Philippines
	Bhutan
	Vietnam
	Malaysia
	Myanmar
	Maldives
	Mongolia
	Laos
	Kazakhstan
OCEANIA	(OCEANIA)
	Samoa
	Solomon Islands
	Tonga
	Vanuatu
	Papua New Guinea
	Palau
	Fiji
	Marshall Islands
	Micronesia
	Tuvalu
NORTH/LATIN AMERICA	(NORTH/LATIN AMERICA)
	United States
	Chile
	Argentina
	Uruguay
	Ecuador
	Paraguay
	Brazil
	Venezuela
	Peru
	Bolivia
	Guyana
	Colombia
	Panama
	Guatemala
	Costa Rica
	Nicaragua
	Belize
	El Salvador
	Honduras
	Mexico
CARIBBEAN	Jamaica
	Saint Lucia
	Dominican Republic

: Countries prepared by JICA in the past
: Countires prepared in the Study
: Regions prepared in the Study (covering several countries)

AFRICA	(AFRICA)
	Uganda
	Ethiopia
	Ghana
	Gabon
	Cameroon
	Kenya
	Côte d'Ivoire (Ivory Coast)
	Democratic Republic of the Congo
	Zambia
	Djibouti
	Zimbabwe
	Sudan
	Senegal
	Tanzania
	Nigeria
	Namibia
	Niger
	Burkina Faso
	Benin
	Botswana
	Madagascar
	Malawi
	Republic of South Africa
	Mozambique
	Rwanda
	Liberia
	Mauritius
MIDDLE EAST	(MIDDLE EAST)
	Yemen
	Iran
	Egypt
	Saudi Arabia
	Syria
	Tunisia
	Palestine
	Morocco
	Jordan
	Iraq
EUROPE	(EUROPE)
	United Kingdom
	Turkey
	Balkan
	France
	Kosovo
	Macedonia
	Bosnia-Herzegovina

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Chapter 1 Projected Influence of Climate Change in India

India, located in South Asia, is a large country in terms of population of more than one billion and a land area of around 3.3 million km^2. This country has various geographical features, namely, the Himalayan Range in the northernmost region, plains in the northern area, the vast Deccan Plateau, coastal areas, and islands. Land areas in the north have a continental climate with high summer temperature and cold winter. In contrast, the coastal regions are with more even temperature throughout the year. The climate regimes vary from humid in the northeast area to arid in the west area. A semi-arid area belt in the peninsular region extends between the humid west coast and the central and eastern parts of the country. The most important feature of its climate is the season of concentrated rains called monsoon.

The possible climate change impacts on India have been revealed through recent intensive scientific efforts, of which the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report published in 2007 would be the most authoritative. The temperature would rise larger in the north than the southern area in India. The influence to glacier, sea level, precipitation as well as temperature due to climate change would affect the country.

The possible impacts on India by climate change have been projected as follows:

(1) Water Cycle

- Precipitation would decrease from December to February of the dry season, and increase during the rest of the year.
- Number of rainfall days would decrease, but rainfall intensity would increase over a major part of the country.
- The severity of droughts and intensity of floods in various parts of the country would increase.
- There would be a general reduction of available runoff. Hence, intensive development of groundwater resources would be indispensable. However, groundwater would be affected by precipitation and evapotranspiration change in terms of groundwater recharge, quality degradation in alluvial aquifers due to increase of floods, and saline intrusion due to the rise of sea level. Increased rainfall intensity may lead to higher runoff and possibly reduced recharge.
- Warming, sea level rise and melting of glaciers would adversely affect the water balance in different parts of India, and quality of groundwater along its coastal plains.

(2) Agriculture and Food

- Indian agriculture largely depends on the rainfall quantity and its distribution, and millions of small and marginal farmers depend on rainfed agriculture for their livelihood. This situation is vulnerable to possible climate change.
- Food security in India would be adversely affected due to the increase in frequency and intensity of droughts and floods caused by climate change.
- Decrease in crop production due to temperature rise would be offset by CO_2 fertilization. However, if the temperature rise is higher, crop production in the western part would decrease due to reduced crop durations.

(3) Coastal Zone

- The coastal zone stretching over 7,500 km is a densely populated area. Erosion and flooding in the coastal zone would be exacerbated by sea level rise and tropical cyclones.
- Land loss and population displacement, increased flooding of low-lying coastal areas, loss of yield and employment resulting from inundation, and salinization could occur due to sea level rise. Damage to coastal infrastructure, aquaculture and coastal tourism due to erosion of sandy beaches is also likely.
- Malaria outbreak may reach higher latitudes and altitudes in India.

(4) Ecosystem

- There could be change in the ecosystem of forest; such as shifts in forest boundary, changes in species assemblage or forest types, change in net primary productivity, possible forest dieback in the transient phase, and potential loss or change in biodiversity.
- Sea level rise would submerge mangroves as well as increase the salinity of wetlands. This would favor mangrove plants that tolerate higher salinity. On the other hand, increased snowmelt in the western Himalayas could bring larger quantities of fresh water into the Gangetic delta, of which condition would have significant consequences for the composition of the Sundarbans mangroves, favoring mangrove species that have relatively lower tolerance to salinity. Further, changes in local temperature and precipitation would also influence the salinity of the mangrove wetlands and have a bearing on plant composition.
- Coral reefs could be adversely affected due to coral bleaching by sea-surface temperature rise.

(5) Energy

- Electricity demand would be enhanced by the increasing space cooling requirements and pumping requirements of groundwater. Electricity demand in the agriculture sector would also be enhanced for irrigation needs.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological

data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

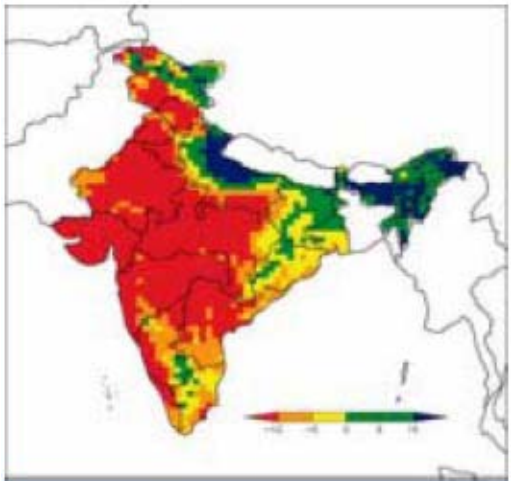

Figure: Projections of mean incremental annual number of rainy days for the period 2041-2060, based on the regional climate model HadRM2.

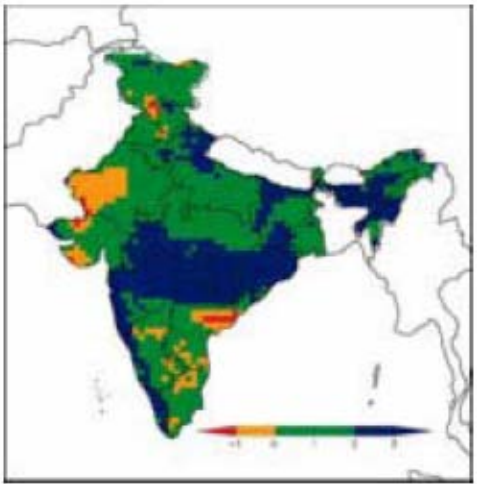

Figure: Projections of mean incremental rainy day intensity (mm/day) for the period 2041-2060, based on the regional climate model HadRM2.

Source: Ministry of Environment and Forests, Government of India (2004), p.71, Figures 3.14 & 3.15

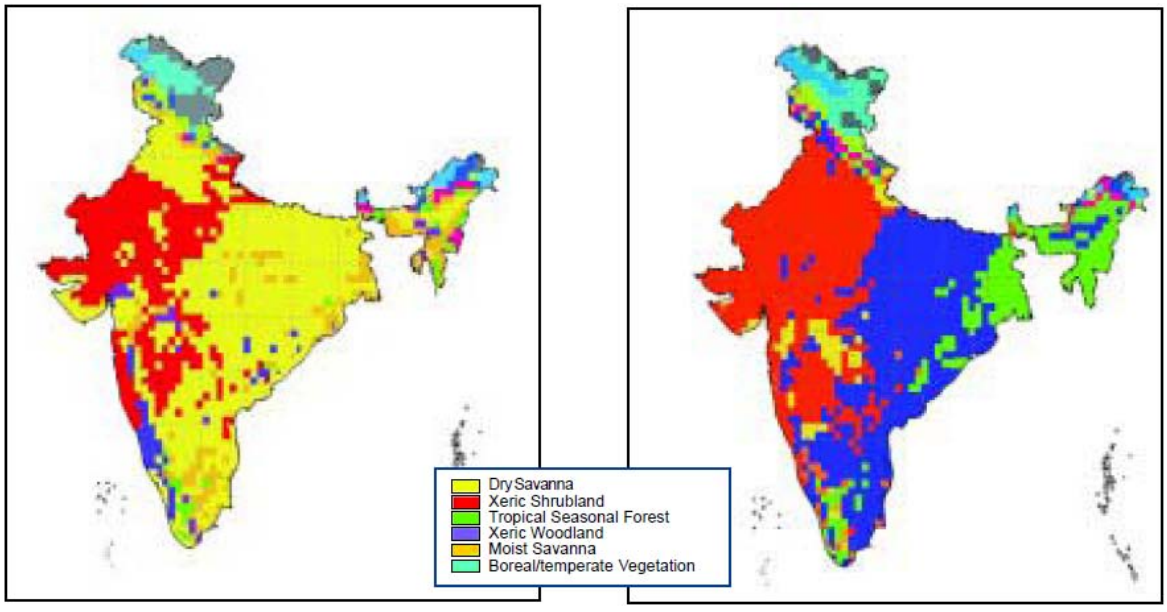

Figure: Vegetation map for the year 2050 (right) under GHG run of HadRM2 considering all grids of India and potential vegetation (including grids without forests). The control run (without GHG increase) is shown on the left.

Source: Ministry of Environment and Forests, Government of India (2004), p.ix, Figure 8

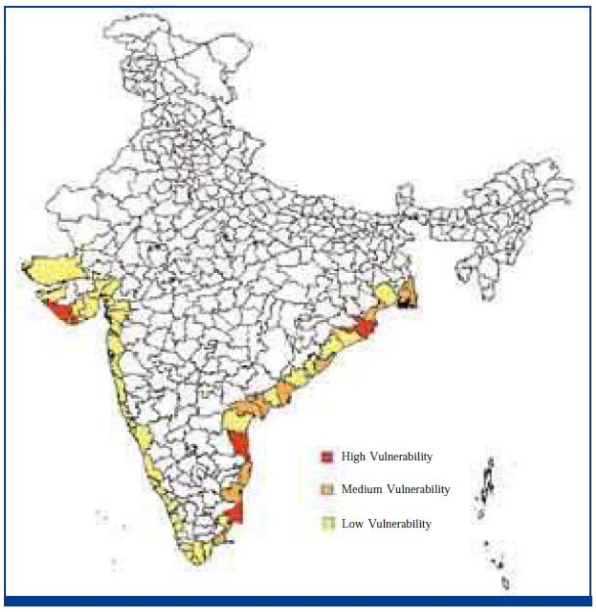

Figure: Coastal districts vulnerable to climate change.

Source: Ministry of Environment and Forests, Government of India (2004), p.x,Figure 9

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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- Ministry of Environment and Forests, Government of India. (2004). India's Initial National Communication to the United Nations Framework Convention on Climate Change.
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Chapter 2 Projected Influence of Climate Change in Indonesia

The Republic of Indonesia (Indonesia) is an island country in Southeast Asia, which consists of more than 13,000 islands and a total coastline of 81,000 km. Indonesia's climate is dominated by monsoons. The rainfall pattern in Indonesia consists of three types: (i) monsoon rainfall with a monthly rainfall peak in December; (ii) more localized rainfall pattern in the eastern equatorial part with a monthly rainfall peak in July-August; and (iii) equatorial rainfall characterized by two monthly rainfall peaks in March and October. These three types of rainfall pattern result in a wet season that varies in length from as long as 280 to 300 days or as short as 10 to 110 days, with the rainfall amount varying from 4,115 mm to as low as 640 mm. The rainfall variability is strongly affected by the phenomena associated with the El Nino-Southern Oscillation (ENSO), where rainfall decreases by El Niño and increases by La Niña influence generally.

The possible climate change impacts in Indonesia have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Moreover, the government of Indonesia has made an effort to estimate the climate change impact in the country, of which the recent result was reported in its second national communication to UNFCCC in 2010.

The possible impacts of climate change in Indonesia have been projected as follows:

(1) Water Cycle

- By 2025, the wet seasonal rainfall from December to February in Java, Bali, West Nusa Tenggara, East Nusa Tenggara, and Papua would increase while it would decrease in other parts. The number of districts which have water scarcity problem would also increase.
- By 2050 and 2080, most of the Indonesian region would experience higher rainfall than under the current condition, with the exception of the northern parts of Sumatra and Kalimantan.
- Dry season rainfall from June to August in most parts of Java might decrease by 2025, turn to increase by 2050, and then decrease again by 2080, particularly in West Java and South Sumatra.
- The onset of the wet season in Java and Bali, still with some uncertainty, would be delayed by 30 days in 2050.
- Tropical cyclones which bring strong winds and heavy rainfall to Indonesia would strengthen due to sea surface temperature increase.

(2) Agriculture and Food

- The change in the onset of the wet season and its length would influence rice production levels and cropping patterns. Currently, the delayed onset of the wet season due to the El Niño phenomena causes decreasing cumulative cropping area during the wet season. This consequently increases the cropping area in the dry season, compensating for the decrease in the wet season; however this cultivation generally has a high risk of experiencing drought.
- Long dry season would adversely affect not only annual crops but also perennial crops, as it will generally destroy young plants.
- Behavior of pests and diseases would change. There are some indications of climate-induced change; as ENSO has influenced the appearance of pests and diseases. Furthermore, types of major crop pests and diseases have shifted recently.
- Changes in rainfall and temperature increase would adversely affect the dairy cattle production and reproduction performance due to, for example, reduction of dry matter intake of cattle.
- Climate change would adversely affect the rice production mainly by the increasing temperature, precipitation change and land loss due to sea level rise, with some compensation by CO_2 fertilization. However, the decrease in rice production would occur mainly due to rice field conversion rather than climate change effects.
- Sea level rise would inundate crop lands and badly affect fish and prawn production. The probable increase of coral bleaching due to sea temperature rise would harmfully affect fishery.

(3) Coastal Zone

- Reefs, offering the habitat for thousands of species of reef fish, also function as a high energy and wave absorber that reduces the risk of coastal erosion. Damages to reef, which would be brought by coral bleaching and high waves due to increasing frequency of storms, will lead to loss of biodiversity in coral area and further coastal erosion.
- Sea level rise would cause permanent inundation of some of the coastal area, and would also bring temporary but large inundation with high tide. Land subsidence as a consequence of land development along the coastal area would exacerbate this inundation. The large coastal cities such as Jakarta, Medan, Semarang, and Surabaya would also be affected by inundation.

(4) Ecosystem

- Forest fires would become more serious due to decreasing rainfall in the dry season and the shortening of the length of the wet season in some parts of the country.
- Forest ecosystems would be adversely affected by climate change in terms of biodiversity loss due to forest fires, disappearance or reduction of density of certain species due to shifts in ideal temperature and rainfall range, increasing forest disease and pest infestation, increase or the decrease of forest productivity, etc.

(5) Health

- Due to significant deterioration of air quality, industrial areas like Jakarta would suffer from increase of heat stress and smog-induced cardiovascular and respiratory illness.
- Among ten major health problems treated at the state hospitals in Indonesia in 2006, outbreaks of dengue fever, malaria, leptospirosis and diarrhea were found to be significantly correlated with the occurrence of extreme climate events associated with ENSO. These diseases would be exacerbated by climate change.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

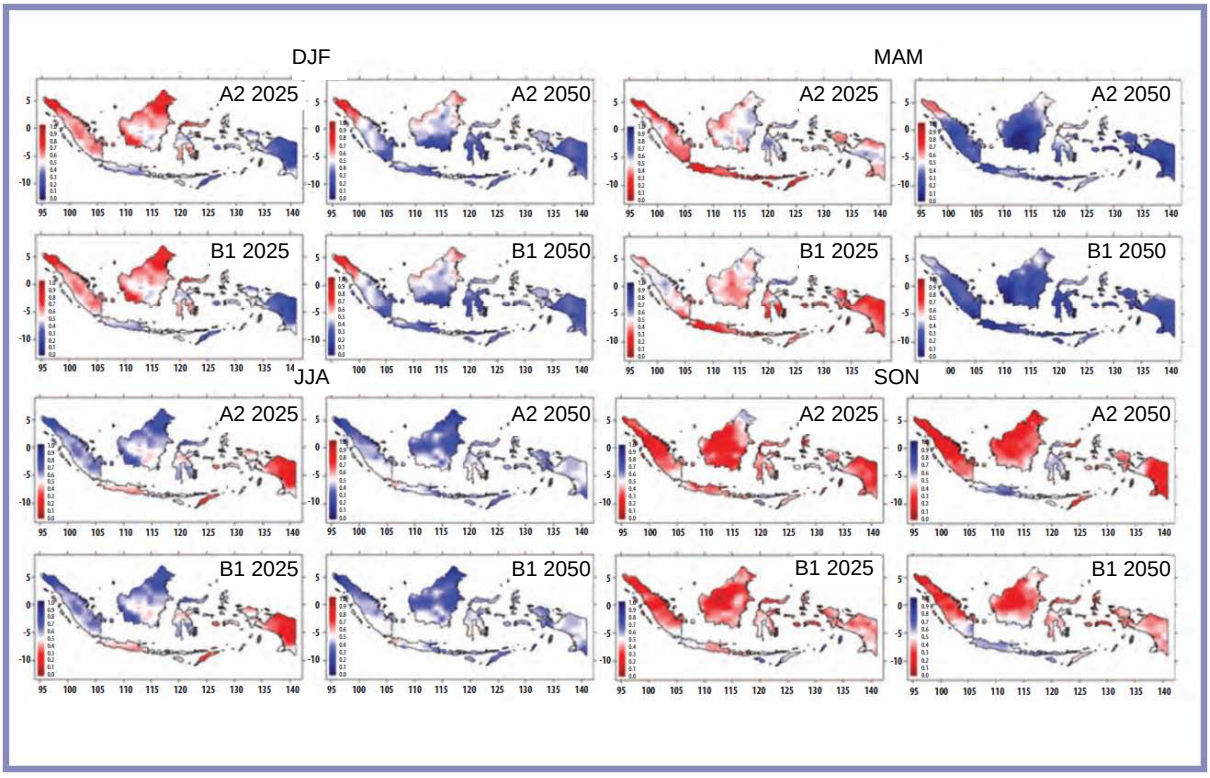

Figure: Level of probability for seasonal rainfall to change in the future for IPCC SRESA2 and SRESB1 Note: rainfall in areas colored dark red will decrease in the future, and rainfall in areas colored dark blue will increase in the future with relatively high level of confidence

Source: Boer et al. (2009) (Ministry of Environment, Republic of Indonesia (2010), p.IV-8, Figure 4.5)

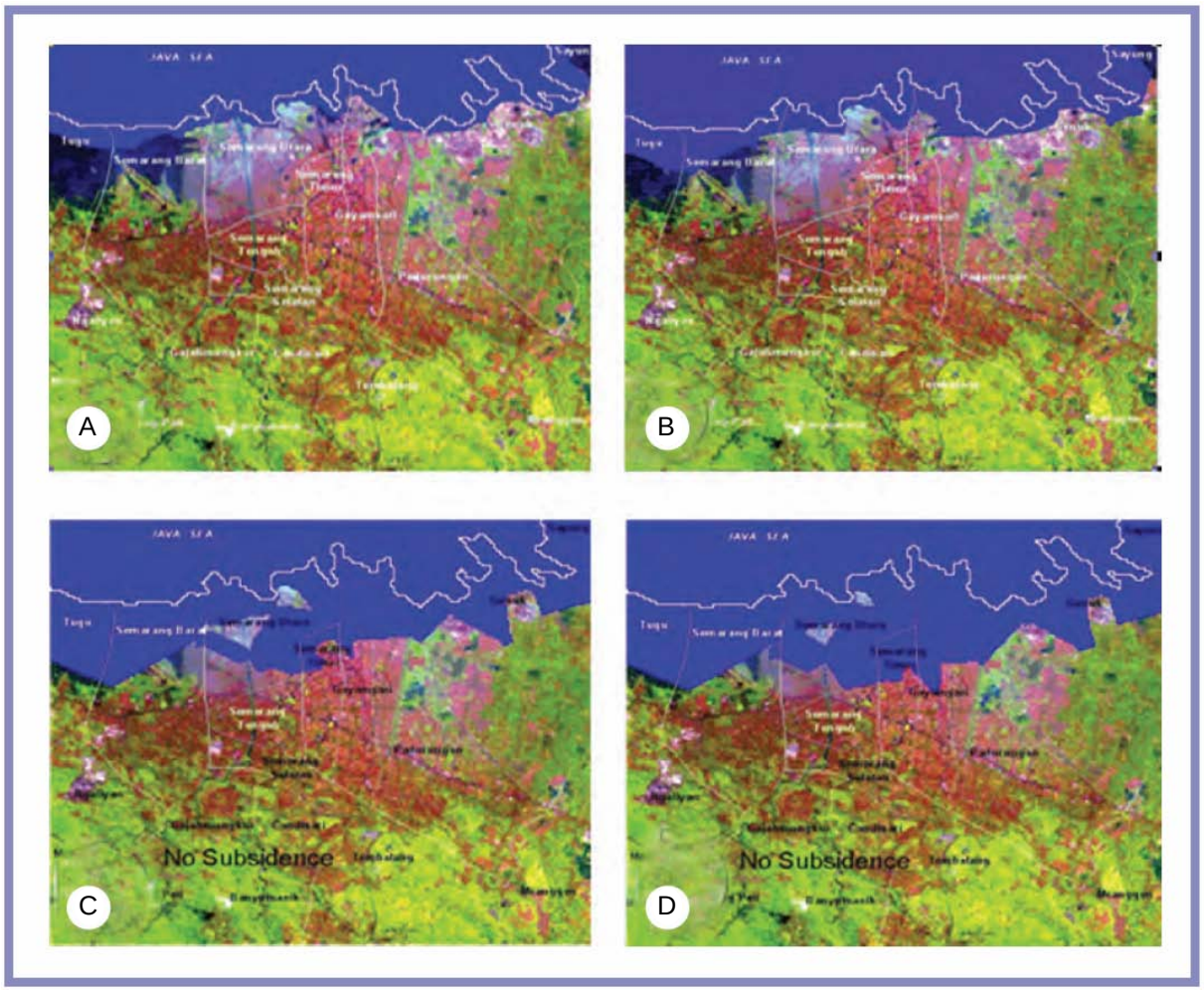

Figure: Distribution of floods based a sea level rise of 0.25 m (A), 1.0 m (B), and sea level rise + high tide equal to 2.28 m (C) and 3.03 m (D) in Semarang

Source: Hariati et al. (2009) (Ministry of Environment, Republic of Indonesia (2010), p.IV-38, Figure 4.30)

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
- IPCC. (2007). AR4 WG II: Impacts, Adaptation and Vulnerability, Chapter 10 Asia.
- Ministry of Foreign Affairs Japan. (2011). Japan-Indonesia Relations: http://www.mofa.go.jp/region/asia-paci/indonesia/index.html
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Chapter 3 Projected Influence of Climate Change in Kyrgyz Republic

Kyrgyz Republic (Kyrgyz) is a landlocked country of Central Asia. It is located at the junction of two mountain systems namely, the Tien Shan and the Pamirs. About 93% of its territory lies at an elevation higher than 1,000 m, and 42% lies higher than 3,000 m above sea level. This mountainous country can be classified with four climatic zones: valley-submountain zone (from 900 m to 1,200 m in elevation), mountain zone (from 900 - 1,200 m to 2,000 - 2,200 m), high-mountain zone (from 2,000 - 2,200 m to 3,000 - 3,500 m), and nival belt zone (from 3,500 m and higher). The valley-submountain zone is characterized by hot summer, snowless and temperate winter with significant lack of precipitation, while the nival belt zone has severe and very cold climate where the maximum temperature does not exceed 4-7^{o}C. It is a belt of moisture accumulation such as snowfields and glaciers.

The possible climate change impacts on Kyrgyz have been revealed through recent intensive scientific efforts, of which IPCC 4th Assessment Report published in 2007, would be most authoritative. Furthermore, the government of Kyrgyz has made an effort to estimate the climate change impact in the country, the recent result of which was reported in its second national communication to UNFCCC in 2009.

The possible impacts of climate change in Kyrgyz have been projected as follows:

(1) Water Cycle

- The precipitation in summer would decrease, while it would increase in winter. It may lead to an increase in the frequency of very dry spring, summer, and autumn seasons. Conversely, very high precipitation would become more common in winter.
- The reduction of glacier area by 2100, which varies depending on the climate change scenario, would reach to an extent ranging from 64% to 94% of the glacier area in 2000.
- River flow would significantly decrease in the future, except in the duration up to 2025. In this duration, the increase of glacial melting component would compensate the reduction of discharge. The reduction of flow after this duration would be mainly caused by the increase of evaporation.
- The glacier water feedback reduction would render significant influence on intra-annual distribution of the river flow, essentially reducing its summer maximum and shifting it to an earlier season.
- Lake waters would behave in a similar way as the rivers flow, that is, these would increase in the beginning of the 21st century, followed by a significant decrease. Waterline recession would occur in the Issyk-Kul Lake, the largest lake in Kyrgyz. The Chatyr-Kul Lake, which

is also one of the large lakes in Kyrgyz, would exist only in the form of a small reservoir which will completely dry out by 2100.

(2) Agriculture and Food

- Humidity would decrease in Kyrgyz, and probable reduction of river discharges in summer would adversely affect agricultural crops.
- Based on the temperature rise assumption, the northwest and southwest regions would be favorable for cultivation of cotton and grapes. Grapes would be cultivated on the lakeside plain of the Issyk-Kul region and even in Internal Tien Shan at heights of up to 2,400 m.
- Although there would be various climate-related influence on the agriculture sector, productivity would essentially be dominated by other factors such as methods of cultivation and irrigation, varieties of cultivated plants, and use of fertilizers.
- Climate change would be generally favorable to the growth of pasture vegetation productivity.

(3) Health

- Climate warming promotes spread of many infectious and parasitic diseases due to creation of favorable conditions for infections agent. The greatest values of morbidity rate should be expected during the summer season.
- Increased rate in cardiovascular system diseases and blood system diseases in the northern and southern regions would be expected, especially for elderly people. The highest values of morbidity rate should be expected during the summer season.
- Especially in the vulnerable age category of 70 years old and older, the morbidity of cancer for men rises in summer, while it is opposite for women. In this regard, morbidity of cancer for males would increase as temperature rises, but would decrease for females.

(4) Disaster

- Serious climate-induced disasters in Kyrgyz are landslides, mudflows and high water, and snow avalanches. These disasters had caused large damages to the country. Climate change would alter the probability of disasters as follows:

  Southern Region: The probability of landslides would either remain the same or slightly increase. Mudflows, high waters and breaches of high mountainous lakes would increase. Avalanches would increase in Chatkal area and considerably decrease in Toktogul area.

  Central Region: Mudflows, high waters and breaches of high mountainous lakes would considerably decrease. Avalanches would slightly increase. Landslides have not been assessed yet due to statistical data shortage.

  Northern Region: Mudflows, high waters and breaches of high mountainous lakes would considerably decrease. Avalanches would essentially increase. Landslides have not been assessed yet due to statistical data shortage.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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Chapter 4 Projected Influence of Climate Change in Nepal

The Federal Democratic Republic of Nepal (Nepal) is a landlocked country located in South Asia. The elevation of the country increases from about 60 m above mean sea level at the Terai Plain in the south to more than 8,800 m at the Himalayan mountain range in the north, of which the highest peak, Mt. Everest, rises to 8,848 m. The climate is predominantly influenced by monsoons, and much of the precipitation is received in the season from June to September. Nepal is one of the poorest countries in the world, and the recent uncertain political situation since the 1990s has delayed its development. This low level of development and the complex topography renders it vulnerable to climate change.

The possible climate change impacts in Nepal have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. The influence of climate change has not been fully recognized yet; however, Nepal is already experiencing its influence. As the glacier melt has been enhanced in the Himalayas, 20 glacier lakes are already at risk of bursting, with six of them identified as critical.

The possible impacts of climate change in Nepal have been projected as follows:

(1) Water Cycle

- Change in precipitation has not been agreed among GCMs; however, it could be said that there would be a tendency of decrease in winter and increase in monsoon and post monsoon seasons.
- The glacier melt would increase river flows during the monsoon season.

(2) Agriculture and Food

- Possible decline in rainfall from November to April would adversely affect the winter and spring crops.
- Rice production would increase through CO_2 fertilization; however, the negative effect of temperature rise would emerge beyond 4^{o}C increase. This situation would be slightly more severe in the hills than the Terai.
- Wheat production would also receive positive impact from CO_2 fertilization and negative impact from temperature rise. However, unlike in rice production, the response to temperature rise in wheat production is less severe in the hills and mountains than in Terai.
- The situation regarding maize production would be similar to that of wheat production under climate change. However, the negative influence of temperature rise would be more severe.
- Yaks, which are popular livestock in Nepal, are raised in elevations ranging from 3,000 m to 5,000 m. Their movement from 3,000 m to 5,000 m and vice versa depends on the

availability of forages and suitable ambient temperature. They are also very sensitive and non-tolerant to high temperatures. Climate change could have some influence on yaks and other livestock.

(3) Mountainous Area

- The mountainous regions are susceptible to disastrous hazards due to floods from glacial lake outbursts, in addition to landslides and river erosions which are exacerbated by the increase in rainfall intensity.

(4) Ecosystem

- Climate change would result into shifts in agro-ecological zones, prolonged dry spells, and higher incidences of pests and diseases. New alien and invasive species would emerge and spread their habitat.
- The incidence of forest fire would increase due to extreme climatic conditions, and would lead to forest land loss as well as species and habitat loss.

(5) Health

- Many of the common diseases in Nepal are climate-related. With changes in climate, diseases such as malaria, Japanese encephalitis and kala-azar may spread to new regions. The current lack of primary healthcare for majority of the population also contributes to the vulnerability.

(6) Energy

- Approximately 90% of Nepal's electricity production is from hydropower (although 18 million of a total population of 28 million does not have access to electricity). Hydropower systems would be affected by irregularities in stream flow, siltation from landslides and flood events induced by climate change.
- Renewable energy sources would be adversely affected. The condition of micro-hydro projects in the hills and mountains would be the same as that of hydropower. A potential increase in the number of cloudy days and changes in the form of precipitation (from snowfall to hailstones) would adversely affect solar power potential in the mountains. Furthermore, increased incidence of forest fires induced by temperature rise would threaten the availability of already-scarce fuel wood sources.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

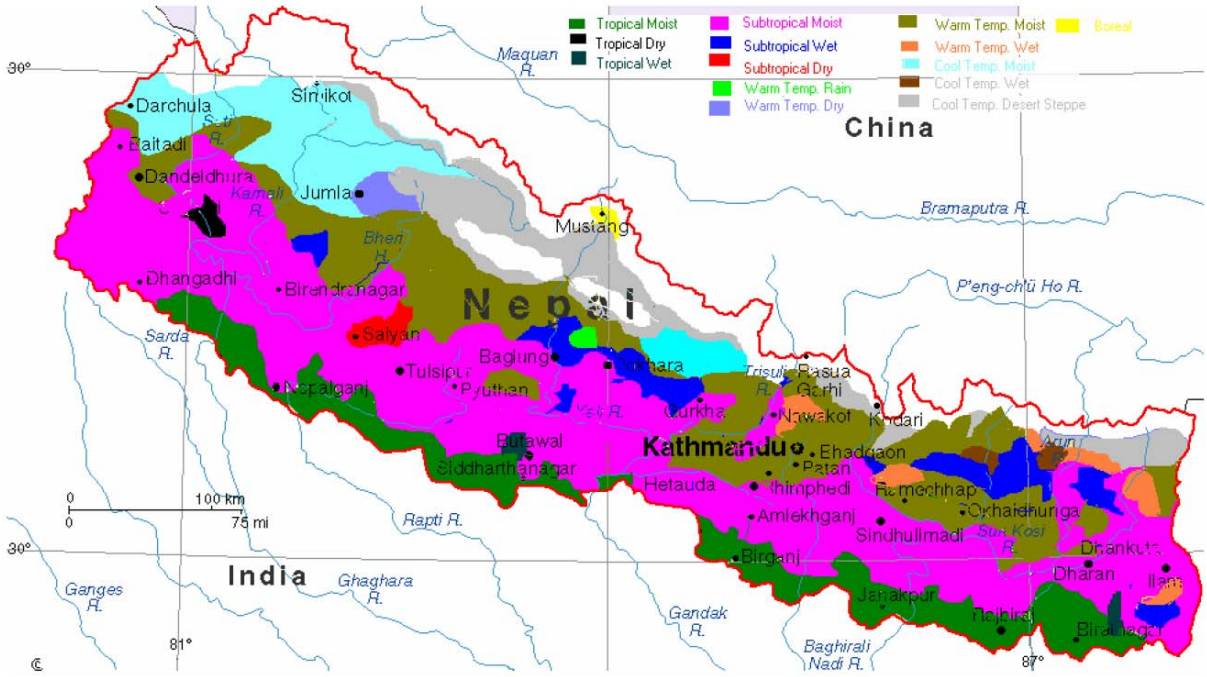

Figure: Forest Types and their Distribution in Nepal based on Holdridge Classification (at existing 1xCO2 condition)

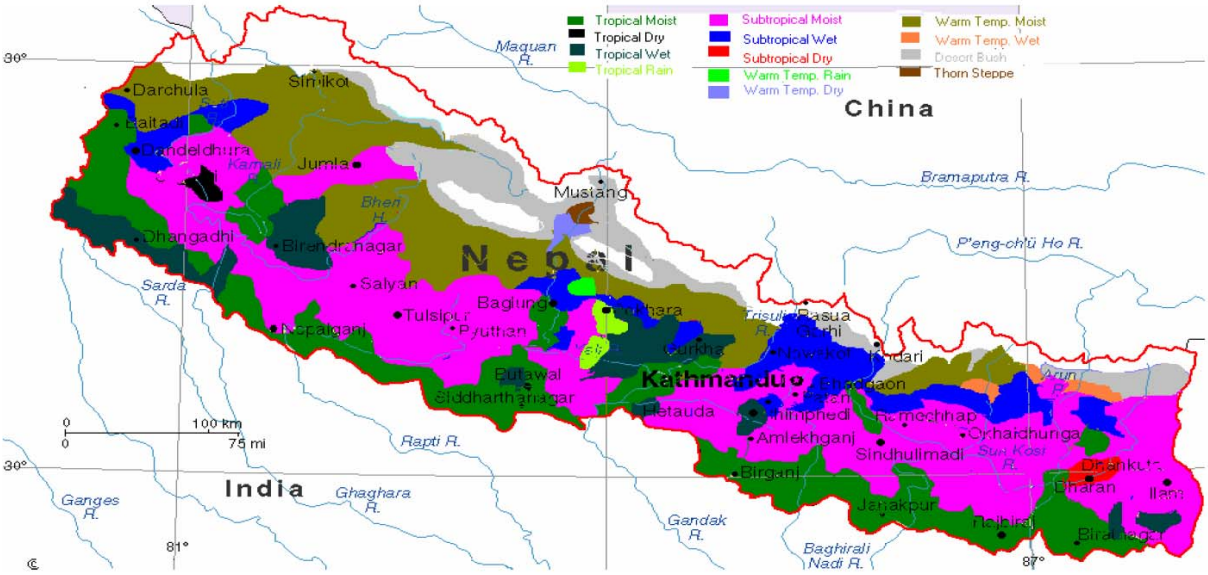

Figure: Forest Types and their Distribution in Nepal based on Holdridge Classification (at 2xCO2 condition)

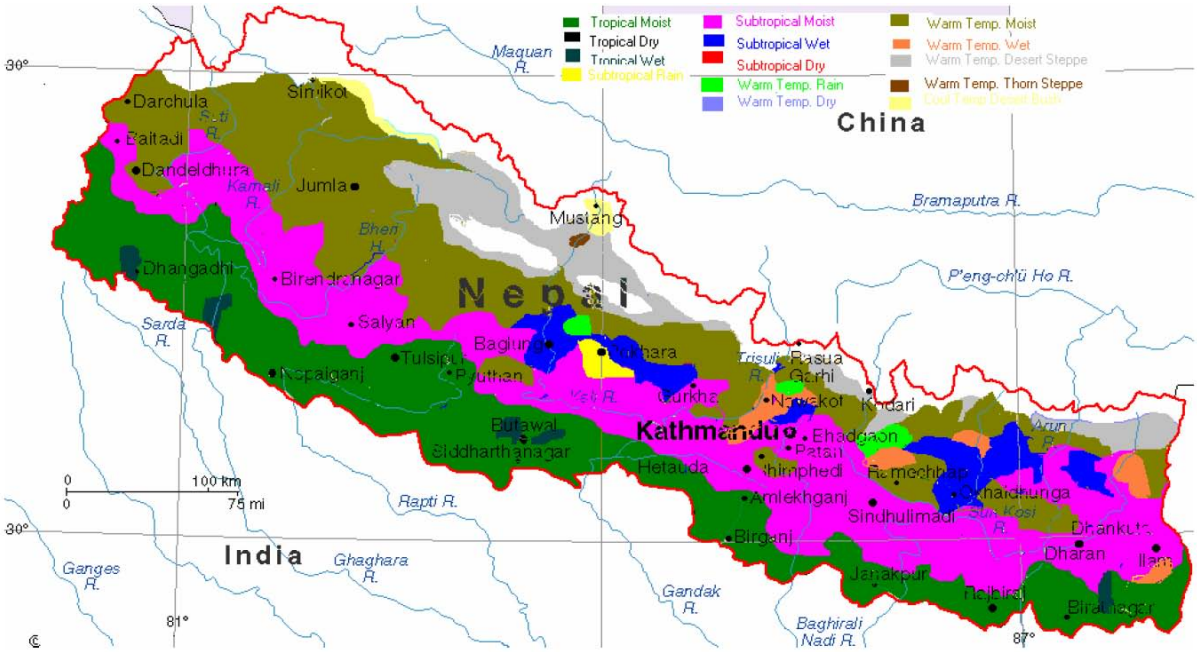

Figure: Forest Types and their Distribution in Nepal based on Holdridge Classification (at 20% Precipitation and 2°C Temperature Incremental)

Source: Ministry of Population and Environment, Government of Nepal (2004), p.108-109, Figure 5.11-5.13

Reference:

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Chapter 5 Projected Influence of Climate Change in Pakistan

The Islamic Republic of Pakistan (Pakistan) is located in South Asia. Pakistan has significant variations in altitude and topography, of which conditions lead to its diversity in climate, natural environment, and socio-economy. The country has mild and moist winters, and hot and dry summers in the north, to semi-arid and arid in the west and parts of the south. Its temperature can fall as low as -26^{o}C over the northern mountains, and reach as high as 52^{o}C over the central arid plains. The northeastern mountains and sub-mountainous areas receive more than 1,700 mm annual precipitation with a major share (over 1,000 mm) from the summer monsoon. On the other hand, the extremely arid plains of southwest Balochistan receive only 30 mm in a whole year.

The possible climate change impacts on Pakistan have been revealed through recent intensive scientific efforts, of which IPCC 4th Assessment Report published in 2007 would be the most authoritative. The seasonal distribution of precipitation would be influenced by climate change; however, the prediction on annual precipitation has not been consistent among several GCMs and remains uncertain.

The possible impacts of climate change in Pakistan have been projected as follows:

(1) Water Cycle

- Seasonal distribution of precipitation would be influenced.
- Quality of drinking water would be degraded due to sea water intrusion.

(2) Agriculture and Food

- Crops would suffer from heat stress. Particularly, wheat, cotton, mango and sugarcane would be more severely affected, since temperature is expected to go far beyond the optimal range.
- A fractional increase in temperature would affect a shift in potential boundaries of crop production since the central and southern parts are arid with maximum temperatures exceeding 40^{o}C in summer.
- Temperature increase coupled with variations in rainfall can increase the net irrigation water requirements of sub-humid, semi-arid and arid climate zone; however, no significant effects would be observed in humid zones.
- Water use for cooling of crops might become an essential element of crop production systems.
- Temperature rise would cause hastened maturity leading to shortening of the growing season length.
- Use of poor quality groundwater would increase, which would cause secondary salinization.

- The palatability and nutritional quality of the forage would decrease due to CO_2 concentration. This is more likely to occur in lower latitude rangelands where forage quality is already inadequate, like in the central and southern regions.

(3) Coastal Zone

- The country's largest city, Karachi, which houses almost 10% of the total population, and about 40% of all manufacturing units, is situated on the coast and would be influenced by climate change, especially the rise in sea level.
- On the west (Makran) coast, erosion already threatens coastal property, coastal agriculture land and habitats. Such effects may intensify in the event of further sea level rise. Loose sediments produced by erosion, and in some places accretion, would pose a serious threat to the fisheries sector and navigation.
- Sea level rise could cause significant flooding impacts in the coastal zone, particularly in the low-lying deltaic regions, by reducing coastal drainage. A storm surge by intensified cyclones would exacerbate coastal zone damage.
- Saltwater would penetrate further upstream and inland, of which condition would further be exacerbated by drought. The aquifer would also be salinized by sea water intrusion.

(4) Mountainous Area

- The mountains are likely to get warmer and their soils, drier. The frequency of droughts is likely to increase. In addition, increased ice melts at higher latitudes could loosen frozen soil and stones, making landslides and avalanches more common.

(5) Ecosystem

- Cold and temperate conifers would show a northward shift, pushing against the cold conifer/mixed with woodland, which in turn encroaches upon the southern and lower edges of the alpine tundra. Similarly, the northern boundaries of warm conifer/mixed forest will also move north, pushing against the southern boundaries of the temperate conifer/mixed forest. Accompanied with the northward shift, changes in species composition may occur.
- High temperature and increased precipitation would reduce the dormant period of insects. Meanwhile, longer summers with early onset of growth may lead to more development of weeds in spring, which in turn could aggravate the spread of forest pests and pathogens.
- Nutrient availability in coastal waters would be depleted, thus, adversely affecting seaweed formation.
- Sea level rise would increase the risk of bleaching in small coral communities, which are found in patches along the Balochistan coast.
- Vegetated wetland systems might be submerged during a tidal cycle for progressively longer periods, and may die due to water logging.
- Mangrove ecosystems are unlikely to adapt quickly enough to the range of sea level rise, where the build-up of sedimentation level would be the main limiting factor. Sedimentation

rate may further be reduced due to the change in water flows, and erosion would also intensify. Further, higher temperatures may affect the composition, distribution and productivity of mangroves, while lower precipitation can contribute to salt stress.

(6) Energy

- Hydroelectricity, supplying 34% of the total electricity demand in Pakistan, would be influenced by the change of either annual precipitation or seasonal distribution.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

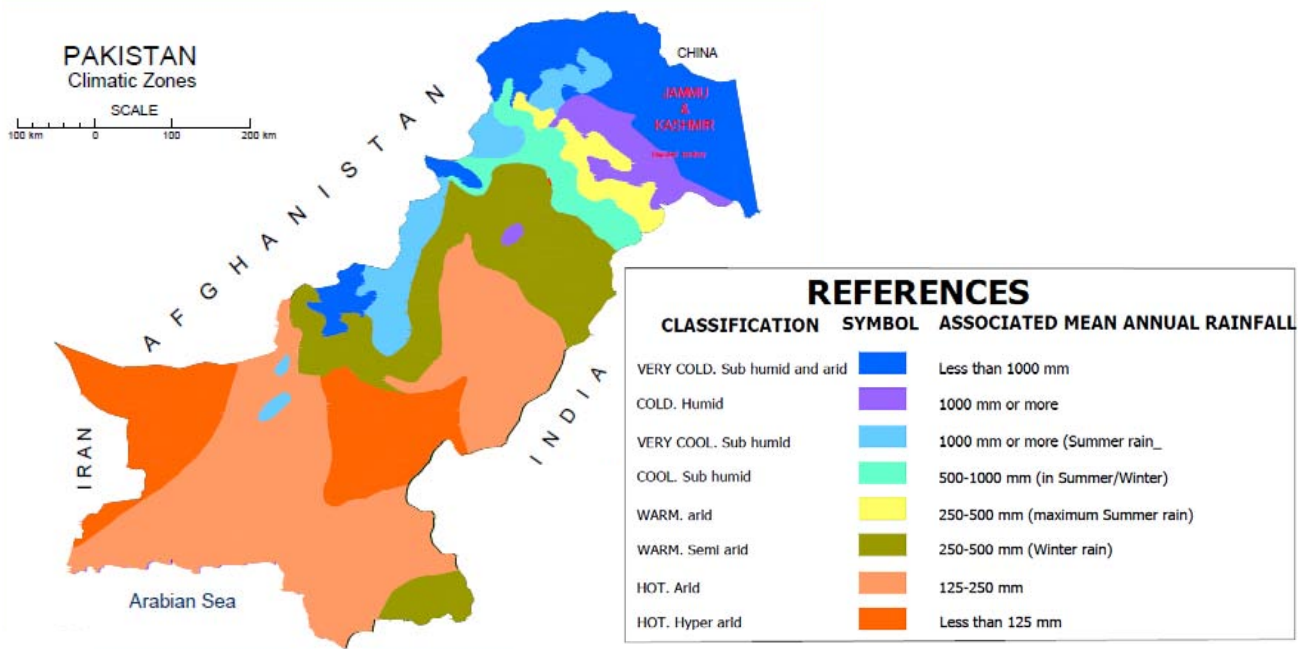


Figure: Climatic Zones of Pakistan

Source: Ministry of Environment, Government of Islamic Republic of Pakistan (2003), p.22, Exhibit 2.2

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
- IPCC. (2007). AR4 WG II: Impacts, Adaptation and Vulnerability, Chapter 10 Asia.
- Ministry of Environment, Government of Islamic Republic of Pakistan. (2003). Pakistan's Initial National Communication on Climate Change.
- Ministry of Foreign Affairs Japan. (2011). Japan-Pakistan Relations: http://www.mofa.go.jp/region/asia-paci/pakistan/index.html

Chapter 6 Projected Influence of Climate Change in Bangladesh

The People's Republic of Bangladesh (Bangladesh) is located in South Asia. It is an extremely low-lying country, of which only in the extreme northwest where land elevations exceed 30 m above mean sea level. Geologically, its land area may be divided into three categories; i.e. floodplain (80%), Pleistocene terrace (8%), and tertiary hills (12%). Most of these areas, except the highlands, or say 95% of the country, are exposed to monsoon flooding. Floodplains located in the north-western, central, south-central and north-eastern regions are subjected to regular flooding, while the coastal plain is subject to cyclones and storm surges, salinity intrusion and coastal inundation. In addition to these exposures to climate change, Bangladesh's persistent poverty would lead to its vulnerability to climate change.

The possible climate change impacts in Bangladesh have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. The influence of sea level rise in conjunction with change of river flow would adversely affect the country.

The possible impacts of climate change in Bangladesh have been projected as follows:

(1) Water Cycle

- Precipitation would decrease in the winter and increase in the monsoon season. This tendency would enhance winter drought in certain areas and flooding in the monsoon season.
- Inland flooding would be exacerbated by the riverbed level change. The high water levels in the estuaries due to sea level rise would result in lower velocity of river flows, which would lead to higher sedimentation in the river courses. The impedance of drainage due to sedimentation would alter the river courses in the low floodplains.
- The effect of saline water intrusion in the estuaries and into the groundwater would be enhanced by low river flow, sea level rise and subsidence. Sea level rise of 88 cm[1] would allow the salinity front of 5 ppt to intrude by more than 60 km to the north. The availability of fresh water for public and industrial water supply would fall.

(2) Agriculture and Food

- Coastal agriculture would be significantly affected by saline water intrusion. Moreover, increased periods of inundation may hamper agricultural productivity.
- Agricultural product would be affected by various factors: temperature rise, moisture stress

[1] Model projections of the IPCC SRES scenarios give a global mean sea-level rise of 0.09 to 0.88 m by 2100.

in dry season, salinity intrusion, and increased flood would decrease the productivity, while CO_2 fertilization would increase it. Temperature rise of 4°C would decrease some 28% and 68% of the production for rice and wheat, respectively. However, the doubling of CO_2 concentration with a similar rise in temperature would result into an overall 20% increase in rice production and 31% decrease in wheat production.

- Tea plantations in the northeast would suffer from moisture stress in winter.

(3) Coastal Zone

- Riverbank erosion and bed level change would substantially increase in the coastal rivers and estuaries due to increased river flows.
- The coastal area is frequently hit by severe cyclonic storms, generating long wave tidal surges. Cyclones and storm surges would become more intense due to climate change.

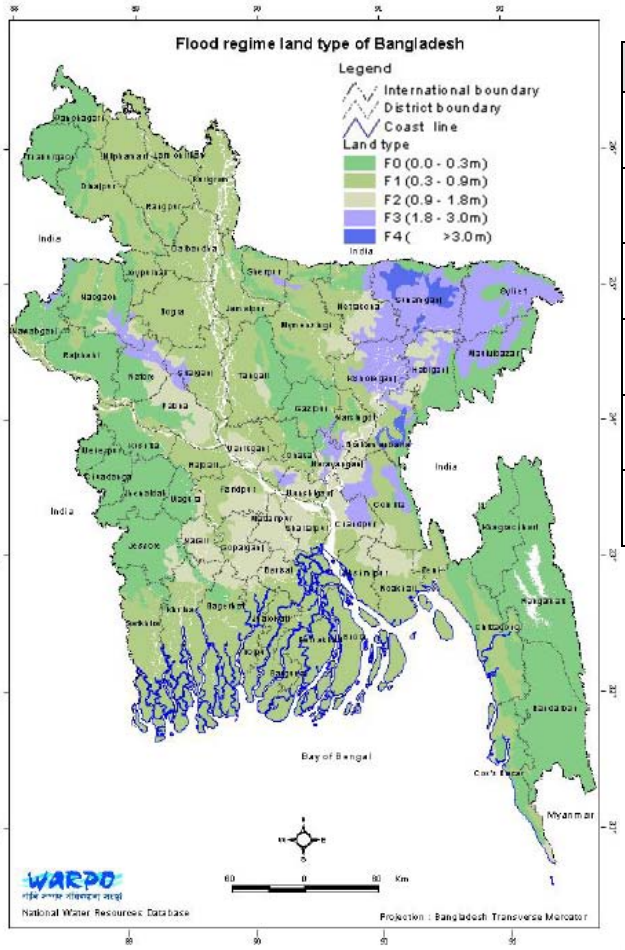
(4) Ecosystem

- Increased runoff in the forest floors by the increased rainfall in the monsoon season would enhance soil erosion problems.
- Prolonged floods in forest areas would severely affect the growth of many timber species. In contrast, enhanced evapotranspiration in winter would cause increased moisture stress.
- Due to a combination of high evapotranspiration and low flow in winter, salinity of the soil would increase. As a result, the growth of freshwater species would be severely affected. Eventually, species offering dense canopy cover would be replaced by non-woody shrubs and bushes, while the overall forest productivity would decline significantly.
- The degradation of forest quality might cause a gradual depletion of the rich diversity of forest's flora and fauna of the Sundarbans ecosystem.

(5) Health

- High summer temperatures could result in enhanced deaths due to heat stress.
- The combination of higher temperatures and potential increases in summer precipitation could create favorable conditions for greater intensity or spread of many infectious diseases.
- Water logging would be enhanced in the coastal areas. Increased inundation period would threaten human health due to the increasing potential for water-borne diseases.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.



Land type	Max depth of flooding	Seasonally flooded	Permanently flooded
Medium Highland 1 (F0)	0.3 m	16%	0%
Medium Highland 2 (F1)	0.9 m	44%	1%
Medium Lowland (F2)	1.8 m	23%	1%
Lowland (F3)	3.0 m	11%	3%
Very Lowland (F4)	> 3.0 m	1%	1%
Total		95%	6%

Figure: Current Flood Regime and Land Type of Bangladesh

Source: Ministry of Environment and Forest Government of the People's Republic of Bangladesh (2005), P.1, Figure-1

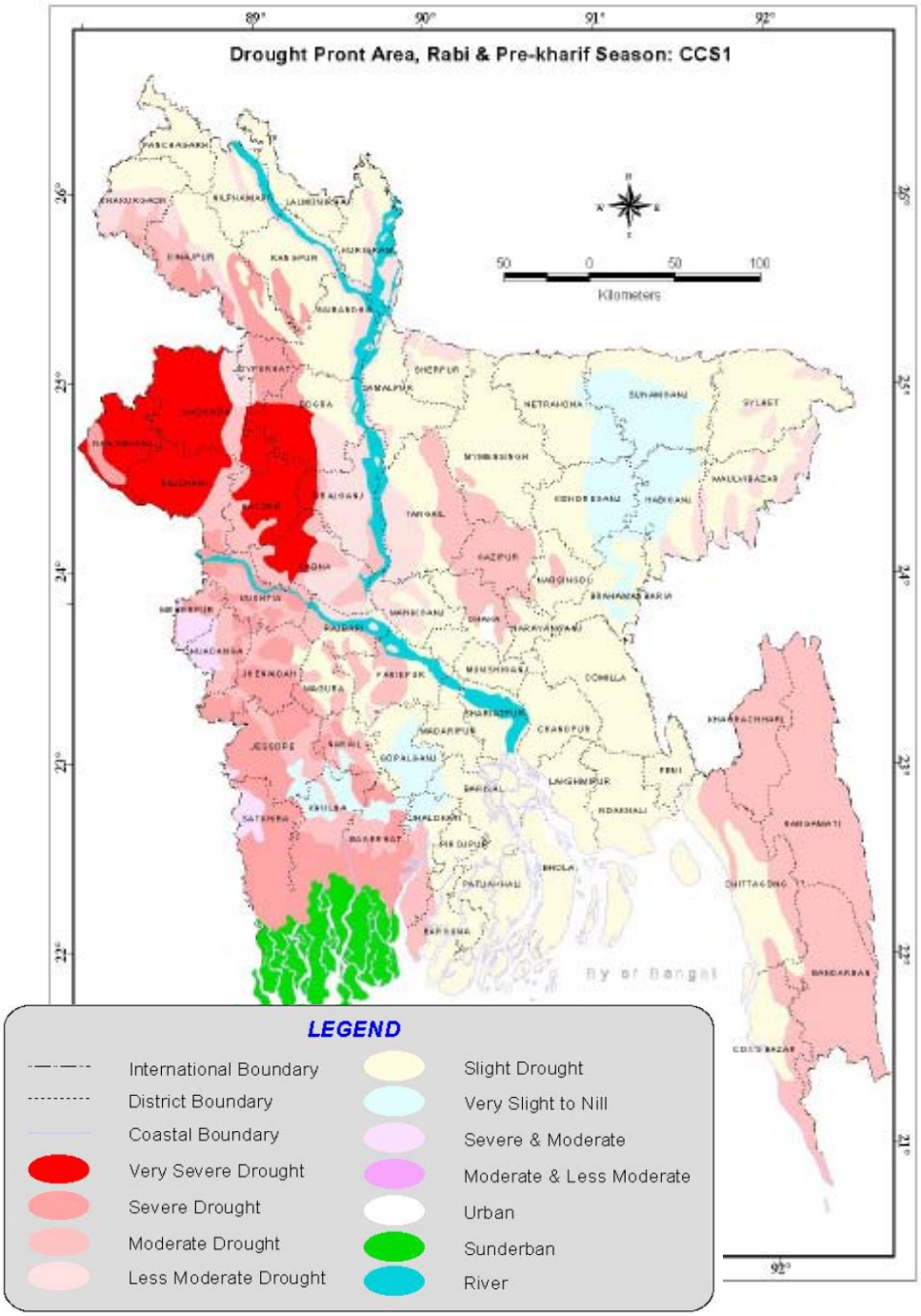


Figure: Drought Impacted Area in 2030

Source: Ministry of Environment and Forest Government of the People's Republic of Bangladesh (2005), p.15, Figure-6

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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- Ministry of Environment and Forest Government of the People's Republic of Bangladesh. (2005). National Adaptation Programme of Action (NAPA).
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Chapter 7 Projected Influence of Climate Change in Myanmar

The Union of Myanmar (Myanmar) is the largest country in Southeast Asia, occupying the western part of the Indochina Peninsula. The country experiences monsoon climate and receives much rain in the monsoon season from May to October. It faces the Bay of Bengal and the Andaman Sea, and its coastline extends to around 2,000 km. Its land could be geologically divided into three areas: west mountainous area, central lowland, and east plateau.

West Mountainous Area: High mountains with over 2,000 m of elevation range from north to south. The coastal areas located on the west slope of these mountains are facing the Bay of Bengal, where precipitation is abundant with more than 5,000 mm/year due to the southwest monsoon from the Indian Ocean hitting high mountains. Many rivers flow into the bay, and islands, with dense mangrove cover and coastal delta developed with narrow coves, are rich in nature.

Central Lowland: The area exists between the west mountainous area and the east plateau. It is composed of three large river basins of the Ayeyarwady River, the Chindwin River and the Sittang River. The southern area receives much precipitation from the southwest monsoon; however, its other areas lying leeward of the high mountains are relatively dry. Reclamation of forest land to irrigated paddy field has been developed in this lowland, and the increase of fuelwood demand also contributes to the severe deforestation problem in the area. The lowland coastal delta areas covered with mangroves often suffer from storm surges.

East Plateau: This large plateau area ranges from 1,500 m to 2,000 m in elevation, and extends into the Malay Peninsula. However, the plateau is divided by deep valleys, which obstruct the mutual communication and transport of each block. A number of ethnic minorities has also been left living their own life due to this plateau. The coastal line facing the Andaman Sea is a typical submerged shoreline, and about 800 islands are scattered offshore. This part in Malay Peninsula receives abundant precipitation like the west mountainous area, while the northern part receives less but moderate precipitation between 1,000 mm to 2,000 mm.

Myanmar seems to have already suffered from the influence of climate change, of which cyclone Nargis in 2008 would be the most notable extreme event induced by climate change. It is reported that around 134,000 people were killed during this disaster.

The possible climate change impacts in Myanmar have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Since both the National Communication and National Adaptation Programme of

Action under UNFCCC have not been submitted yet, a detailed estimation of the influence by climate change is not available. The possible impacts of climate change in Myanmar described as follows are therefore only general interpretations from the IPCC 4th Assessment Report.

(1) Water Cycle

- The monsoon depressions and tropical cyclones generated over the Indian Ocean would modulate the monsoon anomalies. Precipitation during the monsoon season would increase and would decrease during non-monsoon season. Intensity of heavy rainfall events would also increase. It would enhance erosion leading to sedimentation of the drainages and flooding in the monsoon season.
- The monsoon deficiency due to El Niño might not be as severe, while the favorable impact of La Niña seems to remain unchanged.

(2) Agriculture and Food

- Irregularity of precipitation would adversely affect the rainfed paddy production.
- Productivity for rainfed paddy would decrease significantly if temperature increases more than 2.5^{o}C. Irrigation meanwhile would become more important.

(3) Coastal Zone

- Besides sea level rise, intensified storm surges would bring large damage to the coastal zone.

(4) Ecosystem

- The abundant mangroves would be harmed by sea level rise and storm surge.
- A lot of plant species and animals would become extinct.
- Forest fire incidence would be exacerbated due to temperature rise.

(5) Health

- Water-borne diseases would be exacerbated due to increased inundation duration and higher sea surface temperature especially in the coastal area.
- Areas which are prone to malaria outbreak, which is the leading cause of death in Myanmar, would spread to higher altitude areas with temperature rise.

The adaptation to climate change in Myanmar could alleviate the projected climate impacts listed above. However, a specific study on the influence of climate change in Myanmar shall be implemented as a first step of adaptation.

Reference:

- ADCA (Agricultural Development Consultants Association). (1995). Kunibetsu Nogyo Noson Kaihatsu Joho Shushu Chousa Hokokusho: Myanmar Renpo (in Japanese).
- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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Chapter 8 Projected Influence of Climate Change in Maldives

The Republic of Maldives (Maldives) comprises 1,190 islands in 20 atolls spread over 900 km in the Indian Ocean. Of these, only 199 islands are inhabited with a population of slightly over 300,000. The highest point of the land is 2 m above sea level. This island nation attracts some 500,000 tourists annually. Its atolls are ringed by the seventh largest coral reef in the world and among the richest in species diversity. In recent years, nature-based tourism has served as the engine of growth for the economy and accounts for about 70% of gross domestic product (GDP).

The possible climate change impacts in Maldives have been revealed through recent intensive scientific efforts, of which the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report published in 2007 would be most authoritative. The global sea level rise is projected to be about 0.19-0.58 m, while that projected for Maldives is 0.5 m during the 21st century. Surrounding sea surface temperature is projected to rise within the range of 0.51 to 3.77°C in the Indian Ocean. For Maldives, the annual maximum daily temperature is projected to increase by 1.5°C during the 21st century. The 20-year maximum temperature event, which was 33.5°C in 2001, is expected to be experienced more frequently. The annual precipitation is expected to increase during the summer period (June-August), while the changes in annual rainfall intensity are unclear. It is likely that the maximum tropical cyclone wind intensities could increase. Maldives lies out of the tropical cyclone zone due to its proximity to the equator and there have been past incidences where cyclonic storms have passed over Maldives especially in the northern islands (Figure). Sea level rise would cause regular tidal inundations in most islands of Maldives even in case of medium prediction and storm surges may completely inundate the small to medium islands.

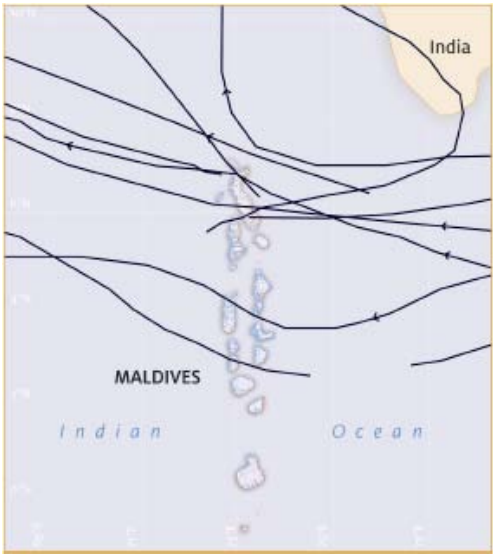

Figure: Cyclone Tracks over Maldives between 1877 and 2004

Source: Ministry of Environment, Energy and Water, Republic of Maldives 2007, p. 17, Figure 4.5.

The possible impacts of climate change in Maldives have been projected as follows:

(1) Water Cycle

- Potential sea level rise and storm surge would affect the salinization of groundwater for washing, bathing and other uses, except drinking water.
- Although rainfall is anticipated to increase during the summer period, changes in seasonal rainfall intensity may impact on rainwater harvesting for drinking water, which 90% of

households rely on.

- Rainwater storage tanks in each household of the community are very vulnerable to inundation potentially caused by sea level rise and storm surge.

(2) Agriculture and Food

- Agriculture is already under stress due to poor soil, limited land available for cultivation and water scarcity.
- The critical impacts of climate change include: heat stress on plants, changes in soil moisture and temperature, loss of soil fertility through erosion of fertile top soil, less available water for crop production, changes in level of water table, salinization of freshwater aquifer and loss of land through sea level rise.
- In addition to the existing heavy import dependency, flooding would cause significant damage to crops, agriculture farms, home gardens and vegetation.
- Tuna is the key fishery product for Maldives. The dependency on pole-and-line tuna fishing method with live bait makes tuna fishery vulnerable to climate change and variability, since coral reef systems are highly vulnerable to changes in sea surface temperature and other climate changes.

(3) Coastal Zone

- The location of infrastructures within close proximity to the coastline makes them highly vulnerable to sea level rise and storm conditions.
- There are at least 350 piers in resorts and inhabited islands, and the two international airports are within 50 m from the coastline.
- About 80% of the powerhouses are located within 100 m of the coastline. About 90% of the islands have their waste disposal sites within 100 m of the coastline and on the ocean-ward side of the island. More than 75% of communications infrastructures are located within 100 m from the coastline.
- For the design and construction of infrastructures, climate change hazards have not been taken into account. With the predicted rise in sea level and increased frequency and intensity of extreme weather, critical infrastructures such as airports, harbors, coastal protection structures, tourist facilities, hospitals, schools and utilities are subject to high risk.

(4) Ecosystem

- The coral reefs function as natural sea defenses for the highly vulnerable islands. The two major economic activities, namely, tourism and fisheries, are reef-based and provide more than 80% of the total revenues of the country. The reefs also provide food and are source of coral sand used as construction material.
- The rise of sea surface temperature will lead to significant bleaching of coral, which is the key resource for economic activities in Maldives. During the 1998 El Niño event, coral bleaching was first reported in mid-April. Bleaching was reported to be severe from late

April to mid-May with some recovery evident by late May.

- Increased sea surface temperature and oceanic CO2 concentration may change the calcification rate of coral reefs resulting in slower growth, which is expected to decline by 14-30% by 2050. Combining with the interruption of human activities, reefs will not be able to keep pace with the predicted sea level rise.

(5) Health

- Changes in temperature and rainfall regimes are causing higher incidence of vector-borne diseases such as dengue and scrub typhus. There is evidence that dengue outbreaks are becoming more frequent and it appears it is associated with El Niño southern oscillation (ENSO) events.
- Water-borne diseases such as shigellosis could increase as a result of disruption of sewage and water systems due to flooding.
- The health risks related to vulnerability to climate change are further compounded by local characteristics such as accessibility and quality of healthcare, high population congestion, low income levels, and the high level of malnutrition among children, which varies across the atolls. It is noted that in 2004, the prevalence of underweight children under five years old was estimated at 27%. The forecasts indicate that one in four children may still be underweight in 2015.

The adaptation to climate change in the Republic of Maldives is intended to alleviate the projected climate impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in the sensitive sector for climate change is indispensable. Besides, the availability of human resources to utilize these data for climate change adaptation becomes crucial; therefore, human resource development and capacity building would also be rendered as important adaptation measures.

Reference:

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Chapter 9 Projected Influence of Climate Change in Brazil

The Federative Republic of Brazil (Brazil) is the largest country in South America, and fifth in the world. In its vast area, Brazil has unique flora and fauna among the countries in the world, which vary widely by region. In the north region, the Amazon territory in Brazil is governed by equatorial climate and monsoon climate with plenty of annual rainfall of around 3,000 mm, and contains approximately 30% of the remaining tropical forests in the world. The northeast region has two main biomes namely, the Cerrado and the Caatinga. The Cerrado is under the tropical savanna climate with annual rainfall ranging between 1,000 and 1,200 mm, while the Caatinga is under semi-arid climate conditions with an annual rainfall of less than 500 mm. In addition, some equatorial climate lies in the coastal area in this region. The south region is under warm oceanic climate with modest annual rainfall ranging between 1,250 mm and 2,000 mm, and has seasonal thermal change unlike the north and northeast regions. Brazil is known as a large agriculture country. At the same time, it is also famous for its high urbanization rate of more than 80%.

The possible climate change impacts in Brazil have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Moreover, the government of Brazil has made an effort to estimate the climate change impact in the country, the recent result of which was reported in its second national communication to UNFCCC in 2010.

The possible impacts of climate change in Brazil have been projected as follows:

(1) Water Cycle

- The annual rainfall in the Amazon and Cerrado areas would decrease especially between July and August.
- El Niño has strongly influenced the monsoon climate and its occurrences have determined extreme events of rain deficiencies, and as a consequence, low discharges into the region’s river. The relationship between El Niño and climate change is still uncertain; however, attention shall be given since the change in global temperature can lead to various environment changes including intensification of the global hydrological cycle.
- The rivers are serving the demands of consumptive use, such as irrigation, water supply, hydroelectric power generation, diluting pollutants from sewage. Hence water conflicts among these sectors would increase due to climate change. In the state of Ceará, large-scale reductions in the availability of stored surface water could lead to an increasing imbalance between water demand and water supply after 2025.

(2) Agriculture and Food

- Among the major nine crops in Brazil, with the exception of sugarcane, there would be significant reduction of cotton, sunflower, coffee, rice, beans, corn, and soy beans. In addition, cassava, although revealing an increase in area in other regions of Brazil, would decrease in area in the northeast region, where it is a staple food for the population. However, it must be highlighted that the effects of pests and diseases, and extreme weather events that could drastically modify the predictions have not been considered yet.
- In Brazil's future production area, the coffee leafminer (*Perileucoptera coffeella*) and the nematode *Meloidogyne incognita* are likely to increase. The risk of *Fusarium* head bright incidence in wheat crops is very likely to increase under climate change in south Brazil.
- Brazil is the largest exporter of meat in the world. Zebu, which is the predominant species of cattle herd, could regulate body temperature very well in heat stress conditions, and high temperatures have less effect on the cells of their bodies compared to European cattle.
- Heat stress is responsible for big losses in chicken yield, with a reduction in body weight and increase in mortality rates.

(3) North Region (Amazon) and Forest

- Future annual and seasonal mean rainfall change over the Amazon is still uncertain.
- Temperature rise associated with decrease in water availability in soil could lead to the gradual replacement of tropical forest with savannah in a part of the Amazon. Change and decrease of ecology and biomes would be observed all over the Amazon, and the northeastern area of Amazon lowland would be most prominent.
- With temperature rise and more frequent droughts, the Amazon forests would lose much moisture, becoming much more vulnerable to fires, and there could be a significant increase in tree mortality rates. Forest fires would have strong negative effects on the Amazon's vegetation.
- Forest loss in the Amazon would lead to a hotter and drier climate in the region, and can change the levels of rainfall in vast areas of South America. Evapotranspiration in the Amazon feeds the rains that flow through the Andes and reach the south central, southeast and south regions of Brazil.
- Some types of forest can benefit from climate change, particularly those currently affected by the limitations of their minimum temperature and rainfall requirements, or by gains in net productivity as a result of CO_2 fertilization.
- The possible influence on human health due to rainfall reduction and temperature rise in the Amazon area are mainly the following four aspects: worsening in the access to good quality water, reduction in the abundance of extractive goods for subsistence, increase in the inhalation of smoke from forest fires, and changes in the cycles of endemic transmissible diseases such as malaria and leishmaniasis. In cases of drought, small river bank communities would be isolated without sufficient water and without any possibility for fishing as a result of the drying up of access bayous.

(4) Northeast Region (Savanna and Semi-arid Zone)

- The northeast region has more than 20 million people, which makes it the most densely populated dry region in the world. This region has the highest child mortality rate and the lowest life expectancy in Brazil.
- Climate change influences on human health in this vulnerable area include water shortage, diseases associated to poor hygiene such as infectious diarrhea in children, worse food security situations that cause malnutrition, etc.
- The projected water scarcity in the future would enhance migration from rural to urban areas, as it has occurred historically. The poorest population and subsistence farmers would be the most strongly affected.
- Water supply problems would hit a large part of the northeast region's population, and the situation could occur with greater frequency.
- Temperature increase of $2^{o}C$ might cause extinction of one-fourth of the 138 tree species in the Cerrado area by 2050.
- The Caatinga is the only exclusive Brazilian biome, which is home to unique fauna and flora, with many endemic species not found anywhere else on the planet, and a great part of it has already been altered by extreme climate. The Caatinga could be replaced with vegetation more typical of an arid zone, with a predominance of cactuses by the end of the 21^{st} century.

(5) Urban Area

- The expansion of urban areas occurs mainly at the outskirts, illegal lots and buildings, and in fragile areas, such as floodplains and unstable soils, with great pressure on natural resources. Moreover, low-income people are generally concentrated in risky areas, such as in foot of valleys, low grasslands bordering bodies of water and steep cliffs, or in slums or degraded properties due to lack of maintenance. Since the risks of flooding and landslides would increase due to the increasing number of days with heavy rains, the population, especially the poorest, would be adversely affected.
- The future temperature increase, coupled with the "heat island phenomena" in urban areas, could have significant impacts on human health especially in large cities, with a worsening in the health of those with high blood pressure.
- Air pollution generates an increase in hospital admissions especially those with respiratory problems and heart disease, neonatal deaths, and so on. This air pollutant mainly occurs in dry weather especially during winter, when there is greater frequency of the so-called thermal inversion that tends to trap pollutants. Temperature rise would intensify this phenomenon.
- The sea level rise could lead to the abandonment of buildings located in low urban areas and to the displacement of the population living along the coast and service centers installed in beaches.
- Sewage in coastal cities is collected and transported to the sea through underwater

conveyance structures without any prior treatment. Since sewage disposal flow is designed to be consistent with the condition of the current sea level, future sea level rise could cause the malfunctioning of the system.

(6) Coastal Zone

- Strong rains brought by eastern waves certainly accompanied by powerful breakers driven by the wind coupled with sea level rise could cause greater damage to the whole of the coastal area. The south and southeast regions are subject to additional risk of future intensification of extratropical cyclones caused by climate change. The projected impacts on the coastal zone are the following:
  - coastal erosion;
  - damage to coastal protection works;
  - effects of salt spray on concrete structure (buildings and maritime works) and historical monuments;
  - structural or operational damage to ports and terminals;
  - damage to urbanization works in coastal cities;
  - structural damage or operational losses to sanitation works;
  - exposure of buried ducts or structural damage to exposed ducts;
  - landslides on coasts (or sea cliffs) in the coastal zone;
  - saline intrusion in estuaries and aquifers that can affect the capturing of freshwater;
  - alteration of the mangrove occupation area and local ichthyofauna, which can result in impacts on birds, including migratory ones;
  - damage to ecosystems due to lack of freshwater caused by effects related to salt disequilibrium;
  - damage to coral reefs

(7) Energy

- The Paranã River watershed is installed with more than 50% of the country's hydroelectric power generation capacity in operation. At the same time, this river water is used for urban and rural use in the watershed with the largest population density. The flow of water from hydroelectric power plants has been used to regulate water availability and to manage extreme flooding events. Attention shall be given to hydroelectric power generation since climate change would exacerbate both water availability and flood condition, and would bring about water conflicts.

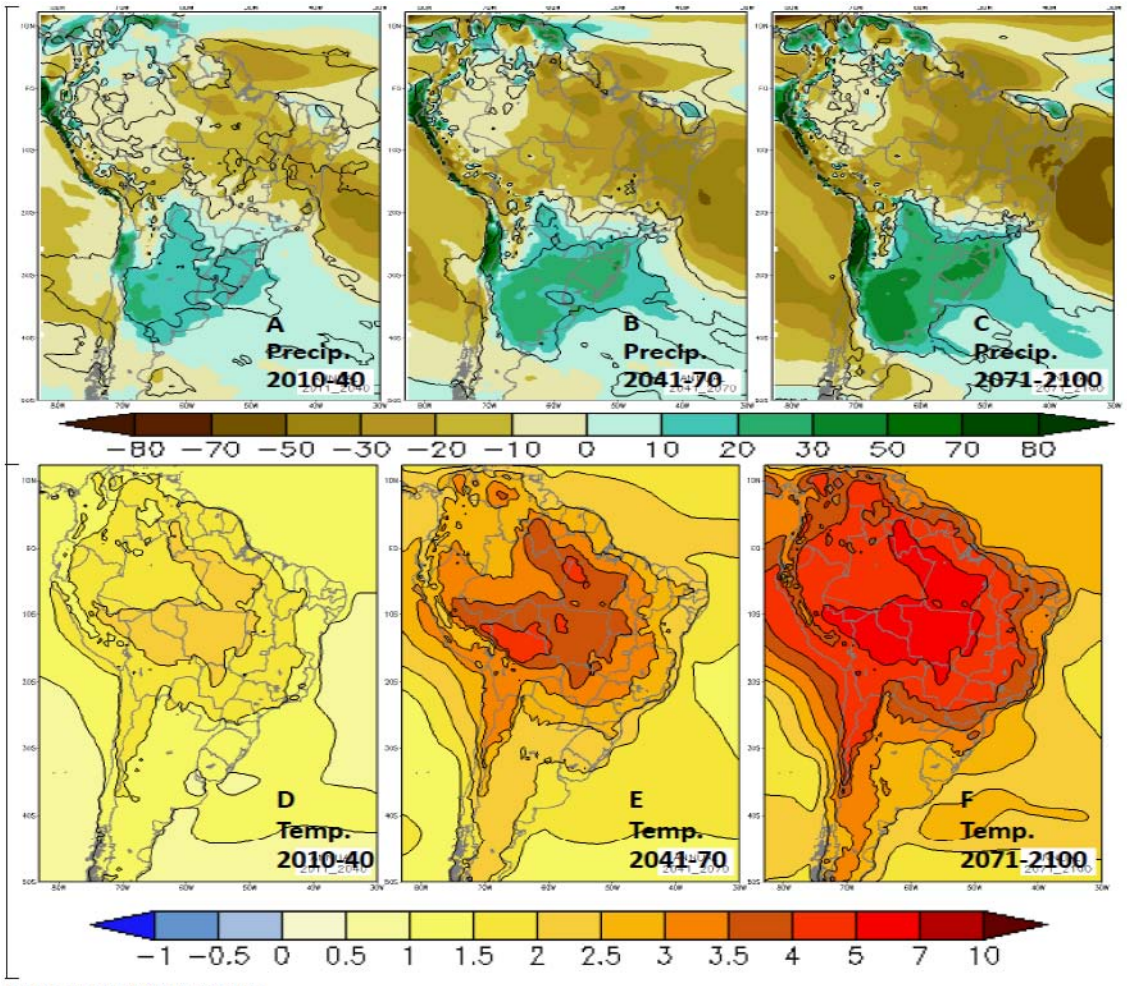
(8) Health

- Endemic infectious diseases of greatest importance in Brazil related to climate change are malaria and dengue fever, and their incidence can either increase or decrease at the regional level. Based on the Special Report on Emissions Scenarios (SRES) and socio-economic scenarios, some projections indicate decreases in the length of the transmission season of

malaria in areas where rainfall reduction is projected, such as the Amazon.

- Health-related problems raised by climate change would be different among the Amazon, semi-arid area, and urban areas. The projected conditions are explained in individual related sections.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.



Source: MARENGO *et al.*, 2010a.

Figure: Projected rainfall (%) and temperature (^{0}C) changes for South America for 2010-2100 (Scenario A1B) in relation to the base period 1961-1990 generated by the Eta-CPTEC model, 40 km from HadCM3's projections

Source: MARENGO et al. (2010a) (Ministry of Science and Technology, The Federative Republic of Brazil (2010), p.393, Figure 1-3)

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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- Ministry of Foreign Affairs Japan. (2011). Japan-Brazil Relations: http://www.mofa.go.jp/region/latin/brazil/index.html
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Chapter 10 Projected Influence of Climate Change in the Democratic Republic of the Congo

The Democratic Republic of the Congo (DRC) is located in central Africa, which lies over four climate zones (Köppen-Geiger climate classification): the tropical rainforest climate zone of the Congo basin, surrounded by the monsoon climate zone and the tropical Savanna climate zone at the outermost, and humid subtropical climate zone at the most southern area. A series of severe conflicts occurred during most of the 1990s had damaged the country's infrastructure severely, of which condition would easily lead to vulnerability to climate change. Moreover, the eastern area still remains in a fragile situation.

The possible climate change impacts in DRC have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Furthermore, the government of DRC has made an effort to estimate the climate change impact in the country, of which recent result was reported in its second national communication to UNFCCC in 2009. Nevertheless, the collective view regarding precipitation change has not been reached yet, because each result of GCM is not consistent with each other.

The possible impacts of climate change in DRC have been projected as follows:

(1) Water Cycle

- Rainfall and its seasonal distribution would be influenced, generally with the increase of intense and total precipitation in a year.
- The Congo River would increase its water discharge due to the precipitation increase.
- The increased intensity of rainfall and river flooding would cause more loss of human lives, erosion, and destruction of basic infrastructure and houses.

(2) Agriculture and Food

- No serious impact to crop growth has been identified; however, the following matters shall be ensured:
- Planting season of corn shall be reconsidered in order to reduce the risk of drought at the flowering stage.
- The growth failure of banana will occur beyond 35-40^{o}C, while the optimum temperature is around 28^{o}C.
- A higher temperature would be advantageous for peanut cultivation.
- Low agricultural land near the coastal area would be influenced by increased river flood with sea level rise. Especially, the large orchard along the Boma-Muanda Highway would be damaged.

- Agropastoral activities in islands on the lower reach of the Congo River, such as Mateba Island, would be damaged.

(3) Coastal Zone

- The current decline of the coastal line would worsen due to the sea level rise.
- The mangrove forest has been deforested due to use of fuelwood. This would lead to erosion of coastal zone. The increased river flood and projected sea level rise associated with consecutive high tides would exacerbate coastal erosion.
- Much of infrastructure in Boma, and roads and bridges in the marshy area between Boma and Muanda, would be damaged due to flooding.
- Deterioration of living circumstances combined with the population growth trend of the coastal area will lead to the migration in the near back of the coastal zone. This would cause some social problems such as random and arbitrary occupation of land belonging to other communities.

(4) Ecosystem

- Currently, the ecosystem on the coastal area has deteriorated mainly due to cutting of mangrove trees and oil spill from extraction operations at offshore oil field. The projected sea level rise would worsen this situation by damaging the mangrove and sea water intrusion, which could lead to disappearance of swampy area as habitat for abundant wildlife.

(5) Health

- The worsening condition of drainage in the lowland area due to sea level rise would bring about increase of waterborne disease in the area.
- The past trend of malaria disease outbreak in lower Congo shows a strong relation to low rainfall and a high minimum temperature caused by ENSO. The enhanced influence of ENSO as well as a minimum temperature rise due to climate change would worsen the situation.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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Chapter 11 Projected Influence of Climate Change in Tanzania

The United Republic of Tanzania (Tanzania) is located in eastern Africa, facing the Indian Ocean. Tanzania is one of the most wildlife-rich countries in the world, where 12 national parks, the Ngorongoro Conservation Authority Area, 23 game reserves and 44 game-controlled areas exist. These protected areas cover 38% of the total land area. Most of Tanzania experience tropical Savanna climate, with some exception at the northern part in the coastal area, which experience monsoon climate, and the central area with semi-arid climate[1]. These climate conditions maintain the current biodiversity. In Tanzania, the agriculture sector, including livestock, plays a major role in the economy, which employs 80% of the workforce and contributes to more than half of GDP; however, this sector is vulnerable to climate change.

The possible climate change impacts in Tanzania have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. The icecap on Mt. Kilimanjaro has been influenced by the temperature rise, and is predicted to disappear by 2020. The seasonal and geographical distribution of future climate change in Tanzania has been studied; however, the result still has some uncertainties, especially in precipitation change.

(1) Water Cycle

- Precipitation would change with the general increase over Tanzania; however, there would be seasonal decrease especially in the eastern and southern area of the country.
- River discharge would be influenced by the precipitation change, and will cause impact on water use and damage to infrastructure such as hydropower stations, farms along rivers, and human settlement.

(2) Agriculture and Livestock

- The temperature rise accompanied with CO_2 fertilization effect would contribute to agricultural production; however, precipitation decrease as well as pest and disease occurrence exacerbated by climate change would harm the productivity.
- Temperature rise would alter the distribution of agro-ecological zones. Areas used for perennial crops could be suitable for annual crops. Agricultural areas with rain-fed mixed crop with livestock systems in semi-arid areas would undergo more than 20% reduction of the growing period to 2050.
- Cattles would be affected by temperature rise, since it is not heat-tolerant.

[1] Köppen-Geiger climate classification

- Increased precipitation is likely to be harmful to grazing animals because it implies a shift from grassland to forests, and also a shift from livestock to crops.
- The foliage species composition with the most palatable species would be grazed out and replaced by more climate-tolerant species. Precipitation increase would foster foliage growth; however, there would be some possibility that crude protein content would be lowered as plants lignify upon reaching maturity. Thus, the overall carrying capacity of rangelands could possibly become lower.
- The area of ticks as vectors of livestock disease such as sleeping sickness and nagana disease would be extended through the increase of breeding grounds with vegetation enhancement.
- Fish yield, especially in Lake Tanganyika, could be reduced.

(3) Coastal Zone

- The coastline of Tanzania, which is about 800 km, would be influenced by sea level rise. Total land loss is estimated to be 247 km^2 and 494 km^2 for the sea level rise of 0.5 m and 1.0 m, respectively.
- Mangroves are the most vulnerable resources followed by sand and mud flats. Out of 494 km^2 of inundated area at 1.0 m sea level rise, mangroves cover 258 km^2 while sand/mud covers 105 km^2.
- Sea level rise would cause salt water intrusion in Tanzania's aquifer and deltas like the Rufiji Delta.
- Sea level rise could increase flooding at the coast.
- The coasts could be affected by potential changes in the frequency and intensity of ENSO events and coral bleaching.

(4) Ecosystem

- Forests would be influenced and current life zone might be replaced.
- The possible influence on foliage growth and animal infectious disease would give adverse impact on wild animals. The wildlife forms an important source of food and income for some local communities in Tanzania.

(5) Health

- The highlands of Tanzania are likely to become more susceptible for transmission of malaria.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

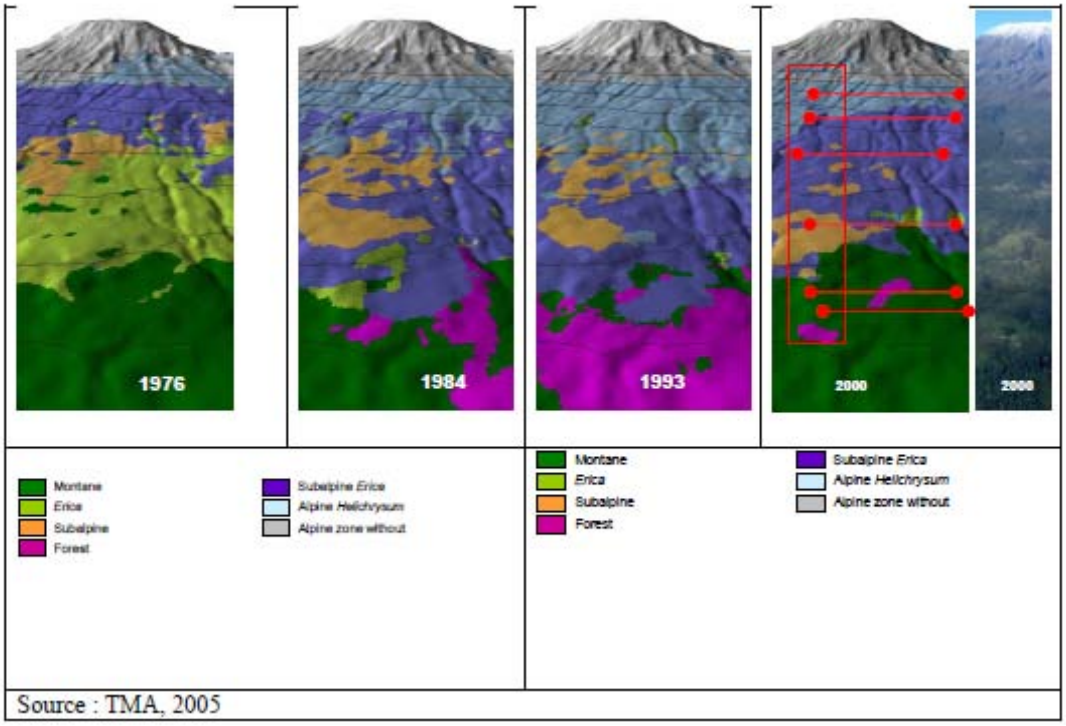

Figure: Changes in vegetation cover at Mt. Kilimanjaro

Source: Ministry of Environment, The United Republic of Tanzania (2007), p.10, Figure 1

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
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Chapter 12 Projected Influence of Climate Change in Nigeria

The Federal Republic of Nigeria (Nigeria), which has the largest population in Africa, is located at the bending of Western Africa. There are variations of climate in the country from south to north: monsoon climate on the coastal area of the south edge, tropical savanna climate zone in the most part, semi-arid climate zone in the north and desert climate in the most northeastern area[1]. Accordingly, the annual precipitation varies from the southern area with more than 3,500 mm to the northern area with less than 600 mm. There are generally two seasons (dry and wet) in the year, but length of the rainy season varies from 9-12 months in the south, and decreases to 3-4 months in the extreme northeast.

The possible climate change impacts in Nigeria have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. However, there are still discrepancies between the results of GCMs: some projecting a significant drying while others simulating a progressive wetting with an expansion of vegetation into the Sahara. Thus, the prediction of future climate change influence to Nigeria still remains uncertain.

The possible impacts of climate change in Nigeria have been projected as follows:

(1) Water Cycle

- Change in annual precipitation and rainfall pattern, and fluctuation of extreme dry and wet years would occur.
- Rainfall harvesting, used mainly in the rural areas and covering more than 50% of water consumption in these localities, would be influenced.
- If precipitation would decrease in the Sudan-Sahel region, groundwater which is the main source of water supply in the region, will be affected.
- Water resources along the coast would be polluted by the intrusion of salt water.
- Flood conditions in the southern coastal area would be exacerbated due to probable increase of precipitation in the south and sea level rise.
- Some parts of the country such as the southeastern areas would suffer from rain-induced erosion, while the northernmost parts would suffer from wind-induced soil erosion.

(2) Agriculture and Food

- CO_2 fertilization effect would be superior in C3 crops to C4 crops. Hence, C4 crops, which

[1] Köppen-Geiger climate classification

are more common in Nigeria, could be generally adversely affected, as C3 crops would grow faster.

- Various pests, including the tobacco cutworm, rice stink bug, rice weevil, and soybean pod borer would probably expand their distribution areas. Also, the increase of extreme events could create conditions for outbreaks of disease and pests.
- In the case of the reduction of precipitation in the Sudan-Sahel region, crop productivity would drop.
- Decreased rainfall would reduce the primary productivity of the grassland areas. Declining availability of surface water resources for animals and the possible increase in salinity at watering points due to increase of evaporation in the precipitation reduced area, would occur. New ecoclimatic environment for livestock would emerge, possibly shifting towards the coast in many parts of the country.
- Upwelling along the Gulf of Guinea affected by increased ocean temperature could make the ocean unsuitable for fisheries, causing a reduction in, and possible collapse of, fishing activities. Moreover, wetland loss and increased salinity due to sea level rise would reduce estuarine fishing.

(3) Coastal Zone

- Coastal settlements including large cities, transport infrastructure including roads, railroads, and ports would be threatened by sea level rise.
- Energy production facilities such as power plants, as well as oil and gas production facilities could be subject to damage from the sea level rise.
- Agricultural lands in the lowlands along the coast would be lost leading to socio-economic and socio-cultural problems.

(4) Ecosystem

- There could be a shift of boundaries of major ecological zones as well as tremendous impact on the wildlife they support.
- Probable persistent flooding and water-logging due to sea level rise or extreme weather events could render forest regeneration more difficult. Many of the organisms in the forest ecosystem of Nigeria are already near their tolerance limits.
- The savanna biome in the northern area would be very vulnerable to reduction in rainfall. This could result in widespread degradation of habitats.
- Mangrove forests and wetlands would be lost due to sea level rise.

(5) Health

- Increased wetness anticipated for the southern part could trigger increase in asthmatic attacks.
- Climate change would influence malaria transmission. Anopheles species would disappear from previous thickly forested areas in the southern area, following the loss of forests upon

which they depend on. However, sea level rise and increased coastal flooding may result in greater quantities of brackish water, which anopheles species prefer.

(6) Energy

- Probable decrease in precipitation would adversely affect the supply of hydroelectric power, which is sensitive to river flow.
- Fuelwood, which is an important energy source in Nigeria, would be adversely affected by climate change such as rainfall decrease, frequent thunderstorms, soil erosion, and so on.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

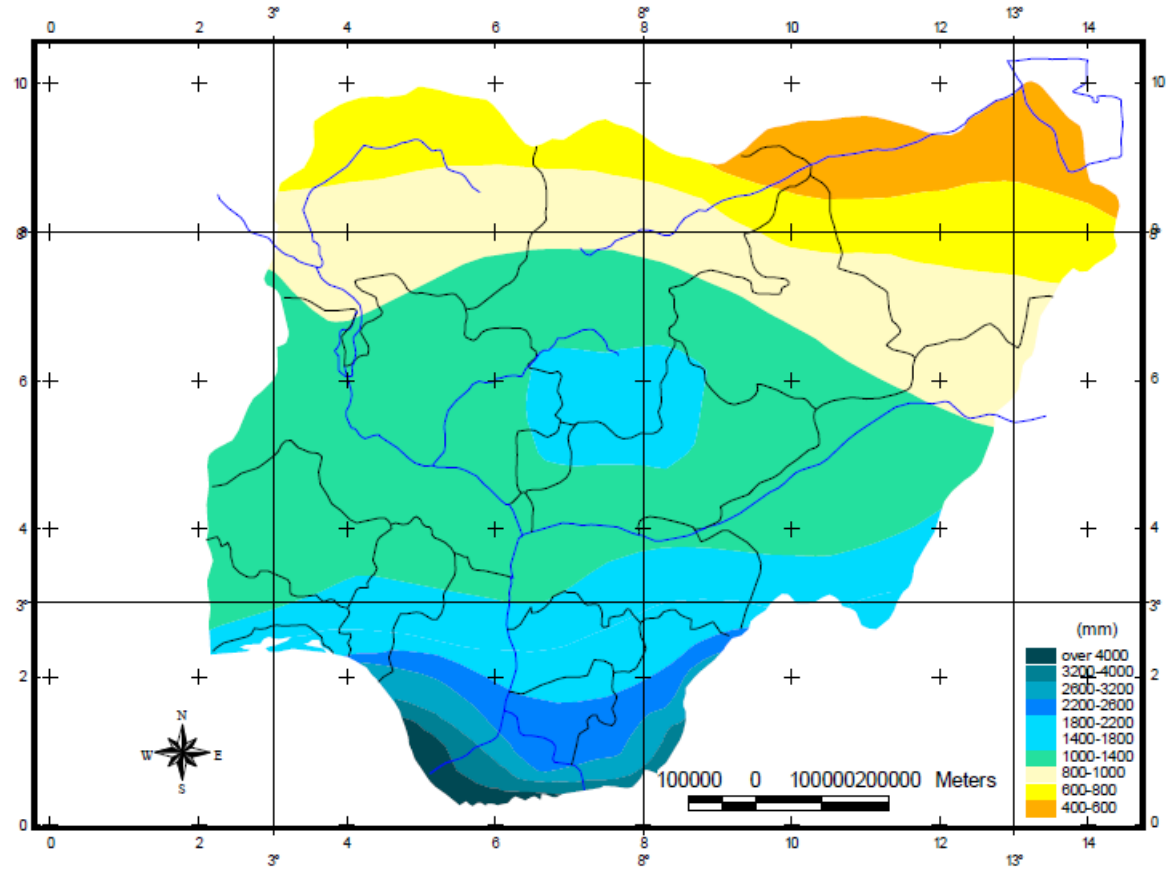

Figure: Current Spatial Variation of Annual Rainfall in Nigeria

Source: Ministry of Environment of the Federal Republic of Nigeria (2003), p.17, Figure 1.5

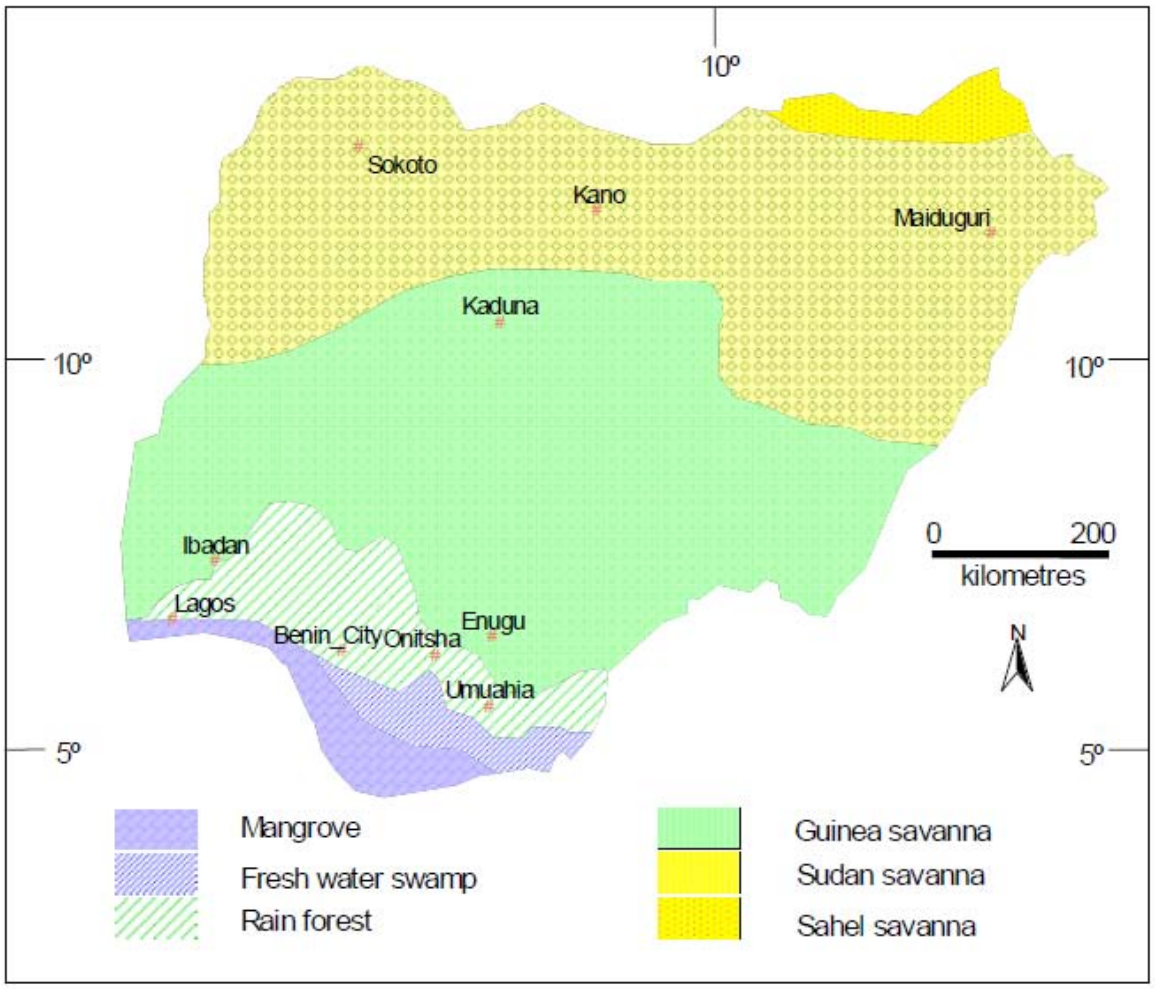

Figure: Current Vegetation of Nigeria

Source: Ministry of Environment of the Federal Republic of Nigeria (2003), p.18, Figure 1.6

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
- IPCC. (2007). AR4 WG II: Impacts, Adaptation and Vulnerability, Chapter 9 Africa.
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- World Bank. (2011). Nigeria: Country Brief: http://go.worldbank.org/FIIOT240K0

Chapter 13 Projected Influence of Climate Change in Madagascar

The Republic of Madagascar (Madagascar) is located in the southwestern edge of the Indian Ocean, separated from eastern Africa by the Mozambique Channel. Madagascar has rich diversity in its flora and fauna, much of which is unique to the island. Madagascar is the fourth biggest island in the world, and most parts are highlands. Overall, Madagascar enjoys a tropical climate, with regional variations; hot and humid in the east, and semi-arid and hot in the west and southwest. The highlands, the western region and the south region have dry season from May to October; however, it rains almost all-year round in the eastern region where forests are dominant.

The possible climate change impacts in Madagascar have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Climate change would affect seasonal rainfall, and exacerbate the intensity of tropical cyclones. The ENSO would influence the Madagascar regional climate; however, there have been no fixed predictions about the extent of influence.

The possible impacts of climate change in Madagascar have been projected as follows:

(1) Water Cycle

- There is still uncertainty in the prediction of precipitation change; however, its influence would not be uniform in terms of areal and seasonal precipitation. Generally, precipitation in the wet season would increase, and would decrease in the dry season.
- In the wet season, water needs would be covered adequately, but there would be some risk of pollution, flooding due to tropical cyclone especially, damage to infrastructures, and so on.
- In the dry season, water would be in short supply and there would be the risk of water conflicts.

(2) Agriculture and Food

- Temperature rise could alter the growing season of cereal crops.
- Soil erosion would be exacerbated in the wet season, and water deficit leading to water conflict for irrigation water could occur in the dry season. Some studies about rice production in the eastern highlands have indicated the risk of rice production.
- Some studies about sugarcane production in the southwest coast have shown water demand increase and drop in yields under climate change. Furthermore, temperature rise would facilitate the increase of parasites harmful to sugarcane.
- Vanilla production in the northeast would be damaged by tropical cyclones.
- Shrimp production would be damaged due to tropical cyclones. Mangrove destruction due to

tropical cyclone and sea level rise would also harm the production.

(3) Coastal Zone

- Sea level rise would bring about several influences such as submerging of infrastructure, loss of beaches, displacement of population, loss of income activities for the inhabitants, and insecurity of coastal navigation.

(4) Ecosystem

- Forest reduction and degradation of forest resources would be aggravated, and some plant and animal species would disappear.

(5) Health

- The prevalence rate of malaria would increase as a result of the disruption of climate barriers.
- Water-caused diarrheal diseases would increase due to contamination of water resources by floods.
- Acute respiratory diseases would become more common due to air pollution.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

Reference:

- IPCC. (2007). AR4 WG I: the Physical Science Basis, Chapter 11 Regional Climate Projections.
- IPCC. (2007). AR4 WG II: Impacts, Adaptation and Vulnerability, Chapter 9 Africa.
- Ministry of Foreign Affairs Japan. (2011). Japan- Madagascar Relations: http://www.mofa.go.jp/region/africa/madagascar/index.html
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Chapter 14 Projected Influence of Climate Change in the Republic of South Africa

The Republic of South Africa (South Africa) is located in the southernmost region of the African continent, and its land has various geographies such as fertile plain, high mountainous area and the desert. This geographical complexity brings about varied climate in the country; humid subtropical on the southeastern coastal area, oceanic climate on the east area and south coastal area, Mediterranean climate at the southwestern area, desert climate on the western area, and semi-arid climate on the central and northern part[1]. South Africa is experiencing several socio-economic difficulties, where some causes would have been lasting from the apartheid era in the 20th century. These include the inequity of income and wealth, high unemployment rate, and the largest number of people living with HIV/AIDS in the world. These social vulnerabilities are firmly related to its vulnerability to climate change.

The possible climate change impacts in South Africa have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. Higher temperature rise has been predicted in the interior part of the country (currently arid and semi-arid area). The land would suffer from drying especially in the southwest in winter, while the much broader scale poleward shift in the circulation across the South Atlantic and Indian Ocean would occur. The prediction of future precipitation remains uncertain in South Africa, since the calculation results of GCMs are not consistent with each other.

The possible impacts of climate change in South Africa have been projected as follows:

(1) Water Cycle

- Rainfall is likely to decrease over the country, more significantly in the southwestern area and west margins.
- With the exception of the winter rainfall region in the southwestern area, the robust drying in winter that corresponds to the dry season will not contribute to the bulk of the annual mean drying. More than half of the annual mean reduction would occur in spring, and can be thought of as a delay in the onset of the rainy season.
- Summer rainfall over the convective region of the central and eastern plateau and the Drakensberg Mountains would increase. Rainfall decrease in spring and increase in fall would occur over the eastern area.
- Although the stream flow in South Africa would not decrease significantly, the projected reduction in the amount or reliability of rainfall, or an increase in evaporation due to higher

[1] Köppen-Geiger climate classification

temperatures would exacerbate the lack of surface water resources. Even without climate change, it is predicted that South Africa will have fully utilized its surface water resources by about 2030.

- Desertification could be exacerbated due to the reduction of rainfall over the arid and semi-arid regions, which covers nearly half of South Africa.
- Climate change would alter the magnitude, timing and distribution of storms that produce flood events.

(2) Agriculture, Food and Forestry

- The rangelands, which occupy over 70% of the land, would be affected by aridification. The fodder production on the savanna region would decrease by about one fifth. On the other hand, the fodder production on the grassland would not be influenced due to the offset by CO_2 fertilization.
- The predicted hotter and drier climate will reduce maize production in the western marginal areas; however, the eastern wet area would increase its production and would possibly offset the yield decrease in said marginal areas.
- Specialty crops grown in specific environmentally favorable areas may also be at risk.
- Tree crops would be affected by aridification. Currently, only 1.5% of the country is suitable for tree crops, and much of these areas are relatively marginal.
- An increase of pest and disease as well as invasive plants would affect the agricultural sector.
- Fisheries could be affected by changes in estuaries, coral reefs, and upwelling.
- Forestry production, particularly in *Pinus Patula* and *Pinus Radiata* plantations, would be damaged with a substantial loss of production.

(3) Ecosystem

- Significant reduction of current biomes would be brought about especially in the western, central and northern parts of the country. The southern area, which is home to the Cape Floristic Kingdom, would also be affected.
- Species composition would be changed, which may lead to significant changes in the vegetation structure in some biomes. Of the 16 centers of endemism in South Africa, more than half would experience bioclimatic changes that would result in loss of species.
- Most animal species would become increasingly concentrated in the proximity of the higher altitude, eastern escarpment regions with significant losses in the arid regions of the country.
- Sea level rise would not have a substantial effect on the marine biodiversity. However, the predicted rise in temperature would affect the sea surface temperature, and would cause the migration of species residing along the coast and alternation of nearshore currents. The nutrient and larval supply to the coast would be affected, and the occurrence of red tide would increase in the west coast, causing mass mortalities of fish, shellfish, marine mammals, seabirds and other animals.

- Sand inundation in the eastern coast and an increase in storms, which would accelerate the rate of disturbance events and favor short-living rather than long-living marine species, are predicted.

(4) Health

- Malaria risk would increase in terms of area and duration due to the increasing temperature and length of summer, although the country lies at the south edge of the current malaria distribution area.
- Schistosomiasis transmission risk would increase, and to make matters worse, the distribution of snail host for such disease would increase due to frequent flooding triggered by climate change.
- It would become possible for urinary schistosomiasis to exist in an area which is currently free from such disease; for example, in the western region of the country.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

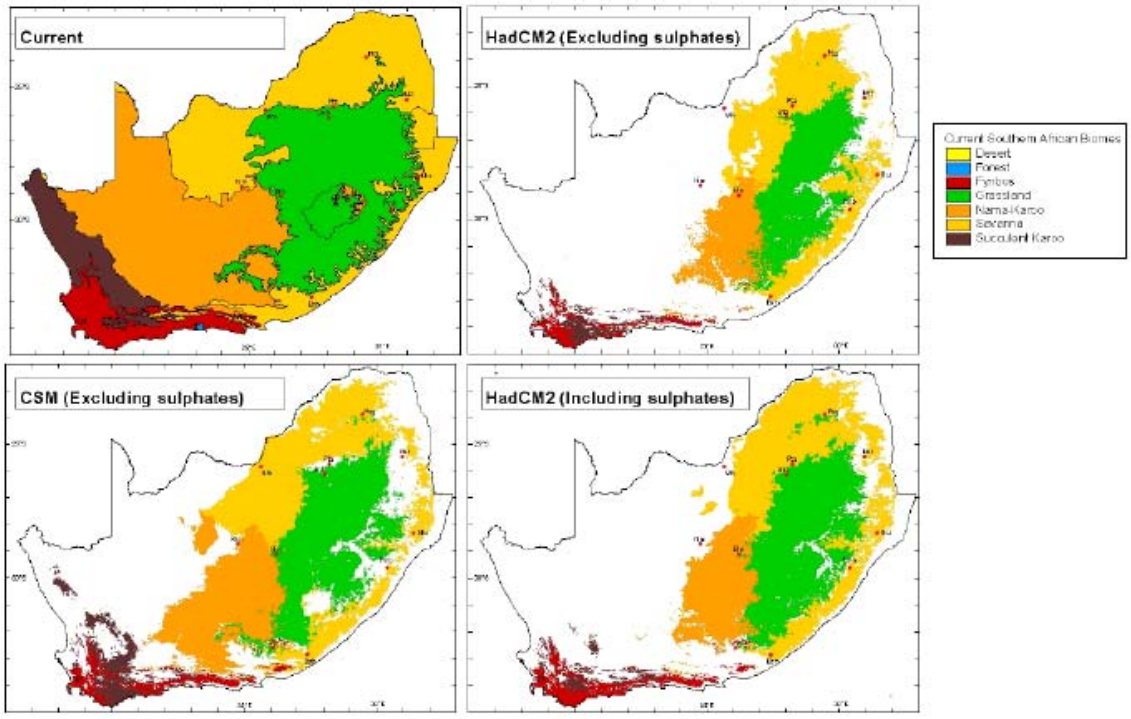

Figure: Current and potential distribution of South African biomes ()

Source: Rutherford et al (1999) (Dynacon (Pty) Limited and Wiechers Environmental Consultancy (2000), p.40, Figure 3.3)

Reference:

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Chapter 15 Projected Influence of Climate Change in Tunisia

The Republic of Tunisia (Tunisia) is located in northern Africa. With an opening on the Mediterranean Sea on its north and east, and a coastal line of 1300 km, Tunisia has been developed mainly in the coastal areas. About two-thirds of the total population, more than 70% of economic activities, and a great part of the irrigated agriculture are concentrated in the coastal areas. These could be vulnerable to sea level rise caused by climate change. Opposite to the Mediterranean climate in the coastal area, the central part and the southern part of the country is under a desert climate[1].

The possible climate change impacts in Tunisia have been revealed through recent intensive scientific efforts, of which the IPCC 4th Assessment Report published in 2007 would be the most authoritative. The predicted results still remain uncertain; however, temperature rise in the country would occur, especially in the summer season, and the risk of summer drought could increase. Nevertheless, among the several influences of climate change, sea level rise would be the most concern in Tunisia.

The possible impacts of climate change in Tunisia have been projected as follows:

(1) Water Cycle

- Precipitation would decrease. The annual number of precipitation days would also decrease.
- Currently, more than 80% of precipitation in Tunisia is taken up by evaporation. Decrease in precipitation with enhanced evaporation in spring and early summer would lead to reduced summer soil moisture.
- There could be a possibility that rainfall events would become more intensive, resulting in the disappearance of streaming waters rather than absorption by the soil. Furthermore, sea level rise would damage the aquifer on the coastal area. Hence, groundwater could deteriorate due to climate change.
- Fossil water, which is not directly affected by climate change, would be influenced in terms of water use due to increasing water demand and degradation of present water resource.

(2) Agriculture and Food

- Many coastal farmlands covering large areas in the coastal areas would be lost due to soil erosion and/or salinization of groundwater.
- Irrigation systems would be affected through the deterioration of water resources.

[1] Köppen-Geiger climate classification

Malfunctioning of irrigation and drainage facilities due to sea level rise would also be considered.

- Transition in the ecosystem in the lowland and lagoons due to sea level rise would affect fishery, probably with the reduction of productivity. Coastal and lagoon fisheries and clam harvesting would be most vulnerable.

(3) Coastal Zone

- The coastal areas, which is the most economically and socially important area of Tunisia, would be adversely affected by sea level rise.
- Water treatment plants recently installed on the coastal zone would be damaged by sea level rise.

(4) Ecosystem

- Wetlands on the coastal area would be influenced by sea level rise. The Lake Ichkeul, which was recognized during the Ramsar Convention, is located on the lowland and has connection with the sea (although indirectly at present). This would thus be affected through intrusion of seawater.
- Forests on the coastal area could be influenced due to the receding coastal line and salinization of groundwater.

The adaptation to climate change in India is intended to alleviate the projected impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in sensitive sectors for climate change is indispensable. Besides that, the availability of human resources to utilize these data for climate change adaptation is crucial. Therefore, human resource development and capacity building would also be regarded as important adaptation measures.

Figure: Potential Impact of Sea Level Rise on the Lake Ichkeulx
Blue green represents the loss of wetland, Right blue represents upward migration of wetland with loss of cropland.

Source: Ministère de l`Environnement et de l`Aménagement du Territoire, Republique Tunisienne (2001), p.64, Figure 3.1

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Chapter 16 Projected Influence of Climate Change in Oceania

Oceania is one of the World Wildlife Fund (WWF) ecozones, which includes the Pacific Ocean islands of Micronesia, the Fijian Islands, most of Polynesia except New Zealand, most of Melanesia including New Guinea, Vanuatu, the Solomon Islands, and New Caledonia. Most islands are composed mostly of volcanic high islands such as Fiji and coral atolls such as Solomon Islands. The climate of Oceania islands is either tropical or subtropical, and range from humid to seasonally dry seasons.

The possible climate change impacts in the Oceania region have been revealed through recent intensive scientific efforts, of which IPCC 4th Assessment Report published in 2007 would be most authoritative. The global sea level is projected to rise by 0.19-0.58 m. The observed sea level rise during 1950-2000 is 0.17±0.05 m, and the average rate for sea level rise is expected to increase. The close estimation is applicable to the Oceania region. The projected regional temperature indicates an increase over the Pacific Ocean but is slightly smaller than the global average. Generally, annual rainfall in the Oceania region is projected to increase (see Figure below). However, the wet and dry cycles associated with ENSO have serious impacts on water shortage as observed during the 1998-2000 La Niña. Generally, in the South Pacific region, there is no clear picture with respect to regional changes in frequency and movement of tropical cyclone, but increases in intensity are indicated. ENSO fluctuations have a strong impact on patterns of tropical cyclone occurrence in the South Pacific.

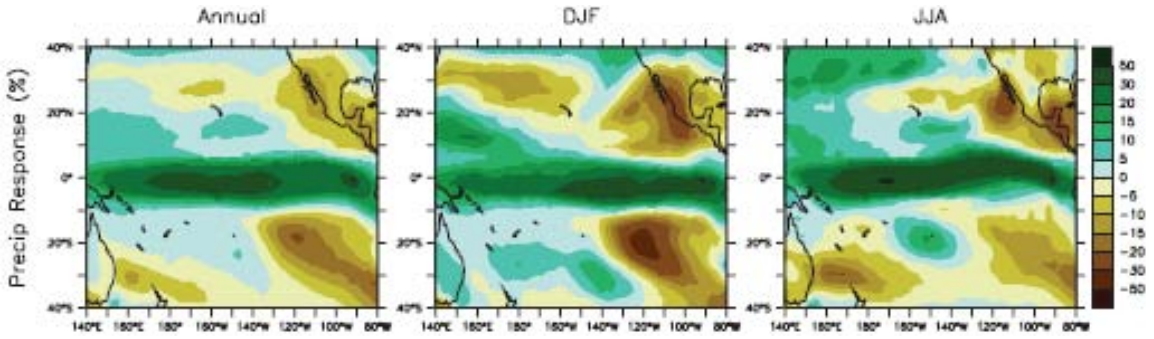

Figure: Precipitation Changes over the North and South Pacific Ocean between 1980-1999 and 2080-2099

Source: IPCC (2007) WG I, p.915 Figure 11.25

The possible and typical impacts of climate change in the Oceania region have been projected as follows:

(1) Water Cycle

- Rising sea levels/coastal erosion cause damage to water supply infrastructure and saltwater intrusion into freshwater lens on low-lying areas and atoll islands.
- ENSO phenomenon led to serious water shortage over the entire region. For instance, water supplies were compromised severely during the 1997/1998 drought in Honiara, Solomon Islands by 30-40%. Particularly, countries such as Kiribati, where only 44% of the population have access to safe water, will be very vulnerable to such drought event.
- Low rainfall typically leads to a reduction in the amount of water that can be physically harvested, a reduction in surface water, and a slower rate of recharging the freshwater lens. This will potentially cause prolonged drought in most small islands in the region.

(2) Agriculture and Food

- Local food production is vital for small islands, where ecological dependency of economies and societies is very high.
- Increased intensity/frequency of cyclones can typically have dramatic effects on agriculture and food production that often last for many years. Also, after the immediate effects, pests and diseases will come in later, damaging the newly growing crops.
- Tropical cyclone will have serious impacts on commercial agriculture as well as subsistence agriculture. For high islands (Fiji), it is estimated that a few percentage of its GDP will be reduced, while for a group of low islands (Kiribati), average annual damage to GDP will be more than 15%.
- Storm surges and flooding can wash away food crops especially on low-lying areas and cause waterlogging of soil. Inundation would destroy food stock for livestock as well as the direct loss of stock. Saltwater intrusion in low-lying coastal areas of the atolls is already threatening food crops and livelihoods.
- Sea level rise and coastal erosion are becoming more evident, reducing the land area available for agriculture and reinforcing resettlement of farmers.
- El Niño and La Niña brought about prolonged drought with negative impacts on food production in the Oceania region. The future extreme weather is expected to exacerbate the damages.

(3) Coastal Zone

- Coral reefs are important as they are the main source of sediment for beach formation, serve as protection against storm events, and are productive habitats and ecosystems. During the recent El Niño, there were lower sea levels, which resulted in warmed coral habitats and coral bleaching.
- As sea surface temperatures already frequently exceed the temperature tolerance of coral species (25°C to 29°C), it is likely that any increase in sea surface temperature will result in more frequent and severe episodes of coral bleaching.
- For instance, in 1976, the total area of mangrove forest throughout Solomon Islands was

approximately 650 km^2. However, no recent information on distribution and condition of mangroves are available, and thus, possible effects of sea level rise on mangrove systems are unknown.

- In Solomon Islands, coastal erosion is affecting some villages. Protective works along the shoreline have been eroded and parts of the road passing through it have been washed out. This process has been observed over a number of years, but seen at a faster rate in recent years. In addition, erosion of roads is particularly worsened by rainfall runoff from the steep hill overshadowing the village. If it were not for the outer ridge of the reef, which acts as a buffer for stronger wave energies, erosion would be more severe and could have affected the village.

(4) Ecosystem

- Oceanic islands have unique biodiversity through high endemism due to ecological isolation.
- For instance, Solomon Islands has one of the highest diversities of corals as evidenced by a record of 494 species and a total of 1,019 fish species.
- There has been recent coral bleaching, which coincided with higher than usual sea temperatures
- Cyclones can devastate reefs, especially when they hit areas where wave action is usually slight. Unusually low tides coinciding with high air temperatures can damage corals, e.g., in 1983 and 1997/1998, many coral reef flats died because of a lowering of sea level in the southwest Pacific during the strong El Niño event.
- Coral bleaching will affect fishery resources that many of the residents depend on for their living.

(5) Health

- Climate change can be linked with malaria, mental illness, malnutrition, diarrhea, acute respiratory infections, micronutrient deficiency, parasitic diseases due to poor sanitation, tuberculosis, leprosy and non-communicable diseases.
- Changes in temperature and rainfall regimes will cause higher incidence of vector-borne diseases such as dengue and scrub typhus.
- Waterborne diseases such as shigellosis could increase as a result of disruption of sewage and water systems due to flooding.

The adaptation to climate change in the Oceania region is intended to alleviate the projected climate impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in the sensitive sector for climate change is indispensable. Besides, the availability of human resources to utilize these data for climate change adaptation becomes crucial; therefore, human resource development and capacity building would also be rendered as important adaptation measures.

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Chapter 17 Projected Influence of Climate Change in the Caribbean

The Caribbean region comprises more than 7,000 islands, islets, reefs, and cays. Some islands in the region have relatively flat terrain of non-volcanic origin. These islands include Aruba (possessing only minor volcanic features), Barbados, the Cayman Islands, Bahamas or Antigua. Others possess rugged towering mountain ranges like the islands of Cuba, Hispaniola, Puerto Rico, Jamaica, Dominica, Montserrat, Saint Kitts, Saint Lucia, Saint Thomas, Saint John, Tortola, Grenada, Saint Vincent, Guadeloupe, Martinique, and Trinidad and Tobago. The climate of the region is tropical but rainfall varies with elevation, size and water currents. The region enjoys year-round sunshine, divided into dry and wet seasons with the last six months of the year being wetter than the first half. Hurricanes, which at times batter the region, usually strike northwards of Grenada, and to the west of Barbados. The principal hurricane belt arcs to the northwest of the island of Barbados in the eastern Caribbean.

The possible climate change impacts in the Caribbean Sea have been revealed through recent intensive scientific efforts, of which IPCC 4th Assessment Report published in 2007, would be most authoritative. The Caribbean region experienced a mean average sea level rise of 1 mm annually during the 20th century. The global sea level is projected to rise by 0.19-0.58 m. The observed sea level rise during 1950-2000 is 0.17±0.05 m and the average rate of sea level rise is expected to increase. Annual temperature is projected to increase by the end of the 21st century. Annual mean rainfall is projected to decrease over the whole region of the Caribbean, while increases in some areas are expected during the December-February period (see Figure below). It is likely that the maximum tropical cyclone wind intensities could increase. The phenomena in the two El Niño years of 1997 and 2002 indicate that El Niño caused reduction of tropical hurricanes while La Niña caused increase of such events in the North Atlantic and Caribbean.

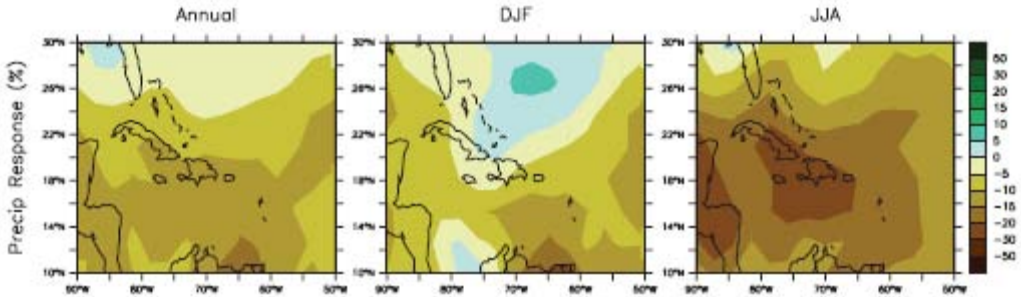

Figure: Precipitation Changes over the Caribbean Sea between 1980-1999 and 2080-2099

Source: IPCC (2007) AR4 WG I, p.913 Figure 11.23.

The possible impacts of climate change in the Caribbean region have been projected as follows:

(1) Water Cycle

- Since most of the islands depend on surface water catchments for water supply, the future demand could not be met during periods of low rainfall. For instance, in Haiti, water resources are distributed by five rivers, which comprise nearly 60% of the country's water resources.
- During the wet season, rivers that are quickly filled with water carry sediment loads. Water sources with little protection are contaminated not only by soil erosion but also by water runoff, making it unsuitable for water supply. Drinking water is scarce and such situation further reduces the availability of this basic service.
- On the other hand, drought has adversely affected the availability of surface water and groundwater. Springs and rivers may even dry up completely, which seriously affects agricultural production.
- Drought will reduce the groundwater levels coupled with saltwater intrusion.
- Possible sea level rise will cause saltwater intrusion into freshwater lens, which most of the islands depend on for portable water needs.
- Some countries such as Bahamas, Antigua and Barbuda, and Barbados have invested to build desalination plants to secure water supply.

(2) Agriculture and Food

- The vulnerability of the agriculture sector is closely linked to that of water and soil conditions. Winds, floods, and droughts have direct impacts on agriculture. These events exacerbate soil erosion leading to the loss of soil moisture. In Haiti, it is anticipated that by the middle of the 21st century, more than half of the land would be in danger of desertification due to climate change.
- Considerable areas of farmlands are already contaminated by saline soils.
- The anticipated climate changes will affect the seasonal variation of agro-climatic patterns affecting farmers in their farming practices that may result in crop failure and endanger national food security.
- Higher temperatures and increased periods of drought are expected to increase the number of generations of insect pests for agriculture in most islands.
- High temperatures together with low rainfall usually provide an environment conducive to destructive fires. It is evident that fires are some of the greatest threats to the local sugar crop.

(3) Coastal Zone

- Coastal areas, which are the lowest parts of the watershed, are highly eroded in most small islands. They receive runoff, waste and all sediments flowing down the steep slopes of the

mountains. In Haiti, the land surfaces are degraded due to deforestation, destruction of mangroves and uncontrollable urbanization particularly in Port-au-Prince.

- Erosions of beach and coral reef in most islands are threatened by sea level rise and uncertain extreme events, which will cause heavy losses in tourism.
- The vulnerability of other sectors such as health, education, industry, commerce, fisheries, transport, etc. is dependent on the coastal areas due mainly to floods and cyclones.
- The beach-based and marine diving-based ecotourism in many islands will be negatively affected by climate change through erosion of beach and coral bleaching.

(4) Ecosystem

- The majority of coastal communities depend on coastal resources and reefs for their livelihood. Fringing reefs are major source of biodiversity, which provide coastal protection as natural barriers against erosion, livelihood for artisanal fisheries and recreation for the local population.
- Sea level rise would affect the lower and narrower beaches reducing turtle nesting habitat substantially.
- Beach erosion was determined to occur in areas which have high population densities and are dependent on coastal activities.
- Natural forces such as wind, waves, tides and currents, as well as human activities such as beach sand removal and inappropriate construction of shoreline structures are continuously causing shoreline changes at numerous locations around the country. As a result of sea level rise, erosion patterns will change the shorelines.
- Large increases in freshwater flow into the wetlands for some countries such as Haiti may affect the ecological balance of the ecosystem. Degraded wetlands as a result of other development pressures or inappropriate upstream land uses can result in the reduction of the wetlands' capability to serve as a natural filter and buffering system for coral reefs from upstream flows.
- In the event of increased frequency and intensity of severe events such as flooding, the degraded wetlands' reduced capacity to buffer flood conditions may result in damages to coral reefs.
- Coral reefs are also sensitive to heavy damage from hurricanes. The reefs are physically damaged and destroyed during high wave or storm surge events.

(5) Health

- Changes in temperature and rainfall regimes are causing higher incidence of vector-borne diseases such as malaria and dengue.
- Waterborne and foodborne diseases such as typhoid, shigellosis, and hepatitis A and E could arise due to contamination of flood waters.
- Acute and/or chronic health problems may arise from chemical contamination of water by agrochemicals and other hazardous wastes.

- One potentially significant problem in this regard is leptospirosis, a potentially fatal disease which is transmitted by urine of rodents.

The adaptation to climate change in the Caribbean region is intended to alleviate the projected climate impacts listed above. For the implementation of effective adaptation to climate change, accumulation of meteorological data and basic data in the sensitive sector for climate change is indispensable. Besides, the availability of human resources to utilize these data for climate change adaptation becomes crucial; therefore, human resource development and capacity building would also be rendered as important adaptation measures.

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