ADAPTATION SCIENCE AND POLICY STUDY
BOOK 1 : FINAL REPORT

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LAPI ITB

TEAM COMPOSITION

1. Djoko Suroso, Ph.D. (Team Leader)
2. Dr. Ibnu Sofian (Science Basis)
3. M.S. Fitriyanto, M.Sc. (Science Basis)
4. Dr. Eng. Hamzah Latief (Coastal Areas, Oceans, and Small Islands Aspect)
5. Oman Abdurahman, M.T. (Water Resources Aspect)
6. Dr. Budhi Setiawan(Water Resources Aspect)
7. Dr. Asep Sofyan (Human Health Aspect)
8. Wilmar Salim, Ph.D. (Food Production Systems and Food Security and Human Settlement Aspect)
9. Dr. Ruminta (Food Production Systems and Food Security)
10. Cometta S. Guritno (Assistant)
11. Riga Anggarendra, S. Si. (Assistant)
12. Aditya B. Harmeigi, S. Si. (Assistant)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

LIST OF DOCUMENTS ASSESSED AND THEIR CODES

NO.	CODE	DOCUMENT
1	CC-F	SEAMEO BIOTROP, 2008, *Relationship of Climate Change and Strategic Food Production.*
2	CCPI	Santoso, H. & Forner, 2006, Climate Change Projections for Indonesia, *Center for International Forestry Research: Tropical Forests and Climate Change Adaptation.*
3	CSI	Ministry of Marine and Fisheries (DKP), 2008, *Strategies of Disaster Adaptation and Mitigation for Coastal and Small Islands Due to Climate Change.*
4	ICCSR-AS	National Development Planning Agency (Bappenas), 2010, *Indonesia Climate Change Sectoral Roadmap: Agriculture Sector.*
5	ICCSR-HS	National Development Planning Agency (Bappenas), 2010, *Indonesia Climate Change Sectoral Roadmap: Health Sector.*
6	ICCSR-MFS	National Development Planning Agency (Bappenas), 2010, *Indonesia Climate Change Sectoral Roadmap: Marine and Fisheries Sector*.
7	ICCSR-SB	National Development Planning Agency (Bappenas), 2010, *Indonesia Climate Change Sectoral Roadmap: Science Basis-1 & Science Basis-2*.
8	ICCSR-WS	National Development Planning Agency (Bappenas), 2010, *Indonesia Climate Change Sectoral Roadmap: Water Sector*.
9	ICR	Ministry of Environment (KLH) & Ministry of Public Works (PU), 2007, *Indonesia Country Report: Climate Variability and Climate Change, and Their Implication.*
10	IPCC AR4 (Science Basis)	IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, Eds., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
11	IPCC AR4 (Sectoral Aspects)	IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.
12	IPCC AR5	IPCC, 2010, *Potential Regional Participation in the IPCC's Fifth Assessment: Information-Sharing Workshop, Background Information* (Rev. 16/1/2010)
13	Jakstra	Ministry of Public Works (PU), 2008, *Policies and Strategies of Spatial Planning for Climate Change Mitigation and Adaptation.*
14	PIT-PI	Ministry of Environment (KLH) & National Council on Climate Change (DNPI), 2009, *Preparation of Thematic Information to Anticipate Climate Change Impact to National Priority Issues on Food, Health, and Extreme Climate Phenomena Sectors.*
15	PNAS	Naylor, et. al., 2006, Assessing Risks of Climate Variability and Climate Change for Indonesian Rice Agriculture, *Proceedings of the National Academy of Sciences of the United States of America.*
16	RAN-MAPI	Ministry of Public Works (PU), 2007, *National Action Plan of Climate Change Mitigation and Adaptation.*
17	RAN-PI	Ministry of Environment (KLH), 2007, *National Action Plan in Facing Climate Change.*
18	SLRJ	Hadi, S. for Ministry of Environment (KLH), 2007, *Impact of Sea Level Rise in Northern Coast of Jakarta and Kepulauan Seribu.*
19	SNC	Ministry of Environment (KLH), 2010, *Second National Communication.*
20	STI-CC	Assessment and Application of Technology Agency (BPPT), 2009, *Science and Technology Identification upon the Impacts of Climate Changes in Marine Sector:*

NO.	CODE	DOCUMENT
		Observation, Identification, and Model Simulation for Predicting Temperature and Sea Level Rises in Indonesia.
21	STRAPI	Ministry of Health (Depkes), 2010, *Adaptation Strategy for Climate Change in Health Sector.*
22	VA Lombok-CMS	Ministry of Environment (KLH) & GTZ , 2010, *Study of Vulnerability and Risk to Climate Change for Lombok Island: Coastal and Marine Sector.*
23	VA Lombok-WS	Ministry of Environment (KLH) & GTZ , 2010, *Study of Vulnerability and Risk to Climate Change for Lombok Island: Water Sector.*

1. INTRODUCTION

1.1 Background

At international level Indonesia has played an important role in various negotiations on climate change, and of being the host of the 13th Conference of the Parties to the UNFCCC (United Nations Framework Conventions on Climate Change) in Bali which formulated the Bali Action Plan. These initiatives are not only to provide some international contributions to save the globe, but also to actively push collective efforts against climate change as one of the most vulnerable countries.

Some factors influence the vulnerability of Indonesia, especially due to its geographical features and socio-economic circumstances. In fact Indonesia has already experienced noticeable adverse effects in recent years: significant increasing trend of temperature is observed in many parts of the region, rainfall patterns are changing in form of delay or advance of the onset of rainy or dry season, or in appearance of shorten or lengthen of these seasons.

As a result, Indonesia recognizes that tackling the climate change should be an integral part of the development program of Indonesia. Recently the Government of Indonesia (GoI) has issued the document of the Indonesia Climate Change Sectoral Roadmap (ICCSR) (March, 2010). The document includes an overview of climate adaptation status and planning in four sectors, namely water, marine and fisheries, agriculture and health. Although this is an important step, however, an effective implementation of such a roadmap needs to be backed up by other elements that altogether would constitute a comprehensive strategy for climate change adaptation.

To accomplish the comprehensiveness of the adaptation strategy, a study is therefore conducted to provide complementary information. The study has focused on what have been done in terms of science and policy development, what are the gaps, what technology needed and available to support adaptation measures, and indication on how much the cost of adaptation programs.

1.2 Goal of the Study

The overall goal of this study is to assist the GoI to develop information to support the formulation of national strategy and mid-and-long term plans to prepare adaptation from negative impacts of climate change.

1.3 Specific Aims

Specifically, aims of the study that become scope of assessment are as follows:

1. Take stock of recently completed and existing works to model climate variability and change in Indonesia
2. Take stock of studies that cover the impacts of climate change on economy, technology, knowledge, infrastructure, institution, social life, human development and land use planning
3. Take stock of studies that look into the impacts of climate change on water resources, agriculture, coastal zone, human health and natural ecosystems
4. Identify key information on existing plans, policy, strategy outlined to deal with the impacts of climate change and undertake a gap analysis of current adaptation policy and initiatives, by government and non-governmental organizations, and their likely impacts
5. Identify technology needs and availability for key priority adaptation measures
6. Identify financing needs and flows for key priority adaptation measures

7. Based on the results of the above activities, provide information to key policy makers, scientific community and non government organizations on the level of scientific, policy, and financial preparedness of Indonesia to deal with negative impacts of climate change and their gaps that need to be met in the mid- and long-run

1.4 Methods of this Study

Under the leadership of the DNPI (National Council on Climate Change), i.e. DNPI's Head of Secretariat, the expert team implemented several steps below to reach the above goal and aims:

- Institutional survey
- Literatures and formal documents reviews
- Discussions with relevant stakeholders involved in climate change adaptation
- Desk studies
- Focus Group Discussions (FGDs)
- Workshops

The main sources of information might include strategy and policy documents and papers from the GoI as well as the relevant IPCC (Intergovernmental Panel on Climate Change) and UNFCCC documents that become the benchmarks of this study.

1.5 Expected Outcomes

Major outcomes being expected from this research are as follows:

1. Information on the status and capacity of available science basis to support adaptation planning
2. An outline of policy and strategy gaps that relate to climate adaptation measures
3. Information on climate change adaptation measures including technology and financing needs
4. Improved understanding of policy makers, scientific community, and governmental organizations on what has been done and needs to be done for climate adaptation

2. IMPLEMENTATION OF THIS STUDY

Process of this study began with the first meeting between DNPI and the expert team in early March 2010. This meeting had resulted in agreements on some adjustments of the term of references that became the basis of the implementation of the study. Results of that initial meeting were then further elaborated in internal meetings of the expert team as follows.

2.1 Methods of Study

One important consensus resulted from the first meeting with DNPI was an agreement that due to time constraint, this study constitutes only a **Rapid Assessment Methodology.** The expert team carried out desk study by reviewing these documents to identify and review some key data and information from them. The identification process is initialized by formulation of indicators that, as proposed by the expert team, refer to the recent international documents, i.e. IPCC Assessment Report 4 (AR4, 2007) and IPCC AR5 (outline, 2010) as benchmarks.

Information of all relevant documents needed was obtained by performing relevant institutional surveys, FGDs, and workshops. The documents were then legally obtained through facilitation of DNPI. Involvements of all relevant stakeholders are essential, not only to explore related data and information, but also to enhance awareness and ownership of the output of this activities as well as the sustainability of the outcome.

2.2 Key Implemented Activities

Specific aims are then elaborated into key activities of this study as follows:

- Take stock and review of recent documents of the science basis study on climate change and variability in Indonesia
- Take stock and review of recent documents of study on hazards and impacts of climate change on some aspects (or sectors) described below
- Identify key information on existing documents including plans, policies, and strategies of climate change adaptation measures by the government and initiatives by non-governmental organizations
- Undertake a **gap analysis** of the relevant documents above by using the indicators that are formulated from the aspects of the IPCC AR4 (2007) and AR5 (outline, 2010)
- Identify technology and financing needs for key priority adaptation measures
- Based on the results of the above activities, provide recommendations to key policy makers, scientific community, and non-governmental organizations on the level of scientific, policy, and financial preparedness of Indonesia to deal with negative impacts of climate change and their gaps that need to be met in the mid-and-long run

2.3 Scope of Assessment (Aspects)

To implement the gap analysis, it is necessary to firstly formulate a benchmark to which the gaps would be measured upon the related documents. In principle the team decided to refer to the most recent documents regarding to the climate change issues in international level. The team then selected the documents of the Intergovernmental Panel on Climate Change, the Fourth Assessment Report (2007) and the Fifth Assessment Report, (Outline of IPCC AR5, 2010) as the benchmark. The rationale for selecting the IPCC Assessment Report as the benchmark is that the

Government of Indonesia (GoI) should refer all its efforts on climate change adaptation to the latest development on climate science and policy achieved by international communities. Contents of the outline of AR5 documents which are relevant to this study are as follows:

A. Physical Science Basis (Working Group I):

1. Observations: Atmosphere and Surface
2. Observations: Ocean
3. Observations: Cryosphere
4. Information from Paleoclimate Archives
5. Carbon and Other Biogeochemical Cycles
6. Clouds and Aerosols
7. Anthropogenic and Natural Radiative Forcing
8. Evaluation of Climate Models
9. Detection and Attribution of Climate Change: from Global to Regional
10. Near-term Climate Change: Projections and Predictability
11. Long-term Climate Change: Projections, Commitments, and Irreversibility
12. Sea Level Change

B. Impacts, Adaptation, and Vulnerability: Global and Sectoral Aspects (Working Group II)

Natural and Managed Resources and Systems, and Their Uses

1. Freshwater Resources
2. Terrestrial and Inland Water Systems
3. Coastal Systems and Low-lying Areas
4. Ocean Systems
5. Food Production Systems and Food Security

Human Settlements, Industry, and Infrastructure

6. Urban Areas
7. Rural Areas
8. Key Economic Sectors and Services

Human Health, Well-Being, and Security

9. Human Health
10. Human Security
11. Livelihoods and Poverty

As a result, a classification comprising of six groups of related aspects can be derived from the IPCC AR5 to be implemented to this study, i.e.:

1. Science basis
2. Food production systems and food security
3. Human health
4. Human settlement systems
5. Water resources and systems
6. Coastal areas, oceans, and small islands

This classification is similar to and thus replaces the classifications of climate change impacts into aspects of economy, technology, knowledge, infrastructure, institution, social life, human development, and land use planning as well as climate change impacts into sectors of water resources, agriculture, coastal zone, human health, and natural ecosystems, as requested by the terms of reference of the study.

However, the document of IPCC AR5 is still in the form of an outline, so that further identification of the indicators for the gap analysis was derived from the previous IPCC AR4 documents (2007). The aspects derived from the IPCC AR4 document were then matched into the aspects outlined in the IPCC AR5 according to the comparison of the outlines of both documents as follows:

Table 1 Comparison of the selected outlines of the IPCC AR5 and IPCC AR5 in Physical Science Basis (Working Group I)

Outline of IPCC AR5 (2010)	Related Outline of IPCC AR4 (2007)
2. Observations: Atmosphere and Surface	3. Observations: Atmospheric Surface and Climate Change
3. Observations: Ocean	5. Observations: Ocean Climate Change and Sea Level
4. Observations: Cryosphere	4. Observations: Changes in Snow, Ice, and Frozen Ground
5. Information from Paleoclimate Archives	6. Palaeoclimate
6. Carbon and Other Biogeochemical Cycles	2. Changes in Atmospheric Constituents and Radiative Forcing 7. Coupling Between Changes in the Climate System and Biogeochemistry
7. Clouds and Aerosols	2. Changes in Atmospheric Constituents and Radiative Forcing 7. Coupling Between Changes in the Climate System and Biogeochemistry
8. Anthropogenic and Natural Radiative Forcing	2. Changes in Atmospheric Constituents and Radiative Forcing
9. Evaluation of Climate Models	8. Climate Models and Their Evaluation
10. Detection and Attribution of Climate Change: from Global to Regional	9. Understanding and Attributing Climate Change
11. Near-term Climate Change: Projections and Predictability	10. Global Climate Projections 11. Regional Climate Projections
12. Long-term Climate Change: Projections, Commitments, and Irreversibility	10. Global Climate Projections 11. Regional Climate Projections
13. Sea Level Change	5. Observations: Ocean Climate Change and Sea Level

Table 2 Comparison of the selected outlines of the IPCC AR5 and IPCC AR4 in Impacts, Adaptation, and Vulnerability: Global and Sectoral Aspects (Working Group II)

Outline of IPCC-AR5 (2010)	Related Outline of IPCC-AR4 (2007)
Natural and Managed Resources and Systems, and Their Uses	
3. Freshwater resources	3. Freshwater resources and their management
4. Terrestrial and inland water systems	3. Freshwater resources and their management
5. Coastal systems and low-lying areas	6. Coastal systems and low-lying areas
6. Ocean systems	4. Ecosystems, their properties, goods, and services 16. Small islands
7. Food production systems and food security	5. Food, fibre, and forest products
Human Settlements, Industry, and Infrastructure	
8. Urban areas	7. Industry, settlement, and society
9. Rural areas	7. Industry, settlement, and society
10. Key economic sectors and services	7. Industry, settlement, and society

Outline of IPCC-AR5 (2010)	Related Outline of IPCC-AR4 (2007)
Human Health, Well-Being, and Security	
11. Human health	8. Human health
12. Human security	7. Industry, settlement, and society
13. Livelihoods and poverty	7. Industry, settlement, and society
Regional Chapters	
29. Small islands	16. Small islands

As a consequence, this study examined assessment on those aspects according to the relevant outlines of the IPCC AR4 document as describe in the **Table 3** below.

Table 3 Relationship between Aspects to be Studied and Outline of the IPCC AR4

Aspects to be Studied	Relevant Outline of the IPCC AR4
1. Science basis	All components of the outline of IPCC AR4: Physical Science Basis
2. Food production systems and food security	5. Food, Fibre, and Forest Products
3. Human health	8. Human Health
4. Human settlement systems	7. Industry, Settlement, and Society
5. Water resources and systems	3. Freshwater Resources and Their Management
6. Coastal areas, oceans, and small islands	6. Coastal Systems and Low-lying Areas; 4. Ecosystems, Their Properties, Goods, and Services; 16. Small Islands

2.4 Identified and Reviewed Documents

This study has identified several documents to be assessed as main documents as they comprise comprehensive adaptation issues in almost all aspects that are assessed in this study.

Table 4 List of Documents Assessed

Documents Assessed	Type of Information	Aspects that Relevant to This Document
CC-F	Policy and strategy at sectoral level	Food Production Systems and Food Security
CCPI	Science basis	Science Basis
CSI	Policy and strategy at sectoral level	Coastal Areas, Oceans, and Small Islands
CBA	Policy and strategy at sectoral level	Water Resources and Systems
ICCSR	Policy and strategy at national level	All aspects
ICR	Policy and strategy at sectoral level	Water Resources and Systems; Coastal Areas, Oceans, and Small Islands; Human Health
Jakstra	Policy and strategy at sectoral level	Water Resources and Systems; Human Settlement Systems; Food Production Systems and Food Security
PIT-PI	Policy and strategy at sectoral level	Human Health
PNAS	Science basis	Science Basis
RAN-MAPI	Policy and strategy at sectoral level	Water Resources and Systems
RAN-PI	Policy and strategy at sectoral level	Water Resources and Systems; Coastal Areas, Oceans, and Small Islands

Documents Assessed	Type of Information	Aspects that Relevant to This Document
SLRJ	Science basis	Science Basis; Coastal Areas, Oceans, and Small Islands
SNC	Country report in policy and strategy	All aspects
STI-CC	Science basis	Science Basis
STRAPI	Policy and strategy at sectoral level	Human Health
VA Lombok	Case study with comprehensive scientific assessment	All aspects except Human Health

2.5 Summary of Work Scheme

A summary of work scheme is developed which consists of key activities, methods of study, and primary outcomes as follows:

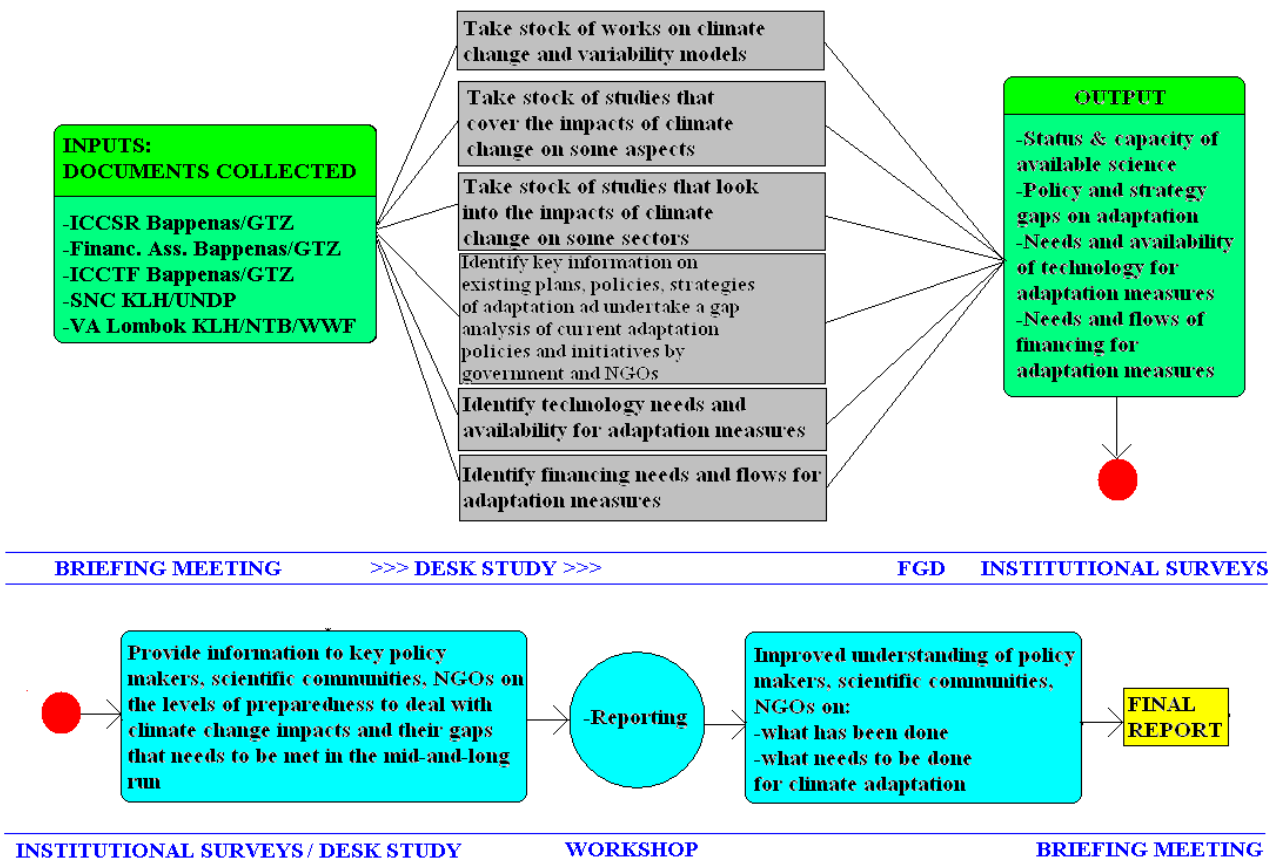

Figure 1 Work Scheme

3. REVIEW ON STUDIES OF SCIENCE BASIS OF CLIMATE CHANGE

3.1 Observations: Atmosphere and Surface

Atmosphere and Surface Observations that becomes a major subject in the recent issues of climate change is included in Chapter 2 of the IPCC AR5 of WG (Working Group) I report. However, this report is still in the form of outline, therefore the indicators applied in this study are derived from Chapter 3 of the IPCC AR4 Working Group I with the title of Observations: Atmospheric Surface and Climate Change.

That chapter describes seven themes to be considered as categories of indicators used in this study (see **Table 5**) below. From these themes, about 25 indicators are then derived; they are not only some common climatology parameters such as land, air, and ocean temperatures, but also the parameters related to climate change like El Niño-Southern Oscillation (ENSO) and tropical/extra-tropical interactions, teleconnections, and other oscillations and modes (e.g., Indian Ocean Dipole mode or IOD) (see also Table in *Annexes*).

Table 5 Themes and indicators of Observations: Atmosphere and Surface

No.	Theme	No.	Indicator
1	Changes in surface climate: temperature	1.	Land temperature
		2.	Air temperature
		3.	Ocean temperature
2	Changes in surface climate: precipitation, drought, and surface hydrology	4.	Precipitation
		5.	Evapotranspiration
		6.	Changes in soil moisture, drought, runoff, and river discharge
3	Changes in the free atmosphere	7.	Temperature of the upper air: troposphere and stratosphere
		8.	Water vapor
		9.	Clouds
		10.	Radiation
4	Changes in atmospheric circulation	11.	Surface or sea level pressure
		12.	Geopotential height, winds, and the jet stream
		13.	Storm tracks
		14.	Blocking
		15.	The stratosphere
		16.	Winds, waves, and surface fluxes
5	Patterns of atmospheric circulation variability	17.	Teleconnections
		18.	El Niño-Southern Oscillation and tropical/extratropical interactions
		19.	Pacific decadal variability
		20.	Other oscillations and modes
6	Changes in the tropics, sub-tropics, and in monsoons	21.	Changes in the tropics
		22.	Changes in the monsoons
7	Changes in extreme events	23.	Evidence for changes in variability or extremes
		24.	Evidence for changes in tropical storms
		25.	Evidence for changes in extratropical storms and extreme event

Among these different indicators, the ICCSR-SB (Science Basis-1/SB-1: *Analysis and Projection of Climate Change in Indonesia* written by Dr. Tri Wahyu Hadi) has studied eight of them, i.e.: air and ocean temperatures, precipitation, changes in the monsoons, changes in drought, winds and waves due to atmospheric circulation, ENSO, and IOD. However, among them only four indicators are rated as complete.

3.2 Observations: Ocean

The subject of Ocean Observation will be included in Chapter 3 of the IPCC AR5 Working Group I. This chapter will be consisting of all ocean parameters. The part of ocean parameters such as sea surface temperature (SST), surface heat flux, and ocean current changes are described in Chapter 5 of the IPCC AR4 Working Group I, namely Observations: Ocean Climate Change and Sea Level. Furthermore, the other ocean parameters related to climate change are discussed in Chapter 5, such as ocean circulation and salinity changes, ocean acidification, oxygen concentration change, dissolved inorganic carbon, and air-sea carbon dioxide flux (see **Table 6** and *Annexes*).

Table 6 Themes and Indicators of Observations: Ocean

No.	Theme	No.	Indicator
1	Changes in global-scale temperature and salinity	1.	Sea surface temperature (SST)
		2.	Surface heat flux
		3.	Salinity
2	Regional changes in ocean circulation and water masses	4.	Ocean surface current
		5.	Ocean circulation
		6.	Extreme events
3	Changes in ocean biochemical	7.	Ocean acidification
		8.	Oxygen concentration
		9.	Nutrient
		10.	Dissolved inorganic carbon

On the other hand, the national level of ICCSR-SB report (Science Basis-2/SB-2: *Analysis and Projection of Sea Level Rise and Extreme Climate* by Dr. Ibnu Sofian) contains the analysis of surface current and chlorophyll-a characteristics, extreme event, and SST changes in Chapter 2 and 5. However, due to the short period of observational data, the analysis of the climate change impacts on these ocean parameters in the ICCSR-SB report is rated as incomplete, except the SST that using the National Oceanic and Atmospheric Administration Optimum Interpolation (NOAA OI) data from 1983. Furthermore, the effect of climate change on the surface current and Indonesian Through Flow (ITF) transport are also missing. The salinity changes and other biogeochemical parameters characteristics are not mentioned in the ICCSR-SB report.

Finally, global and regional ocean model such as the HYCOM (Hybrid Coordinate Ocean Model) and Regional Ocean Modeling Systems (ROMS) are used to investigate the effect of climate change on the salinity, SST, air-sea flux, and carbon fluxes. The example of climate change impacts on the ITF is described in the **Box 1**.

Box 1 The Effect of Climate Change on the Indonesian Through Flow (ITF)

The effect of climate change on the southward water transport of the Makassar Strait as the main gateway of ITF can be seen in **Figure 2**. The water transport is calculated based on the HYCOM model output using the NCEP (National Centres for Environmental Prediction) reanalysis data as the forcing parameter. The NCEP climatology contains air temperature, specific humidity, net and shortwave radiations, wind stresses and speed.

The Indonesian Seas Model Domain (ISMD) spans from 90°E to 150°E and from 15°S to 15°N, with the spatial resolution of 15 km (**Figure 3**). The ISMD model is nested on the Near Global Model (NGD) domain which is using the same forcing data with the ISMD model. The NGD model ranges from 0°E to 300°E and from 60°S to 60°N with grid spacing of 75 km (**Figure 4**). The model output is validated using the altimeter data as shown in **Figure 3** (for the NGD the figure is not shown). The model results as shown in **Figure 2**, indicate that the transport of ITF increases about 2 S_v ($S_{verdrup}$, 1 S_v = 1 million m^3 sec^{-1}). The increasing of ITF may be caused by the differences of SLR (Sea Level Rise) between the Pacific and Indian Oceans, in which SLR in Pacific Ocean approximately 2-3 mm yr^{-1} higher than the one in the Indian Ocean (ICCSR-SB, 2010).

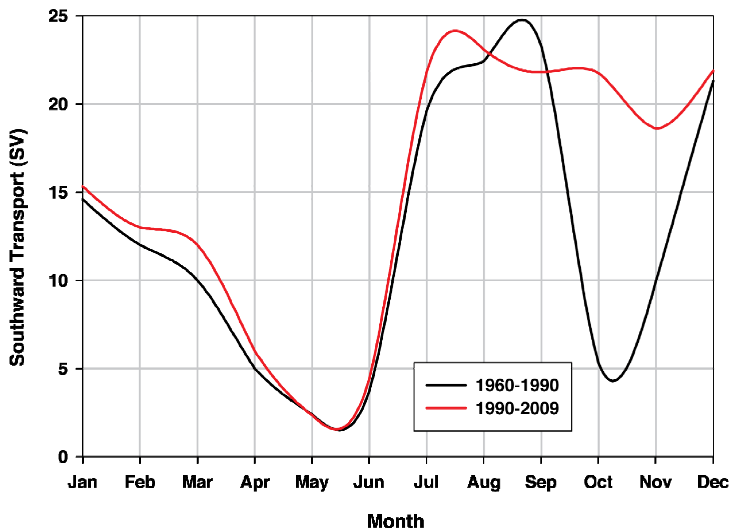

Figure 2 Climatology of Southward Makassar Strait Transport for 1960-1990 and 1990-2009

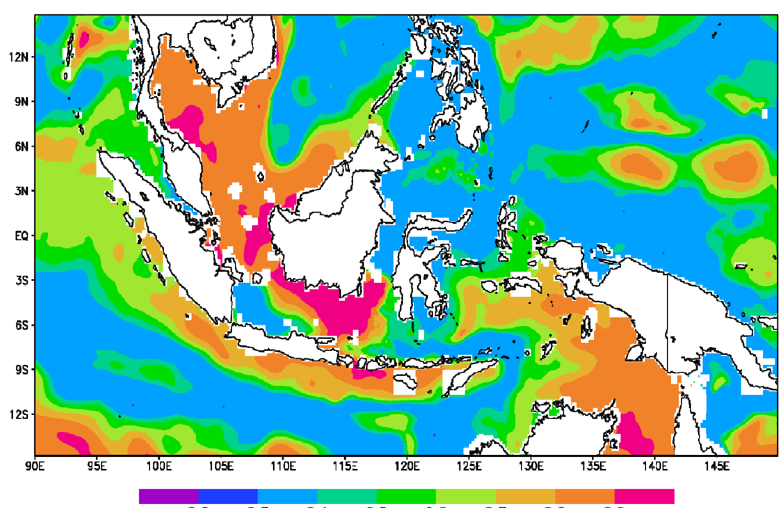

Figure 3 The Spatial Distribution of Determination Coefficient (R^2) between Modeled-sea Level (1990-2009) and Altimeter (analysis made for this study by Dr. Ibnu Sofian)

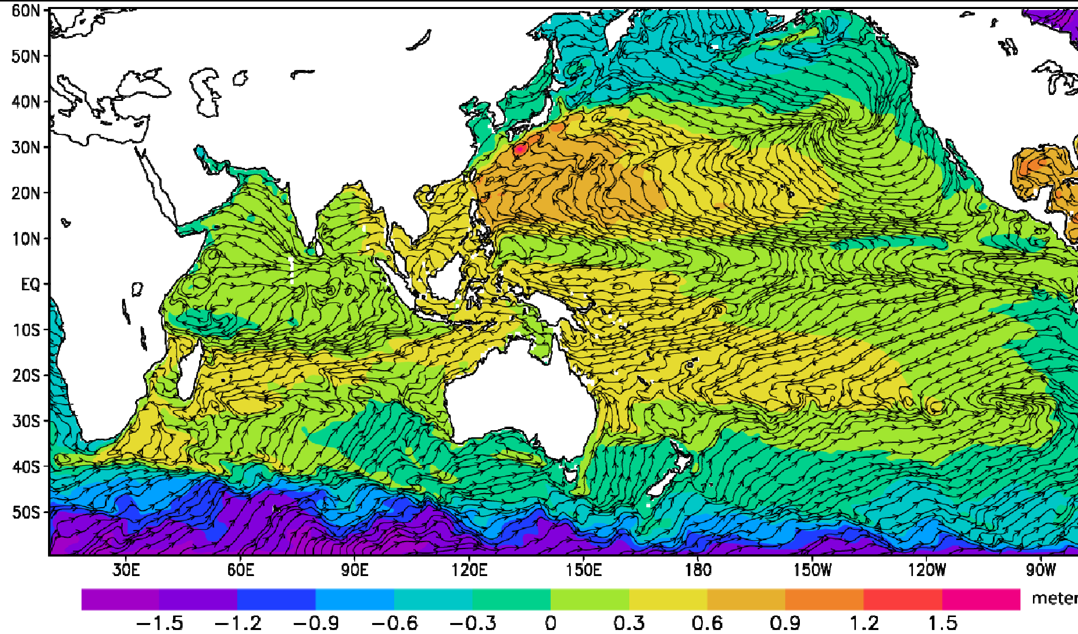

Figure 4 The Spatial Distribution of Sea Surface Height Superimposed with the Surface Current Direction

3.3. Observations: Cryosphere

The subject of Cryosphere is included in the Chapter 4 of IPCC AR4 with the title of Changes in Snow and Frozen Ground. Cryosphere consists of snow cover, river and lake ice, sea ice, glaciers and ice caps, ice shelves and ice sheets, and frozen ground. The cryosphere is intricately linked to the surface energy budget, the water cycle, sea level change and the surface gas exchange. Recent decreases in ice mass are correlated with rising surface air temperatures. This is especially true for the region north of 65°N, where temperatures have increased by about twice the global average on that region from 1965 to 2005.

Furthermore, the IPCC AR4 also reported that the total cryospheric contribution to sea level change ranged from 0.2 to 1.2 mm yr^{-1} between 1961 and 2003, and from 0.8 to 1.6 mm yr^{-1} between 1993 and 2003. The rate increased over the 1993 to 2003 period primarily due to increasing losses from mountain glaciers and ice caps, from increasing surface melt on the Greenland Ice Sheet and from faster flow of parts of the Greenland and Antarctic Ice Sheets. Estimates of changes in the ice sheets are highly uncertain, and no best estimates are given for their mass losses or gains. However, strictly for the purpose of considering the possible contributions to the sea level budget, a total cryospheric contribution of 1.2 ± 0.4 mm yr^{-1} SLE (Sea Level Equivalent). Due to the thermosteric process, ice melting and ice lost, the sea level rise (SLR) in 2100 will reach 20-80 cm relative to the sea level in 2000.

On the other hand, the ICCSR-SB document in Sub-chapter 4.2.2 also stated the cryospheric contribution to the sea level changes based on the USGS (United States of Geological Surveys) report that was published in 2009. USGS (2009) reported that the ice lost in Greenland and Antarctica is higher than previous estimation. The contribution of ice lost and melting in these regions to the global sea level rise possibly reach to 2 mm yr^{-1} during the last few years. Eventually, based on this report, the global SLR in 2100 will reach up to 150 cm.

Moreover, in the ICCSR-SB document, the estimation of SLR post-IPCC AR4 also was investigated by using the sea surface height from the model (MRI model from IPCC AR4) and the global sea level rise from USGS-estimated SLR. The average SLR over the Indonesian Seas will reach up to 175 cm in 2100.

Nevertheless, the ICCSR-SB document had not analyzed the ice cap changes in the Jayawijaya Mountains, Papua. Recently, it is indisputable to investigate the changes as one of proxies of global climate change hazard and impact in Indonesia. According to the research expedition of BMKG, Columbia University, and Ohio University of USA in May 2010, the ice cap in this mountain have decreased until 78 percents in the period of 1936 – 2006 (source: e.g., http://www.antaranews.com/berita/1274195588/lapisan-es-puncak-jaya-tinggal-22-persen).

3.4. Information from Paleoclimate Archives

The information of Paleoclimate Archives is reported in the IPCC AR4 of WG I in Chapter 6 as well as outlined in the IPCC AR5 of WG I report in Chapter 5, under the title of Paleoclimate. There are seven indicators that can be generated from the science basis component, i.e: CO_2 concentration, air temperature, sea surface temperature (SST), ice-snow cover, solar radiative forcing, sea level change, and abrupt climate change.

These chapters describe the main conclusions as follows:

1. The concentrations of CO_2 (379 ppm) and CH_4 (1,774 ppb) in atmosphere are supposed to exceed by far the natural range of the last 650 kyr (kilo year before present). Moreover, the ice core data shows that CO_2 varied within a range of 180 to 300 ppm (part per million) and CH_4 within 320 to 790 ppb (part per billion) over this period. Over the same period, Antarctic temperature and CO_2 concentrations co-vary, indicating a close relationship between climate and the carbon cycle
2. For the Last Glacial Maximum, proxy records for the ocean indicate cooling of tropical sea surface temperatures (average likely between 2°C and 3°C) and much greater cooling and expanded sea ice over the high latitude oceans. Climate models are able to simulate the magnitude of these latitudinal ocean changes in response to the estimated Earth orbital, greenhouse gas and land surface changes for this period, and thus indicate that they adequately represent many of the major processes that determine this past climate state
3. During the last glacial period, abrupt regional warming (likely up to 16°C within decades over Greenland) and cooling occurred repeatedly over the North Atlantic region. They *likely* had global linkages, such as with major shifts in tropical rainfall patterns. It is *unlikely* that these events were associated with large changes in global mean surface temperature, but instead likely involved a redistribution of heat within the climate system associated with changes in the Atlantic Ocean circulation

On the other hand, the ICCSR-SB report also stated about the paleoclimate archive about sea surface temperature from 150 kyr based on the recent research results from Hansen (2006). The paleoclimate archives are stated in Chapter 4. The time-series of SST based on the paleoclimate data are presented in Figure 4-1, thereafter. However, the ICCSR-SB report did not explain the analysis of paleoclimate data about the concentration of green house gasses (GHGs) and sea level rise.

3.5. Carbon and Other Biogeochemical Cycles

The subject of Carbon and Other Biogeochemical Cycles is explained in the IPCC AR4 WG I, mostly in Chapter 7 (Coupling between Changes in the Climate and Biogeochemistry), but also in Chapter 2 (Changes in Atmospheric Constituents and Radiative Forcing). In principle the main subject in this chapter is about carbon cycle that contains terrestrial and ocean carbon fluxes, and its relationship with the climate. Themes and indicators derived from this subject are described in **Table 7**.

Table 7 Themes and Indicators of Carbon and Other Biogeochemical Cycles

No.	Theme	No.	Indicator
1	Carbon cycle	1.	Terrestrial carbon flux
		2.	Ocean carbon flux
2	Chemically and Radiatively Important Gases	3.	Atmospheric Carbon Dioxide
		4.	Atmospheric Methane
		5.	Ozone
		6.	Stratospheric Water Vapor
3	Reactive Gases and the Climate System	7.	Methane
		8.	Nitrogen Compound
		9.	Molecular Hydrogen
		10.	Global Tropospheric Ozone
		11.	Hydroxyl Radical
		12.	Stratospheric Ozone

However, the subject about carbon cycle and other biogeochemical cycles are not discussed in any documents in national level including the ICCSR-SB document. Nevertheless, this report also provides a preliminary result of a recent investigation is described in **Box 2**.

Box 2 Estimation of Terrestrial Carbon Flux in Java Island

The CASA (Carnegie Ames Stanford Approach) model is the easiest method to estimate the terrestrial carbon flux by using the satellite remotely sensed data such as the MODIS or other high resolution of the satellite-derived data. The Net Primary Production (NPP) is calculated based on the Enhanced Vegetation Index (EVI), fraction of Photosynthetically Active Radiance (fPAR), solar radiation, water deficit, and temperature stress. **Figure 5** shows the NPP for 2001. The NPP is ranging from 0 to 1600 g C/yr. The lowest NPP (near to 0 g C/yr) occurred at the Jakarta and Surabaya. Moreover, the NPP over the northern coast of the Java Island also shows the low NPP about 0 to 600 g C/yr except at the Alas Roban that reached to 1400 g C/yr.

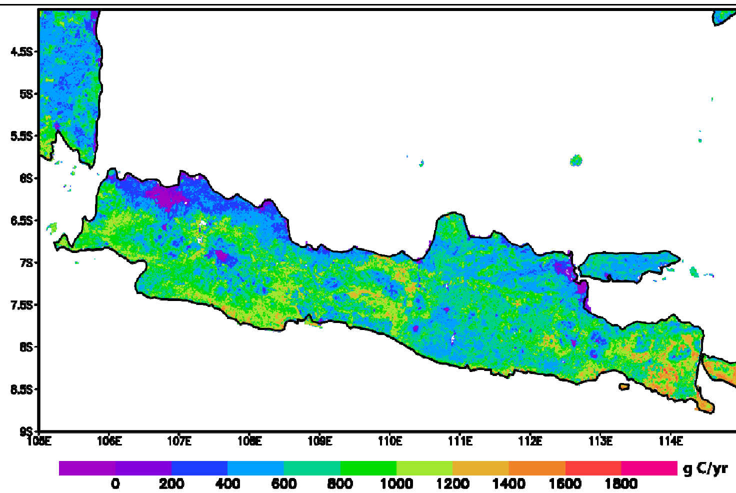

Figure 5 The spatial distribution of Net Primary Production (NPP) based on CASA model in 2001. The NPP is ranging from 0 to 1800 g C/yr

On the other hand, the terrestrial carbon sink/flux can be calculated from the NPP relatives to the total respiration. Based on the previous research results, the total respiration at the tropical forest varies from 839 to 900 g C/yr, with the average of 850 g C/yr. Therefore, the total terrestrial carbon flux at the Java Island is ranging from -850 to 700 g C/yr as shown in **Figure 6**.

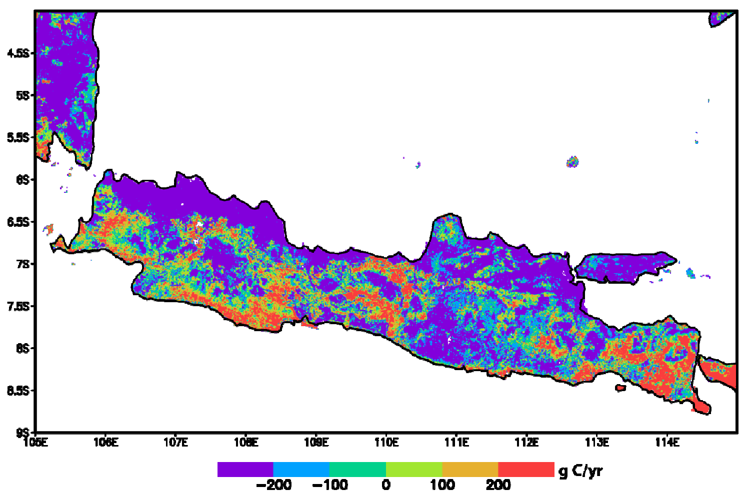

Figure 6 The spatial distribution of CASA model-estimated total carbon flux in 2001, with the negative and positive fluxes indicate carbon source and sink, respectively

3.6. Clouds and Aerosols as well as Anthropogenic and Natural Radiative Forcing

These components of the IPCC AR5 WG1 report, actually, become the areas that have not been investigated in Indonesia yet as there is no document or paper that publish on these themes. However, this report provides the themes and indicators to be guidelines for researches in the future, as described in **Table 8** and **Table 9** below.

Table 8 Themes and Indicators of Clouds and Aerosols

No.	Theme	No.	Indicator
1		1.	Developments related to Aerosol Observations
		2.	Modeling the Aerosol Direct Effect
		3.	Estimates of Aerosol Direct Radiative Forcing
		4.	Aerosol Influence on Clouds
2		5.	Aerosol emission and burdens affected by climatic factors
		6.	Indirect effects of Aerosol on Clouds and Precipitation
		7.	Effects of Aerosol and Clouds on Solar Radiation at the Earth's Surface
		8.	Effects of Aerosols on Circulation Patterns

Table 9 Themes and Indicators of Anthropogenic and Natural Radiative Forcing

No.	Theme	No.	Indicator
1	Anthropogenic changes in surface albedo and the surface energy budget	1.	Radiative forcing by anthropogenic surface albedo change: land use
		2.	Radiative forcing by anthropogenic surface albedo change: black carbon in snow and ice
		3.	Other Effects of Anthropogenic Changes in Land Cover
		4.	Tropospheric water vapor from anthropogenic sources
		5.	Anthropogenic heat release
		6.	Effects of carbon dioxide changes on climate via plant physiology: 'physiological forcing'
2	Natural forcing	7.	Solar variability
		8.	Explosive volcanic activity

3.7. Evaluation of Climate Models

The subject of evaluation of climate model is described in Chapter 8 of IPCC AR4 (WG I) report with the same title. Based on the evaluation results, almost all of the Atmospheric and Oceanic General Circulation Models (AOGCM) can simulate the climate, multi decadal, decadal, and monsoonal variability. The modern coded of AOGCM can also simulate the Madden Julian Oscillation (MJO), extreme weather, and elaborate with the ice-snow melting. However, the models cannot simulate asymmetry time intervals between La Nina and El Nino. Moreover, the modeled-MJO still show infrequent and week MJO comparing with the observational data. Finally, the models unable simulate effect of volcano eruption and Meridional Overtuning Current on short and long terms abrupt climate changes, respectively.

The evaluation of the AOGCM is still incomplete in the ICCSR-SB document. However, the AOGCM was also used for modeling of monsoon variability in that report. In addition, the Hybrid Coordinate Ocean Model (HYCOM) was implemented in this document to simulate the ocean surface current over the Indonesian seas, in which is explained in Chapter 2 of ICCSR-SB report. The model validation was conducted by using the altimeter and tide gauges against the model-estimated sea level in Chapter 3 and 4. The analysis of extreme wave and projection of ENSO was conducted by using the altimeter significant wave height and model-estimated $NINO_3$ SST, respectively. Eventually, the analysis of climate change impacts on the surface current, heat balance, and water transport are missing in the ICCSR-SB report.

3.8. Detection and Attribution of Climate Change: from Global to Regional

The subject of Attribution of Climate Change: from Global to Regional is stated in Chapter 9 of IPCC AR4 (WG I) report with the title of Understanding and Attributing Climate Change. This chapter is the summary of Chapter 3 to Chapter 6 of that report. This chapter explains the recent climate change based on the paleoclimate, observational, and hindcast model output.

The ICCSR-SB document did not provide the description of this component; it only explained about the recent sea level rise, SST changes both from paleoclimate and recent observational data, and climate variability (ENSO) in Chapter 4 and 5. Nevertheless, the changes of radiative forcing and human-induced global warming are not discussed in the ICCSR-SB report.

3.9. Near-term Climate Change: Projections and Predictability

The near-term projection of climate and ocean climate are included in the Chapter 10 and 11 of IPCC AR4 (WG I) with the title of Global Climate Projections and Regional Climate Projections, respectively. The IPCC AR4 reported that the models are forced with concentrations of greenhouse gases and other constituents derived from various emissions scenarios ranging from scenarios without mitigation to idealized long-term scenarios. Mainly, the model is used to assess the temperature, precipitation, climate variability, sea level, ice cover, atmospheric, and ocean circulation changes.

The sea level and temperature, ENSO time interval changes, and dynamic ice melting both in Antarctica and Greenland are discussed in the ICCSR-SB report in the Chapter 4 and 5. The results based on the trend analysis on the observational data, indicate that sea level and SST rise over the Indonesian Seas are 0.02°C yr^{-1} and 6 mm yr^{-1}, respectively. Nevertheless, the models that were used for the projections are only limited to MRI, NASA GISS, Miroc, CCCSMA.

3.10. Long-term Climate Change: Projections, Commitments, and Irreversibility

The long-term projection of rainfall, air and sea surface temperatures, and sea level rise are discussed in Chapter 4 of ICCSR-SB1 and Chapter 5 of ICCSR-SB-2 respectively. The projection of rainfall pattern over the Indonesian region is using the ensemble methods from several IPCC model outputs. The sea level projections used the blended method from the several global sea level rises as the basis and the monthly ocean topography for the regional sea level rise trend.

The projections of interannual variations of ENSO are conducted by using the SST characteristics in the $NINO_3$ region from the MRI model output. The projection of ENSO is described on the ICCSR-SB2 Chapter 5. The ENSO projections are based on the SRES A1B, A1, and B2 scenarios. However, the timetable of ENSO is only based on the SRES A1B scenario.

3.11. Sea Level Change

The sea level change is presented in Sub-chapter 5.5 and Chapter 10 of the IPCC AR4 document. Estimation of sea-level rise was conducted by using altimeter, tide gauges, and calculation based on thermosteric process on the ocean temperature and salinity from the depth of 700 m until the surface (Sub-chapter 5). While Chapter 10 explained the sea level rise based on the model projections.

The oceans are warming. Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m. It is consistent with the Third Assessment Report (TAR), where the global ocean heat content (0–3,000 m) has increased during the same period, equivalent to absorbing energy at a rate of 0.21 ± 0.04 Wm^{-2} globally averaged over the Earth's surface. Two-thirds of this energy is absorbed between the surface and a depth of 700 m. Global ocean heat content observations show considerable interannual and inter-decadal variability superimposed on the longer-term trend. Relative to 1961 to 2003, the period 1993 to 2003 has high rates of warming but since 2003 there has been some cooling. The sea level rise rate based on the recent observational data shows that sea level rises is 3.1 ± 0.7 mm yr^{-1}. The model-estimated sea level rise ranges from 20 cm to 80 cm in 2100.

The ICCSR-SB document presents the sea level rise based on the altimeter, tide gauges and model-estimated sea level. However, the contribution of thermosteric process on the SLR is not discussed in the ICCSR-SB document. The ICCSR-SB presents the sea level rise over the Indonesian seas is higher than global sea level rise. The sea level rise over the Indonesian Seas is reaching up to 8 mm yr^{-1}, while the global SLR is only 3.1 ± 0.7 mm yr^{-1}. Finally, the newest sea level rise estimation based on the dynamic ice melting is stated in ICCSR-SB report by using blended global sea level rise from USGS (2009) and Meteorological Research Institute (MRI) model output.

Nevertheless, there is no document in Indonesia which reported the investigations on the indicators of ocean density changes, regional variations in the rate of sea level change, and ocean mass changes.

4. REVIEW ON STUDIES OF CLIMATE CHANGE HAZARDS, VULNERABILITIES, AND IMPACTS

4.1 Introduction

At present, various studies of hazards, vulnerabilities and impacts of climate changes have been conducted in Indonesia. This chapter describes reviews on these studies with indicators derived from the contents and scope of the IPCC AR4 report, while structure of the reviews follows the outline of the IPCC AR5 document. Five aspects will be presented into the next five sub-chapters below, i.e.:

1. Food production systems and food security
2. Human health
3. Human settlement systems
4. Water resources and systems
5. Coastal areas, oceans and small islands

In each aspect, a gap analysis method is implemented in a table or matrix form to review the relevant documents in national level according to those indicators. Key information picking from the IPCC AR4 document is then described in the gap analysis matrix as components and themes. A series of indicators are deducted from the report in accordance to the themes. These indicators, therefore, become approaches to measure the review of the relevant national level documents according to the IPCC AR4 as a benchmark.

In principle, the main objective of this method is to investigate about what has been done and what should be conducted toward climate change in Indonesia for the future in terms of hazard, vulnerability, and risk/impact components (see Section 2.4).

4.2 Food Production Systems and Food Security

These subjects of climate change hazard and impact in the food production systems and food security are included in the Chapter 5 of the IPCC AR4 report with a title of "Food, Fibre, and Forest Products". The main concern of the report is the impact of climate change on food production systems and food security, which become the new title of the chapter in the upcoming IPCC AR5 report.

The IPCC AR4 identifies four dimensions of climate change impacts on food security. They are:

a. Food availability (production and trade) that could be mixed and vary regionally
b. Stability of food supplies which depends on changes in the pattern of extreme events
c. Access to food, which also depends on changes in the pattern of extreme events
d. Food utilization, particularly through health consequences

In that report the food security encompasses agriculture, forestry and fisheries sectors, not only agriculture.

Themes and indicators are then derived according to concepts above that are described in the IPCC AR4 report (see **Table 10** below).

Table 10 Themes and indicators of the stimuli, vulnerability, and risk/impact of food production systems and food security aspect

Component	Theme	Indicator
Stimuli	Basic climate	Increases in mean temperature
	Extreme events	Frequency of extreme events (heat stress, drought, flood)
		Severity of extreme events (heat stress, drought, flood)
Vulnerability	Vulnerability analysis	Crop yields in different latitude
Risk/impact	Risk analysis	Livestock production
		Forest production
	Multiple stressor	Water resources availability, biodiversity loss, air pollution
		Overexploitation of stocks, biodiversity loss, water pollution, and changes in water resources
		Sea level rise
	Projection	Projection of food production based on temperature increase
		Projection of rice production loss due to **sea level rise**
		Projection undernourished population
		Projection of forest production based on latitude
		Projection of food and forestry trade
		Projection of food real prices
		Crop response to elevated CO2 with FACE model
	Impact analysis	Agricultural labor supply
		Poor community

There are three documents that are reviewed and compared to the AR4 as the benchmark of this study. Those documents are: ICCSR-AS, Jakstra, and CC-F.

Stimuli

There are two themes covered in this section, i.e. basic climate and extreme events. The main indicator for basic climate stimuli on food production is the increase in mean temperature. Generally, global findings suggest that the increase of 1-3^{o}C in mid- to hi-latitude regions increases yield, while the increase of 1-2^{o}C in low-latitude regions decreases yield. As for the extreme events theme, there are two indicators: frequency and severity of extreme events such as drought, flood and heat stress.

If we compare those indicators with the one used in the ICCSR-AS study, we find that this document has identified the effect of change in rainfall pattern and ENSO-related extreme events on crop yields; however it is not based on different latitude. Moreover, the ICCSR-AS has not taken into account the risk of climate change on livestock and forest production, it focuses only on staple food (rice and corn) production.

Vulnerability

Indicators used in the IPCC AR4 to provide data and information for the vulnerability analysis are as follows: increases in mean temperature; crop yields in different latitude; frequency of extreme events (heat stress, drought, flood); severity of extreme events (heat stress, drought, flood); livestock production; forest production; water resources availability, biodiversity loss, air pollution; and overexploitation of stocks, biodiversity loss, water pollution, and changes in water resources.

If we look how those indicators are used in the ICCSR-AS, with regard to the indicator of water resources availability, biodiversity loss and air pollution, that according to the IPCC AR4 increases the sensitivity to climate change and reduce resilience in agricultural sector, the ICCSR-AS has only included the water resources availability in its analysis. Similarly, for the indicator of overexploitation of stocks, biodiversity loss, water pollution, and changes in water resources, which according to the IPCC AR4 increases the sensitivity to climate change in fisheries sector, the ICCSR-AS has only included water resources changes in its analysis. Thus, the analysis in ICCSR-AS is incomplete. However, the analysis in ICCSR-AS has included the effect of sea level rise on rice fields, which has been overlooked by the IPCC AR4. The sea level rise may inundate coastal areas, where some rice farming areas are located.

Another report that is reviewed in this study is the Jakstra by Ministry of Public Works (2008). In its vulnerability analysis this report doesn't employ all indicators used in the IPCC AR4. The focus of analysis in the report, which covers provinces of Nanggroe Aceh Darussalam, DKI Jakarta, Nusa Tenggara Barat, Kalimantan Timur, Sulawesi Selatan, and Maluku, is mainly on rice cultivation, since rice is the main staple food of Indonesia. To measure the exposure of rice field to climate change impact, the report uses elevation data, size and slope of the rice field, as well as rice production and productivity, and population and rice consumption per capita. From those data food balance in each province is generated.

In the meantime, in order to measure the susceptibility of each province, three indicators used in the report are: water balance (consists of water availability for irrigation, length of irrigation, condition of irrigation, and size of irrigated rice field); crop failure due to drought or flood; and crop loss due to land conversion. In the IPCC AR4 water resources availability is one the multiple stressors on food production. The indicator of crop failure used in Jakstra corresponds to impact of severe extreme event such as drought and flood on crop production as discussed in AR4. In addition, the Jakstra contributes an additional indicator in its analysis, i.e. crop loss due to land conversion, which has not been considered in the IPCC AR4.

The third report assessed in this study is CC-F by SEAMEO BIOTROP. The study is part of a project between Ministry of Trade and *Kemitraan* (Partnerships for Governance Reform) and is aimed at formulating climate change adaptation strategy for Indonesia's strategic food commodities. This study has used most of indicators used in the IPCC AR4, except for several points. In the vulnerability analysis, the risk of crop yield does not consider different latitude and livestock and forest production are not included in the analysis.

<u>Risk/Impact</u>

There are a number of projections that the IPCC AR4 has discussed in order to measure the impact of climate change on food production systems. Those are:

- Projection of food production based on temperature increase
- Projection of undernourished population
- Projection of forest production based on latitude
- Projection of food and forestry trade
- Projection of food real prices
- Crop response to elevated CO_2 with FACE model

Based on the review of the ICCSR-AS, only few of those projections that have been done in the ICCSR-AS, and that also in partial manner. For example, projection of corn production due to temperature increase and projection of rice production have been done, however they are focusing only on Java. In addition, projection of rice production loss due to sea level rise has also been conducted, as well as projection of rice crop production using SRES scenario. However, the other projections have not been conducted. Then if we look at the impact analysis on agricultural labor supply and the poor community that are discussed in the IPCC AR4, none of these analysis were done in the ICCSR-AS.

While in the Jakstra none of the projections in the IPCC AR4 were done, in CC-F, projection of food production based on temperature increase has been conducted, in particular the projection of several food production losses in 2050 due to early maturity and respiration rate as impacts of temperature increase by major islands. Another projection that has been done is the rice production loss due to sea level rise, something that has been overlooked by AR4. However, what has been done in CC-F is only the projection of potential loss of rice fields in Java and three provinces outside Java.

However, several projections mentioned in the IPCC AR4 have not been done in that study, namely: projection of undernourished population, projection of forest production and crop response to elevate CO_2. And with regard to food and forest trade and food prices, the CC-F has a discussion on food trade as well as projection of food price index in the world market. Lastly, for the impact analysis that study has not measured the impact on agricultural labor supply although there is a discussion of survey results with farmers as respondents, as well as the impact on the poor community.

4.3 Human Health

The subject of climate change impacts on human health is exclusively described in the chapter 8 of Impact, Adaptation and Vulnerability sections of the IPCC AR4 (2007). The chapter stated that human health is directly exposed to the climate change through the changes in weather pattern, such as temperature, precipitation, sea-level rise and extreme climate; and indirectly influenced by changes in water, air, food quality and quantity and changes in the ecosystems, agriculture, industry and settlements and the socio-economy. As shown in **Figure 7**, the health impacts from direct and indirect exposures of climate change can also be modified through changes in environmental, social and economic, and health system conditions.

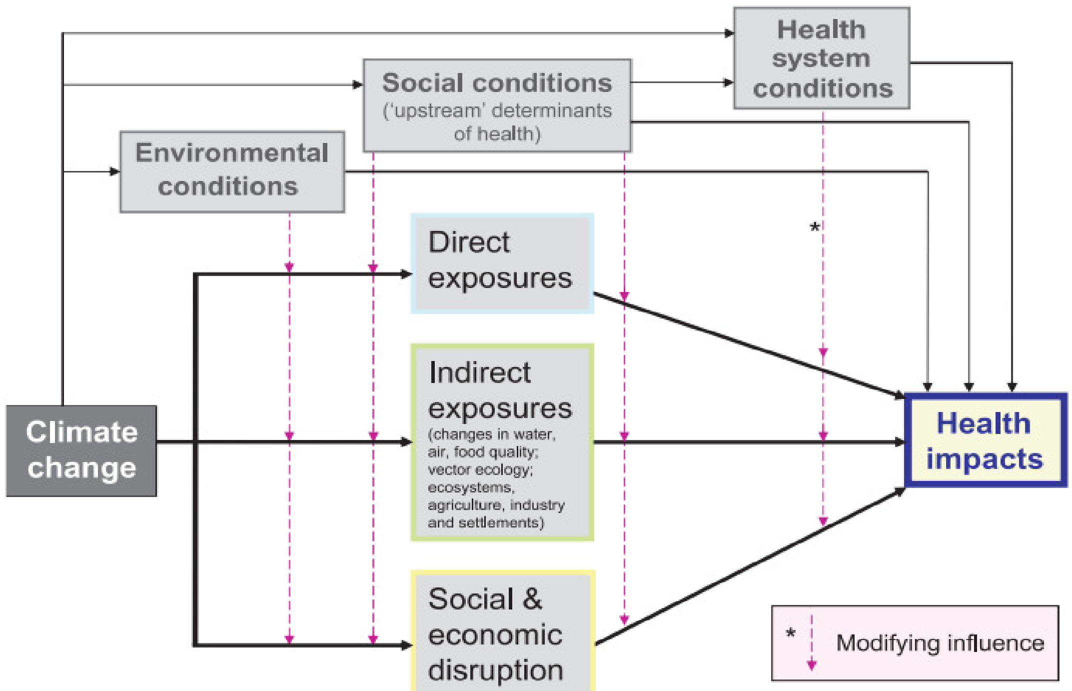

Figure 7 Pathways by which climate change affect human health (IPCC AR4, 2007)

Based on the IPCC AR4 report, there are some evidences of climate change effects on human health, including:

1. alteration of the distribution of some infectious disease vectors
2. alteration of the seasonal distribution of some allergenic pollen species
3. increased heat-wave related death

Furthermore, it is also mentioned the future trend impact of climate-change-related-exposures to human health on the IPCC AR4 report, which consists of:

1. increasing case of malnutrition
2. people suffering from death, disease, and injury from climate or weather-related extreme events, such as heat waves, floods, storms, fires and droughts
3. changing range of some infectious disease vectors
4. mixed effects on malaria
5. increasing the burden of diarrheal diseases
6. increasing cardio-respiratory morbidity and mortality associated with ground-level ozone
7. increasing the number of people at risk of dengue
8. benefits to human health

In the determination of vulnerability of population health, it is important to identify the vulnerability factors that can modify the effects of climate change on human health. In addition, the population health itself is an important element of adaptive capacity. Where there are a heavy burden of disease and disability, the effects of climate change are likely to be more severe than otherwise. The total number of population at risk, the age structure of the population and the density of settlement are important variables in determining human health vulnerability to climate change.

Other factors, such as the socio-economic and local environmental conditions may also influence the effects of climate change on human health. Meanwhile, the availability of health infrastructures and services is important in order to reduce the impacts. Poorer population tends to be more vulnerable, as it will limit the ability of population to obtain proper health care and protection to climate change impacts.

Adaptation to climate change in the health sector requires a variety of approaches, ranging from international, national and regional levels, and also individual adaptation to the health system. It is also important to assign the adaptation measures to be impact-specific in order to prevent the possibility of the mal-adaptation implementation.

Adaptation measures in the health sector can also relate to the adaptation of other sectors or vice versa, for example, measures to integrate adaptation to the water-borne disease could involve the country efforts to combat water scarcity; others such as a national energy conservation programs and transportation policy could include measures to reduce urban heat and emission of ozone and other air pollutants.

The identification of the factors that limit the implementation of adaptation measures is one of the most important elements in order to apply proper adaptation. Whilst, the implementation of strategies, policies and adaptation measures to address climate change impacts may have the implication (potential risk) that need to be identified to evaluate the adaptation results.

Current Assessment of Climate Change Impacts on Human Health in Indonesia

Efforts to identify the climate change impacts on human health in Indonesia have been done in several reports. In the human health chapter, this study has identified five related reports, including ICCSR-HS, ICR, Jakstra, PIT-PI, and STRAPI.

A series of indicators has been assigned to identify the current knowledge of Indonesia in the assessment of impacts and vulnerability. These indicators are derived from the IPCC AR 4 and have been grouped into three main components, namely: stimuli, vulnerability, and impacts/ risks. The indicators are presented in the **Table 11** below.

Table 11 Indicators of the stimuli, vulnerability and risk/impact of health sector

Component	Theme	Indicator
Stimuli	Direct	Temperature
		Precipitation pattern
		Sea-level rise
		Extreme Events
	Indirect	Water, air, and food quality
		Ecosystems, agriculture, industry, settlements, and economy
Vulnerability	Vulnerability factors	Burden of pre-existing diseases in the area
		Population density
		Socio-economic condition
		Age structure of population
		Local environmental conditions
		Quality and availability of public health care and infrastructure
Risk/Impact	The current state of knowledge of the associations between climate factors and	Temperature-related mortality and morbidity
		Winds, storms, and floods
		Drought, nutrition, and food security
		Food safety

	health outcome	Water and disease
		Air quality and disease
		Aeroallergens and disease
		Vector-borne, rodent-borne, and other infectious diseases
		Ultraviolet radiation and health

Stimuli

Climate change impacts to human health are complicated and involved several different pathways. IPCC AR4 has explained that changes in climate factors are such as temperature, precipitation, sea-level rise and extreme weather has both direct and indirect impacts to health. Changes in water, air, food quality and quantity; and changes in the ecosystems, agriculture, industry, settlement, and the economy are affected by climate that, in the long term, can also have impacts to human health. These direct and indirect exposures can cause deaths, disability and suffering from diseases.

In the national level, the document of ICCSR-HS has adopted AR4 approach to describe the stimuli. In the ICCSR-HS, these climate factors are known as climate hazards and have described the pathways of how human health will be affected by them. The changes in climate will affect the changes in regional weathers in the form of climate extreme, temperature rise, changes in precipitation pattern, and sea-level rise. The report has presented the temporal data of temperature variability, and temporal and spatial data of precipitation variability in some areas of Indonesia. As for the sea-level rise and extreme weather events, no historical information (both temporal and spatial) has been given. In addition, the indicators of indirect stimuli have not been included in the report. Although, if the full report of ICCSR (including other sectors, i.e. water and agricultural sector) is considered, it can be used to derive the indicators of indirect stimuli.

On the other hand, the document of Jakstra provided the information of global and national change in the climate factors of temperature, precipitation, sea-level rise and extreme events. As given in the report, some of the recorded changes in Indonesia are as follows (Jakstra, 2008):

- Temperature has increased consistently from time to time
- Sea-level rise has been consistently observed between 1 and 9 mm per year
- In the period of 1907-2006, 345 extreme events were recorded and 60% of them are climate-related
- It has been studied that the precipitation in the dry season (June-August) at the southern part of the equator has the tendency to decrease, while it has increased in the northern part of the equator

In addition, the report also has the information of the future trends of the climate factors at several provinces in Indonesia.

The report of PIT-PI provided temporal data of temperature, precipitation and humidity. While, extreme weather is associated with El-Nino and La-Nina. The report gives temporal and spatial data of changes in average rainfall and rainfall variability in Indonesia for the year of 1981-2007. These changes are compared to the change in the baseline year of 1951-1980. In addition to the data of rainfall, temperature data and extreme climate are given in the same manner. The report did not include information of sea-level rise in Indonesia.

ICR report described the past and future change in the stimuli. It provided information on the direct stimuli, such as past and future changes in temperature, rainfall, sea level rise; and also changes in hydrology (water condition) which is the indirect stimuli of climate change impact on human health. The information is equipped with temporal historical data and has also included the information from other studies. In addition to the historical data, the report has also given the information on the prediction of future change in temperature and sea-level rise, both global and national level.

The document of STRAPI did not specify the factors that stimulate impacts on human health. The report only mentions changes in precipitation briefly. Condition of the stimuli of human health impacts due to climate change in Indonesia is not reported in the document.

Vulnerability

The future vulnerability to climate change can affect the impact on human health; furthermore the health of population itself is an important element of adaptive capacity. Where there is a heavy burden of disease and disability, the effects of climate change are likely to be more severe than otherwise. In addition, the population density and the age structure of the population are important variables in any projections of the effects of climate change.

Poverty can limit the ability of a human to face the impacts of climate change. Therefore, changes in the socio-economic condition can affect the ability of people to face the impacts of climate change. Whilst, the availability of health services and infrastructures are also important factor in facing the hazards of climate change. For examples, in the future trends of malaria, access to cheap and effective anti-malarias, insecticide-treated bed nets and indoor spray programs will be important. Emergency medical services have a role in limiting excess mortality due to heat waves and other extreme climate events.

Other determinants of vulnerability could be impact-specific, for example, heat waves are exacerbated by the urban heat-island effect, so that impacts of high temperatures will be modified by the size and design of future cities. In addition, the vulnerability determinants could be different based on the profile of the region, i.e., the vulnerability in the urban and rural populations, vulnerability in coastal and low-lying areas, and mountain regions.

In the ICCSR report, Vulnerability is a function of exposure (E), sensitivity (S), and adaptive capacity (AC). Population density is used as the indicator of exposure, while the welfare status and infant mortality rate are used as sensitivity indicators. As for the adaptive capacity indicators, ICSSR included the health facilities and health care distribution, and the access to safe water supply and sanitation. As the result, the report of ICCSR presented the spatial data of vulnerability indicators in the form of GIS map. According to the assessment conducted in the report, Java Island is the area with the highest level of population density and regions of Papua, West Papua and Maluku have high percentage of poor population (>30%). In the term of impact-specific vulnerability assessment, the vulnerability of three main endemic diseases in Indonesia has been calculated in the report. Based on the calculation, the result shows that a large area of Papua and a small part of Sulawesi and Nusa Tenggara are highly vulnerable to malaria disease. Some areas of South Sumatera, East Java, and South Kalimantan are highly vulnerable to DHF disease. The areas with high vulnerability for diarrhea diseases spread in the islands of Sumatera, Kalimantan, Sulawesi, Nusa Tenggara, and Papua.

The document of Jakstra has the same formulation to the ICCSR-HS report to determine vulnerability, although the data is not published in the report. Exposures are presented by the population density and the populated areas. The sensitivity indicators are: population, i.e. total population, under age-five group population, elderly group population, handicapped (disable) population; prevalence, i.e. figures (level) of diseases incidence; and poverty. Adaptive capacities are divided into planned and spontaneous adaptation. Planned adaptation include health infrastructure, such as hospital service level, sanitation of water supply and toilets sanitation; and proactive measures such as the availability of immunization program. While, spontaneous adaptation determined by the availability of local wisdom related to the community and environmental health.

As the result of assessment, the report of Jakstra has analyzed the vulnerability of several provinces, such as West Nusa Tenggara, Maluku, East Kalimantan, DKI Jakarta and Nanggroe Aceh Darussalam (NAD). The report highlighted that the province of West Nusa Tenggara and NAD have the highest vulnerability to climate change impacts on health sector. There is no discussion about vulnerability to climate change on human health in the reports of STRAPI and ICR. Meanwhile, in the PIT-PI report, the analysis of vulnerability determinants includes three main factors: (1) the environmental factors, such as temperature, humidity and precipitation; (2) health service factors, such as ratio of health care facilities to population and ratio of physicians to population; (3) genetic/demographic factors, such as population density and poor population. The result of analysis is presented in the form of vulnerability map. The report stated that West Papua, East Nusa Tenggara, West Kalimantan, and North Sumatera are the areas that have the highest vulnerability on health sector. However, similar to the Jakstra report, no data is presented in the report.

As summary of the vulnerability assessment that has been conducted, Indonesia has used a more specific classification of vulnerability indicators. However, the use of weighting method needs an accurate and plausible justification from the analyst, and therefore can be different from the point of view of various experts. Furthermore, the availability of the data often becomes a problem in some areas to conduct the vulnerability assessment. In addition, factors of the pre-existing diseases burden and local environmental condition has not been fully elaborated in the reports.

Risk/Impact

The AR4 document has described the known relationship between climate/weather change and its impact on human health. In addition to climate change, as shown in **Figure 7**, changes in environmental, socio-economic and health system can also modify the health outcomes. There are 10 known climate change impacts on human health based on AR4, including: heat- and cold-waves; winds, storms and floods; drought, nutrition and food security; food safety; water and disease; air quality and disease; aeroallergens and disease; vector- and rodent-borne, and other infectious diseases; occupational health; and ultraviolet radiation and health.

These impacts have been assigned as the indicators of climate change impact on human health in this study. But it is necessary to look over the indicators as some indicators can be considered irrelevant in the case of Indonesia, such as heat waves which specifically do not occur in Indonesia. Nevertheless, there is direct effect of temperature on human health. There are some studies worldwide that link the changes in temperature with the number of deaths. So, in this case the heat waves and cold waves indicators have been re-assigned as temperature-related mortality and morbidity.

The occupational health can also be considered as the temperature-related mortality and morbidity. This is due to most of the relationship between the climate change impact on occupational health consist of indoor and outdoor workers that suffering from heat stress and heat stroke; or diminished people ability to perform task, both physically and mentally. The re-assigned indicators are described in **Table 11** above.

ICCSR-HS report has adapted the information on climate change impacts from the AR4 reports, but has only classified three main impacts of climate change on health, which consist of increased disaster potential, malnutrition problems, and increased diseases events. In addition, the ICCSR-HS report has also developed the methodology to analyze the impacts, but only the study of the impacts on diseases events that has been considered, which consist of two vector-borne diseases (malaria and DHF) and one water-borne disease (diarrhea). As the result of the assessment, ICCSR-HS has calculated the risk of malaria, DHF, and diarrhea diseases in Indonesia and presented them in the form of GIS map.

Similar with the ICCSR-HS, the document of PIT-PI has also developed the spatial and temporal studies of malaria and DHF in 7 provinces of Indonesia. The temporal data of climatic factors, such as temperature, precipitation and humidity are interpolated with the temporal data of malaria and DHF cases. However, unlike the ICCSR-HS, the result is not presented in GIS based map. The report has found that most of the malaria and DHF cases in the areas of study have more correlation with change in the precipitation pattern.

The Jakstra report only provided brief information on the impacts of climate change on human health. The health aspects related to the climate change described in the report are the hazards of famine, increasing prevalence of vector-borne and water-borne diseases, and respiratory and eyes irritation. Similarly, STRAPI report has only shortly mentioned some the impacts and has not elaborated further studies of the indicators. The report stated that potential climate change impacts on health are direct and indirect. Direct impacts are the occurrence of heat waves and extreme cold season. Other direct impacts are due to heat, such as increase in asthma and skin cancer incidences. In addition, climate change triggers the increase and spread of DHF, malaria, cholera, encephalitis, Hantavirus, and other infectious diseases outbreak. In Indonesia, the climate change impacts are marked by the development of vector-, air-, and water-borne diseases. Increased concentration of greenhouse gases such as CO_2, CH_4, CFC and NO_x followed by increased respiratory disease such as Acute Respiratory Infection (ARI). Malaria, dengue, diarrhea and cholera cases are predicted to increase in line with increase in temperature and more contaminated water resources.

In the case of ICR document, climate change impact on human health is discussed in a sub-chapter of the report. It is said that the impact of extreme events related to ENSO may contribute to the outbreak of human diseases. Based on the temporal data in the report, dengue cases in Indonesia have been found to be increased significantly from year to year, peaking in La-Nina years (in 1973, 1988, and 1998).

As shown in the gap analysis, current knowledge on the relationship between climate and human health is still very limited. Thus, Studies of the climate change impacts need to be enhanced. Some of the studies that have been done are the climate change impacts on vector-borne diseases in Indonesia, such as malaria and dengue (ICCSR-HS and PIT-PI) and a water-borne disease, diarrhea (ICCSR-HS). Some impacts, i.e. the impacts of extreme weather events and malnutrition, have been mentioned but either no further study is conducted or only brief information is given. In the other side, impact on food safety (food poisoning), air quality and diseases (respiratory and cardiovascular diseases), aeroallergens and diseases (allergenic diseases), and ultraviolet and health (skin cancer, eye irritation, etc) have not yet been studied in Indonesia.

4.4 Human Settlement Systems

The IPCC AR4 (2007) report identifies key areas of vulnerability that may occur on human settlement systems due to climate change. They are as follow (pp. 374-5):

1. *Interactions between climate change and urbanization: most notably in developing countries, where urbanization is often focused in vulnerable areas (e.g. coastal), especially when mega-cities and rapidly growing mid-sized cities approach possible thresholds of sustainability (very high confidence)*
2. *Interactions between climate change and global economic growth: relevant stresses are linked not only to impacts of climate change on such things as resource supply and waste management but also to impacts of climate change response policies, which could affect development paths by requiring higher cost fuel choices (high confidence)*
3. *Increasingly strong and complex global linkages: climate change effects cascade through expanding series of international trade, migration and communication patterns to produce a variety of indirect effects, some of which may be unanticipated, especially if the globalised economy becomes less resilient and more interdependent (very high confidence)*
4. *Fixed physical infrastructures that are important in meeting human needs: infrastructures susceptible to damage from extreme weather events or sea-level rise and/or infrastructures already close to being inadequate, where an additional source of stress could push the system over a threshold of failure (high confidence)*
5. *Interactions with governmental and social/cultural structures that are already stressed in some places by other kinds of change: examples include population pressure and limited economic resources, where in some cases structures could become no longer viable when climate change is added as a further stress (medium confidence)*

There are several "indicators" discussed in the IPCC AR4 along the line of Stimuli-Risk/impact-Measures framework used in this study. Those indicators are as follow (see also **Table 12** below):

1. "Indicators" used as the bases are:
   - Increases in the mean temperature
   - Intensity of extreme events
   - Frequency of extreme events
   - Interaction with other non-climate sources of change
2. "Indicators" used in vulnerability analysis are those of specific geographic, sectoral and social contexts, and not estimated by modeling and estimation
3. "Indicators" used in risk analysis are those of high-risk location (coastal and riverine areas) and climate-sensitive resource economic areas
4. To analyze impacts, social economic costs analysis uses gross domestic product and per capita income as indicators. Poverty level is also used as indicator of vulnerability

Table 12 Themes and indicators of the stimuli, vulnerability, and risk/impact of human settlement systems aspect

Component	Theme	Indicator
Stimuli	Temperature	Increases in mean temperature
Basic data	Extreme events	Intensity of extreme events
		Frequency of extreme events
	Other source	Interaction with other non-climate sources of change

Component	Theme	Indicator
Vulnerability	Vulnerability analysis	Specific geographic context
		Specific sectoral context
		Specific social context
Risk/impact	Risk analysis	High-risk locations (coast, river)
		Climate-sensitive resource economy: agriculture and forest industries, water demands and tourism
	Impact analysis	Social economic costs: GDP, percapita income
		Poor community

The only document discusses about the impacts of climate change into human settlement is the Jakstra produced by the Directorate General of Spatial Planning, Ministry of Public Works. Having reviewed the Jakstra document, it can be seen how those not-very-specific "indicators" that the IPCC AR4 discussed, to some extent have been included in this report. In its vulnerability analysis this report distinguishes two groups of indicators, i.e. exposure indicators and sensitivity indicators. The exposure indicators such as are elevation, area size, concentration of infrastructures, population, population density, and migration are corresponding to the specific geographic, sectoral and social contexts referred in the IPCC AR4 as the indicators for vulnerability analysis. Meanwhile the sensitivity indicator such as the urban poor is corresponding to the poverty level discussed in the IPCC AR4, although the report by the Ministry of Public Works focuses only on the poor in urban areas. Thus several indicators indicated in AR4 for analysis the vulnerability of settlement, industry and infrastructure to climate change have been included in that report. Only the indicator of climate-sensitive resource economic areas, such as agriculture and forest industries, water demands and tourism that were not included in the analysis.

4.5 Water Resources and Systems

The aspect of water resources and systems is included in the Chapter 3 of the IPCC AR4 report where the original title is "Freshwater resources and their management". This chapter comprises major features of water systems in terrestrial and inland such as flood, drought, erosion, sediment transport, and hydrological basin. Hence, the discussion of the water resources and systems should not separate both terrestrial and inland water systems.

Actually, the IPCC AR4 highlighted that the climate change is only one of multiple pressures to water resources and systems (see **Figure 8**). The major and original pressure, indeed, comes from human activities that affects the water resources and systems indirectly through climate change (i.e., through emission of GHG) and changes of land use. Moreover, land use is the most important feature that determines intensity and magnitude of the climate change itself and of the impacts on water resources and systems through influences on the hydrological cycle (water quantity and quality, mean state and variability).

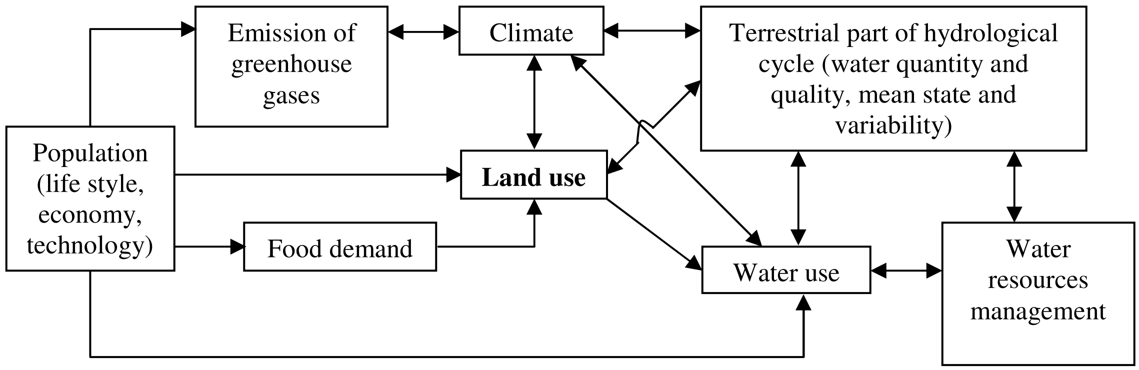

Figure 8 Scheme from the IPCC AR4 report illustrates how human activities and climate change impact to the water resources and systems (source: IPCC AR4, p. 175)

This concept of the IPCC AR4 is then implemented to derive the themes and indicators in **Table 13** below. Stimuli to the impact or hazards of climate change to the water resources and systems comprise of precipitation variability, temperature rise, and intensity and frequency increases of extreme climate events (e.g., ENSO, IPO) from atmosphere, as well as sea level rise. The report also conveys indicators of surface water, ground water, floods and droughts, water quality, as well as erosion and sediment transport that become parts of current sensitivity or vulnerability; while assumption about future trends includes both climatic and non-climatic drivers. In the context of climate change impact, the IPCC AR4 document suggests the theme of key future impacts and vulnerabilities, which includes same indicators of the current vulnerability.

Table 13 Themes and indicators of the stimuli, vulnerability and risk/impact of the water resources and systems

Component	Theme	Indicator
Stimuli	Potential Hazards from Atmosphere	Precipitation variability
		Temperature rise
		Increase of intensity and frequency of extreme events (ENSO & IPO)
	Potential Hazards from Ocean	Sea level rise
Vulnerability	Current Sensitivity/ Vulnerability	Surface water
		Groundwater
		Floods and Droughts
		Water quality
		Erosion and sediment transport
	Assumption About Future Trends	Climatic Drivers
		Non-Climatic Drivers
Risk/Impact	Key Future Impacts and Vulnerabilities	Surface water
		Groundwater
		Floods and droughts
		Water quality
		Erosion and sediment transport

Reviews and assessments are conducted to the documents of ICCSR-WS, VA Lombok-WS, RAN-MAPI, RAN-PI, ICR, and Jakstra due to closely related to the water resources and systems aspect.

Some documents or papers are added to enrich the reviews, e.g.: Adidarma (2010), Fariansyah and Ariwibowo (2009), and Abdurahman et.al. (2010).

The reviews are presented below in accordance to the components of climate change in the water resources and systems aspect.

Stimuli/hazard

The IPCC AR4 stated that main stimuli of climate change on the water resources and systems aspect is precipitation variability. The document reported that a global temperature rise of 2^{o}C can increase 23-29% flooded area in Bangladesh. Meanwhile, extreme flooding and multiannual drought with high intensity can be addressed as sign of intensity and frequency of extreme climate events, while sea level rise up to 0.1 m in the coast of India can decrease freshwater lens from 25 m to 10 m. In this manner, there is no specific formulation in the IPCC AR4 to determine the climate change hazard.

In this context of hazard, at national level, the ICCSR-WS report clearly makes a difference between: (1) direct impact or potential hazard of climate change and (2) hazards itself on water resources. The first type can be considered as stimuli to hazard of climate change on water resources and systems. Meanwhile, the second type is analyzed based on the stimuli or potential hazard and physical potential hazard using the methods of water balance analysis (WBA) and analysis of cummulative frequency distribution (CFD). The ICCSR-WS implemented geographic information system (GIS) to obtain the quantitative hazards both temporally and spatially.

There are a couple indicators of the direct impact of climate change (first type) in ICCSR-WS that can be paired to the indicators of stimuli in the IPCC AR4 report. There is no theme classification as hazards from atmosphere and hazards from oceans in the ICCSR-WS. All information on the first type of hazards is obtained from the science basis analysis of the ICCSR-WS report.

The hazards on the water resources and systems (second type of hazard) in the ICCSR-WS are analyzed based on the climatic and physical potential hazard using WBA method, except for hazard of salt water intrusion (water quality). The simulation used polynomial trend analysis followed by climate projection with the same baseline as result in climate projection. CFD analysis is then applied to the data of total runoff (TRO) and direct runoff (DRO) as the main results of the WBA. Climatic potential hazards are the direct hazards or the stimuli, i.e. both base line and projection of temperature and rainfall, involving three conditions: normal, above normal, and below normal. Physical potential hazards that are considered are land use, slope of land, porosity of soil or rock. Another analysis is conducted in ICCSR-WS report to the hazard of salt water intrusion in Jakarta due to excessive groundwater intake in its coastal areas combined with related sea level rise.

As the results, ICCSR-WS report identifies five hazards of climate change being considered in analysis of water resources and systems; those are: (1) water supply shortage (WSS or in Bahasa is PKA: *penurunan ketersediaan air*), (2) flood, (3) drought, (4) landslide, and (5) salt water intrusion.

The other documents in national level such as RAN-MAPI, RAN-PI, and ICR also mentioned sea level rise, change of rainfall pattern and extreme events as main stimuli to the impact of climate change on the water resources and systems, although these reports did not elaborate these indicators deeply. However, the other documents elaborated only for specific region, such as Jakstra and VA Lombok-WS, i.e. on precipitation variability. An important note is that analysis of scientific basis of climate change is not conducted in all these documents except for VA Lombok-WS. The later presented the same methodology as the ICCSR-WS.

As a whole in the context of stimuli or hazard component, many studies have been conducted in Indonesia, however, only some of them have implemented GIS approach in assessing the water resources and systems by the component such as ICCSR-WS and VA on water resources and systems Lombok. In other side, most of those studies are still conducted in regional scale and has little information in elaborating the component. Therefore, it is important to conduct elaborative studies at smaller scale like VA Lombok-WS, especially about the extreme events such as ENSO as one stimuli or hazard climate change on water resources and systems.

Vulnerability

Knowledge of the current vulnerabilities will be very helpful to identify the impacts that may occur and to formulate adaptation measures. The IPCC AR4 presented a few statements that can be considered to define indicators of vulnerability, as follow: 1) changes in temperature, radiation, atmospheric humidity, and wind speed affect potential evapotranspiration, and may then decrease precipitation on surface water; 2) groundwater correlates more strongly with precipitation than temperature; 3) climate change might already have had an impact on floods and droughts; 4) intense rainfall results in more nutrients, pathogens, and toxins being washed into water bodies; and 5) climate change impacts on water erosion and affects many geo-morphologic process, slope stability, channel change, and sediment transport.

For the future condition of vulnerability, the IPCC AR4 stated the assumption about future trends which consists of climatic and non-climatic drivers as indicators. The most dominant climatic drivers for water availability are precipitation, temperature, and evaporative demand which are determined by net radiation at ground level, atmospheric humidity, wind speed, and temperature. The second drivers of water resources include population, the construction and management of reservoirs, pollutant emissions, and water and wastewater treatment (reusing and recycling water), which all are influenced by changes of land-use.

The ICCSR-WS report, however, had provided some significant differences of approach in comparison to the previous IPCC AR4 document. First, the ICCSR-WS report did not separate the discussions about vulnerability into two parts, i.e. current sensitivity/vulnerability and future vulnerability such in the IPCC AR4, although both subjects are presented. Second, the ICCSR-WS did not clearly state the assumptions of climatic and non climatic drivers to analyze future trend of vulnerability.

Third, for both current and future conditions of vulnerability, the ICCSR-WS document explicitly considered the vulnerability as suggested by the IPCC in general, that vulnerability (V) of a system is a function of exposure (E), sensitivity (S) and adaptive capacity (AC) through the formulation of $V = (E \times S)/AC$. The IPCC AR4 itself described those parts in qualitative way.

Fourth, the ICCSR-WS had implemented geographical information system (GIS) method in describing the spatial figures of future vulnerabilities dealing with each hazard. The vulnerability map is then determined by using weighted-sum method of each component related to each hazard.

In relation to that description, the ICCSR-WS report divided the vulnerability into primary and secondary parts based on the availability of related spatial data. The first part includes seven indicators where the relevant spatial data are available, that are the river basin and land use (i.e., damage rank of river basin), population density, land-use patterns, water demand, confined aquifer and aquifers potential or potency of groundwater basin, land elevation, as well as soil properties. Meanwhile, the second part includes water quality, water infrastructure, the National Action on Forest and Land Rehabilitation (*Gerakan Nasional Rehabilitasi Hutan dan Lahan* or *GNRHL*), the Clean River Program (*Program Kali Bersih* or *Prokasih*), lands subsidence in urban areas, and Landslide Vulnerability Map.

The last difference between both documents is that landslide aspect is considered in the ICCSR-WS report as indicators for current and future vulnerability to climate change on water resources and systems, while there was no significant explanation about it in the IPCC AR4. On the other hand the ICCSR-WS provided lack of information about erosion and sediment transport indicators.

Unfortunately, the other documents have little discussion about the indicators of vulnerability, except the Jakstra and VA Lombok-WS documents. The first gave little information about surface water, groundwater, and water quality in the context of current vulnerability, where there are decreases of river water in the dry season, large utilization of groundwater due to industries that grows rapidly, and declines of water quality in urban areas. The VA Lombok-WS report provided the same methodology as to the ICCSR-WS but was applied in a certain area, i.e. the Lombok Island, NTB.

As summary of the discussion about vulnerability, there are some significant differences in the approaches of the vulnerability between the IPCC AR4 and some documents in national level. However, these studies have not further elaborated the vulnerability indicators of climate change. The national studies also still cover regional scale. As a result, there is no study in Indonesia that deals with the water budget (a comprehensive comparison between water supplies and demands) and the access of people to the water resources in detail ways (infrastructures water, their condition and others). Also, further studies are needed for some missed indicators, e.g. erosion, sediment transport, and water quality, as well as climatic and non-climatic drivers. Presence of landslide appeared in the studies of ICCSR-WS and VA Lombok-WS, however, it should be further investigated in more detailed.

<u>Risk/Impact</u>

According to the IPCC AR4, indicators of the impact/risk of climate change to the water resources and systems are considered as the same as the ones used for the current sensitivity/vulnerability above (see **Table 13**). The indicator for surface water is seasonality flow increases, with higher flows in the peak flow season and lower flows during the low flow season or extended dry periods. Meanwhile, for groundwater indicator, saltwater intrusion of neighboring saline aquifers and salinization of shallow aquifer affect on groundwater recharge rates, the renewable groundwater resources, and groundwater levels. Risks of both floods and droughts increase due to impacts of extremes on human welfare in countries with low adaptation capacity. For water quality, it is stated that biological quality of water is poor due to lack of sanitation and proper potabilisation methods and poor health conditions. For the last indicator, the IPCC AR4 reported that greater rates of erosion will happen unless protection measures are taken.

In the assessment of climate change risks, the ICCSR-WS applied GIS method with the risk formulation of R = H x V, where R, H, and V are risk, hazard, and vulnerability, respectively. The analysis provides risk maps of water supply shortage, flood, drought, and landslide, as well as salt water intrusion (in related areas). Each of these maps is accomplished by qualitative description of impacts from current relevant information. For example, surface water gets impacts by critical water balance condition especially in urban areas, ground water obtains impact by seawater intrusion in coastal area caused by over pumping, and water quality has been influenced by highly polluted water in cities and their surrounding area especially in Java Island. Other impacts considered in the ICCSR-WS report relate to floods and droughts hazards that may cause losses of live, and losses of materials and livelihood, increases in infrastructure damages by flood, decreases of clean water supply, harvest failure, and disease water supply shortage. Meanwhile, there is no information about impacts of water quality as well as erosion and sediment transport in the ICCSR-WS report. But, as in vulnerability component, the report had considered landslide impact.

RAN-PI and ICR documents provided almost all impact indicators, except erosion and sediment transport, however, without scientific basis analysis. Meanwhile, VA Lombok-WS report discussed future impacts of surface water, floods and droughts through that analysis. Other documents reviewed (i.e., RAN-MAPI and Jakstra) missed in analysis of these indicators.

Impacts reported by the RAN-PI are lack of access to drinking water and sanitation, land subsidence due to excessive groundwater pumping causing widespread flood-prone areas and seawater intrusion. Meanwhile, the ICR document stated that many districts in Indonesia may face problem of clean water shortage as the waters in coastal area becomes more saline affecting to soil and groundwater aquifers. The report also informed that extreme dry years will reduce the availability of drinking water especially in urban or metro areas, and the flood will damage farms and contaminate water. Further, the document presented decreases of the water quality of the Citarum watershed, West Java.

This study also assesses some relevant research reports, e.g. Adidarma (2010) and Fariansyah et. al. (2009). The first research reported that water supply shortage and drought hazard could be measured from (i) drought index (i.e. trend of drought, temporal and spatial SPI index, index of variability of rainfall distribution); (ii) low flow of river discharge (i.e. monitoring, index, map, frequency, drought and water quality indicator, rainfall-runoff model); (iii) trend of discharge (i.e. river discharge, long-term variation of precipitation and discharge, trends of rainfall and discharge). The research obtained correlation between climate change, land-use change and flood phenomena in watershed of Bengawan Solo River, Central Java as presented in **Box 3** and **Table 14** below.

Box 3 Impact of Land Use Change and Climate Change to Flood in Bengawan Solo Watershed

Adidarma (2010) mentioned that flood hazard could be shown from indicators such as (i) discharge trend and peak, (ii) map of hydrologic soil (see Figure), and (iii) flood forecasting and early warning system. Some scenarios had been developed by using comparison between current map (2008) and baseline map (1964) in Bengawan Solo Watershed as follow: (i) current map without climate change impact, (ii) current map without land use change with climate change, and (iii) current map with climate change. The results of scenarios are shown in **Table 14**. As shown in the table, the flood and rainfall increases in the watershed near Madiun, for example, due to land use changes are presented by about 58% of peak discharge and 50% of rainfall increases, respectively, relative to the conditions in 1964. These conditions are then triggered by the climate change to become about 102% of peak discharge and 90% of rainfall increases.

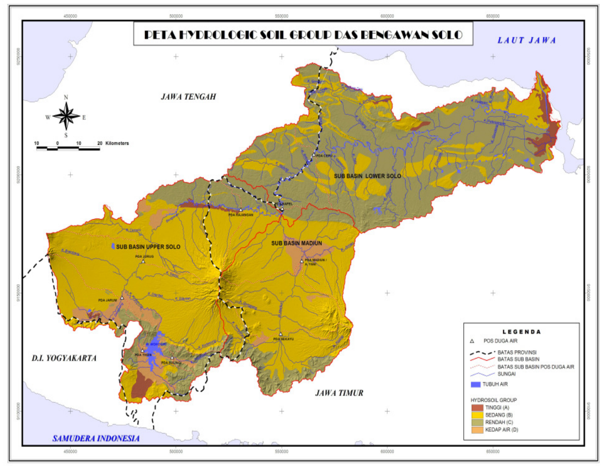

Table 14 Flood Change Scenarios (%) Based on Current Land Use Change (2008) and Baseline (1964)

Scenarios of Bengawan Solo Watershed	Upper Solo		Madiun		Lower Solo	
	Peak Dis. (%)	Vol (%)	Peak Dis. (%)	Vol (%)	Peak Dis. (%)	Vol (%)
With land use change, but without CC	69	64	58	50	48	41
Without land use change, but with CC			26	20		
With land use change and CC			102	90		

Note: Peak Dis. = peak discharge; Vol = volume of river water; CC = climate change

Meanwhile, the second research produce a significant result that the indicator of global climate change impact can also be identified from wet season and fluctuation of water availability (Q_a) in a watershed (see **Box 4** below).

Box 4 Adaptation of Climate Change by Water Allocation Optimization in Renggung Watershed, Lombok, Nusa Tenggara

Climate change impact is indicated by shortening wet season and disturbances of watershed quality which is shown by increases of trend Q_{max}/Q_{min}. In the other side, water demand (Q_d) due to population increases. Previously, estimation of water allocation follows K-factor (FK = Q_a/Q_d) as correction factor that needs to be evaluated for distribution of water usage. Fariansyah et. al. (2009) proposed the method of Release Demand Ratio (RDR), i.e. the ratio between the water given and water demand (Q_r/Q_d), as an indicator of water allocation. In global planning of water allocation, the RDR is a goal optimization to balance the value at all dams in every period.

In Lombok Island, indicator of global climate change is shown by decreases of wet season from 4 to 6 months into only 3.40 months, although annual rainfall is relative stable about 1,487 mm (553 – 2,664 mm). Ratio of Q_{max}/Q_{min} is about 45 – 365 with gradient 1:2 that increases year by year indicating disturbance of the watershed. Water balance condition at Renggung Watershed before supletion is that total water need is about 163.11 million m^3 and water availability is 94.76 million m^3 to result the water need index (*Indeks Kebutuhan Air* or *IKA*) of about 1.73. In condition of after supletion, the index becomes 1.03 as the water availability increases into 158.62 million m^3.

The climate change impact could be seen in water usage especially in dam such as shown in recovery of water level that impacts on instability of spillway and needs to be evaluated as negative impact of climate change adaptation. Time series data to determine discharge plan could also be considered as the impact indicator (Sugiyanto in Abdurahman et. al., 2010), while regionalization is needed in analysis of climate change impact (Hasanudin in Abdurahman et. al., 2010).

As summary, there are few studies on future impacts and vulnerabilities in Indonesia, and many of them are conducted in macro (national) level, except VA Lombok-WS. In addition, these studies are still incomplete (descriptions of some indicators are missed).

An important note is that these studies are just started to be conducted as sectoral program of governmental institutions. The results so far need to be enhanced to gain more significant information on the future vulnerabilities and impacts. Some of these studies obtain relationship between climate change and land use of river watershed as well as flood occurrences in the watershed, while the others relate among season and fluctuation of water availability as well as distribution of water usage in the watershed.

4.6 Coastal Areas, Oceans, and Small Islands

Coastal Areas, Oceans, and Small Islands become major parts of the Earth that receive various impacts of the global climate changes. This is probably the argument why they will be written into three different chapters in the outline of the IPCC-AR5 report, i.e.: Coastal Areas and Low-Lying Areas (Chapter 5), Oceans Systems (Chapter 6), and Small Islands Areas (Chapter 29). This division, however, did not appear in the previous IPCC AR4 document. In that report, discussion on coastal system was written in Chapter 6, while ocean systems became a part of Chapter 4 (Ecosystems), especially in Sub-chapter 4.4.9 with title of Oceans and Shallow Seas, and small island part was described in Chapter 16 with the same title.

To follow the division presented in the AR4 Report and an outline of the AR5, this study discusses the subject of Coastal Areas, Oceans, and Small Islands into a sub-chapter. This sub-chapter is then divided into three different aspects, i.e.:

- Coastal Systems and Low-lying Areas
- Oceans and Shallow Seas
- Small Islands

Each aspect is presented based on the following structure:

- Stimuli, that consists of hazards related to climate change and human-induced pressures
- Vulnerability, that consists of vulnerabilities in both natural and societal coastal systems
- Impact and risk to the natural and societal coastal systems

This study, firstly, identifies some documents that become 'state of the art' studies of climate change impacts on this aspect in Indonesia, i.e. ICCSR-MFS, ICR, and RAN-MAPI as reports in national level, as well as SLR, CSI, and VA Lombok-CMS as cases in specific locations. The second, then the review of these documents based on the indicators derived from the IPCC AR4.

4.6.1 Coastal Systems and Low-Lying Areas

Coastal systems and low-lying areas, depicted as the dashed-line circle in **Figure 9**, are among the most vulnerable regions in Indonesia due to climate change, with the length of 95,181 km of coastline (CSI) and where 74% of the Indonesia's total population (more than 169 million people) live (ICCSR-MFS). The areas consist of two systems, i.e. natural sub-system and societal sub-systems.

The natural sub-system comprises characteristics of land form, such as beaches, rocky shorelines, cliffed coasts, deltas, estuaries, and lagoons, as well as ecosystems contained within each of them like mangroves, salt marshes and sea grasses, and coral reefs. Meanwhile, the societal sub-system consists of infrastructures and human activities. Both sub-systems are highly vulnerable to hazards related to global warming and climate change as stimuli such as: global sea level rise, temperature rise, and increases of CO_2 concentration.

The global sea level rise reinforces the increases of coastal inundation, erosion, and loses of ecosystems. The temperature rise stimulus affects the quantity of sea ice, more frequent coral bleaching and mortality, intensified tropical and extra-tropical cyclones, larger extreme waves and storm surges, altered precipitation/run-off, and ocean acidification as well as ENSO.

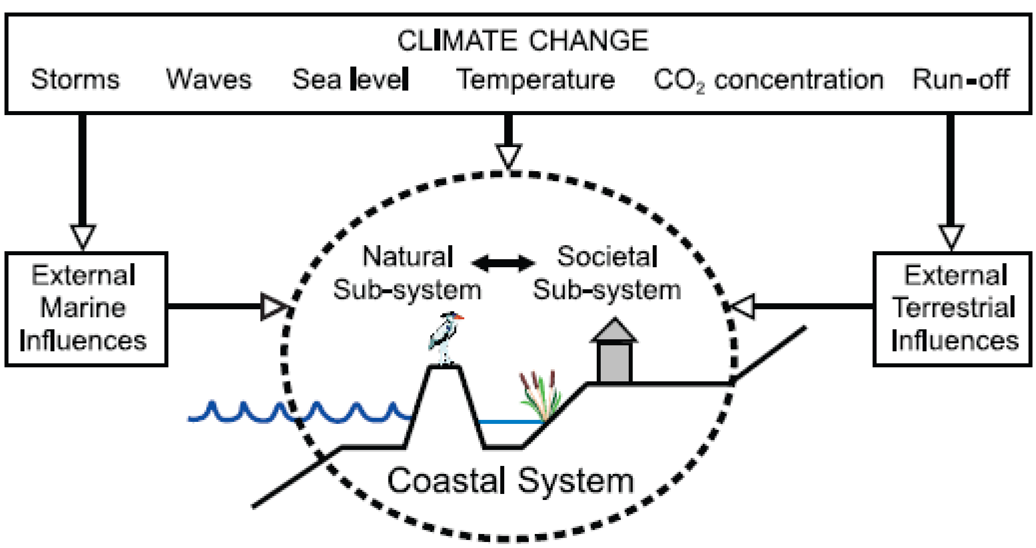

Figure 9 Climate change and the coastal system, showing the major climate change factors, including external marine and terrestrial influences (IPCC AR4)

These hazards raise pressures on the coastal system directly and indirectly through external terrestrial and marine influences (**Figure 9**). The impacts are almost devastatingly negative, such as:

- Increases in sedimentation, threatening the coastal wetland ecosystems
- Intensified degradation of coastal ecosystems (wetlands and coral reefs), seriously impacting the well-being of coastal societies
- Increased flooding and degradation of freshwater, fisheries, and other resources, finally causing impacts to people and its socio-economic system, causing lose of properties, natural resources, and environment

The increasing numbers of people living and utilizing the coastal areas amplified the pressures dramatically. There are also additional stresses due to land-use and hydrological changes in the catchment areas, including dams, which will reduce sediment supply to the coast. This concept stated in the IPCC AR4 report is then implemented to derive the themes and indicators in **Table 15** below.

Table 15 Themes and indicators of the stimuli, vulnerability, and risk of the coastal systems and low-lying areas

Component	Theme	Indicator
Stimuli	Hazard related to climate and sea-level rise	Global sea level rise
		Temperature rise
		CO2 concentration
		Extreme events:
		- cyclones
		- extreme waves
		- storm surges
		- altered precipitation/run-off
		- ocean acidification
		- ENSO
	Human-induced pressures	Growing population and distribution
		Land-use changes: coastward migration
		Land-use changes: aquaculture growth
		Land-use changes: infrastructure growth
		Land-use changes: industries
		Hydrological, sedimentation changes in catchments
		Human and natural induced subsidence
Vulnerability	Natural coastal system	Morphodynamic
		Coastal landform:
		- beaches, rocky shorelines, and cliffed coasts
		- deltas
		- estuary and lagoon
		- mangroves, saltmarshes, and sea grass
		- coral reef
	Societal coastal system	Freshwater resources
		Agriculture
		Forestry
		Fisheries
		Human settlement
		Infrastructure
		Migration
		Biodiversity
		Recreation and tourism
		Transportation
Risk/Impact	Impact to natural coastal	Coastal inundation

Component	Theme	Indicator
	system	Coastal erosion
		Coral bleaching
		Constraint on landward margin of coastal wetland ecosystems
		Degradation of ecosystems (wetlands, coral reefs)
		Natural resources and environments
	Impact to societal coastal system	Human deaths
		Property losses
		Business activities
		Human settlements
		Human health
		Human activities

The above descriptions will be used to review the national-level documents according to the climate change stimuli, vulnerabilities, and impacts as shown in Annexes.

Stimuli

In the stimuli component, the ICCSR-MFS document contains stimuli related to climate change that likely occurred in Indonesia, such as sea level rise, temperature rise, extreme events, and a number of pressures induced by human activities. Other types of stimuli are not considered due to lack or unavailability of data. Cyclone is not specified because this hazard does not likely occur in the surrounding of equator region, but its impact could potentially propagate to such region in the form of storm surge and extreme waves.

The ICR generally tries to explain the condition of climate change in Indonesia. In the coastal sector, this report, however, merely discusses sea level rise and sea surface temperature.

The VA Lombok-CMS report analyzes, in a rather complete way, hazards of sea level rise and extreme events such as waves, tides, ENSO, storm surges, and tsunamis. These kinds of hazard are then represented by the coastal inundation or flooding. Both studies of VA Lombok-CMS and ICCSR-MFS have provided IPCC SRES and hazard-combined scenarios with projection until 2100. In the inundation analysis, land subsidence has also been included for Jakarta (ICR) and Semarang (CSI).

In other side, there is regrettably none of the documents that explain the stimuli related to the increase of CO_2, altered precipitation, and ocean acidification as well as their impacts to coastal areas.

Vulnerability

In the vulnerability component, the ICCSR-MFS provides information on natural vulnerability of human and its activities. This document only elaborated the vulnerability of growing population by describing its projection on 2025 based on the data on 2005. Information of other indicators is not available.

Besides the ICCSR-MFS, only two more documents discussed vulnerability. The first one is the VA Lombok-CMS that analyzes, in a rather complete way, hazards along with vulnerability and risk analyses that are sea level rise, and extreme events such as waves, tides, ENSO, storm surges, and tsunamis. It also provides vulnerability map related to the hazard from sea level rise in the Lombok Island and the Mataram City. The second is the CSI, which is complete enough in analyzing hazard and vulnerability related to climate change with case study in several coastal cities in the northern coast of Java Island.

The three documents above have considered vulnerability factors related to population, human settlements, and infrastructures. In specific way the CSI has conducted study of physical vulnerabilities related to geo-morphology, and coastal condition, erosion rate, and change in coastline. For detailed study, an inundation area projection and the potential loss of land and settlement as well as other physical damages have also been conducted. No analysis of economic impacts on the damages has been carried out.

Risk/Impact

As claimed to be the most complete document of climate change in Indonesia, some impacts and risks are discussed in the ICCSR-MFS report, especially the coastal inundation, while the other impacts have not yet been described in detail. The result from SLR document provides inundation map due to sea level rise with projection of sea level rise until 2050, while it also considers land subsidence in Jakarta. In other side the ICR document explains the impact of land loss and impact to coral and mangrove ecosystems.

While presenting a thorough discussion of inundation map and projections, the document of SLR does not include impacts on environment and human activities. On the other hand, the VA Lombok-CMS provides a discussion of risk for hazard from sea level rise in the Lombok Island and Mataram City. For the Mataram City, the number of infrastructure and building with potential inundation impact has been calculated.

4.6.2 Oceans and Shallow Seas

Beside atmosphere, ocean experiences huge impacts of the climate change, and even it becomes one of large contributors to this global phenomenon, since it covers over 71% of the Earth's surface. Oceans in Indonesian region also delivers significant contributions and receives critical impacts of this world-wide event, not only due to covering of about 62% of 3.1 million km^2 total area of Indonesia, but also this region becomes a crossing area of ocean circulations from and to Indian Ocean, Pacific Ocean, and South China Sea.

With a mean depth of 4,000 m and comprising around 14 billion km^3, the world oceans act as massive reservoirs for inorganic carbon, which is in form of living and dead biomasses. Phytoplankton and low biomass carry out almost half of global primary production, and are the bases of the marine food web (IPCC, 2007). According to primary productivity, oceans have a diverse range of ecosystems, from the highly productive ones (upwelling regions) to those with low productivity (oceanic gyres), depends on sunlight and nutrients supplied from deep waters.

Many of marine ecosystems are critical to the functioning of the Earth system as well as provide goods and services such as fisheries, energy provision, recreation and tourism, CO_2 sequestration and climate regulation, decomposition of organic matter and regeneration of nutrients, and coastal protection. Beside marine biodiversity supports ecosystem function, it also provides services to over 1 billion people relying on fish as their main animal protein source, especially in developing nations.

Similar to the coastal systems and low-lying areas above, the oceans and shallow seas are also affected by climate change through increases of CO_2 concentration, ocean warming, and changes of rain fall and ocean circulation. The hazards could impact marine ecosystems and affect coral reefs, and moreover influence human activities and lifelines. Projections of ocean biological responses to climate warming show the existence of contraction of the highly productive area.

Besides, current extreme climatic events provide an indication of potential future effects. As an illustration, warm-water phase of ENSO could influence large-scale changes in plankton abundance and are then associated on food webs and marine primary productivity. Changes in the occurrence and intensity of ENSO events are likely to have severe impacts on commercial and fisheries sectors. Corals are also affected by warming of surface waters, leading to bleaching (loss of algae symbionts).

These relations of climate change and aspect of oceans and shallow seas from the IPCC AR4 report are then implemented to derive the themes and indicators in **Table 16** below.

Table 16 Themes and indicators of the stimuli, vulnerability, and risk of the ocean and shallow seas

Component	Theme	Indicator
Stimuli	Hazard related to climate and sea-level rise	Global sea level rise
		Temperature rise (ocean warming)
		CO2 concentration
		Extreme events (increased intensity and frequencies):
		- cyclones
		- extreme waves
		- storm surges
		- altered precipitation/run-off
		- ocean acidification
		- ENSO
	Human-induced pressures	Over-fishing and destructive-fishing
		Off shore industries and pollution
		Nutrient and sediment load
		Marine-use changes: marine culture
		Coral mining and tourism activities
Vulnerability	Natural ocean system	CO2 uptake by ocean
		Climate regulation
		Decomposition of organic matter
		Regeneration of nutrient
		Coral reef
		Marginal sea ecosystems
	Societal ocean system	Fisheries
		Energy and mining
		Recreation and tourism
		Transportation
		Biodiversity

Component	Theme	Indicator
Risk/Impact	Impact to natural ocean and shallow seas	Marine ecosystems
		Increasing thermal stratification may lead to:
		- oxygen deficiency
		- loss of habitats
		- biodiversity and distribution of species
		- impact on whole ecosystems
		Reducing upwelling
		Expansion of the sub-polar gyre and contraction of the seasonally stratified sub-tropical gyre
		Reduces surface ocean pH and carbonate ion concentrations
		Increased risk of diseases in marine biota
		Coral bleaching and mortality
		Lower marine ecosystem productivity
	Impact to societal ocean and shallow seas	Food securities
		Business activities (i.e. industry and transportation)
		Human activities

The description above will be used to review the national-level documents according to the climate change stimuli, vulnerability, and impact as shown in *Annexes.*

Some of the documents (e.g. VA Lombok-CMS and ICCSR-MFS) have been very thorough in providing stimuli driven by climate change, such as extreme events, including sea level rise, storm surges, tides, ENSO. The SRES scenarios and scenarios by hazards combination have also been developed and completed by a projection until 2100. But none provides study on stimuli related to CO_2 concentration, altered precipitation, and ocean acidification as well as their impact primarily on oceans and shallow seas environment.

The documents studied are still missing on the study of vulnerability as well as risk and impact of natural ocean system and societal ocean system.

4.6.3 Small Islands

Small islands are highly vulnerable to the climate change impacts, especially due to sea level rise and hydro-meteorological hazards. Such evidences are faced by Indonesian archipelago that consists of more than 17 thousand islands, which many of them have poorly developed infra-structure and limited natural, human, and economic resources, as well as high dependences of livelihood on marine resources.

These small islands are generally threatened by a combination of human pressures and climate change and variability such as sea-level rise, increases of sea surface temperature, and potential increases of extreme weather events like cyclones, extreme waves, storm surges, altered run-off/precipitation, and ocean acidification. These hazards will impact on accelerations of coastal erosion, seawater intrusion, and coastal inundation, thus threatening vital infrastructures, human settlements, and facilities which support the livelihood of island communities. Furthermore, water shortages and increased incidence of vector and water-borne diseases may also deter the human life due to limited water supply and resources.

Increase of sea surface temperature and rise of sea level, increased turbidity, nutrient loading and chemical pollution, damage from storm surges, and decrease in growth rates due to the effects of higher CO_2 concentration on ocean chemistry, are very likely to affect on the coral reefs and other marine ecosystems which sustain island fisheries. These evidences described in the IPCC AR4 report are then used to derive the themes and indicators in **Table 17** below.

Table 17 Themes and indicators of the stimuli, vulnerability, and risk/impact of the small islands

Component	Theme	Indicator
Stimuli	Hazard related to climate and sea-level rise	Global sea level rise
		Temperature rise
		Increased CO2 concentration
		Extreme events:
		- cyclones
		- extreme waves
		- storm surges
		- altered precipitation/run-off
		- ocean acidification
		- ENSO
		Seawater intrusion into freshwater lenses
		Soil salination
	Human-induced pressures	Growing population
		Land-use changes: coastward migration
		Land-use changes: agriculture growth
		Land-use changes: infrastructure growth
		Increased turbidity, nutrient loading, and chemical pollution
Vulnerability	Natural small island system	Morphodynamic
		Coastal landform:
		- beaches, rocky shorelines, and cliffed coasts
		- atoll and lagoon
		- sea grass
		- coral reef
		Forests
	Societal small island system	Freshwater resources (decline of water supply)
		Agriculture and fisheries
		Human settlement, infrastructure, and migration
		Biodiversity
Risk/Impact	Impact to natural coastal system	Coastal inundation (reduction in island size)
		Coastal erosion
		Coral bleaching
		Degradation of ecosystems
		Replacement of some local species
		Decreased fisheries and other marine-based resources
		Decrease in growth rates
	Impact to societal coastal system	Human deaths
		Property losses
		Business activities
		Human settlements
		Human activities
		Human health
		Loss of cultural heritage
		Reduces the amenity value for coastal users
		Recreation and tourism

The description above will be used to review the national-level documents according to the climate change stimuli, vulnerability, and impact as shown in *Annexes.*

In general, the results of document reviews on small islands aspect are similar to the ones on coastal systems and low-lying areas aspect. In specific manner, the SLRJ report has analyzed the projection of coastal inundation area due to sea level rise at a number of islands in the Seribu Islands.

All documents studied are very deficient in providing studies on vulnerability as well as risk and impact of natural small island system and societal small island system.

5. KEY INFORMATION ON EXISTING ADAPTATION MEASURES, TECHNOLOGY, AND FINANCING NEEDS

5.1 Introduction

The adaptation measures of climate change include plans, policies, and strategies being conducted by relevant institutions, which will then be followed by the needs of technology and financing. This chapter describes status and availability of these adaptation measures and needs.

5.2 Food Production Systems and Food Security

Measures

The IPCC AR4 has indicated that changing policies and institutions are one of important variables for assessing the adaptive capacity toward climate change, in which this issue must be integrated with development strategies and programs, country programs and the Poverty Reduction Strategy. The ICCSR-AS as a sectoral roadmap of agriculture sector in Indonesia has identified some changing policies occurring in the Ministry of Agriculture, where climate change has been mainstreamed into the development planning during the formulation of Medium-term Development Plan of that Ministry. Thus, the national government is compliant with the IPCC AR4 in that regard. However, with regard to the assessment of changing practices and locations by sector-wide actors, it is not discussed in the ICCSR-AS.

In Jakstra, some adaptations to climate change that are discussed have included local wisdom in rice planting pattern, the use of food technology such as variety of seed and irrigation system, and the promotion of non-rice cultivation, as indicators of changing practices mentioned in the IPCC AR4. Moreover, the Jakstra also discusses policy that would prevent further land conversion from agricultural land to non-agricultural such as by compensating farmers to maintain their rice cultivation. This is one example of changing policies mentioned in the IPCC AR4. The only thing that the Jakstra does not incorporate in its analysis is the indicator for changing locations, as studies on adaptive capacity in different latitude has not been done.

In the CC-F, several adaptation measures that are discussed are: food diversification, time and plant pattern, land intensification, as indicators for changing practices in the IPCC AR4; increasing production area by penning new rice field as an indicator for changing locations in the IPCC AR4; and the policy to support the above measures as an indicator for changing policies and institutions in the IPCC AR4.

Technology and financing needs

Indonesia has published a Technology Needs Assessment for climate change mitigation (BPPT, 2009), however we need to have another study to assess technology needs for climate change adaptation.

As part of ICCSR-AS study, a companion report to assess financing needs from adaptation strategies for agriculture sector has been partially completed (LPEM-UI, 2010). In that report adaption action plans toward climate change that have been formulated by the Ministry of Agriculture are as follows:

1. Development of climate information network system in the form of the Working Group and Command Post, Early Warning System, Climate Field School of Agriculture, and School of Integrated Crop Management Field (SLI-SLPTT)
2. Preparation of technical guidelines and tools, such as planting calendar atlases, general guidelines for agricultural cultivation in mountain land (Permentan No. 47/2006)
3. Development and improvement of agricultural infrastructure, such as JITUT (Farm Irrigation Network), JIDES (Village Irrigation Network), and others
4. Adjustment and diversification of cropping pattern according to climate condition
5. Assembly of technological innovations that are adaptive to climate change, such as drought-resistant crop varieties, one of which with pool-resistant rice variety(e.g. varieties of GH-TR-1, IR-69,502, IR7018, IR70213, IR70215), and salinity resistant; technology of water-efficient land management, and water conservation technology and rainwater harvesting
6. Institutional development related to climate change, such as the Working Group on Climate Variability and the Research and Development Consortium of Global Climate Change (KP3I)

Based on the champion programs for adaptation as outlined in the ICCSR-AS for agriculture sector for the next five years, it is estimated that the financing needs from national budgets is approximately Rp. 24.269 trillion.

5.3 Human Health

<u>Measures</u>

Adaptation to climate change in the health sector requires a variety of approaches, ranging from national, regional and international levels, and even individual adaptation. Adaptation measures in the health sector can also relate to the adaptation of other sectors, for example, measures to reduce urban heat and emission of ozone and other air pollutants should be included in a national energy conservation programs and transportation policy.

Evaluation is taken toward the implications (potential risks) of implementing strategies, policies and adaptation measures and their impact on health (short-term and long-term negative consequences). For example microdam and irrigation program in Ethiopia that was developed to increase the resistance to starvation, causing a local increase in mortality from malaria (IPCC).

In the ICCSR-HS report of health sector, adaptation strategies are developed in the forms of the efforts to increase the societies' and government's awareness, to develop the knowledge, and to develop the political commitment in the form of policy and law. These measures are divided into individual, central and local government, and NGO's or other institution role in reducing impacts of extreme climate events, such as floods, landslides, and storms; vector-borne diseases; water-borne diseases; and diseases related to air pollution. The report has also established the recommendation for adaptation strategies in the form of health adaptation program in the period of 20 years, from 2010 until 2030 which are divided into 5 years program phase.

The document of Jakstra and PIT-PI did not include the adaptation measures of climate change impacts on health sector. Whilst, the report of ICR has listed the plans for climate change adaptation in the nine sectors, including health sector. The adaptation plans are developed in the context of impact specific adaptation measures, which consist of impacts on vector-borne diseases, water-borne disease and malnutrition. The adaptation measures are divided into short- and long-term adaptation plans as shown in **Table 18**.

Table 18 Adaptation Plans on Health Sector (ICR)

Problems	Impacts	Proposed General Adaptation Program	
		Short term	Long term
1. Increase of vector density	Vector-borne diseases (malaria, DHF, filariosis, etc.)	- Disease surveillance - Case detection (active and passive) - Case holding - Case management - Vector control program (env. Manipulation & modification)	- Integrated Vector Management - Capacity Building - Health Promotion - Clinical Laboratory Improvement
2. Lack of clean water	Water-borne diseases (Diarrhea, Cholera, typhus, etc)	- Disease surveillance - Case detection (active and passive) - Case holding - Case management - Water Quality Control (Physical, chemist and microbiologist) - Water Quality improvement	- Capacity Building - Health Promotion - Environmental Laboratory Improvement - Regional Center Logistic preparation - Environmental health Laboratory Improvement
3. Lack of food	Malnutrition	- Addition food supply - Food Surveillance - Revitalized nutrition food into integrated health post - Village Awareness Program	- Capacity Building - Health Promotion - Healthy agriculture and veterinary

STRAPI report is the continuation of the ICCSR-HS, which further develops the adaptation strategies and policies, the organization of the work to be done in adaptation efforts, from central to local level. Indicators of success have also been set up in order to evaluate the adaptation measures effectiveness. The health sector strategies of adaptation to climate change, in the report, include:

a. Dissemination and advocacy on climate change health sector at central, provincial, district and sub-district levels, involving inter-related sectors (agriculture, forestry, marine, public works), NGOs and private sector
b. Mapping the populations and areas that are vulnerable to climate change in each region
c. Forming a system of health sector response to climate change
d. Preparing legislation based on community empowerment
e. Improving community access to facilities and health services, especially for regions vulnerable to climate change
f. Implementing training programs in climate change adaptation in the public health sector at all levels
g. Implementing programs to prevent and control disease due to climate change
h. Developing appropriate technology in an effort to adaptation due to climate change in accordance with local specific

<u>Technology and financing needs</u>

The study of technology and financing needs on the adaptation to climate change in health aspect has not been developed yet in Indonesia. However, according to the ICCSR-HS, adaptation to climate change in the health sector requires technologies such as:

a. Technology for Early Warning System that should be integrated with disaster response program of the local government

b. Technology for surveillans that can be conducted by simple method or high technology depending on human resource capacity and budget
c. Integrated Information System to support both systems above

5.4 Human Settlement Systems

This study also uses several indicators that are discussed in the IPCC AR4 along the line of Stimuli-Risk/Impact-Measures framework. Those indicators are as follow:

- Competence of individuals, communities, enterprises, and local governments
- Capacity of individuals, communities, enterprises, and local governments
- Access to financial resources of individuals, communities, enterprises, and local governments
- Access to other resources of individuals, communities, enterprises, and local governments
- Linkages with national and global systems

For adaptation measures, the Jakstra uses several indicators such as spontaneous adaptation through local wisdom, protection, relocation, urban design, by-laws regarding climate change impact, and existence of disaster mitigation agency, which correspond to indicators of adaptation discussed in the IPCC AR4 as listed above. Only for the indicators of access to financial resources and linkages to global and national system that are not used in that report. Thus, to some extent Jakstra has incorporated some indicators mentioned in the IPCC AR4, but there are other indicators that have not been incorporated. As for some indicators the rating of this report is complete and for some indicators is out of scope, the overall rating of Jakstra is incomplete.

5.5 Water Resources and Systems

<u>Existing adaptation measures</u>

Prior to review current adaptation measures to climate change in Indonesia, it is important to describe about what have been presented by the IPCC AR4 report on this component. The document presented in five headings, namely: (1) context for adaptation, (2) adaptation options in principle, (3) adaptation options in practice, (4) limits to adaptation and adaptive capacity, and (5) uncertainty and risk: decision-making under certainty. These five titles are then considered as indicators of the adaptation measures.

The context for adaptation is implemented by strategies of Integrated Water Resources Management (IWRM) that becomes the corresponding scientific paradigm for sustainable management of water resources and systems. This is because, as stated by the IPCC AR4, climate and water resources and systems are interconnected in complex ways where any change in one of these systems induces a change of the other. The strategies toward successful IWMR include capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems and including consideration of climate change.

For the second indicator, principle of adaptation strategies, the IPCC AR4 presented results of Technical Assistant Report (TAR) which drew a distinction between 'supply-side' and 'demand-side' adaptation option that applicable to a range of system. **Table 19** summaries some adaptation options for water resources designed to ensure supplies during average and drought conditions.

Table 19 Some Adaptation Options for Water Supply and Demand

Supply Side	Demand Side
Prospecting and extraction of groundwater	Improvement of water use efficiency by recycling water
Increasing storage capacity by building reservoirs and dams	Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method and area planted
Desalination of sea water	Reduction in water demand for irrigation by importing agricultural products, i.e. virtual water
Expansion of rain-water storage	Promotion of indigenous practices for sustainable water use
Removal of invasive non native vegetation from riparian areas	Expanded use of water markets to relocate water to highly valued uses
Water transfer	Expanded use of economic incentives including metering and pricing to encourage water conservation

Each side has a range of advantages and disadvantages, while relative benefits of different options depend on local circumstances. In general, supply-side choices tend to have adverse environmental consequences such as increase in storage capacity or abstraction from water courses. Some adaptation alternatives, such as desalination which involve pumping large volumes of water, use large amounts of energy and may be inconsistent with mitigation policy.

Third indicators are elaborated in the IPCC AR4 report by the important of physical feasibility and effectiveness of specific adaptation options in specific circumstances. Related to that, the importance of adaptation study of real water management system is also stated in the report. Whilst, the fourth indicator is explained more by four different types of limits on adaptation to change water quantity and quality, namely: (1) physical limit, (2) economic constraints, (3) political or social limits, and (4) capacity of water management. For the last indicator, there are two important descriptions in the IPCC AR4 document. First, that it is no longer appropriate to suppose that past hydrological conditions will continue into the future (a traditional assumption). Second, that due to climate change uncertainty, managers of water resources can no longer have confidence in single projections of the future.

At national level, general measures of adaptation are still in the form of policy and strategy, however, they have not yet implemented as real actions. However, a number of activities of sectoral governmental institution could be considered as efforts of adaptation measures, although they are originally not aimed to that. The other important effort on this theme, specifically in Indonesia, is so-called as local or traditional wisdom, which is what has been done by local people to adapt the climate change. For example, local wisdoms in the context of conservation of water, river, and their watershed are reported by the ICCSR-WS and VA Lombok-WS. These attempts have a significant value to be considered as real action of the adaptation measures and seemed to have potential importance to climate change adaptation.

In general, the ICCSR-WS document had discussed almost all of indicators of the adaptation measures of the AR4 report, except uncertainty and risk: decision-making under certainty. The document presented the strategies of balances between conservation and utilization, upstream and downstream, surface and ground water uses, demand and supply management, and the fulfillment of long-term and short-term interests in the water resources management. The descriptions of the document on the development policy for the water resources sector should aim at an efficient use of water resources to meet demands of households, urban areas and the industry. They can also be considered as adaptation options in principle.

The ICCSR-WS report also discussed about adaptation options in practice such as efficiency in the uses of irrigation water through optimization of irrigation techniques and improvement of irrigation management, especially at outside of Java Island. In the mean time, the current information on adaptive capacity as reported by the ICCSR-WS can be addressed as parts of the present adaptation measures. These are including confined aquifer and potential aquifers or groundwater basin, water infrastructures, the National Action on Forest and Land Rehabilitation (*Gerakan Nasional Rehabilitasi Hutan dan Lahan* or *GNRHL*), and the Clean River Program (*Program Kali Bersih* or *Prokasih*). Those activities need continuity and target-focused based on further researches and program directed to minimize or even avoid water shortage risks, flood and drought risks as well as landslide risks. Moreover, the ICCSR-WS report also gave recommendation to implement the Act No. 7/2004 as regulation and technical guidance for the management of water resources. This suggestion is aimed to strengthen adaptive capacity.

At last, the ICCSR-WS document included five priority programs for both long-term and mid-term development planning to be implemented in the seven regions of Sumatera, Java-Madura-Bali, Kalimantan, Sulawesi, Nusa Tenggara, Maluku and Papua. The programs for climate change adaptation on every five years of development in the period of 2010-2030 are briefly described as follows:

1. Vulnerability and risk assessment in regional level based on River Basin Agency (*Balai Wilayah Sungai* or BWS)
2. Increases of catchment capacity and water infrastructure to maintain water balance and to reduce hazards of water resources and systems
3. Increases of water availability at very vulnerable area by using appropriate technology and increases of local water resources
4. Increases of conservation and reduces of hazard intensity in water resources
5. Revitalization of local wisdoms, increases of capacity and people participation in adaptation to climate change impacts on water resources

Almost all of other reviewed documents have lacks of assessments of the adaptation measures in national level, i.e. RAN-MAPI, RAN-PI, ICR, and Jakstra, where each report merely contains one of the indicators, while the VA Lombok-WS has three of the indicators of adaptation measures.

The RAN-MAPI presented the development of new irrigation technologies for agricultural intensification (such as spray and drip irrigation for water savings) as one action of adaptations in practice. Furthermore, as in the ICCSR-WS, the RAN-MAPI also presents a number of action plans that significant as adaptation measures in the level strategy. Some of these plans are: to develop inventory of freshwater intake at the river and irrigation area that is predicted to have negative impact of sea level rise, to build *situ*, *embung* and dam being planned in the Government Work Plan (*Rencana Kerja Pemerintah* or RKP 2008) at Jawa, Sumatera, Sulawesi, Maluku, Bali and Nusa Tenggara, and to continue the water preservation program (*gerakan hemat air*) for all demand such as clean water for domestic use, agriculture, industry, electricity etc.

The RAN-PI document provides recommendations, e.g.: to conduct researches on technologies to treat sea water producing drinking water, and to develop technology of trenches dams in order to increase the river capacity. The ICR suggest the development of storages and inter-basin transfer of water from surplus to deficit regions to achieve optimal distribution and utilization of the water resources. The Jakstra concerns about the strategy of water-saving irrigation technology in areas expected to experience drought.

In the meantime, the VA Lombok-WS contains several recommendations, e.g.: to develop an integrated water resources management as main success parameter (context for adaptation), to maintain water balance both in urban and rural areas with equally distributional access to clean water (adaptation options in principle), and to develop technology to provide water supply based on the clean energy (adaptation options in practice).

The FGD of this study (Abdurahman et. al., 2010) gave remarkable information on the activities of WASPOLA (Water Supply and Sanitation Policy and Action Planning) from Bappenas and its partners. A brief concerning WASPOLA is presented in **Box 5**.

Box 5 Improvement of WASPOLA to Reduce Impact of Water Shortage

WASPOLA Facility (Water Supply and Sanitation Policy and Action Planning-Facility) is a national policy to arrange procurement of clean water and sanitation especially in rural area with the understanding that the water does not only become a social object, but also an economic object. The goal of WASPOLA Facility is to improve access for Indonesians, particularly the poor, to adequate and sustainable water supply and environmental sanitation (WSES) services.

One program of WASPOLA Facility is WASPOLA that is a 5-years-period program including: learning process, policy arrangement and activity action to provide the facility of clean water and sanitation of settlements of small and medium scales. The program is conducted by the government with funding from AusAID (Australia) and the World Bank, through Water and Sanitation Program for East Asia and the Pacific (WSP-EAP).

One of WASPOLA implementation is *ProAIR* program. The goal of this program is improving rural communities to gain capacity in managing their developed facility of clean water and sanitation on a self-supporting basis. This program has successfully been implemented in several regions in Nusa Tenggara Timur (NTT) which has critical condition of clean water (Ahas, 2009).

The FGD of this study (by Sobirin) also highlighted the local wisdoms as an important effort for the climate change adaptation in Indonesia especially ones that deal with conservation of water, river, and their watershed. The resource person suggested four issues related to the local wisdom i.e.: 1) method of local wisdom to be ready for modeling and prediction, 2) method of local wisdom for management of flood and drought, 3) method of local wisdom for management of forestry, agriculture, and land; and 4) method for the adaptation based on local wisdom.

Importance of the local wisdoms in water resources and systems aspect also adopted in the ICCSR-WS report that are stated in three parts of this report. First, it is presented in Chapter 2 that is considered as one of important cross-cutting issues on water management. Second, practices of local wisdoms that are found in all regions of Indonesia are proposed to be part of adaptive capacity (Chapter 3) to reduce vulnerability of water sector to climate change impacts. Third, local wisdom issue is proposed as one of five programs of the adaptation strategies on water sector in Indonesia as described above (see also
Table 20).

Table 20 Some of local wisdoms that are still exist and play the roles on water conservation in Indonesia being considered as the adaptation measures of climate change. Source: the ICCSR-WS with modification

Local Wisdom	Activity	Location
Anjir and Handil	Converting swamp area into agriculture	Banjarmasin (Kalimantan Selatan)
Rimbo larangan	Forest, land, and water preservation	Sumatera Barat
Banda larangan		
Lubuk larangan	Determine river basin	Tapanuli Selatan (Sumatera Utara)
Awing-awing	Forest management and preservation in parallel to water management or conservation	Bali
Repong damar		Lampung
Rimbo penghulu		Jambi
Hutan tutupan		Kalimantan Selatan
Hutan kemenyan		Sumatera Utara
Hutan nagari		Sumatera Barat
Awig-awing	Water resources management and protection	Lombok (Nusa Tenggara Barat)
Eras geniut		

For further elaboration, the other activities of government institutions can be considered as two types of current adaptation measures. There are soft adaptation (in the form of work plans or researches) and hard adaptation (although it was formerly not intended for adaptation in the context of climate change impact). An example of the first activities is the governmental work plan (*Rencana Kerja Pemerintah* or *RKP*) of Ministry of Public Work (MPW) in year 2010-2014. The work plan could be compared to the IWRM from the IPCC AR4 as in **Table 21**, however, the work plan becomes potential to be improved to approach the IWRM strategies.

Table 21 Comparison between the IWRM Strategies and Work Plan of MPW

No.	IWRM strategies in IPCC AR4	Work Plan of MPW 2010-2014
1	Capturing society's views	
2	Reshaping planning processes	
3	Coordinating land and water resources management	a. Development/improvement of irrigation networks b. Development of reservoir, *embung*, *situ*, and other water reservoir construction c. Development of infrastructure for taking and bearer channels of raw water
4	Recognizing water quantity and quality linkages	
5	Conjunctive use of surface water and groundwater	Development of groundwater irrigation infrastructure
6	Protecting and restoring natural systems and including consideration of climate change	

Note: MPW = Ministry of Public Works

Among governmental research activities, which can be considered as the adaptation measures, are water harvesting technology and recharged well technology. An example of the first type of measures is conducted by the State Ministry of Environment in 1996 that followed up Agenda 21 of Rio de Janeiro in 1992. Water harvesting technology or technology of rain water harvesting is developed in dry region such as region of Nusa Tenggara Timur (NTT) province that are developed by the Department of Transmigration and the Agriculture Research and Development Agency of Ministry of Agriculture (*Balitbang Pertanian, Kementerian Pertanian*).

Meanwhile, research and development concerning recharged well technology (*teknologi sumur resapan*) and modeling of artificial groundwater recharge in order to maintain groundwater availability also belong to current adaptation in the form of soft technology for adaptation. The implementation of these technologies and dissemination of the successful ones to all significant regions will become hard technology of the adaptation measures. Some types of appropriate technology of recharged well have been introduced (Soenarto and Hutasoit, 2008). While modeling for artificial groundwater recharge has been investigated in greater Bandung basin by Bureau of Mining and Energy of Government of West Java Province (Hutasoit, 2009). This modeling research includes identification of scenarios of groundwater availability to supply water need with and without artificial groundwater recharge in the basin till year of 2013.

Some other governmental institutions conduct real activities of adaptation measures that are reviewed. Examples are activities of MPW, mostly under the General Directorate of Water Resource (GDWR) in improving water availability, activities of Centre for Geological Environment (CGE), Geological Agency (GA), Ministry of Energy and Mineral Resources (MEMR) in developing groundwater for freshwater resource, activities of Ministry of Forestry (MoF) concerning to forest and land rehabilitation, and activities of Ministry of Environment (MoE) in improving the quality of river.

In general, it can be said that there are very limited actions have been implemented in Indonesia about adaptation measures. Indonesia has also lack of study on conceptual framework of adaptation measure; therefore, it is difficult to conduct the plan of adaptation measures in a region. As the implication, the availability of report dealing with the current adaptation measure is also very rare. However, some current activities or planned activities conducted by the government institutions could be stepped into adaptation measure in action. It means that those activities could be easily transformed into actions of the adaptation measures through reevaluating, refocusing, and redirecting of the activities based on vulnerability assessment in each authority, plan, location and region.

In the mean time, the activities of governmental institution that can be stepped into adaptation measure in action are WASPOLA activities from Bappenas and related institutions as its stakeholders. Other activities in this category are stated in RKP of GDWR, MPW, year 2010 in the form of development of irrigation networks, reservoir, *embung*, *situ*, and other water reservoir construction such as groundwater irrigation and other related infrastructures. These activities included building three new dams in year 2010 for preventing the water shortage impact as response actions to climate change assessment (see the ICCSR-WS). The other activities in this category are activities of GA namely: "supplying freshwater facility by mean of groundwater development in the region with water scarcity", *GNRHL* activities from MoF, and *Prokasih* activities from MoE.

Technology and Financing Needs

In short, the technology needed for the adaptation divided in two types, namely technology for the soft adaptation and technology for the hard adaptation. The first type is including technology for policy development, planning, dissemination, assessment, development of database and information all in the context of the adaptation measures. While the second type is covering all construction development in the context of the adaptation measures such as development of dam for avoiding flood as well as conserving water resources; and bore hole construction for providing water resources, etc. The financing need follow the technology and activity needs for the adaptation.

Until now there is also not much information available concerning assessment of technology and financing need for the adaptation measures in national level. However, a number of technology need and financing need can be identified based on the recent policy, strategy, action plan, and other significant sources as responses to climate change issues, for instance: the RKP or work plan of government of relevant institution, the result of the ICCSR-WS, etc.

Technologies of soft adaptation needed could be proposed, for example: method for predicting change of land use in the future; method for calculating water balance in various conditions of hydrometeorology, hydrology and hydrogeology of Indonesia region; method for calculating the quantity and distribution of water resources, water availability, water need and budget (comparison between water availability and water need); technology for improvement irrigation management.

Related to technology of hard adaptation, it is clear that all developments targets contain significant benefits for the adaptation such as activities of RKP year 2010 of DGWR, MPW. Principally, needed technologies of hard adaptation are emerged from the results of other studies of climate change impact on water resources. As summary, a list of technology needed for the hard adaptation is presented below for example:

1. Technology for water infrastructure development including: i) development or improvement of irrigation network, ii) development or improvement of groundwater irrigation infrastructure; iii) development of reservoir, *embung*, *situ*, and other water reservoir construction (RKP year 2010 and 2010-2014 of DGWR, MPM)
2. Technology for groundwater development for providing fresh water resource in the water-scarcities region (RKP year 2010 and 2010-2014 of GA, MEMR)
3. Technology for agricultural intensification (such as spray and drip irrigation for water savings (RAN-MAPI)
4. Technology for desalination of sea water and recycle water for drinking water and other domestic uses (RAN-PI)
5. Technology of dam trenches to increase river capacity (RAN-PI)
6. Technology for creation of storages and inter-basin transfer of water from surplus to deficit regions for achieving more equitable distribution of water wealth and its optimal utilization (ICR)
7. Technology of water-saving irrigation in areas expected to experience drought (Jakstra)
8. Technology for others relevant hard adaptation such as: improvement of WASPOLA, implementation of water harvesting, well recharge and artificial groundwater recharge
9. Technology for optimal implementation of *GNRHL* and *Prokasih* including their monitoring and evaluation

On the financing need for the adaptation, the information is more limited. As a representation, this study refers to the result of cost-benefit analysis (CBA) that has been studied in parallel to the ICCSR-WS study. The CBA study tried to calculate cost and benefit of the adaptation in water sector. The bases of calculation are comparison of the water availability and its cost among scenarios of business as usual (BaU), Work Plan of Government of MPW year 2010 (RKP), and climate change (see **Box 6**).

Box 6 A Case of Financing Need: Develop Reservoir to Maintain Water Availability

The CBA study focused on the impact of water availability for household (water for drinking, washing, and cooking) and agriculture (water for paddy field). This study applied three scenarios to gain cost and benefit of the MPW programs related to the adaptation in year 2010-2014. These scenarios are BaU, RKP, and climate change, which are regionally based on Agency of Watershed (*Balai Wilayah Sungai-BWS*).

The BAU scenario assumed that there is no adaptation program undertaken to face the impact or the risks of climate change. Hence, items of rehabilitation, operation, and maintenance in the RKP are assumed to be BAU condition. The RKP scenario, in practice, consists of all activities in the RKP that involve development of new water infrastructures, which are belong to the champion programs from the ICCSR-WS. Those activities also have been planned by MPW since 2009; unfortunately, they had not been associated with climate change. Meanwhile, the climate change scenarios are additional plans to build three new dams as a response to climate change assessment. The three new planned dams are the Lausimeme Dam in Deli Serdang District, North Sumatra (BWS Sumatera 2), Passeloreng DAM in Wajo District, South Sulawesi (BWS Pompengan), and Pandanduri DAM in East Lombok District, West Nusa Tenggara (BWS Nusa Tenggara I).

There is no any explanation on the total budgeted cost in 2010 for the BAU scenario. In the mean time the total cost for RKP scenario in year 2010 is around IDR 2.44 trillion, in which 1.41% (IDR 0.34 trillion) of it is used for goods expenditure and 98.59% (IDR 2.4 trillion) is for capital expenditure. With the assumption that the development of an infrastructure will be finished in five years, if the construction begins in early 2010, it will be finished by the end of year 2014. With the assumption (used for proxy and simplification) that the amount of development costs in each year is constant, so the amount of cost required for five years is IDR 12,192,818,368,000 (five times the cost of year 2010). While the cost of climate change scenario (the building three new dams) is around IDR 2.44 trillion rupiahs, in which 1.41% (IDR 0.34 trillion) of it is for good expenditure and 98.59% (IDR 2.4 trillion for capital expenditure. So the total cost incurred for the water sector adaptation program is the cost of infrastructure development plan in RKP 2010 plus the cost of building new dams in 3 BWS. Total cost for 5 years (2010-2014) for the adaptation is IDR 14,662,678,368,000.

CBA study that was conducted in parallel with the ICCSR-WS study could be estimated amount of water availability and changes in year 2005 – 2029. Without any construction, in year 2010-2014, there is a decline in the amount of water in a relatively large amount of 34,091.41 million m3 from 2005-2009 periods. In year 2015-2019, there will still be a decline in the amount of water but in a smaller amount of 2,048.35 m3. Even in year 2020-2024 and 2025-2029, there will be an increase in the amount of water. Occurrence of water availability fluctuations in this scenario is mainly due to season difference in each period (LPEM-UI, 2010).

As summary, it is clear that information concerning technology and financing needs of climate change adaptation in Indonesia is generally not available. However, references for identifying this technology and financing needs still can be traced by following the recommendation of those studies and information concerning the current adaptation measures in Indonesia. For instance, policies and strategies as recommended by the ICCSR-WS, RAN-MAPI and other documents need appropriate technologies for both hard and soft adaptations. Other examples are technology needs in implementing or continuing the activities of WASPOLA, RKP of GDWR, MPW, groundwater development from GA, MEMR, GNRHL from MoF, and Prokasih from MoE. All these technologies still need research and assessment to finally be implemented in the theme of technology need for the adaptation measures in Indonesia. Meanwhile, for the financing need, it will basically follow the selected activities and their technology to be implemented in adaptation measures. As an example, in this case, a calculation of financing need from the CBA study is further elaborated. This work of CBA, can be considered as starting point to further research on theme of financing need for the adaptations measures, although it involved some simplifications and assumptions. Hence, the financial need for the adaptations measures in Indonesia also becomes subject to be further investigated.

5.6 Coastal Areas, Oceans, and Small Islands

5.6.1 Coastal Systems and Low-Lying Areas

Adaptation forces can be used to against sea level rise (e.g., global sea level rise, storm surges, and tidal surges) that potentially inundates the coastal system and low-lying areas. These adaptation measures are classified as: to protect coastal areas, to accommodate hazard, and to retreat the coastal line as recommended in the IPCC AR4 based on the concept of Coastal Zone Management Strategy (IPCC CZMS), as shown in **Figure 10**.

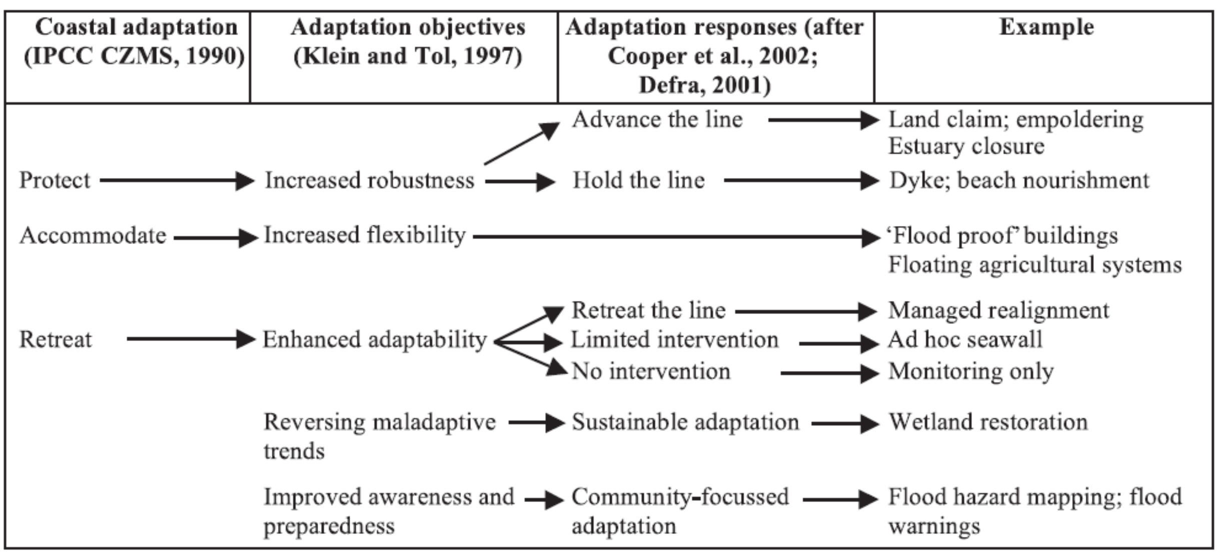

Figure 10 Evolution of Planned Coastal Adaptation Practices (ICCSR, 2010)

Furthermore, these adaptation measures also involve technologies that especially are used in protecting coastal areas as follows:

- Hard protection, which is coastal protection by building structure such as sea wall, dike, breakwater, offshore break water, estuary closer, etc.
- Soft protection, which is protecting and increasing the ability of natural protector such as maintaining coral reef, dune, and coastal forests (mangrove and coastal trees)
- Hybrid, which is the combination of hard and soft protections

As an effect, technology used in anticipating hazards caused by climate change, particularly sea level rise, is very relying to the purpose of the adaptation, material values, and the type of regions which must be protected. Moreover, considerations of technology needs also includes hazard level, vulnerability, and its potential impact to human and environment, as well as the cost and benefit analysis results. Besides, technology needs also depend on resources (i.e., budget and available technology) so that they can be used for indicators to measure current ability in adapting the disaster potential due to climate change.

From the analysis of available documents, we know that a few initiatives has been carried out in implementing the above adaptation methods, such as elevation increases of the road to the Soekarno-Hatta International Airport, sea-walls and breakwaters to protect coastal areas, as well as mangrove and coastal forests planting in some regions.

However, the ICCSR-MFS document has conceptually but quite comprehensively described the strategy to adapt the impacts and risks of climate changes as a part of national planning program, which is also supported by the national-scale risk maps. This adaptation strategy also consists of technology, i.e., "*Elevation adjustments and strengthening the structures of buildings and vital facilities in coastal zones related to climate change*".

5.6.2 Oceans and Shallow Seas

According to the IPCC AR4, adaptation responses to climate change in oceans and shallow seas usually include:

- Autonomous way, which is independent and self directed in facing hazard and impact climate change
- Reactive way, e.g. by improving resilience
- Anticipatory adaptive way, i.e., by:
  - reducing and managing stresses on species and ecosystems against habitat destruction, over-exploitation, eutrophication, and acidification
  - maintaining connectivity of diverse population and small and isolated population

Technologies are used in anticipating climate change impact to oceans and shallow seas, i.e.:

- In data collections of dynamic, physical, biological, and sea chemistry parameters
- In mapping of parameters and its future projections, such as mapping of fishing ground and fish migration pattern due to changing of its ecosystem
- In supplies of SOP (standard operating and procedure), such as readiness of the fishery system (boats, cold-chains, etc.) and marine-culture system to anticipate climate changes
- In development of technology to increase alternative livelihoods

This study reveals that even none of these types of adaptation measures (including technology and financing needs) have been studied in Indonesia so far, except ICCSR-MFS and RAN-PI in limited scopes. The first discusses autonomous and reactive adaptations, ocean regulations, while second examines ocean regulations, capacity strengthening strategies, and the links between adaptation and mitigation, although all topics are incomplete.

5.6.3 Small Islands

Adaptation measures to anticipate impacts of climate changes in small island aspect are principally similar to ones in coastal systems and low-lying areas aspect, especially in themes of protect and accommodate. Exceptions are taken for some items in retreat that need to be abandoned, considering the limited areas of small islands. Meanwhile, some treatment methods in adaption for small islands are same as ones for oceans and shallow seas, such as autonomous, reactive, and anticipatory adaptive methods.

The technology needs for this aspect are also same with ones in coastal systems and low-lying areas aspect, which are hard, soft, and hybrid protections for coastlines and the coastal areas. In regard that many small islands are surrounded by oceans and shallow seas, the needs of technology for climate change adaptation for the two aspects are also similar.

An important need in anticipating the decrease of quantity of clean water (drinking water) in small islands is the sea water filtering technology. Therefore, sabo dam technology has limited implementation due to inadequate area of small islands.

The implementation of renewable energy technology such as energy alternatives from ocean (OTEC, ocean current energy, tide energy) as well as from wind and solar are very suggested in term of climate change adaptation.

As previous statements, the analyses of economy (CBA) and socio-economic are important elements in deciding policy to choose the technology alternatives in climate change adaptation in small islands.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 General

In general, the study concluded that there is still a big gap between several studies related to climate change issues as initiated by many institutions in Indonesia compared to the IPCC AR4 report. For science basis, there are lacks of current efforts to understand about how the global climate changes also occur in Indonesian region and climate change impacts on various aspects. As a result of limited understanding of climate change in Indonesia, many institutions still perform a relatively small number of adaptation actions to anticipate the changes of climate and their collateral hazards in Indonesia.

Related to the conditions above, this study suggests the relevant institutions in Indonesia to enhance studies on science basis in Indonesia, especially on some indicators that are still missed compared to the science basis reported within the IPCC AR4. Therefore, it is also suggested to launch two publications that contain two specific themes, i.e.:

1. A synthesis of this report with focuses on information of state of the art, gap analysis, and adaptation priorities based on the review of the existing available documents on adaptation science and policy
2. a synthesis of scientific information on climate change issues in Indonesia including future climate projection and climate risk assessment at the province level, especially for the high risk regions

The publications could be made in the form of books, in order to disseminate and to facilitate communication between policy makers, scientists and societies.

To enhance the efforts on climate change adaptation measures in almost all sector, it is significant to refer to the recent results and commitments in international level, i.e., the IPCC AR5 and IPCC AR4 reports. According to these documents, the adaptation measures can be conducted systematically with classification of water resources and systems, coastal areas, ocean, and small islands, food production systems and food security, human health, as well as human settlement systems.

Following the sectoral impacts approach of the climate risk assessment as presented in the AR4 report, Indonesia has initiated a number of climate change impact assessments. However, the methodology and scope of assessment applied still need further improvement as indicated throughout this report. Several recommended activities to follow up this study include:

a. To formulate adaptation actions and to integrate them into the development planning at local levels (Province/City/District) for years 2012-2014 as the basis for implementation of adaptation actions for the next phase of 2015 onward
b. To address cross-sectoral issues such as food security, energy security, spatial planning, human security, infrastructures and settlement development
c. To harmonize among the regulations related to climate change such as Act No 32 of 2009 on Environmental Protection and Management, Act No 26 of 2007 on Spatial Use Management, Act 24 of2007 on Disaster Management)
d. To synchronize and clarify the tasks and functions among government institutions dealing with climate change policy in Indonesia, especially Bappenas, DNPI, and KLH
e. To conduct technological and financial needs assessment for climate change adaptation

6.2 Science Basis

Recent studies on science basis for understanding the climate change in Indonesia are very limited. Some indications are:

a. Still less climate change parameters are investigated in comparison to the IPCC's indicators
b. Less climate models with high spatial resolution and long term projection are run
c. Lack of well documented, spatially distributed, and long term measured data are observed

In principle, more advance studies are needed in the near future to enhance the contribution of the relevant science as basis for understanding the climate change. Combinations of observations, data analysis, as well as modeling and projections could be utilized to conduct such researches.

These studies could address the directions or subjects in accordance to the indicators derived from the IPCC AR4 and the outline of AR5 reports. Some of these indicators are even not investigated yet but critical as well, such as carbon and other biochemical properties in atmosphere and oceans, clouds and aerosols, extreme climatic events (IOD, ENSO), as well as paleoclimate archives and cryosphere observations.

Success of these scientific efforts will mainly depend on policies related to capacity building on science basis of climate change as follows:

a. Development and enhancement of networking of related experts and institutions as priorities of climate change science basis in Indonesia at least for phase 2015 onward
b. Designing research policies and directions for climate change in Indonesia according to the gap analysis to the indicators derived from the latest IPCC reports as the benchmark; these studies are aimed not only to fulfill the needs of climate change adaptation
c. Facilitation of scientific groups to review and assess the climate change models that are currently available in international communities, and to disseminate the recommendation to stakeholders. These results have benefits, for example:
    - To make decision upon funding allocation, whether to buy a packaged, customized model software but expensive or an open, cheap source of model but need of expertise manpower
    - To fulfill science basis for climate change adaptation measures at sector and local levels
d. Development and coordination of data sharing related to climate change between experts and institutions, which is probably initiated by sharing of metadata

6.3 Food Production Systems and Food Security

The three reports assessed in this study (ICCSR-AS, Jakstra, and CC-F) suggest that for vulnerability analysis as well as the measurement of adaptive capacity with regard to food security, the three reports have incorporated most indicators used in global studies as indicated in the IPCC AR4 report. This is regardless that the focus of two earlier reports is only on agriculture and specifically rice as the main staple food of Indonesia, and only the third report that specifically addresses the food production. Moreover, both earlier reports have not included many projections that are mentioned in the IPCC AR4 report as listed above. Therefore, the rating of both reports is incomplete, due to lack of coverage of other food product, as well as the missing projections. Meanwhile, the third report has relatively conducted more analysis in accordance with the IPCC AR4, although it is not as thorough as this document. Thus, its overall rating is also incomplete but with degree of completion higher than the two earlier reports. Finally, all reports have an extra point as they use additional data in its analysis, compared to what the IPCC AR4 report has, i.e. the inclusion of sea level rise (in ICCSR-AS and CC-F) and land conversion (in Jakstra) as factors for crop loss. This can be a significant contribution to the upcoming IPCC AR5 report.

As recommendation, this study would suggest that more studies to be conducted in the next few years, especially aimed at making contribution to the IPCC AR5 preparation, either in terms of using other indicators that have not been used for Indonesia, or by conducting studies for different regions/parts of Indonesia to enrich studies on the impact of climate change on Indonesia's food production. Moreover, it has to be realized that food security is not only determined by a good food production system, it has to be supported by a good distribution system as well. Therefore, further study to analyze food distribution system in Indonesia is also recommended.

6.4 Human Health

According to the indicators stated in IPCC AR4, we found that ICCSR-HS report is rated as more complete than the others. However, each of other documents has specific objective, for example the STRAPI specifically describe the SOP (standard operating and procedures) to implement adaptation action of the health sector as well as the arrangement of the organization system for carrying out the action in the Ministry of Health, both in national and regional/local level. Other reports, such as Jakstra, PIT-PI, and ICR have included study of climate change impact on human health, but not in exclusive discussion.

Almost all of the documents, except for the STRAPI report, have described the direct stimuli. In the case of indirect stimuli, however, none of the documents have fully described the effects the modifying conditions of aspects of climate change on human health.

Description and calculation of vulnerability factors has been discussed in detailed manner for some provinces in the Jakstra report. The ICCSR-HS performed the calculation of vulnerability in national scale, especially for malaria, DHF and diarrhea. Nevertheless, the availability of the data of vulnerability factors in Indonesia is still limited.

In Indonesia, a comprehensive study of climate change impacts on human health is also still lacking. The impacts on vector-borne diseases (malaria and DHF) and water-borne disease (diarrhea) have been specifically studied in the ICCSR-HS report. Other documents have briefly mentioned the impacts of heat (temperature-related mortality and morbidity), disasters (winds, storms and floods) and malnutrition (drought, nutrition, and food security), but only in the form of general description. Meanwhile other impacts on human health, i.e., food poisoning (food safety), allergenic diseases (aeroallergens and disease), and ultraviolet-induced diseases (ultraviolet radiation and health), have not been studied yet in Indonesia.

The adaptation measures to climate change impacts on human health in Indonesia is currently still at the level of preparation of the adaptation step guideline. ICCSR-HS report has made the guidelines of adaptation measures for national and regional level (province) spanning to the next 20 years, divided into the five years periods. In addition, the STRAPI report has established the policies and strategies of adaptation, and the organization starting from central to local levels. This report also provides the success parameters of the adaptation strategies implementation that can be used as evaluation materials for preparing better and more efficient adaptation measures.

As a result, it is important to develop impact-specific adaptation measures in order to be well targeted and efficient, which have been carried out in the ICR report for vector-borne and water-borne diseases as well as malnutrition. In general, study on adaptation of human health with integrated and multi-sectoral approach as well as the limits to adaptation measures and the implications of adaptation policies and strategies are needed. These studies on adaptation have to consider many impact of climate change such as heat (temperature-related mortality and morbidity), disasters (winds, storms and floods), malnutrition (drought, nutrition, and food security), food poisoning (food safety), allergenic diseases (aeroallergens and disease), and ultraviolet-induced diseases (ultraviolet radiation). They also should regard the actual impacts of climate change on human health in geographical manner, regional and local level.

Moreover, since the impacts of climate change on health are complex problems involving many parties, the coordination, organizational and institutional aspects becomes very important, for example the cooperation between the climatology data provider (BMKG) and the health sector practitioners for data collection and surveillance system. Cross cutting issues are also critical, e.g., problems of water-borne disease with water sector and malnutrition with agricultural sector.

Finally, because many indicators of adaptation measures in the IPCC AR4 and AR5 reports have not been elaborated by documents in national level, it is necessary to develop guideline of the measures both in national, regional and local levels. The guideline should follow the science basis results in order to prevent mal-adaptation and over adaptation.

6.5 Human Settlement Systems

As previously mentioned, the only available document that can be classified as assessing the impact of climate change on human settlement systems is the Jakstra document, produced by the Directorate General for Spatial Planning, Ministry of Public Works. As of eleven indicators assessed (see Table of Human Settlement Systems in *Annexes*), only four indicators under the category of vulnerability/risk are available and rated as incomplete i.e. specific geographic context, specific sectoral context, specific social context, high risk locations. The indicators classified as stimuli i.e. increases in mean temperatures, intensity of extreme events, frequency of extreme events and interaction with other non-climate sources of change are not available at all. The three other indicators (climate-sensitive resource economy, social economic cost and poor community) under the category of risk are also not available.

Based on the result of the gap analysis presented above and as there is only one study available for the review, it suggests that study on the impact of climate change on settlement, in Indonesia still needs to be further enhanced in the near future. However, recent development in this field seems to be more promising. For an example, an international conference on cities and climate change was just organized in Solo. In addition, the Indonesian Planners Association also will host an international conference on climate change and urbanization in November this year. Currently, the Directorate General on Spatial Planning has just started a study on vulnerability assessment to climate change for regional development. One of the sectors to be assessed is urban settlement. The Mercy Corps Indonesia, a UK based NGO, has also initiated a vulnerability assessment in the cities of Semarang and Bandar Lampung. The “Paklim”, a joint project between the Ministry of Environment and GTZ, Germany, has implemented an integrated adaptation and mitigation study in several cities in Java. However, to further enhance the adaptive capacity of urban areas all over Indonesia, the Working Group of Adaptation under the DNPI should take a lead to coordinate all these initiatives as well as to facilitate the replication of the most suitable method of vulnerability assessment into other vulnerable urban areas.

6.6 Water Resources and Systems

In general, systematic and integrated supports of researches as well as data and information on the climate change adaptation in the water resources and systems aspect are not sufficiently available in Indonesia. This situation is represented by facts that this study has found several gaps attached to the national-level documents of climate change study on hazard, vulnerability, risk/impact, and adaptation of the water resources and systems in comparison to the IPCC AR4 report as the benchmark. In the stimuli components, all indicators have been investigated completely by available documents (ICCSR-WS, VA Lombok-WS, RAN-MAPI, RAN-PI, ICR, and Jakstra); although some reports have been rated as incomplete.

With regard to the IPCC AR4, in general, only the ICCSR-WS report has all of indicators of vulnerability, risk/impact, and adaptation measures almost completely. Specific to the vulnerability component, the VA Lombok-WS report has performed almost similar in comparison to the ICCSR-WS. Meanwhile, the other documents generally have missing in the indicators of vulnerability.

The indicators of current vulnerability and risks/impacts that had not been reviewed yet by all available documents are erosion and sediment transport; while the indicators that were mostly investigated by all of these documents are flood and drought, although they are not as thorough as in the IPCC AR4 report. Besides, all of the documents had also not considered uncertainty as an indicator of adaptation measure, however, it is interesting that all documents assessed in this study had reported adaptation options in practice that consist of policies, strategies, and researches, e.g. to implement appropriate technologies for both hard and soft adaptations.

The ICCSR-WS and VA Lombok-WS reports also introduced indicators of vulnerability that had not described by the IPCC AR4 report, i.e. the landslide and traditional or local wisdom. More specifically, the ICCSR-WS report had involved the strategy of integrated water resource management (IWRM) as an important elaboration of indicator of adaptation. In addition, the two reports had used the tool of geographic information system (GIS) and projection. Hence, these two documents could be used as a benchmark to initiate the adaptation measures to climate change, both at the level of research, policy and strategy in Indonesia, although both studies were still incomplete.

Concerning to the technology need for adaptation measures, there is no document that considers this subject, while the financing need is provided, in limited information, by the CBA study. This study suggested that an analysis of the financing need should consider collaterals benefits of the selected adaptations measures.

This study also assessed several recent other studies or report activities, that contained significant information for adaptation measures in the context of Indonesia. The CBA study had implemented the cost and benefit analysis method to estimate the financing need for adaptation measures. There are also studies of low flow in the Bengawan Solo watershed; the method of Release Demand Ratio (RDR) as indicator of distribution of water allocation in a watershed (with case of the Renggung Watershed, Lombok); technology of rain water harvesting, technology and modeling of artificial groundwater recharge. Some adaptation actions Indonesia can also be reported, although most of them were originally not aimed for climate change study, such as WASPOLA activities, development of irrigation networks and groundwater for irrigation; reservoir, *embung*, *situ*, and other water reservoir constructions, and water infrastructures.

As recommendation, this study suggests still more studies to be conducted in climate change issues on water resources and system in Indonesia. In principle, these studies have to focus on the indicators of IPCC AR4 report that have not been elaborated by available studies in Indonesia. This effort is also aimed to make contribution to the IPCC AR5 preparation, either to elaborate additional indicators that have specifically been used in Indonesia, or to complete studies for different regions/parts of Indonesia.

Hence, the next studies are recommended to: 1) perform an integrated approach between meteorology and hydrology in the context of climate change adaptation; 2) conduct more detail assessment in the indicators that have incomplete and missing ratings, especially science basis research related to vulnerability, risk/impacts, and adaptation measures in water resources and systems in meso-regional scale and micro-district/city scales to figure out a better adaptation strategies. Also, the next study is recommended to: 3) strengthen inter-institutional roles in researches to solve cross-cutting issues; 4) enhance and revitalize the capabilities of local wisdoms in order to be implemented for adaptation measures of climate change in scientific manner; 5) synchronize policies and strategies of the adaptation measures based on the hydrology of catchment area of the surface water (*Daerah Aliran Sungai-DAS* or *Wilayah Sungai-WS*) and conjunctive to hydrogeology and hydrometeorology; 6) implement the vulnerability studies on pollutant emissions, urbanization, water and wastewater treatments, erosion, and sediment transport; and 7) apply the integrated water resource management (IWRM) that is supported by comprehensive studies of adaptation.

6.7 Coastal Areas, Oceans, and Small Islands

In general, all documents assessed in this study reported that almost all indicators in the IPCC AR4 had been performed in the sub-aspect of coastal systems and low-lying areas, although many of the indicators have been rated as incomplete. All documents have missing information especially in the themes of vulnerability and impact of societal coastal system, as well as cost and benefit of adaptation and the link between adaptation and mitigation.

In the sub-aspects oceans and shallow seas, almost all documents are rated as incomplete in human induced pressures stimuli and vulnerability components. They, even, have missed description in the components of risk/impact and adaptation measures. Quite similar situation occurs in the sub-aspect of small islands: just few documents have complete rating. Coastal inundation becomes a significant indicator that has been assessed by almost all documents.

In this aspect, the ICCSR-MFS plays a significant role that adaptation measures of climate change had been mainstreamed into the national development planning. This effort should be continued to implement at the province and district/city levels for all Indonesian region such as the VA Lombok-CMS report at the Lombok Island and Mataram City as well as the CSI report at several coastal cities of northern coast of the Java Island. Meanwhile, efforts by other documents in national levels, e.g., ICR and RAN-MAPI, had presented studies on adaptation plans, however they are still in the form of general description.

Regrettably, there is none of the documents explaining the stimuli related to the increase of CO_2, altered precipitation, and ocean acidification as well as their impacts to coastal areas, oceans, and small islands. Also, there are no reports that provide study on climate change impacts and adaptation measures specifically to the environments of oceans, shallow seas, and small islands.

At last, the ICCSR-MFS document could become a benchmark in national level to conduct studies and implementations of climate change adaptation measures in the future. Adaptation measures are mainly directed to against some climate change impacts, which are recently represented as coastal erosion and inundation. In this context, local factors should also be considered such as land subsidence and socio-economic conditions.

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