Synthesis Report

Risk and Adaptation Assessment to Climate Change in Lombok Island, West Nusa Tenggara Province

COOPERATION REPUBLIC OF INDONESIA FEDERAL REPUBLIC OF GERMANY

gtz

WWF

AUTHORS

Adviser
Prof. Dr. Ir. Gusti Muhammad Hatta, MS., Minister of Environment

Editor in Chief
Dra. Masnellyarti Hilman, MSc., Deputy Minister for Conservation of Natural Resource and Environmental Damage Control, Ministry of Environment

Coordinator
Assistant to the Deputy for Climate Change Impact Control, Ministry of Environment

Ministry of Environment Team
Dadang Hilman
Agus Gunawan
Yulia Suryanti
Sabitah Irwani
Gatot Setiawan

GTZ Team
Heiner von Luepke
Tilman Hertz
Chandra Panjiwibowo
Katryn Pasaribu

Expert Team Coordinator	: Djoko Santoso Abi Suroso Ph.D
Atmosphere Expert	: Dr. Tri Wahyu Hadi
Ocean Climathology Expert	: Dr. Ibnu Sofian
Marine Expert	: Dr. Hamzah Latief
Water Resource Expert	: Dr. Oman Abdurahman
Agricultural Expert	: Dr. Halil
Technical Assistant	: Hendra Julianto
	Edi Riawan

WWF Team
Ari Muhammad
Lya Anggraini

1st Edition August 2010

ACKNOWLEDGEMENTS

Guideline and Risk Assessment Results of Climate Change and Adaptation in Lombok island, West Nusa Tenggara aims to provide guidance and reference for decision makers at the regional level in assessing potential risks arising from climate change impacts as well be landing in determining adaptation options that most effective. It is expected that this document can be assessed and replicated for other areas in Indonesia. This document is dynamic and will always be updated as needed through a participatory process improvement methodology and the parties.

Highest appreciation is addressed to Mr. Gusti Muhammad Hatta, Minister of Environment, for the support and encouragement in the completion of this document. Also, to Mrs. Masnellyarti Hilman, Deputy Minister for Conservation of Natural Resource and Environmental Damage Control Issue, Ministry of Environment, who initiated and supported the development of this document.

The process of making this document can not be separated from the support of several institutions that had established partnerships with very nice and extraordinary dedication of the following parties:

State Ministry of Environment

1. Mrs. Sulistyowati, Assistant to the Deputy for Climate Change Impact Control, Ministry of Environment
2. Mr. Sudirman, Head of the Environmental Management Centre for Bali and Nusa Tenggara
3. Mr. Dadang Hilman, Head of Climate Change Adaptation Division
4. Mr. Agus Gunawan, Head of Sub-Division for Adaptation in Agriculture and Coastal Region
5. Ms. Yulia Suryanti, Head of Sub-Division for Adaptation in Forestry Sector
6. Mr. Gatot Setiawan
7. Ms. Sabitah Irwani

Local Government of West Nusa Tenggara Province

1. Mr. Tadjuddin Erfandy, Head of the Environment Agency and Research Lombok
2. Mr. Eko B. Sutedjo, Head of the Cooperation Administrative and Natural Resources Bureau

GTZ Indonesia

1. Heiner von Luepke
2. Chandra Panjiwibowo
3. Tilman Hertz
4. Rama Ruchyama
5. Kathryn Pasaribu
6. Citara Nayla Iqbal

WWF Indonesia

1. Fitrian Ardiansyah, Program Director for Energy and Climate
2. Ari Muhammad, Program Coordinator for Climate Change Adaptation
3. Lya Anggraini
4. Muhammad Ridha Hakim WWF-Indonesia Nusa Tenggara Program

Highest appreciation also goes to all parties and participants of workshops on adaptation to climate change in Jakarta and Lombok, West Nusa Tenggara which has give many inputs in improving this document.

Risk Assessment and Adaptation to Climate Change in the island of Lombok, West Nusa Tenggara can be completed with the support from the GTZ (*Deutsche Gesellschaft für Technische Zussamenarbeit*) within the framework of Policy Advice Programme for Environmental Protection and Climate Change (PAKLIM) and its support is gratefully acknowledged.

Foreword from the Minister of Environment

Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change to climate that can be traced back directly and indirectly to human activities thereby influencing atmospheric composition and climate variability. Nowadays it is widely acknowledged that green house gas emissions resulted from human activities, especially from industrial activities are accused as the main cause for climate change.

Although the total amount of green house gases (GHG) emissions generated by Indonesia is still far lower than the one generated by developed countries, an increase of green house gas emissions in the future is very likely, due to current trend and expectation of Indonesia's economic development. Therefore it is the right moment for Indonesia to actively participate in global GHG emission reduction programs. Indonesia's commitment on this regard is reflected by the President's statement at the G-20 Forum on 25th September 2009 in Pittsburg-US where – on behalf of the government - he announced the plan to voluntarily reduce emission by 26% in 2020 compare to business as usual without any outside help.

Due to high population and the significant number of livelihoods depending on agriculture and fisheries, besides its location in archipelagic, Indonesia can be considered as one of the most vulnerable countries to climate change impacts.

It is presumed that crop failure, uncontrolled-climate-related diseases, and infrastructure damages due to extreme climate hazards will be among the expected climate change impacts. A shifting rainy season is another effect of climate change that can have an impact on water availability and interfere with the planting and harvesting season.

Though the public has already experienced such impacts, these issues have not been well addressed yet by the relevant actors, including central and local government. This delayed actions could become latent future problems, because it could mean facing higher vulnerability in the future.

Referring to Act Number 32/2009, there is an urgent need to have an adaptation assessment related to Strategic Environmental Impact Study, which particularly stated vulnerability and adaptive capacity to climate change. This assessment will play a significant role in spatial planning, program planning and other development processes mandated by this act.

In line with the existing decentralization process, one strategic action for dealing with climate change impacts at local government is providing national guidelines on how to assess vulnerability and adaptation, as well as risk of climate change impacts at local level, that it will eventually be useful and essential input for decision making process at this level.

However, as the impacts of climate change are different in every region, methodologies for determining vulnerability and subsequent adaptation options have to take into account specifically local condition. Thus, appropriate numbers of pilot studies and activities have to be done in order to further explore the proper understanding of climate change impacts in Indonesia which has distinct character amongst local situations. On such basis we can properly plan the adaptation actions and avoid mal-adaptation.

The Project "Risk and Adaptation Assessment to Climate Change in Lombok Island, West Nusa Tenggara" has been coordinated by the Ministry of Environment with support from GTZ, WWF-Indonesia, and West Nusa Tenggara Government. This study is based on a comprehensive-scientific analysis and also shows how the results can be integrated into local development planning. It is the first of its kind in Indonesia.

In conclusion, we expect that the Risk and Adaptation Assessment to Climate Change Study in Lombok Island, West Nusa Tenggara, can be replicated in as well as a stimulation for other regions to do a similar assessment in order to ensure a successful mainstreaming effort of climate change issues into development planning at local level.

Jakarta, July 2010

Gusti Muhammad Hatta

Foreword
Deputy Minister of Natural Resources Conservation Improvement and Environmental Degradation Control

Climate change is now a reality; therefore substantial action is required to increase efforts on climate change adaptation as a necessary component in sustainable development. With 80,000 km coastline, 17,000 islands, most economic activities in coastal zones, and many people depending on climate sensitive sectors such as agriculture, Indonesia is very vulnerable to climate change. Impacts are already felt in various parts of the country and particularly poor communities need assistance to become more resilient to climate change.

Although climate change issues still posses uncertainties, no-regret strategies should start with addressing the issues of climate variability and understanding the impacts based on the current and best available technology and knowledge.

Understanding climate change impacts at local level is an essential and fundamental element to address the problem by conducting assessments on vulnerability, risk and climate change adaptation. However, available tools and methods for doing such kind of assessments at international level are diverse and rarely tested by developing countries, including Indonesia.

A case study on Lombok Island of Nusa Tenggara Barat province, which has been coordinated by the Ministry of Environment and supported by GTZ, has given a chance to obtain useful lessons learnt from the process. Some of the essential lessons are:

- the need for more verifiable, qualified and continued climate data series from dense network of meteorological observation stations for climate study particularly in developing climate scenarios and projections as a basis of the assessment;
- the need for better available socio-economic data from relevant stakeholders for detailed and accurate assessment;

- The need to enhance resources, including increasing number of climate change related experts as well as funding sources.

Although it also found that no risk is expected from increasing or decreasing annual rainfall on Lombok Island, it is found that there is high risk from shifts in annual NDJF (November, December, January and February) rainfall. This means that there is an anticipated risk for the agricultural sector that has to be overcome by main actors/stakeholders in the Province of Nusa Tenggara Barat.

Finally, it is really expected that this best practice example in the area of adaptation can be replicated in other many areas in Indonesia in the coming future.

Jakarta, July 2010

Masnellyarti Hilman

EXECUTIVE SUMMARY

Our climate is a valuable resource. It determines the effectiveness and efficiency of development activities in various sectors. However, global climate change issues are increasingly threatening the development activities at national and regional levels. This is not an exaggeration: several reviews of history suggest that the impact of climate change can be fatal to the survival of a nation. Several studies about the extinction of the Mayan civilization in Central America around the year 950 AD concluded that the cause was to be found in a long drought that struck people most vulnerable to climate change (Peterson and Haug, 2005).

The present study on climate change impacts on the island of Lombok contains a vulnerability assessment and a risk analysis of climate change. Analysis of change and projection of climate change was realized by focusing on two approaches: (1) bottom-up and (2) top-down. The bottom-up approach was needed to identify current climate change or change that will happen in the near future while the top-down approach was necessary to identify climate change in the distant future.

The bottom-up approach was taken for the identification of climate change on the basis of local climate observation data. From rainfall and temperature data observed in Mataram, it is known that the annual rainfall pattern in Lombok is a pattern with peak monsoonal wet months of December-February and peak dry months of July to September. The pattern of rainfall between the years 1961-1990 shows that, on average, January is the peak period of the rainy season. However, after the 1990s, and especially during the last ten years, this pattern has changed dramatically as it has been observed that rainfall is lower in January than in December and February. Reduced rainfall in January represents one of the significant dangers of climate change for Lombok Island. Comparison of monthly average temperature in the period 1991-2007 with 1961-1990 baseline average showed an increase in the temperature range up to 0.5 ° C. Changes in temperature need to be studied more closely because of possible local effects (urban heat island effect or heat island).

The top-down approach is the analysis of climate change resulting from global climate model outputs or the GCM program (General Circulation Model) generated by the IPCC (Intergovernmental Panel on Climate Change). From the results of an analysis of several global model outputs, validated by the existing observational data, it was found that average temperatures on Lombok will increase by around 1 º C between the years 2020 to 2050 (around 2030) relative to the average measured in 1961-1990, and will further increase between 2-3 º C in the period 2070-2100 (around 2080). The projection for rainfall patterns did not show much change until 2030. However, in the year 2080 a shift will occur where the rainfall will decrease in transition months and the early wet season (October-November, March-April). Rainfall will also be more concentrated during wet months (December- January), especially for the scenario of moderate and high CO_2 emissions (A1B and A2).

Results of analysis of Sea Surface Height (SSH) using historical data tides (Benoa (Year?) as a reference point) and the altimeter shows a rate of increase of 3.5 mm / year to 8.0 mm / year, respectively, on the North and South Coast of Lombok Island and Sumbawa. Meanwhile, model output based on the scenario of the IPCC Special Report on Emission Scenario (SRES) show that the increase in SSH will vary from 4 mm / year to 8 mm / year until 2100. This means that in the year 2030 the increase in SSH will vary from 10.5 cm to 24 cm relative to the SSH in 2000, 28 cm to 55 cm in the year 2080 and 40 cm to 80 cm in the year 2100. In addition to the impact resulting from SSH, many experts predict that global warming will bring about increased sea surface temperature (SST) in tropical regions which will enhance the frequency of occurrence of extreme weather events. In turn, these will increase the frequency of occurrence of storm surges. This can be seen from the results of an analysis of the potential occurrence of El Nino and La Nina on the results of the IPCC models. Based on the projections until the year 2030, it has been shown that there will be an increase in the frequency of El Niño and La Niña, from previously every three to seven years to every two to three years.

Analysis of monthly data from NOAA (National Oceanography and Atmospheric Agency) Optimum Interpolation (OI) version 2 (Reynolds and Smith, 1994) shows that the increase in sea surface temperature (SST) is higher on the northern coast of Lombok and Sumbawa Island than the increase in SST on the southern coast. The increase in SST on the northern coast reaches 1.2 º C / century, and the increase in SST on the southern Coast Ranges only between 0.2 º C / century to 0.4 º C / century. Differences in the level of increase in SST between the northern and southern coast is caused by differences in depth and topographic conditions. Meanwhile, the global increase in sea surface temperature ranges from 0.3° C to 0.4 ° C (Rayner, et al., 2003).

The sectors that have the potential to be significantly affected by climate change on the Island include the sectors of water resources, agriculture and coastal and marine. The method used to determine the climate change impacts includes a hazard analysis of climate change, followed by the analysis of the sectoral vulnerabilities (water resources, agriculture, and coastal and marine areas). The hazard and the vulnerability analysis allowed one to combine them in a risk analysis. On the basis of this risk analysis, adaptation strategies were formulated.

In the Water sector, the relevant climate hazards are drought, declining water availability and floods. The area to which a high risk is associated is Mataram. The necessary adaptation strategies include (1) Increasing the capacity of data and information, and researching the impact of climate change on the water sector at micro level, (2) Increasing the availability of water in highly vulnerable areas through appropriate technology and the development of local water resources, (3) Improvement of flood prevention and response to flooding through spatial planning, watershed management and river flow, the arrangement of housing, flood risk management, and community participation.

In the agricultural sector, the relevant climate change hazard is the failure of crop planting and, generally, crop failure. Areas having a high risk include Central Lombok district and some districts in East Lombok as well as district Bayan. Adaptation

Strategies for the agricultural sector relate to the improved irrigation of agricultural and rainfall dependent agricultural land.

Meanwhile, for the coastal and marine sector, the relevant climate change hazard is sea water temperature rise, increased frequency and intensity of weather extremes, changes in rainfall patterns and river flow, changes in ocean circulation patterns and sea level rise. The area where a high risk has been identified is Mataram. Adaptation strategies in this sector include: the physical adaptation of coastal areas and small islands, the social management of population, infrastructure and facilities management, improved management of coastal resources, marine, and fisheries, ecosystem management of coastal areas and small islands in an integrated way, the preparation of regulation concerning climate change adaptation policies, inventory of data as well as research and development of human resources.

Lessons from this study include (1) how "to do" mainstreaming of climate change in development policy, namely the integration of risk assessment and climate change adaptation into RPJMD West Nusa Tenggara Province, (2) the study shows that the formulation of adaptation strategies are more appropriate when they are preceded by a Risk Assessment so as to avoid under- over- or maladaptation, (3) the Adaptation Strategy formulated for each relevant sector (then further elaborated into the program and adaptation activities) must be integrated into the strategic plan of each Department, including Department of Irrigation, Agriculture, Department of Marine and Fisheries and also various other related Agencies; (4) On the basis of this study was compiled the Ministry of Environment's Draft Regulation on Implementation of Control Policy in the Regional Impacts of Climate Change.

Important insights have been drawn from this study, and this study can rightfully be considered as representing a crucial milestone on the way towards providing Indonesia with the tools to increase its Resilience in the face of climate change. However, replication of the activity is still necessary so as to refine the method in order to further increase its accuracy. Such a replication is under way: the analysis is currently in process in South Sumatra Province and Tarakan Island where it is also planned to complement the analysis with the integration of local development scenarios as well as with a method for economic assessment of impacts & prioritization of adaptation options.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1

INTRODUCTION

1.1 Background

Whether we agree to it or not, our climate is one of most important economic drivers. The climate should be understood as a key factor that determines the effectiveness and efficiency of various development activities in various sectors during present time as well as in the future. The climate has often been simply defined as the average weather condition in a particular geographical region during certain period of time (30 years). More broadly, the climate can be defined as a "state of the climate system" (IPCC-Glossary, 2009). This broad definition of climate system signifies the importance of complex interaction of all earth's components: the atmosphere (air), hydrosphere (ocean), lithosphere (earth crust, volcanoes, soil, etc.), cryosphere (ice sheets), and the biosphere (vegetation) in forming the past, present, and future climate condition.

It is known throughout history that the climate condition varies temporally and spatially, and it changes either gradually or suddenly. Thus, the climate in the past had already undergone *natural* changes. However, experts in the IPCC (Inter-governmental Panel on Climate Change) have concluded that the increase in greenhouse gases - especially carbon dioxide - as the result of industrial activities throughout the 20th century until now has been causing global warming and triggered a global climate change. This issue is believed to induce various changes such as a global volume expansion of ocean water and melting of sea ice in both the North Pole (Green Land) and South Pole (Antarctica) so that the earth's average sea level will increase.

Whatever the causes, climate change can and will continue to occur - and only the nations that pay attention to and anticipate the climate behavior can gain advantages and avoid terrible losses. The potential impact of climate change is something that one should not underestimate. This is not an exaggeration: several reviews of history suggest that the impact of climate change can be fatal to the survival of a nation. Several studies about the extinction of the Mayan civilization in Central America around the year 950 AD concluded that the cause was to be found in a long drought that struck people most vulnerable to climate change (Peterson and Haug, 2005).

Based on results from various climate projection models for the next one hundred years period, global warming is predicted to affect climate patterns that will increase the probability of extreme weather events. Considering that many negative impacts will happen, the international community has called out for action for mitigation (in the form of greenhouse gases emission reduction that are of anthrophogenic cause) and adaptation (in the form of a development strategy that will help reducing the negative impacts of climate change)

To anticipate the negative impacts that may happen, the Provincial Government of West Nusa Tenggara has initiated the mainstreaming of climate change into its development plans. This excellent initiative needs to be supported with more fundamental academic research because the development of adaptation to climate change strategies must be based on a thorough vulnerability and risk assessment. The process of mainstreaming the Risk and Adaptation Assessment in the Lombok Island into the Mid-Term Development Plan (2009-2013) of the NTB Province was able to be performed as the two documents were prepared at the same time. Moreover, the Government of NTB provided an excellent support to enable the completion of this study.

The scope of the study area is the Lombok Island which is a part of the NTB Province, with a land area of 4,738.70 km^2 (23.51% of the total land area of the NTB Province) and the length of coastline is 2,333 km.

1.2 Goal and Objectives

The goal of this study is to identify the magnitude of hazards caused by climate change, and the vulnerability and risk level of various sectors that may be affected by climate change impacts in the Lombok Island. The results of this study then will be used to develop adaptation strategies to respond the potential impacts of climate change. Several objectives to be achieved by this study are:

1. To analyze the baseline condition and the projection of climate change in the Lombok Island.
2. To analyze magnitude and pattern of hazard, vulnerability and risk of climate change on coastal, water, and agriculture sectors in the Lombok Island.
3. To formulate adaptation strategies to reduce risk and vulnerability caused by climate change on coastal, water, and agriculture sectors in the Lombok Island.
4. To integrate identified adaptation strategies to climate change in the Lombok Island into the development planning of the NTB Province.

1.3 Approach, Conceptual Framework, and Methods of Study

It has been so far known that there are five approaches[1] of the Climate Change Impact, Adaptation, and Vulnerability (CCIAV) assessment. The four of them are classified as "a conventional approach" which are: impact, adaptation, vulnerability, and integrated assessment[2]. The fifth approach is identified as "an emerging approach" within the CCIAV studies. This fifth approach adopts a risk assessment framework and has started to be implemented in the mainstreaming of climate change adaptation into development policies (IPCC, 2007). There has been another important trend that is the shift from research-driven approaches to integrated assessments towards policy-making, where decision-makers and stakeholders either participate in or drive the assessment (UNDP, 2005).

In the context of mainstreaming climate change into development policy in Indonesia, it is recommended to differentiate climate risk and adaptation assessment into macro, meso and micro levels to suit the hierarchical structure of government: national, province and local (see Table 1.). Each level of assessment represents the detail of

[1] An approach is defined as the overall scope and direction of an assessment and can accommodate a variety of different methods. A method is a systematic process of analysis.
[2] A more detailed discussion can be read in *Decentralised Vulnerability Assessment to Climate Change Assessment in Indonesia: Using Regional-Multi Sectoral Approach at Provincial Level* by Suroso (2008).

analysis taken; hence it indicates the level of accuracy of the results which corresponds to adaptation needs for each level of government's structure. For an example, at the micro level assessment, it contains quantitative analysis, the accuracy of results is high, it should come out with recommendation on adaptation measures, and it fits with the need of local government to adapt to climate change.

This Lombok's study adopts a risk assessment framework. It means that it is a "policy-driven" study so that it intends to integrate the assessment into plan making of the NTB Province. Under the classification illustrated in Table 1, the level of assessment of the Lombok's study is meso level which means combination of qualitative and quantitative analysis, producing moderate accuracy result and formulating adaptation strategies.

Table 1.1 Various Levels of Risk and Adaptation to Climate Change

Study Levels	Data/Analysis Needs	Study Scope	Planning Levels	Accuracy	Expenditure
Macro	Qualitative	National	Adaptation policies	Low	Low
Meso	Combination of qualitative and quantitative	Province	Adaptation strategies	Moderate	Moderate
Micro	Quantitative	Local	Adaptation measures	High	High

Source: modification from Messner (2005) in Suroso (2008)

Risk assessment framework has been well developed within natural disaster communities and has started to be adopted on climate change study (Klein, 2004). Since the Third Assessment Report, definition of vulnerability from the IPCC has been confronted to take into account social vulnerability (O'Brien, et al., 2004) and to reconcile with risk assessment (Downing and Patwardhan, 2005). The framework and methods for vulnerability assessment must also include adaptative capacity indicators (*Turner, et al.*, 2003; *Schroter*, 2005; *O'brien and Vogel*, 2006).

Affeltranger, et al. (2006) proposed a risk notation (Risk), as a function of Hazards and Vulnerability using the formula[3]:

Risk (*R*) = *Hazards* (*H*) X *Vulnerability* (*V*)

As known, vulnerability is defined by the IPCC (2001) as: "*a function of character, magnitude and rate of Climate Change and the variation to which a system is exposed, its sensitivity and its adaptive capacity*". In the context of risk and adaptation assessment to climate change, based on the risk notation from Affeltranger et al. And based on the vulnerability definition from the IPCC above, we can determine two definitions as follows:

1) Hazard due to climate change is a function of characteristic, magnitude, and rate of climate change and variability.
2) Vulnerability of a system to climate change is a function of exposure, sensitivity, and adaptive capacity.

Step by Step Procedures on Risk and Adaptation Assessment to Climate Change

Step 1: Formulation of Problems and Identification of Vulnerable Sectors to Climate Change

This step is very important in laying the foundation for the implementation of study. Techniques which can be implemented include brainstorming, public consultations, and focus group discussions. This step aimed to determine sectors which are considered to be vulnerable to climate change and serves also as a forum for early interaction with stakeholders in concerned regions. In this step, we can also communicate data needs and availability between the involved experts in this study and related institutions in the region.

Step 2: Analysis of Hazard Due to Climate Change

In this step, character, magnitude, and rate of hazards are analyzed based on current and historical climate information, and also future projections of climate change.

[3] More detailed discussion on risk definition cab read in *Decentralised Vulnerability Assessment to Climate Change Assessment in Indonesia: Using Regional-Multi Sectoral Approach at Provincial Level* by Suroso (2008).

Step 3: Analysis of Vulnerability of Sectors Due Climate Change Impacts

In this step, identification of vulnerability indicators, data collection, and analysis of GIS (Geographic Information System) are conducted, then, vulnerability maps can be produced.

Step 4: Analysis and Evaluation of Risk

As defined by Affeltranger, et al. (2006), risk is a result of overlay between hazard and vulnerability. Thus, risk levels are obtained from overlay between maps resulted by Step 2 and Step 3 above.

Step 5: Formulation of Adaptation Strategies Based on the Risk Study

Having completed Step 1 to Step 4, a good understanding on the level of risk of vulnerable sectors will be obtained so that appropriate adaptation strategies/measures to respond to climate change impact can be determined.

Step 6: Mainstreaming Adaptation Strategies into Development Policies

Climate risk assessment and policy making do not occur in a vacuum, particularly within the context of provincial governments. Climate change is only another factor to consider among the many aspects that a provincial government already takes into account in all its policy-making. Climate change considerations may revise policies through the application of risk management processes in prioritizing adaptation options. The emphasis here is on understanding the scope and variation of climate change, and applying risk assessment as a method to determine adaptation responses based on the risks. 'Best' knowledge of climate change, together with use of risk assessment procedures, can help local government prepare to help the community adapt to known climate change.

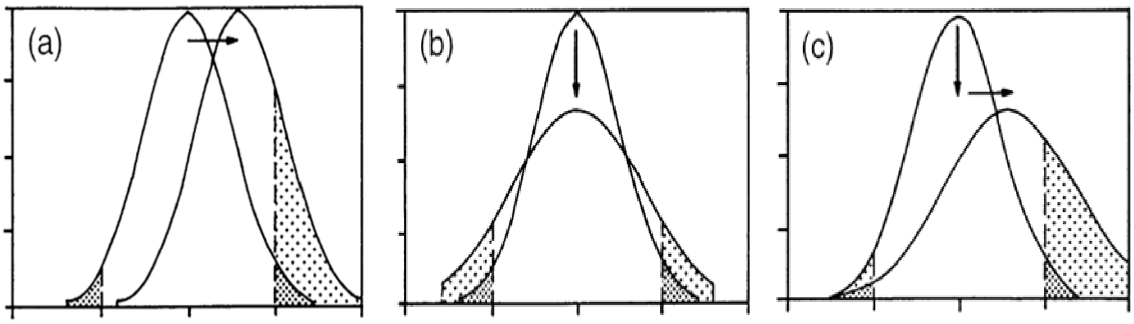
Risk management is well fitted into plan making and review processes at the stages where issues are being identified and a range of possible response options evaluated. The iterative process of plan formulation, monitoring and evaluation enables for revision of plans over time to take account of improved understanding of risks due climate change. In considering climate change issues, the period over which the decision will have effect is of fundamental importance. Generally, whenever a decision is likely to have effects that will last 30 years or more, the implications of climate change should be taken into account.

2

ANALYSIS OF CLIMATE HAZARDS DUE TO CLIMATE CHANGE IN LOMBOK ISLANDS

Detection or identification of climate change is the basis of climate change hazard analysis. According to Meehl (2000), climate change can be identified by comparing the probability distributions of climate parameters observed within two consecutive 30-year periods, as shown in Figure 2.1. Based on this understanding, the climatic changes that occurred within a 30 year period are defined as climate variability. It also implies that an attempt to identify the current climate change will require at least observational (historical) data from the past 60 years

Figure 2.1 Statistical identification of climate change by (a) changes in average value (mean), (b) changes in variance, and (c) changes in average value and variance. The vertical axis designates probability, while the horizontal axis represents values of certain climate parameter. (Adapted from Meehl, 2000).

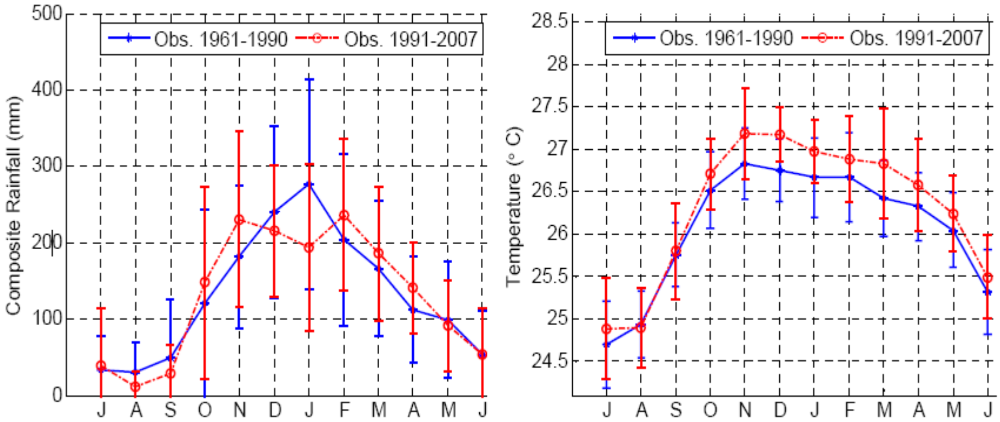


Observational data analysis provides information on current climatic change hazard, but climate projection is needed to obtain qualitative, as well as quantitative, estimates of the climatic changes in the relatively distant future times. In general, various methods for performing climate projections can be divided into two categories: (1) trend analysis of observational data, and (2) computer simulations using global climate models or GCMs (Global Circulation Models). Although there are inherent uncertainties in the GCM output, the latter is the only method to provide information on the possible characteristics of climatic changes in the distant future.

2.1 Analysis and Projection of Rainfall and Temperature

Studies on the climate changes and climate projections on Lombok Island were conducted using two approaches: (1) bottom-up and (2) top-down. Bottom-up approach is the identification of climate change using local and global climate observation data. For the former, long-term rainfall and temperature data have been collected from both global datasets and local stations. From rainfall and temperature data observed in Mataram, it can be seen that the annual rainfall pattern in Lombok is in general of monsoonal type with peak wet months around December to February and the peak dry months around July-September. Rainfall patterns between the years 1961-1990 (1990s) show that January was generally wetter compared to December and February with monthly accumulated rainfall of around 300 mm . However, after the 1990s and especially during the last ten years this pattern has changed dramatically. In the most recent decade, observed rainfall amount is more frequently lower in January compared to the one in December and February, with an average of only around 175 mm. Recent climatological data indicates that the so called "monsoon break" phenomenon has been occurring more often in January. The monsoon break is a period within the rainy season where cloud formation is much more suppressed. The monsoon break over Lombok sometimes lasts long enough (more than two weeks), like that occurred in January 2007, so as to affect the success of agricultural activities.

Figure 2.2 Graphs of monthly average composite rainfall (left) and temperature (right) based on observational data from Selaparang/Ampenan stations for the baseline period 1961-1990 (blue) and 1991-2007 (red). The vertical line (error-bar) indicates standard deviation.



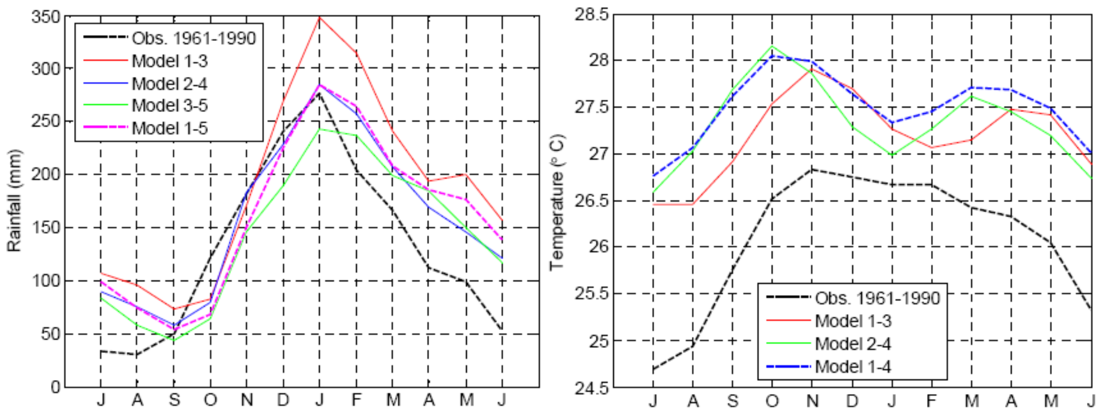
In addition to rainfall, the trend of an increasing monthly average temperature has also been observed during the last ten years, especially for the months of the wet season. The maximum observed monthly average temperature change is only in the range of 0.5 ° C , but this needs to be studied more thoroughly because of the possibility of local effects (urban heat island). Also, there has not been any data to further study the the spatial variation of temperature and rainfall in Lombok Island.

A top-down approach in this study is the analysis of climate change based on outputs of GCMs that were run by institutions recognized by IPCC. In this case, only five models were selected: (1) ECHAM5, (2) GFDL2.0, (3) GFDL2.1, (4) MRI, and (5) CSIRO Mk.2. It is found that these model outputs do not actually follow the trend of observational data. Nevertheless, these sorts of model outputs are the only sources of information on possible climatic changes up to the next 100 years. In this study, a simple data fitting between composites of model output and observational data is applied to obtain the best ensemble average of projected rainfall and temperature (see Figure 2.3).

Results of the preliminary analysis from global model outputs shows that the average temperature on Lombok Island will increase by 1 ° C between the years 2020-2050

(2030s) compared to the average temperature between the baseline period (1961-1990), and will increase to somewhere between 2-3 ° C in the period between 2070-2100 (2080s). The projected rainfall patterns do not show much change in 2030s, compared to the baseline, but a shifting pattern becomes more noticeable in projected data of 2080s. In particular, the rainfall tend to decrease during transition months (March-April) and early wet seasons (October-November). In addition, annual rainfall will be more concentrated during the wet months with shorter periods (December - January). These results are especially prominent for the scenarios where CO2 emissions are relatively high (A1B and A2).

Figure 2.3 Comparison of the composite pattern of monthly rainfall (left) and temperature (right) for the ensemble output (colored lines) and observations (black line). Number represents a model such as described in the text.



Although the results of GCM ouput analysis do not indicate noticeable climate change hazards until 2030s , it is important to note that observed rainfall data show a rather strong signal of interdecadal climate variability that may be affected by the Pacific Decadal Oscillation (PDO) that is attributed to sea surface temperature variations with comparable timescale in the Pacific. It is further identified that there is negative lag (lead) correlation between PDO index (downloadable from http://jisao.washington.edu/pdo/) and rainfall over Lombok Island. As the PDO index indicates, a decrease in annual rainfall over Lombok Island is to be expected, and this is to be carefully monitored, at least until the year 2020.

2.2 Projected Sea Level Rise

The gradual sea level rise (SLR) due to global warming is one of the most complex aspects of global warming impacts, with its accelerated rate of increase being in line with the more intense progress of global warming. SLR leads to increased erosion, shoreline changes and decreased wetland areas along the coast. Wetland ecosystems in coastal areas may be damaged if high-level rise occurs and sea temperature exceeds the maximum adaptation limit of coastal biota. In addition to that, SLR increases the sea-water intrusion rate in the coastal aquifer.

To calculate the trend and rate of SLR on Lombok Island, trend analysis based on historical data (including tide gauges and satellite altimeter data) and outputs of IPCC models were used. Analysis using tide gauges data and the altimeter show a rate of increase of 3.5 mm/yr up to 8.0 mm/yr, respectively in the north and the south coast of Lombok and Sumbawa Island. These are estimated based on SLR from tide gauges at Benoa as reference.

Figure 2.4 Estimated sea level rise using tide gauge data from around Lombok Island.

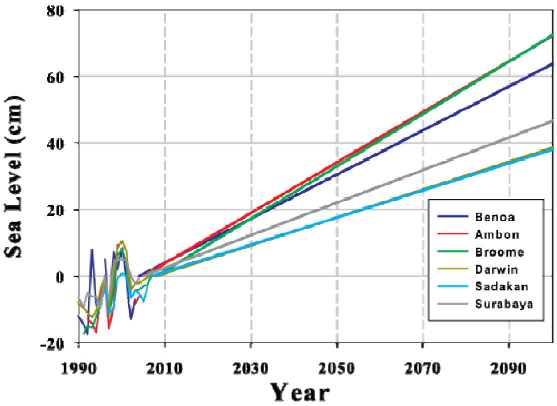
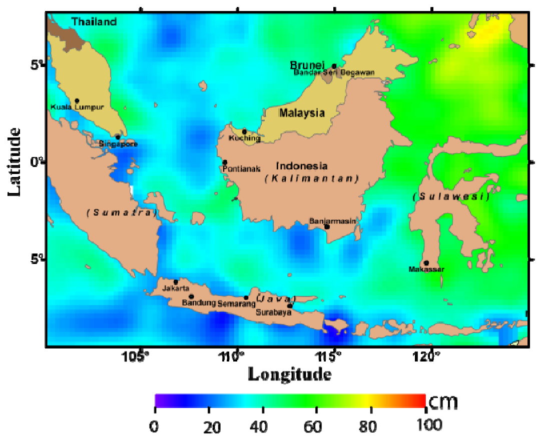


Figure 2.5 Distribution of sea level rise until 2100 based on satellite altimeter data.



By focusing on the SLR estimates using tide gauges and altimeter data, it was found that the SLR in open sea is higher than in semi-enclosed sea. This has implications for the rate of SLR on the north coast of Lombok Island which is lower than on the south coast.

In addition, the IPCC model output shows the similar trend. The sea level data based on the scenario model results from Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenario (SRES). The trend analysis on the model outputs shows that an increase in sea level will vary from 4 mm/yr up to 8 mm/yr until 2100. Moreover, sea level estimation in the north and the south coast of Lombok Island based on IPCC scenario SRESa1b (750ppm) for the year 2030 shows an increase varying from 10.5 cm to 24 cm relative to sea level in 2000. Furthermore, sea level in the year 2080 will reach 28 cm to 55 cm high, while SLR in the year 2100 could reach 40 cm to 80 cm as shown in Figure 2.6 and 2.7 (for SRESa1 and b2, figures not shown).

Figure 2.6 Estimated sea level - North coast of Lombok Island

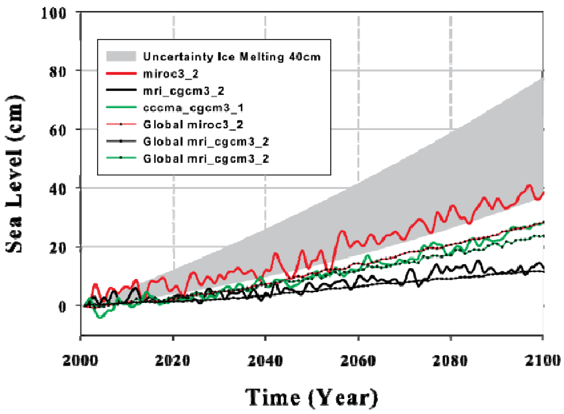


Figure 2.7 Estimated sea level - South coast of Lombok Island

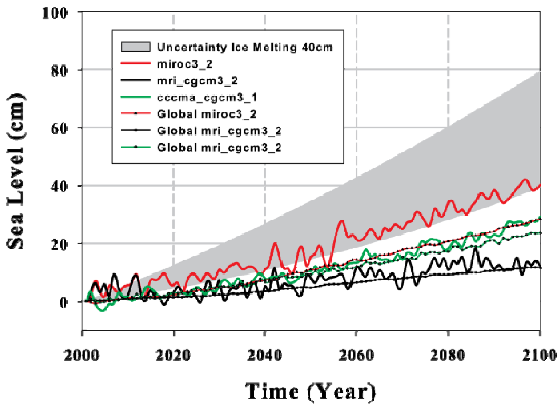


Table 2.1 shows a summary of SLR in Lombok Island varying from 40 cm to 80 cm until the year 2100, based on historical data including tides and satellite altimeter data, and the output data from IPCC models.

Table 2.1 Projections of sea level rise on the north and south coast of Lombok Island.

Period	Sea Level Rise Projection from year 2000						Confidence Level
	Tides		Altimeter ADT		Model		
	N	S	N	S	N	S	
2020	10	12	7–8	9–10	5.1 – 12.9	5.1 –13.1	Moderate
					3.4 – 9.4	5 – 13	
					6.7 – 15.5	4.2 – 11.5	
2050	25	32	17.5–20	22.5 –25	13.6 – 33.4	14.1 – 35.4	Moderate
					11.2 – 20	13.2 – 31.1	
					16.2 – 35	13.2 – 33	
2080	40	52	28 – 32	32–40	27.1 – 59	29.1 – 61	High
					24.1 – 55	26.1 – 58	
					24.1 – 56	23.1 – 55	
2100	50	70	35 – 40	45–50	37.8 – 78	40.1 – 80	High
					36 – 74	38 –75	
					33 – 73	32 –70	

Note: Model based on scenario SRESa1b, b1 and a2

The increase in sea surface temperature (SST) based on monthly data from NOAA (National Oceanography and Atmospheric Agency) Optimum Interpolation (OI) version 2 (Reynolds and Smith, 1994) shows that the SST increase on the north coast of Lombok and Sumbawa Island is greater than the SST increase on the south coast of the Island of Lombok and Sumbawa Island. The increase of SST on the north coast was up to 1.2 ºC / century, and the increase of SST on the south coast ranges only between 0.2º C/century to 0.4ºC/century (Figure 4.2). This difference is caused by differences in depth, and topographic conditions. The north coast borders to the shallow Java Sea, so the mixing layers are perfectly formed, which results in a moderate annual fluctuation between the highest and lowest SST. Meanwhile, the global increase in SST ranges between 0.3°C to 0.4°C (Figure 4.3, Rayner, et al., 2003).

Figure 2.8 Increasing trend of SST in northern and southern coasts of Lombok.

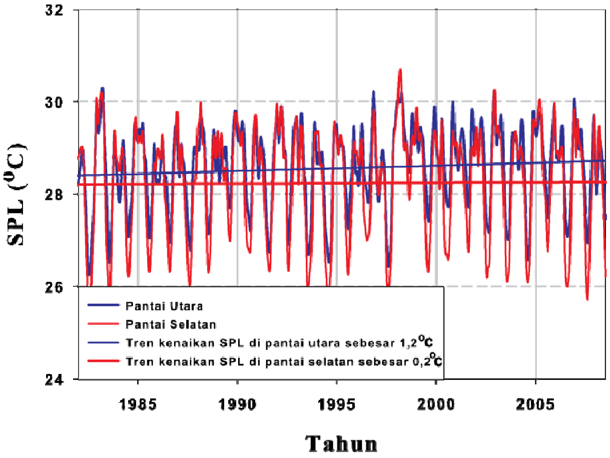
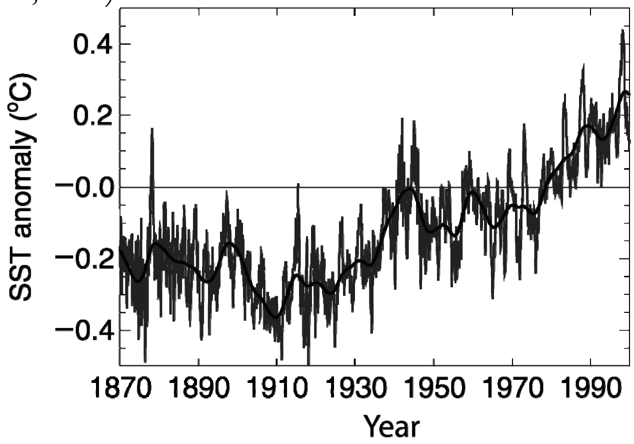


Figure 2.9 Global SST trend based on observational data from 1870 to 2000 (Rayner, et al., 2003).



2.3 Increase Frequency and Intensity of Extreme Weather Events

Table 2.2 shows ENSO frequency of occurrence (time table) from 2001 to 2030, using scenario SRESa1b, based on the MRI model output of NINO3 sea surface temperature (SST). It is found that the average frequency of El Nino and La Nina occurrence will increase to every 2 to 3 years compared to previous years where the frequency was every 3 to 7 years (Timmermann, 1999). Moreover, the normal years (non ENSO year) occur in 2013/2014, 2021/2022 and 2027/2028. Based on projection of up to 2030, we found out that there will be increase in frequency of El Nino and La Nina to once every 2-3 years compared to earlier frequency of once every 3-7 years. Ideally this discussion of ENSO should also be accompanied by analysis of magnitude of ENSO, because impacts of El Nino and La Nina depend on its magnitude.

El Niño is characterized by a declining SST in the Indonesian Sea, and an increasing SST in the eastern part of the tropical Pacific Ocean, with SST increase of more than 0.5°C. Air pressure in Indonesia rises, and this weakens Pacific trade winds while it increases eastern local winds at the same time (although a local western wind burst phenomenon is often found in the starting phase). The decrease of SST and warm-pool (the area in the Western Tropical Pacific enclosed by the 28.5°C isotherm) shifts from

Indonesian waters to the middle part of the Pacific Ocean are reducing rainfall in most parts of Indonesia. This causes potential fire hazard and drought, especially in the eastern part of Indonesia. Meanwhile, La Niña is a natural phenomenon with the opposite effects compared to those of El Niño. La Niña is characterized by an increase in SST in Indonesian waters and decreased SST in eastern tropical Pacific by more than 0.5°C. In the period of La Niña, there is an increased intensity of the Pacific trade wind that causes the shifting of warm-pool more westward, compared to normal conditions. This warm–pool migration causes more intense rain in Indonesia, which increases the risk of flood.

In general, La Niña and El Niño resulted in tidal waves that vary between 2.1 m to 5 m in Indonesian waters, even though El Niño does not cause a significant impact on wave height in the Indian Ocean.

Table 2.2 ENSO time-table based on MRI model output

	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agus	Sep	Okt	Nop	Des
2001	-1.04	-0.86	-0.81	-0.33	-0.55	-0.29	0.12	0.26	-0.34	-0.85	-0.85	-1.02
2002	-1.04	-0.77	-0.47	0.13	0.77	0.75	1.00	1.37	1.47	1.77	1.79	1.60
2003	1.13	0.81	0.09	-0.35	-0.56	-0.61	-1.16	-1.16	-1.05	-0.67	-0.69	-0.95
2004	-0.83	-1.20	-1.19	-0.86	-0.37	-0.78	0.30	0.42	0.77	0.93	0.89	1.13
2005	0.84	0.29	0.00	-0.25	-0.38	-0.75	-0.45	-0.68	-0.32	-0.77	-1.07	-0.99
2006	-0.89	-1.12	-1.19	-1.79	-1.68	-1.04	-0.53	-0.41	-0.36	-0.30	-0.28	-0.55
2007	-0.63	-0.93	-0.80	-0.72	-0.91	-0.29	0.10	0.23	0.43	0.72	0.76	0.69
2008	0.78	0.53	0.23	0.06	-0.90	-0.76	-0.84	-0.36	-0.67	-0.82	-0.75	-1.01
2009	-1.07	-0.78	-0.11	0.07	0.29	1.21	1.39	1.58	1.36	1.29	1.38	1.31
2010	0.98	0.56	-0.26	-1.18	-1.48	-1.23	-1.44	-1.74	-1.56	-1.86	-1.93	-2.11
2011	-1.98	-1.91	-1.63	-1.28	-0.10	1.53	2.21	1.99	2.24	2.40	2.73	3.06
2012	2.75	2.37	1.61	1.00	0.83	-0.06	-0.20	-0.01	-0.78	-1.02	-1.18	-1.59
2013	-1.45	-1.22	-0.54	-0.50	-0.42	-0.11	0.04	0.50	0.38	0.07	-0.08	0.12
2014	0.03	-0.20	-0.27	0.31	0.04	-0.24	-0.35	-0.46	-0.44	-0.14	-0.59	-0.54
2015	-0.70	-0.91	-0.50	-0.13	-0.04	-0.44	-0.15	-0.39	-0.05	-0.26	-0.52	-0.55
2016	-1.09	-0.91	-0.36	0.02	0.11	0.12	0.67	-0.03	-0.43	-0.45	-0.84	-0.97
2017	-1.09	-1.18	-1.30	-0.68	-0.95	-1.33	-1.09	-1.67	-1.91	-2.00	-2.09	-2.20
2018	-1.93	-1.97	-1.80	-1.36	-0.52	1.09	2.24	1.65	1.74	1.94	2.23	2.36
2019	2.50	2.25	1.85	1.39	1.19	0.73	0.50	0.73	0.45	0.17	-0.42	-0.78
2020	-0.82	-1.03	-0.85	-0.74	-1.26	-1.13	-1.41	-1.71	-2.28	-2.16	-2.35	-1.87
2021	-1.51	-1.54	-1.50	-1.09	-0.15	0.14	0.06	0.24	-0.21	-0.27	-0.08	-0.02
2022	-0.06	-0.18	-0.53	-0.56	-0.50	-0.83	-0.48	-0.40	-0.60	-0.71	-0.95	-1.49
2023	-1.40	-1.32	-0.90	-0.46	-0.03	1.05	0.63	1.13	1.04	0.92	0.73	0.25
2024	0.47	0.36	-0.28	-0.94	-1.33	-1.25	-1.31	-0.95	-0.85	-1.03	-0.90	-0.88
2025	-0.86	-0.97	-0.47	-0.66	-0.65	-0.48	-0.53	-0.36	0.29	0.53	0.70	0.50
2026	0.73	0.71	0.42	0.23	-0.56	-0.83	-0.85	-1.23	-1.87	-1.59	-1.64	-1.43
2027	-1.38	-2.00	-1.94	-1.49	-0.48	0.11	0.12	0.40	0.44	0.38	0.06	-0.38
2028	-0.54	-0.26	0.03	-0.20	-0.81	-0.64	-0.27	-0.44	-0.04	0.28	0.02	0.08
2029	0.26	0.39	0.18	-0.34	-0.65	-0.88	-1.37	-1.47	-1.94	-2.25	-1.92	-1.24
2030	-0.92	-0.80	-1.14	-0.89	-0.77	-0.79	-0.19	-0.12	0.51	0.45	0.56	0.37

La Niña El Niño

3

ANALYSIS OF VULNERABILITY AND RISK OF CLIMATE CHANGE ON WATER

3.1 Problem Identification

Results of climate change risk analysis based on observational data show that with regards to annual rainfall, current climate condition is normal, relative to the baseline. Furthermore, the increase in average temperature of not more than 0.5ºC is not significant enough to affect water supply. One thing that has a potential impact on the water sector is a change in climate variability which has been identified during the rainy season (from November to December-January-February).

Climatological hazards of the water sector are climate hazards mentioned in Chapter 2. Thus, climate hazards such as temperature rise, rainfall variability, increasing frequency and intensity of extreme climate, and sea level rise are the potential stimuli to trigger climate hazards in the water sector.

In general, climatological hazards of the water sector are: (1) decreased water supply, (2) drought, and (3) floods. From the climate projection data, it is known that the temperature rise due to global warming could reach 3ºC. In addition, the projection data of rainfall shows tendency to be concentrated on shorter wet months (December-January). In order to define potential hazard better, further analysis is needed so as to get the values of the hydrological parameters from projected rainfall and temperature data. One approach that can be done is to analyze the water balance in order to get estimates of surface water supply.

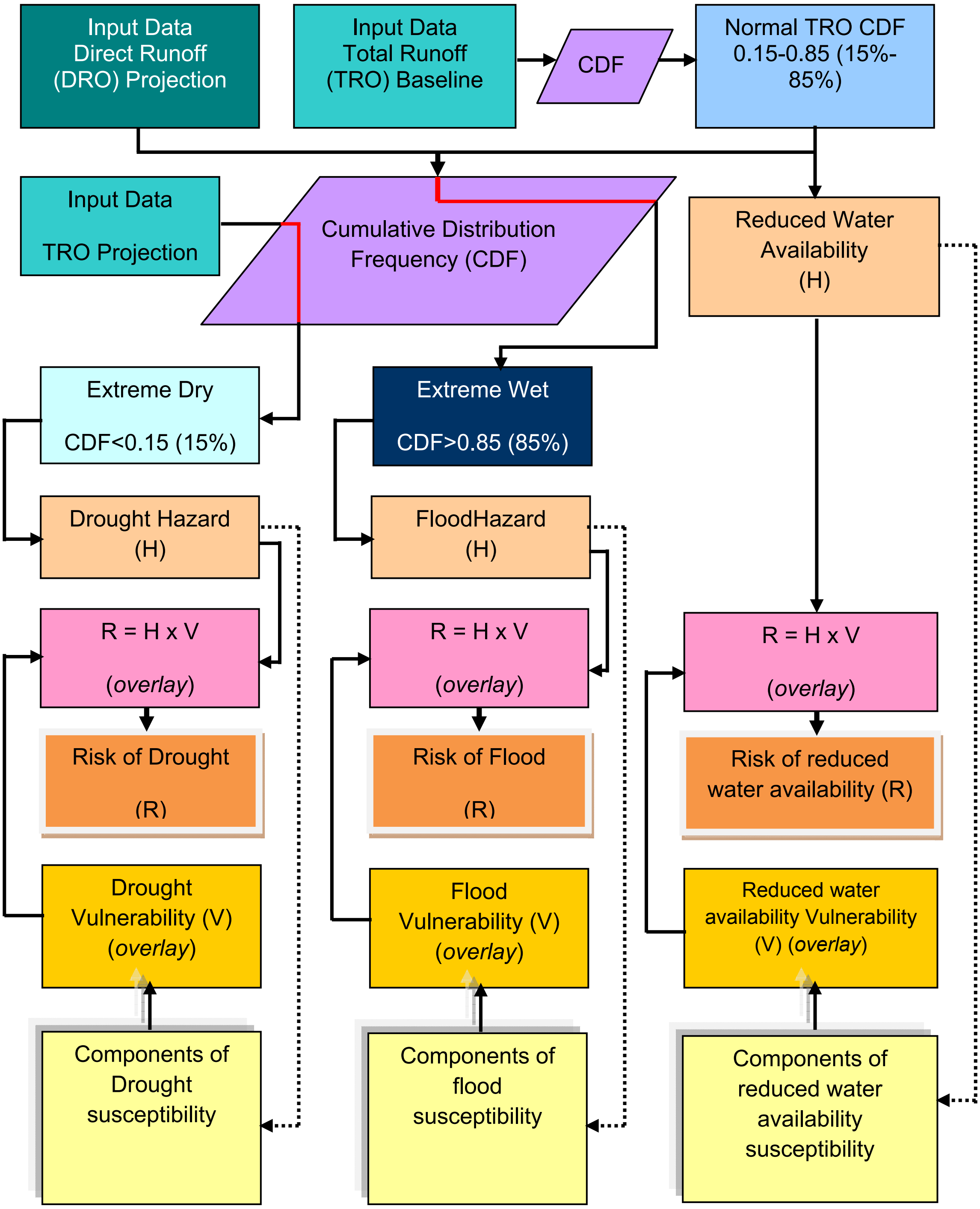
One of the problems faced in a water sector risk analysis (i.e. to identify hazards potential in causing related risk, water balance analysis must be done for each watershed area (DAS)) is the lack of spatial information in climate projection data. To solve this, we recommend the use of rainfall data obtained from the Department of Public Works with the assumption that spatial pattern does not change within the projection period (landuse change static assumption).

3.2 Method of Study

This study used 5 (five) methods for analysis, namely: (1) Water Balance Analysis, (2) Statistical Analysis of CDF (Cumulative Distribution Frequency), (3) Water Budget Analysis (Balance of Water Resources), (4) Weighting, and (5) Geographic Information System (GIS). Some of the analysis is further explained below.

Water balance analysis and statistical analysis of CDF (Cumulative Distribution Frequency) were used to identify further hazards of climate change to the water sector. Water budget analysis was used as an additional risk analysis to the water sector. The weighting analysis and GIS analysis were used to obtain map of hazard, vulnerability, and risk. As a summary, the flow chart and the GIS application analysis are presented in Figure 3.1.

Figure 3.1 Schematic GIS flow charts and GIS application in climate change vulnerability and risk study of the water resources sector



3.3 Vulnerability Analysis

Identification of parameters involved in the climate change vulnerability assessment of the water sector (shown in Table 3.1), is based on 3 main limiting factors, namely: mid-level study approach (meso level), needs assessment results coming from the delivery of spatial information, and data availability. With this we can establish the elements influencing vulnerability (E, S, and AC) based on each hazard.

Table 3.1 Components of water sector vulnerability to climate change

POTENTIAL H	HAZARD (H)	Water Sector Vulnerability (V)	
		Comp	Type
Changes in the rain pattern, increase in T, SLR, immersion	Decreased Water supply	E	1. Population density (spatial)
			2. Land use (spatial)
		S	1. Water needs
			2. Type of soil / rock (spatial)
			3. Rainfall distribution pattern (spatial)
		AC	1. Population welfare(spatial)
			2. Irrigation infrastructure
	Flood zone	E	1. Population density (spatial)
			2. Land use (spatial)
		S	1. Criticality level of SSWS areas
			2. Criticality level of protected forest area
			3. Rainfall distribution pattern (spatial)
		AC	3. Population welfare(spatial)
			4. Irrigation infrastructure
	Drought	E	1. Population density (spatial)
			2. Land use (spatial)
		S	1. Water needs
			2. Rainfall distribution pattern (spatial)
			3. Criticality level of protected forest area
			4. Land slope (spatial)
		AC	1. Population welfare(spatial)
			2. Irrigation infrastructure

Notes: *H: hazards, Pot: potential, T: temperature, SLR: sea level rise, Comp = vulnerability component; E: exposure, S: sensitivity, AC: adaptive capacity, spatial:* types of information with more-detailed accuracy levels or spatial-units

3.3.1 Vulnerability to Decreased Water Availability

From the map of vulnerability to decreased water availability, we can identify municipalities and districts (*kabupaten*) which are generally very vulnerable (very high susceptibility level) to the hazard of decreasing water supply due to climate change for the period 2030 to 2080, namely Mataram and some areas in Central Lombok district, East Lombok district, and West Lombok district. The very high level of vulnerability in Mataram city (covering 70% of its area) is caused by various factors such as: highest population density (in average > 5,761 people/km^2); land use is dominated by residential areas; highest water needs for population, industries, and other (each has an average of 108.22 m^3/year, 647.02 m^3/year, and 1,050.68 m^3/year, respectively); type of soil or rock in relation to the level of water absorption (porosity 30-35%); lack of irrigation infrastructures or water supply facilities such as well spring; and generally very low local rainfall.

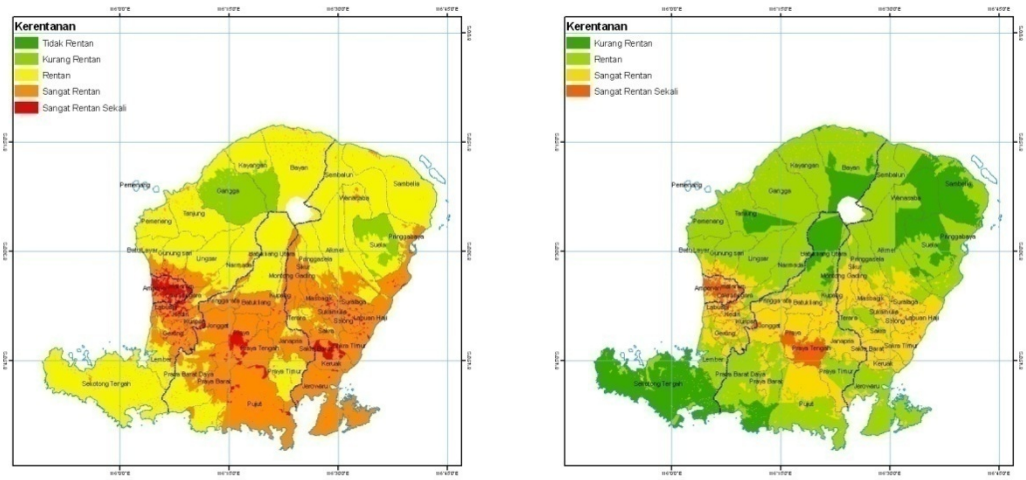
The levels of vulnerability to decreased water supply hazard in Lombok Island based on the map in Figure 3.2b (model 2[4]) are:

(1) Very high vulnerability, covering Mataram city (70%), local areas in West Lombok district (5%), Central Lombok district (10%), and East Lombok district (5%), central part of West Lombok (5%), and approximately 20% is SSWS Dodokan and 5% is SSWS Menanga.
(2) High vulnerability, covering Mataram city (30%), local areas in West Lombok district (10%), Central Lombok district (40%), and East Lombok district (5%), central part of West Lombok (5%), and approximately 50% is SSWS Dodokan, 60% is SSWS Menanga, and 5% is SSWS Putih.
(3) Medium vulnerability, covering northern part of West Lombok district (60%), northern and southern part of Central Lombok district (40%), and northern part and small part in southern East Lombok district (45%), or approximately 30% is SSWS Dodokan, 20% is SSWS Jelateng, 35% is SSWS Menanga, and 65% is SSWS Putih.

[4] Model 2 is climate change vulnerability and risk analysis on water sector without involving society's welfare in the adaptation capacity component.

(4) Low vulnerability, covering West Lombok district (25%), southern part of Central Lombok district (10%); and north of East Lombok district (20%); or 80% is SSWS Jelateng and 30% is SSWS Putih.

Figure 3.2 "Vulnerability to Decreased Water supply" map for Lombok Island: a. with welfare component b. without welfare component



a. b.

3.3.2 Vulnerability to Flood

From the Map of Vulnerability to Flood Hazard below, we can identify several cities/districts which are generally very vulnerable to the flood hazards due to climate change for the period of 2030 to 2080, including the Mataram city and the center part of Central Lombok Regency (Central and Eastern Praya sub district). The very high level of vulnerability of the Mataram, covering 70% of its area, is caused by factors such as: highest population density (an average of > 5,761 inhabitants/km^2), land use is dominated by residential areas; SSWS land in upstream area reaches a critical stage; the protected forest area is in a very critical condition; local rainfall is the highest compared to other areas (> 2,400 mm/year in average); and there is a lack of irrigation infrastructure, water supply facilities, and lack of well springs.

The levels of vulnerability to flood hazards in Lombok Island based on the map in Figure 3.3b (model 2) are:

(1) Very high vulnerability, covering Mataram city (70%), local areas around Mataram city in West Lombok district (2.5%), Central Lombok district (Loteng, 10%), or approximately 20% is SSWS Dodokan.

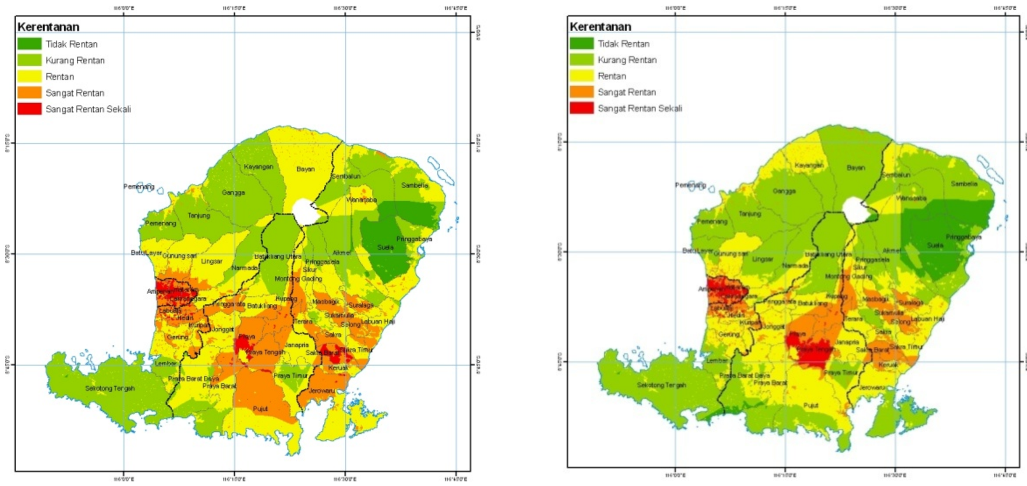
(2) High vulnerability, covering Mataram city (30%), part of Lobar district (5%), part of Loteng district (20%), central part of East Lombok (Lotim, 15%), or approximately 30% is SSWS Dodokan, 30% is SSWS Menanga, and 5% is SSWS Putih area.

(3) Medium vulnerability, covering Lobar district (40%), part of Loteng district (40%) and part of Lotim district (25%), or approximately 40% is SSWS Dodokan, 10% is SSWS Jelateng, 40% is SSWS Menanga, and 20% is SSWS Putih area.

(4) Low vulnerability, covering Lobar district (50%), Loteng district (25%) and Lotim district (40%), or approximately 10% is SSWS Dodokan, 85% is SSWS Jelateng, 30% is SSWS Menanga, and 40% is SSWS Putih area.

(5) Very low vulnerability, covering Lobar district (2.5%), Loteng district (5%) and Lotim district (20%), or approximately 5% is SSWS Jelateng and 25% is SSWS Putih.

Figure 3.3 "Vulnerability to Flood Hazard" map for Lombok Island: a. with welfare component b. without welfare component.



a. b.

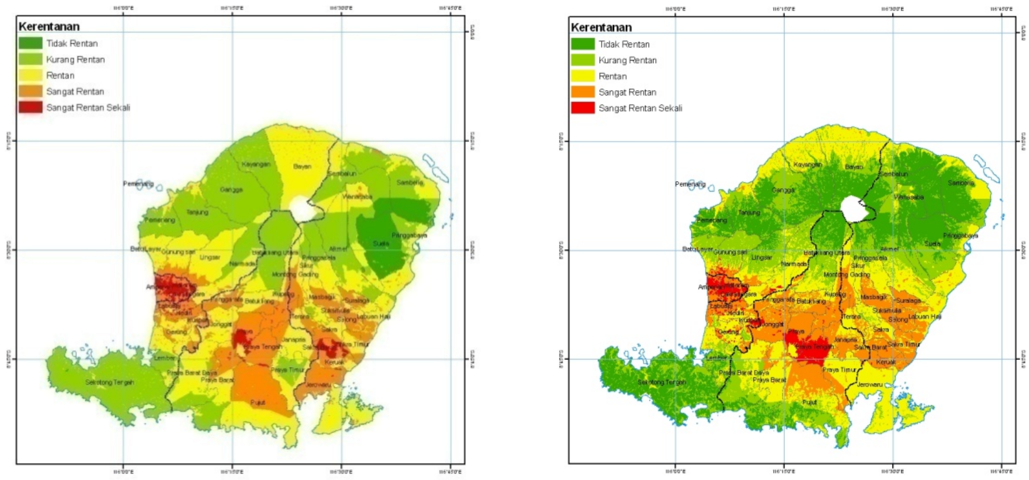
3.3.3 Vulnerability to Drought

From the Vulnerability to Drought map for Lombok Island, we can identify several cities/regencies which are generally very vulnerable to the hazard of drought due to climate change for the period of 2030 to 2080, namely Mataram and the central part of Central Lombok Regency (Central Praya District). The very high vulnerability level in Mataram city, covering 70% of it, is caused by various factors such as: highest population density (in average > 5,761 people/km^2); land use is dominated by residential areas; highest demand in population, industries and other water needs (each an average of 108.22 m^3/year, 647.02 m^3/year, and 1,050.68 m^3/year); the protected forest area is in a very critical condition; and lack of infrastructure irrigation or water supply facilities such as well springs; despite the fact that local rainfall is generally very low.

The levels of vulnerability to drought hazard in Lombok Island based on the map in Figure 3.4b (model 2) are:

1. Very high vulnerability, covering Mataram city (70%), local areas around Mataram city in Lobar district (5%), Central Lombok district (Loteng, 10%), or approximately 20% is SSWS Dodokan.
2. High vulnerability, covering Mataram city (30%), part of Lobar district (10%), part of Loteng district (30%), central part of Lotim district (25%), or approximately 35% is SSWS Dodokan, 30% is SSWS Menanga, and 5% is SSWS Putih area.
3. Medium vulnerability, covering Lobar district (40%), part of Loteng district (30%) and part of Lotim district (40%), or approximately 40% is SSWS Dodokan, 25% is SSWS Jelateng, 25% is SSWS Menanga, and 25% is SSWS Putih area.
4. Low vulnerability, covering Lobar district (25%), Loteng district (20%) and Lotim district (10%), or approximately 5% is SSWS Dodokan, 30% is SSWS Jelateng, 5% is SSWS Menanga, and 30% is SSWS Putih area.
5. Very low vulnerability, covering Lobar district (20%), Loteng district (10%) and Lotim district (25%), or approximately 40% is SSWS Jelateng and 40% is SSWS Putih

Figure 3.4 "Drought Vulnerability" map for Lombok Island: a. with welfare component b. without welfare component.



a. b.

3.4 Risk Analysis

3.4.1 Risk of Decreased Water Availability

The risk of decreased of water availability is defined as the lack of clean water and standard water supply to meet the community's daily needs (i.e. agriculture, industry, and others). Some *embung* (rainwater storage) with high dependencies on rain will dry up. Similarly, rivers, springs, and pressured ground water with local water flow, which are greatly influenced by rain and runoff, will experience shrinkage. Water supply for dams will also be reduced. These qualitative risks may happen on regions which are spatially a part of a decreased water availability risk area.

The GIS analysis is applied to obtain spatial distribution and decreased water availability risk level based on decreased water availability hazard and vulnerability map due to climate change. The levels for decreased water supply risk in Lombok Island and its distribution based on maps of GIS analysis results are shown in Figure 3.5 (model 2):

(1) Very high risk; covering Mataram city (100%), local areas in Lobar district (5%), Central Lombok district (Loteng, 10%), and Lotim district (15%); or approximately 20% is SSWS Dodokan and 30% is SSWS Menanga.

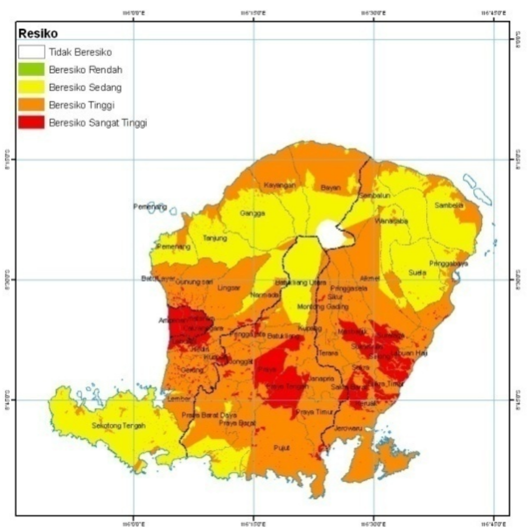
(2) High risk; covering central and southern Lobar district (50%), Loteng district (10%), and Lotim district (60%); or approximately 75% is SSWS Dodokan, 20% is SSWS Jelateng, 60% is SSWS Menanga, and 40% is SSWS Putih.

(3) Medium risk; covering northern and southern Lobar district (45%), Loteng district (30%), and northern Lotim district (25%); or approximately 5% is SSWS Dodokan, 80% is SSWS Jelateng, 10% is SSWS Menanga, and 60% is SSWS Putih.

(4) Low risk, insignificant so that it does not appear on the map.

(5) Very low risk or no risk; limited to areas around Mount Rinjani peak.

Figure 3.5 Risk of decreased water supply map for 2030-2080 periods



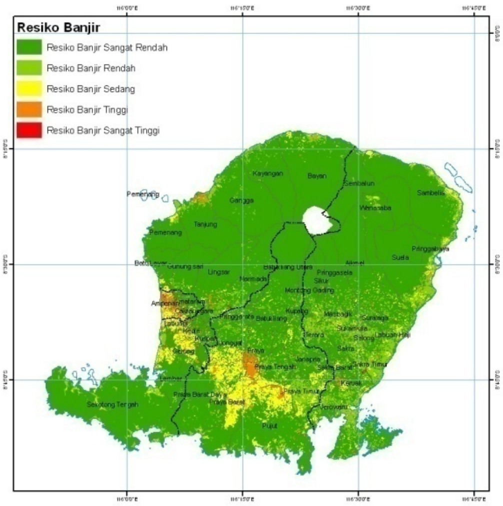
3.4.2 Flood Risk

The flood pool, which is predicted in this study, may lead to losses due to infrastructure damage, reduced population performance, and increasing health problems. Flood water that remains on the ground for quite some time can result in an outbreak of various related diseases such as dengue fever and other diseases like cholera. This condition is worsened by poor quality/minimum sanitation facilities. These flood risks are qualitative, and may happen on regions which are spatially flood risk areas.

To understand the spatial distribution of flood risk and its levels, we conducted GIS analysis to the map of flood and hazard. The results are flood risk levels in Lombok Island and its distribution based on the map in Figure 3.6 (model 2):

1) Very high risk; covering Mataram city (10%), very limited local areas in Lobar district (2.5%), central of Loteng district (2.5%), and Lotim district (2.5%); or approximately 5% is SSWS Dodokan and 2.5% is SSWS Menanga.
2) High risk; covering Mataram city (20%), scattered area in Lobar district (5%), Loteng district (10%), and Lotim (5%) or 10% is SSWS Dodokan, 2.5% is SSWS Menanga, and 10% is SSWS Putih.
3) Medium risk; covering central Lobar district (20%), Loteng districk (30%) and Lotim district (30%) especially coastal areas, or 35% is SSWS Dodokan, 20% is SSWS Jelateng, 20% is SSWS Menanga, and 10% is SSWS Putih.
4) Low and very low risk (no risk); in most area of Lombok Island, especially in high altitude areas.

Figure 3.6 Flood risk map for 2030-2080 period



3.4.3 Drought Risk

Drought risks or drought impacts have more severe impacts compared to the decreased water availability risk, in terms of its intensity and its coverage. Qualitative drought risk and may happen in regions which are spatially drought risk areas are: water supply for water sources like *embung* (rainwater storage), rivers, and well springs. Unpressurized ground water will decline and cause a critical water balance or even water deficit. There will be less clean water for daily populations needs, as well as water for agriculture, industry, and other needs. Other qualitative risks are: the conditions of *embung,* rivers, well springs, and unpressurized ground water (shallow). A number of *embung* or even all of them will experience a lack of water, or even a total dry up. Also, a number of well springs will be reduced.and the rivers will dry up.

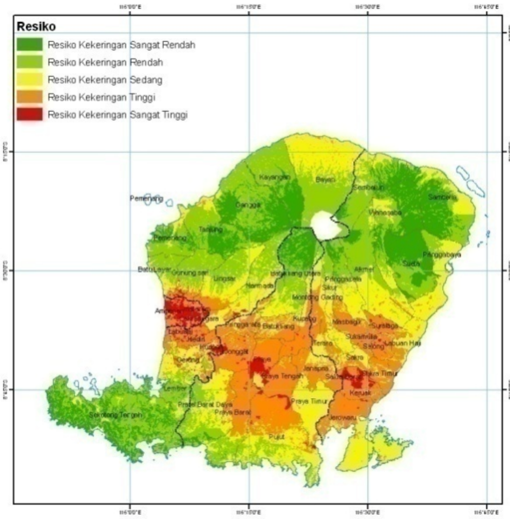
Further drought risk will be experienced by the agricultural sector. Qualitatively, in the dry period there is a high probability of planting failure and failed crop occurances due to a shift in season or a decreasing supply of water, especially for rice and horticultural fields. Agricultural productivity is very much threatened by this risk.

Drought risk levels in Lombok Island and its distribution based on GIS analysis result of drought hazard and risk maps in Figure 3.7 (model 2) are:

1) Very high risk; covering Mataram city (70%), very limited local areas in central Lobar district (<2.5%), central of Loteng district (5%), and Lotim district (5%); or approximately less than 10% is SSWS Dodokan area and 10% is SSWS Menanga area.
2) High risk; covering Mataram city (30%), central Lobar district (7.5%), Loteng district (35%) and Lotim district (20%) or 50% is SSWS Dodokan area, 10% is SSWS Jelateng area, 50% is SSWS Menanga area, and 5% is SSWS Putih area.
3) Medium risk; covering central Lobar district (40%), Loteng district (30%), and Lotim district (25%) or >20% is SSWS Dodokan, 20% is SSWS Jelateng, 20% is SSWS Menanga and 25% is SSWS Putih.
4) Low risk covering cenral Lobar district (40%), Loteng district (20%), and Lotim district (20%) or >20% is SSWS Dodokan, 40% is SSWS Jelateng, 20% is SSWS Menanga and >40% is SSWS Putih.

5) Very low risk (no risk) covering Lobar district (10%), Loteng district 10%) and Lotim district (30%); or approximately 30% is SSWS Jelateng, 5% is SSWS Menanga and 30% is SSWS Putih.

Figure 3.7 Drought risk map for 2030-2080 period

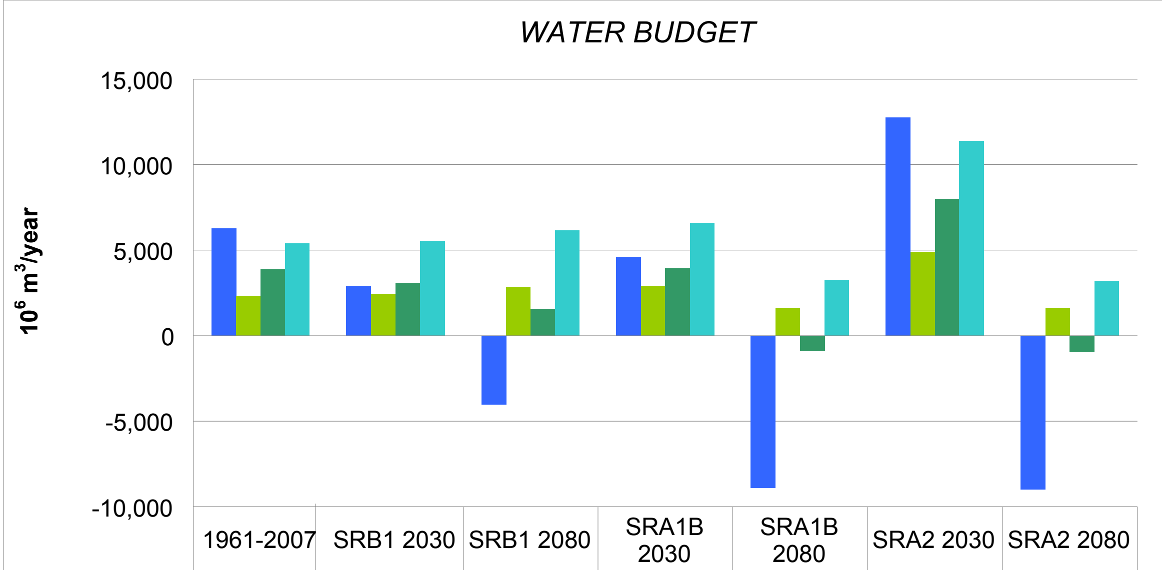


3.4.4 Water Availability Risk: Water Budget Approach

The exact condition of the water resources balance may imply a series of further risks or impacts on the water sector. Among others, the disruption of several sources of water supply in the short term (*embung*, river water, local springs, and free aquifer groundwater) can have a direct impact on clean water supplies for daily needs of people; raw water for agriculture, industry, and others. A water resource balance that is in deficit can have a social impact, such as competition for water resources seizure, declining population performance, agricultural production, industrial and economic performance, and declining population health.

According to the projections, SSWS Dodokan and SSWS Menanga will experience water deficit. Although this projection is for the year 2080, shortages can already arise much earlier, starting from 2030 onwards. In fact, the calculation results by related offices in NTB province show that there are already water deficit in SSWS Dodokan at current time. These different results might be caused by different data being used. Based on the risk map, potential locations for water deficits are: city of Mataram, several areas in Central Lombok District (District Praya), West Lombok District (District Kuripan), and East Lombok regency (district and sub-district of West Sukra Keruak). So as to augment the accuracy of these impacts, further studies are still needed.

Figure 3.8 Graph of water availability projection (optimum amount of surface water plus groundwater) on Lombok Island for each SSWS baseline (1961-2007) up to 2030 and 2080. Land use assumptions in the projection are similar to the baseline condition.



	1961-2007	SRB1 2030	SRB1 2080	SRA1B 2030	SRA1B 2080	SRA2 2030	SRA2 2080
Dodokan	6,269.10	2,859.75	-4,022.81	4,619.40	-8,877.14	12,757.38	-8,990.27
Jelateng	2,327.48	2,446.93	2,837.63	2,882.71	1,635.42	4,898.14	1,607.40
Menanga	3,883.46	3,063.60	1,545.72	3,942.99	-880.25	8,009.98	-936.79
Putih	5,409.79	5,539.38	6,133.51	6,578.50	3,266.89	11,384.20	3,200.09

3.4.5. Other Risks

Other risks and vulnerabilities based on other hazards are the risk of seawater intrusion and the risk of landslides. It can be stated qualitatively that the risk of seawater intrusion is based on the current low ground water level and rate of ground water extraction in coastal areas. Sea water intrusion may occur in the Senggigi beach area, Mataram city – very soon if the rate of groundwater extraction in the area continues as usual.

Based on a qualitative study, the risk of landslides is low to moderate for particular areas which are currently experiencing landslide events. Landslide risk depends on the population density and land use, as well as water catchment conditions in areas with high probability of landslides. Landslide risk is increased during more than normal rainfall periods and land use with critical landslide condition.

4

ANALYSIS OF VULNERABILITY AND RISK OF CLIMATE CHANGE: AGRICULTURE SECTOR

4.1 Problem Identification

A shifting rainfall period in November-December-January–February in the last decade could induce potential risk for the agricultural sector. Decreasing rainfall in January could climatologically become a serious threat to rice farming. A bottom-up analysis (comparing the reduction in rainfall in January with rice crop production or crop failures data) could provide an illustration of such a risk.

Climate change hazards for the agriculture sector may be identified directly from climate projection data or through water balance calculation. A more complex analysis of climate change impact involves utilization of a crop yield simulation model but requires more extensive climate data. With limited climate projection information available, we need to look for alternative methods to transform them into parameters that are directly related to agriculture. This can be done by, for example, constructing a simple regression model between rainfall and temperature to crop yield. However, this approach also cannot produce satisfying results, because agricultural yield productivity is not only affected by climate, i.e. one could say that the effects of climate change on agricultural productivity could only appear on a much more detailed assessment. Since the present assessment is conducted on a more general scale, the vulnerability and risk assessments of agricultural sector are conducted using an extreme condition approach (more detailed discussion in Sub-chapter 4.2).

Planting failure will occur if water availability during the planting season is not enough. For example, for the growing period of November-February, the planting season is early to mid-November. **Growing failure (**failure to grow**)** will occur if there is a lack of water supply mid- to end of December, for the growing period of November to February. **Harvest failure** potential (rice) may occur if stems collapse due to heavy rain, flood, or wind. Harvest period usually occurs from the end of February to March, but it generally begins in February. Therefore, potential harvest failure analysis is conducted for extreme wet conditions by calculating the **total runoff** in February.

4.2 Method of Study

This study consists of hazard, vulnerability, and risk assessments. This hazard analysis is based on the following assumption: **that the possibilities of hazards will occur if there are extreme conditions, whether due to less rainfall condition or more rainfall condition**. The reference of these extreme conditions is the current condition, which is called as the **baseline condition (1961-2007)**. To conduct extreme conditions analysis, we can use the distribution of data with CDF (Cumulative Distribution Frequency) method. Hazard analysis is conducted for three different hazard potential on rice commodity, which are planting failure, growing failure, and harvest failure.

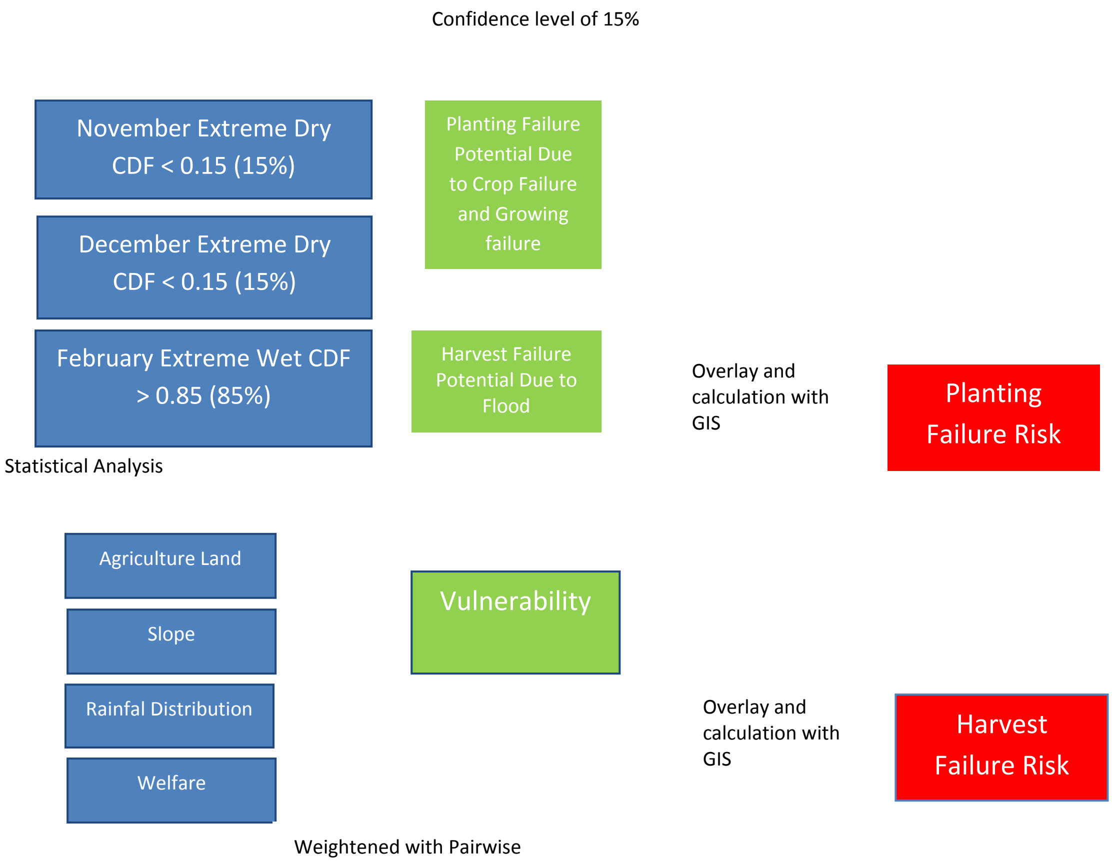
Planting failure will occur if there is a lack of water availability in early to mid-November. Thus, to understand the planting failure, extreme analysis is conducted for minimum water availability (total runoff CDF < 15%) in November. This hazard potential may decrease rice productivity.

Growing failure will occur if there is a lack of water availability in mid- to end of December. Thus, to understand the growing failure, analysis is conducted for minimum water availability (total runoff CDF < 15%) in December. This hazard potential may decrease rice productivity.

Harvest failure occurs when rice stems collapse due to heavy rain and strong wind, or floods. But in this study, wind analysis is not conducted; analysis is only performed for the magnitude of rainfall. Harvest period is at the end of February and March, but generally in February. Thus, to understand the harvest failure, analysis is conducted for extreme wet condition (total runoff CDF > 85%) in February.
This hazard analysis will later be used to produce risk analysis due to climate change on agriculture sector. . Vulnerability levels in the agriculture sector are analyzed using

Pairwise Comparison weighting method. The method is used to obtain the ratio matrix in search of importance intensity from elements of a certain group of data (Saaty, 1980). Components used in this vulnerability analysis consist of Agriculture Land Type, Slope, Rainfall Distribution, and Population Welfare Level. The flow diagram of this methodology is shown in Figure 4.1.

Figure 4.1 Flow chart of potential and probability of hazard and vulnerability analysis for climate change



4.3 Vulnerability Analysis

There are two types of vulnerability that will be assessed: vulnerabilities to planting failure and harvest failure. As seen in Figure 4.1, vulnerability to planting failure is a combination of decrease in production due to planting failure and growing failure. Scenario-1 in the vulnerability assessment for planting failure due to drought is to include a population welfare factor in the analysis model. Then in scenario-2, the population welfare factor was not included in the analysis, in order to find the difference of vulnerability level between one with and without considering the welfare factor. The reason to use the population welfare factor as one of the variables in this analysis is that farmer in general as poor people are considered to be more vulnerable to climate change.

4.3.1. Vulnerability to Planting Failure

Based on the rainfall distribution analysis of Lombok Island, it can be seen which rice field areas are or are not vulnerable to drought. Analysis results of scenario-1 (includes the welfare of the population) and scenario-2 (without including the welfare of the population) show that the number of agricultural areas with high vulnerability to planting failure is higher than those with medium vulnerability (which are indicated by orange color on the map). The number of districts with "high vulnerability" in scenario-1 is less than the number of districts with "high vulnerability" in scenario-2. But the number of districts which are "vulnerable" in scenario-1 is higher than the number of districts which are "vulnerable" in scenario-2. In scenario-1, Kayangan and Praya Timur districts have status of ”vulnerable” to planting failure, however, these districts turn into ”very vulnerable” status in scenario-2 analysis. This indicates that the level of population welfare certainly affects vulnerability level to planting failure in which the poor people (representing farmer in general) are indeed very vulnerable to the planting failure hazards in the case of drought.

Figure 4.2 Vulnerability to planting failure, with welfare factor

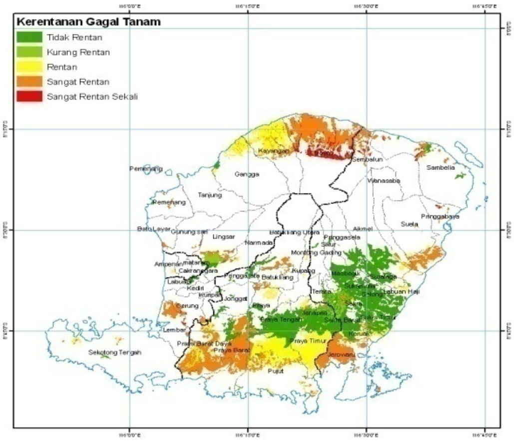
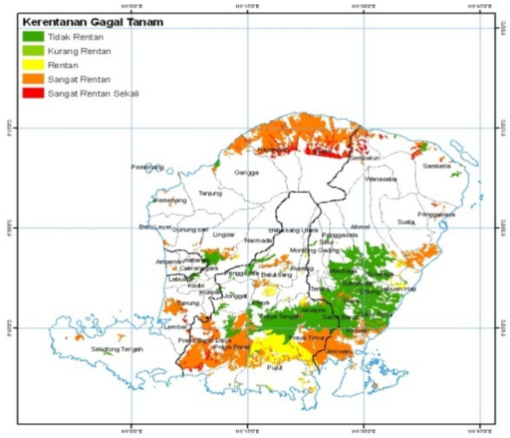


Figure 4.3 Vulnerability to planting failure, without welfare factor



Regions (district) that are stated to be "vulnerable" and "very vulnerable" to planting failure hazards due to drought are commonly found in areas with rainfed rice fields, such as rice fields in Central Lombok regency, and a few districts in East Lombok regency. Regions (district) which were found to be "not vulnerable" and "less vulnerable" are areas with irrigated rice fields such as Masbagik, Suragala, Sukamulia, Selong, Sakra, Janapria and Praya Tengah districts. Areas with very high vulnerability were identified on several locations in the Bayan district.

4.3.2 Vulnerability to Harvest Failure

The results of the analysis for scenario-1 and scenario-2 for the vulnerability analysis for failed harvest showed no significant difference. This means that the population welfare was not a significant factor in determining vulnerability level to harvest failure in Lombok Island. Thus, this also indicates that crop failure is determined by climate variability (rainfall condition) during the 10-15 days before harvest. If rain with high frequency and intensity followed by strong wind occurs during this period, failed harvest probability will be very high. It will lead to decreased quality and quantity in production.

Figure 4.4: Vulnerability to failed harvest based on scenario-1 (includes people welfare factor)

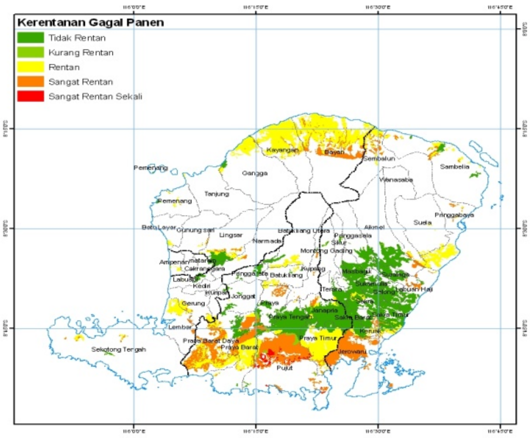
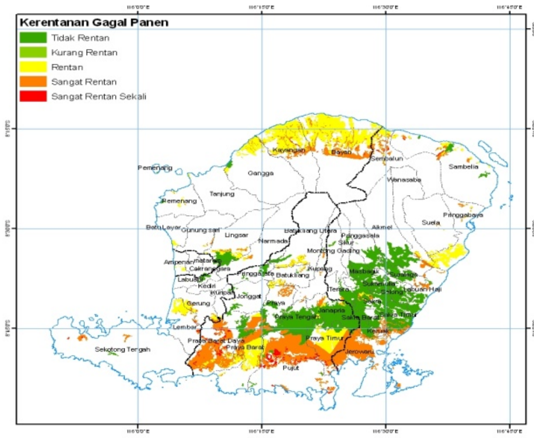


Figure 4.5 Vulnerability to failed harvest based on scenario-2 (excludes people welfare factor)



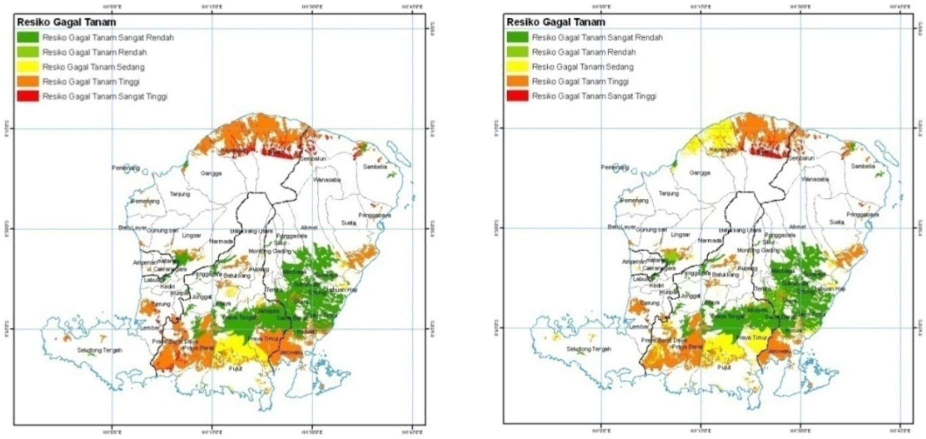
4.4 Risk Assessment

4.4.1 Risk on Planting Failure

According to the maps presented below, there are four levels of planting failure risk, namely: low, medium, high and very high both for scenario-1 and scenario-2. Analysis results indicate that there is no significant difference between scenario-1 and scenario-2 for low and medium risk to planting failure.

A difference exists for the districts with a high risk of planting failure, that there are more districts with high risk in scenario-1 compared to those in scenario-2. In scenario-1, Kayangan and East Praya are districts with high planting failure risk (marked by orange color in the map), while in scenario-2, both districts are rated as medium planting failure risk districts (marked by yellow color in the map).

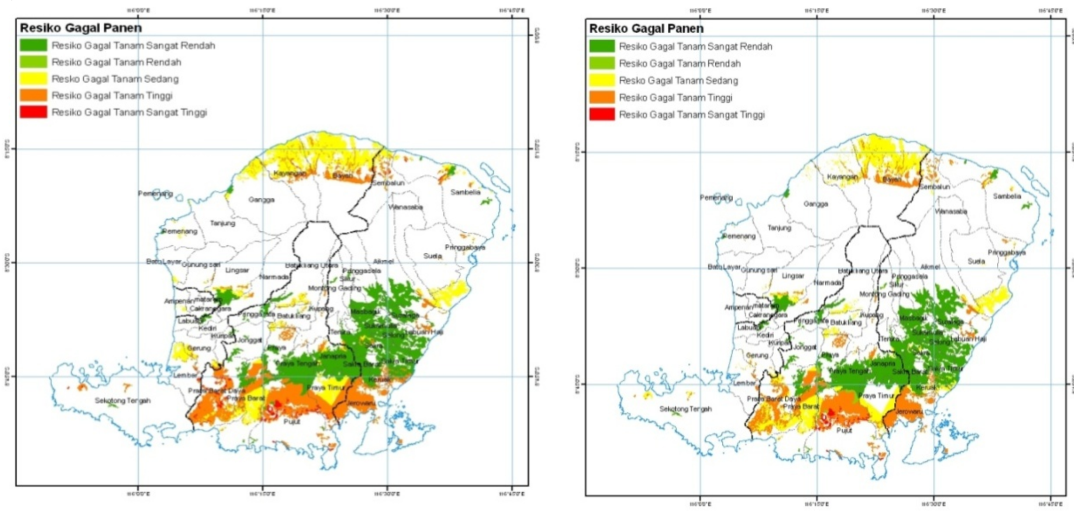
Figure 4.6 Map of medium to high risk to planting failure hazard based on analysis from scenario-1 and scenario-2, respectively.



4.4.2. Risk on Harvest Failure

In the maps below, we can see the differences and similarities on the harvest failure risk for each district based on analysis of scenario-1 and scenario-2. The harvest failure risks with very low to high levels have no significant differences for both scenario-1 and scenario-2. It indicates that the people welfare does not give significant impact on the risk for failed crops. It can be concluded that dominant factors affecting failed crop risk relate to parameters such as farm field types (irrigated and/or rainfed), rainfall pattern and topographical slopes within each area or district.

Figure 4.7 Map of medium to high risk of failed harvest hazard (left: scenario-1, right: scenario-2).



5

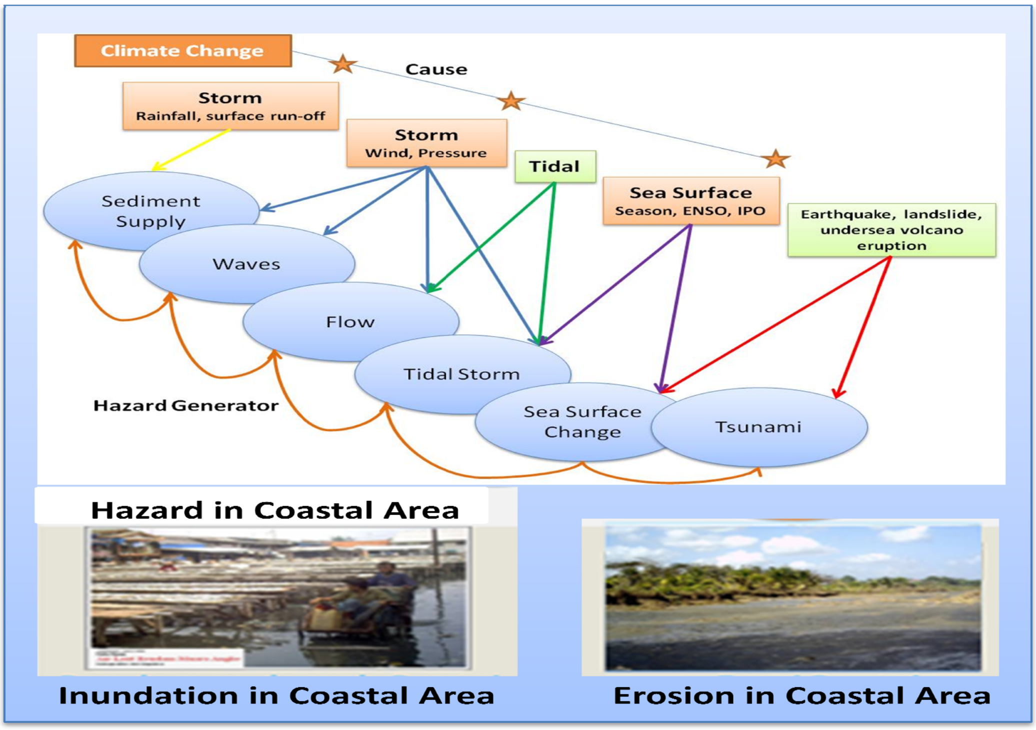
ANALYSIS OF VULNERABILITY AND RISK OF CLIMATE CHANGE: COASTAL SECTOR

5.1 Problem Identification

The equilibrium between oceanic and atmospheric systems as climate determinants is being disturbed by human activities through the increased production of green house gasses (GHG). Accumulation of these gasses triggers global warming which then changes the global climate. The resulting climate change could triggers natural hazards in coastal and ocean environments such as increases of sea surface temperature, increases of frequency and intensity of extreme events (storm, cyclone), changes in rainfall pattern and river stream, changes in natural climate variabilities (El-Nino, La-Nina), changes in ocean circulation patterns and sea level rise. Figure 5.1 shows the interactions between climate changes and triggered potential hazards. This figure also describes influences of one hazard element relative to each other. As a result, an area could experience some climatic forces simultaneously.

To understand those impacts of climate changes to coastal areas, it is necessary to conduct vulnerability and risk assessments for the potential hazards. Spatial mappings of hazards, vulnerability, and risk by using Geographical Information System are, therefore, needed.

Figure 5.1 Interaction among climate change inducted hazards in the coastal and marine sector.



5.2 Method of Study

Assessments of hazards, vulnerability and risk to coastal sector to climate change with a case study in Lombok Island are conducted to formulate adaptation strategies in the form of response or reaction in an effort to minimize the impacts that will arise from climate change.

The term adaptation in a broad sense is every human effort in modifying natural or artificial systems in reacting to the influence of current climate change and its projections in the future in order to reduce damages or improve the opportunities to reach gains from the climate change (Stern, 2008).

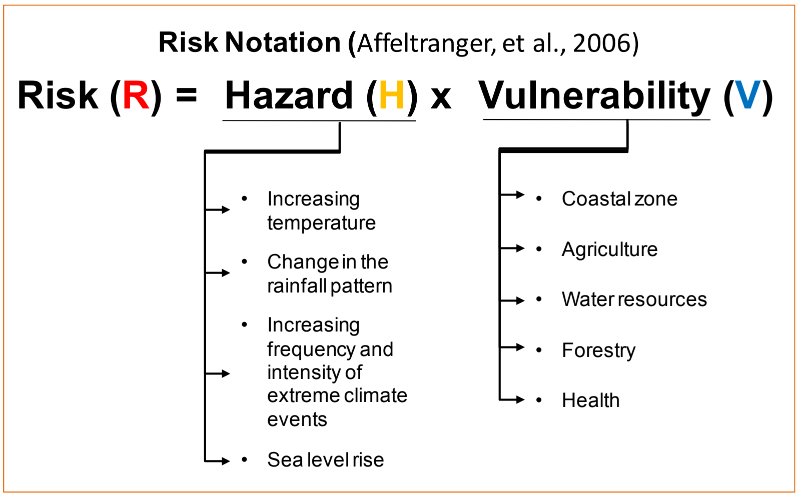
Manyena (2006) emphasized that there are two approaches that need to be considered in managing risks related to vulnerability and resilience. The first is a vulnerability management aiming to reduce vulnerability to hazards triggered by climate change with a top-down method with policy driven (that are driven by policy). This effort is aimed to take the fights associated to more focus on safety, through prevention efforts. Therefore, it requires institutions, system and engineering, based on risk assessments, which are oriented to results or problem-solving, through standard operating procedures (SOPs). Meanwhile, the second approach is to increase resilience to hazards triggered by climate change, by bottom-up method, which is aimed for recovery. This process takes time to dispel and to return to an acceptable state, by means of community based adaptation, through a net-working, with the approaches of culture and local wisdom. This effort is mainly based on vulnerability and capacity analysis, which is oriented to the process.

Both approaches are needed to be conducted simultaneously in facing the hazards caused by climate change. Therefore this assessment considers two types of adaptation, namely: policy-driven adaptation and autonomous adaptation. Related to the purpose of mainstreaming climate change issues into the RPJMD of NTB Province, hence, this study conduct greater effort on the adaptation driven by the policy.

The assessment also involved two levels of adaptation, namely: strengthening the capacity of adaptation and implementation of adaptation actions. The first level includes the provision of information on hazards, vulnerabilities and risks of climate change, while the implementation of adaptation actions includes measures of vulnerability reduction and security improvement in order to reduce risk in coastal areas on climate change. These policy measures will be described more detail in the climate change adaptation strategy and its integration into development policy in the NTB Province.

General approach of the assessment was chosen based on the assessment approach to Climate Change, Impacts, Adaptation and Vulnerability (CCIAV). This approach is derived from risk assessment framework which becomes a new development in the study of CCIAV (IPCC, 2007 in Suroso, 2008). This risk-based approach is used in this assessment to facilitate the mainstreaming of adaptation options into policy making, particularly in the NTB Province, as shown in Figure 5.2. This figure shows the linkage of risk elements (hazard and vulnerability), that are formulated in relation to: the Risk (R) is a cross between the Hazards (H) and Vulnerability (V).

Figure 5.2 Diagram of risk notations.



5.3 Vulnerability Assessment

This vulnerability analysis was conducted for two scenarios which are: [1] with population welfare factor (Vk); and [2] without population welfare factor (Vks). This analysis was conducted on Lombok Island with a particularly detailed analysis for Mataram city and its surrounding areas. In general, Table 5.1 below describes common elements and parameters of vulnerability in coastal areas due to climate changes.

Table 5.1 Common Element and Parameter on Climate Change

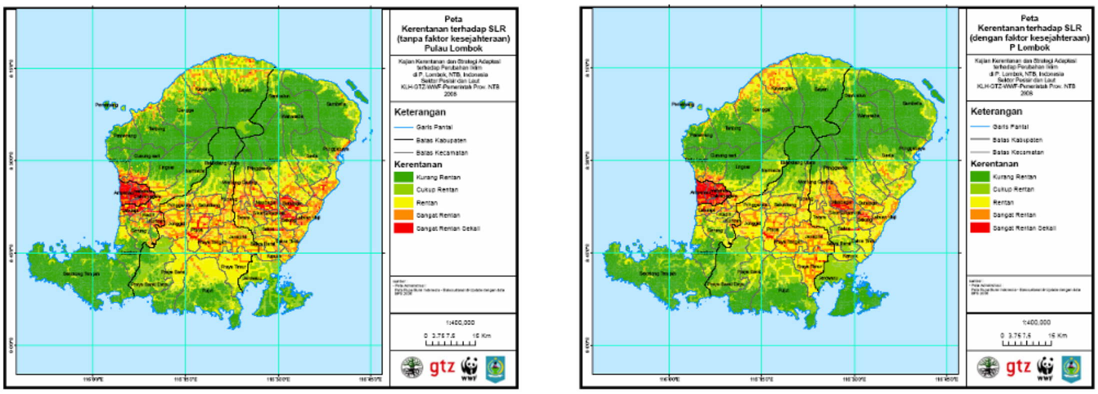
Vulnerability elements	Vulnerability parameters
Geography	• Location and position
Socio-demography	• Population and population density • Age distribution and gender
Infrastructure and facilities	• Residential buildings • Low and high level buildings • Infrastructure (roads and bridges network system, other supporting facilities) • Vital lifelines facilities such as clean water system, electricity network, telecommunication network
Land use, land cover	• Land use map

The levels of vulnerability of the coastal areas in Lombok Island are determined by several factors, among others: population density, land use types, elevation, slopes, vulnerability of vital infrastructure and population welfare. The weight of each parameter was determined according to their effects to the coastal inundation risk and confidence level of the data (in this case, the accuracy level of spatial data). The weighting method used was the pairwise comparison (Saaty, 1980), which is basically to estimate relative importances of parameter to the others.

5.3.1. Vulnerability Assessment of Lombok Island

In the Lombok Island, the analysis has to take account of welfare since poverty is a significant element of vulnerability. Figure 5.3 (left and right sides) shows vulnerability maps with and without population welfare factor, respectively. These information are obtained by overlying the maps of related vulnerability parameters.

Figure 5.3 Vulnerability maps of Lombok Island to potential coastal inundation, with population welfare factors (left) and without population welfare factor (right).



It is shown in those figures that the areas of very high vulnerablity level without regarding to population welfare factor (scenario-1) are more important than ones with consideration of welfare (scenario-2). In contrast, the areas of high to very low level of vulnerability with scenario-1 are more limited in comparison to ones with scenario-2. This result indicates that the population welfare significantly influences the vulnerability, in which poor population has less capability to adapt the hazards rather than population having higher economic level. Table 5.2 shows vulnerability levels and coverages of Lombok Island, with and without population welfare factors.

Table 5.2 Coverage of Vulnerability Level in Lombok

Number	Vulnerability Level	Coverage area (Hectares)	
		Without consideration of population welfare factor	With consideration of population welfare factor
1	Very low vulnerability	67,002.00	204,017.13
2	Low vulnerability	68,512.00	96,366.12
3	Medium vulnerability	85,752.00	107,699.07
4	High vulnerability	37,476.00	38,714.62
5	Very high vulnerability	20,900.00	9,418.43

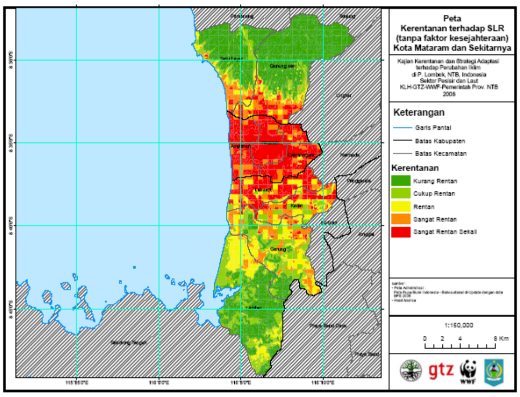
5.3.2. Vulnerability Assessment of the Mataram City and its Surroundings

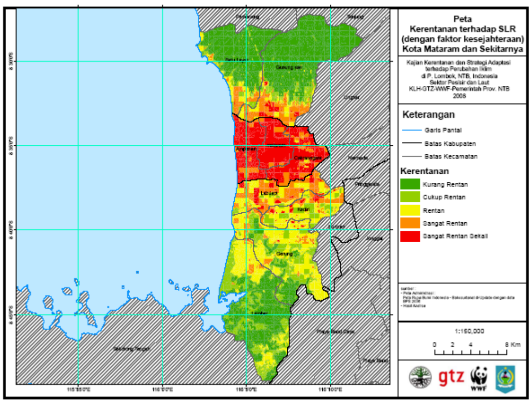
Similar to the analysis for Lombok Island, the one for Mataram city and its surroundings also considered several factors, among others: population density, land use types, elevation, slopes, vulnerability of vital infrastructure and population welfare. The analysis is applied to districts in Mataram City (Ampenan, Mataram, and Cakranegara) as well as in West Mataram Regency (Batu Layar, Gunung Sari, Labuanapi, Kediri, Gerung, and Lembar). Figure 5.4 shows vulnerability maps with and without welfare factors, respectively, while Table 5.3 shows aggregated vulnerability levels of Mataram City, with and without population welfare factors, respectively.

Table 5.3 Coverage of Vulnerability Level in Mataram

Number	Vulnerability Level	Coverage area (Hectares)	
		Without consideration of population welfare factor	With consideration of population welfare factor
1	Very low vulnerability	13,261.60	12,429.88
2	Low vulnerability	5,401.15	5,555.38
3	Medium vulnerability	7,224.36	5,560.73
4	High vulnerability	4,429.75	4,430.74
5	Very high vulnerability	5,826.37	8,166.52

Figure 5.4 Vulnerability maps of Mataram city: potential coastal inundation, with population welfare factor (left) and without population welfare factor (right).





5.4 Risk Assessment

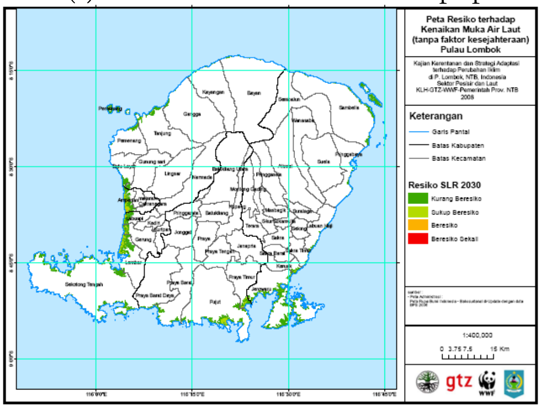
5.4.1. Risk Assessment of the Lombok Island

Table 5.4 shows a summary of risk level with its coverage area both with and without welfare factor, while Figure 5.5 shows a risk map of Lombok Island without population welfare factors and Figure 5.6 shows the same map but with population welfare factors. These information are obtained by overlying projected hazard map to the vulnerability maps.

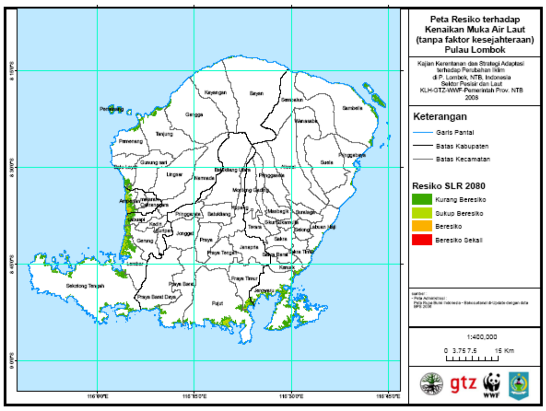
Tabel 5.4 Coverage of Risk Level in Lombok with and without Welfare

No	Risk Level	Coverage area (Hectares)					
		Without consideration of population welfare			With consideration of population welfare		
		Year			Year		
		2030	2080	2100	2030	2080	2100
1	Very low risk	10,540.67	9,817.15	9,449.31	8,358.78	7,611.10	7,347.14
2	Low risk	4,780.11	5,246.72	5,440.64	4,025.99	4,090.59	3,929.19
3	Medium risk	574.28	812.07	978.93	1,876.49	2,141.43	2,330.39
4	High risk	67.75	86.87	93.93	1,701.06	2,119.14	2,355.53

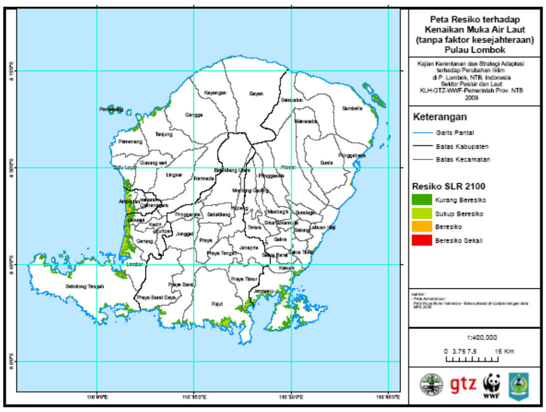
Figure 5.5 Risk maps of projected climate change for year 2030s (a), 2080s (b), and 2100s (c) in Lombok Island without population welfare factor.



(a)

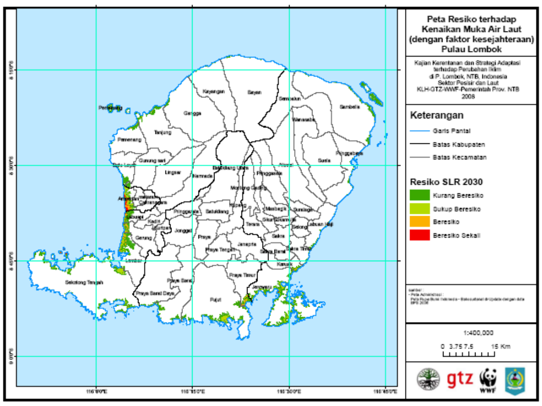


(b)

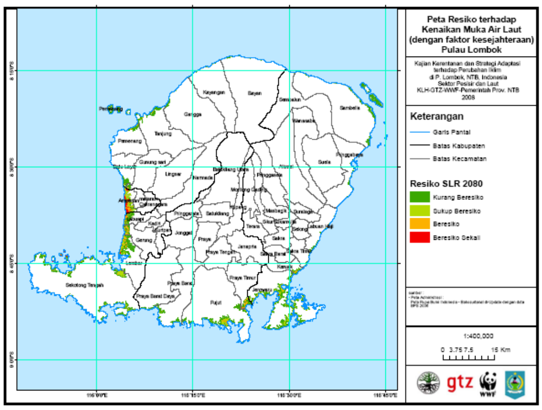


(c)

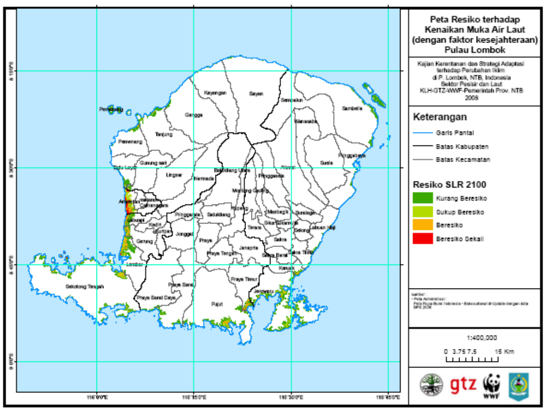
Figure 5.6 Risk maps of projected climate change for year 2030s (a), 2080s (b), an population welfare factor.



(a)



(b)

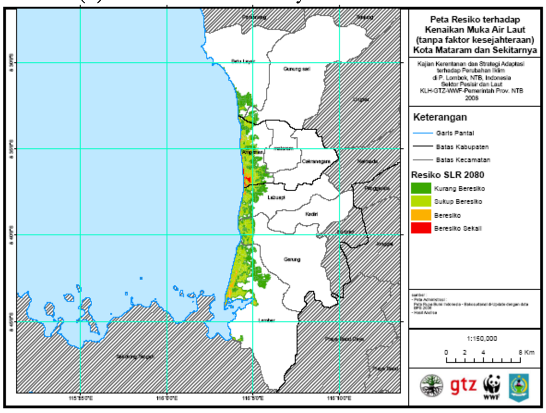


(c)

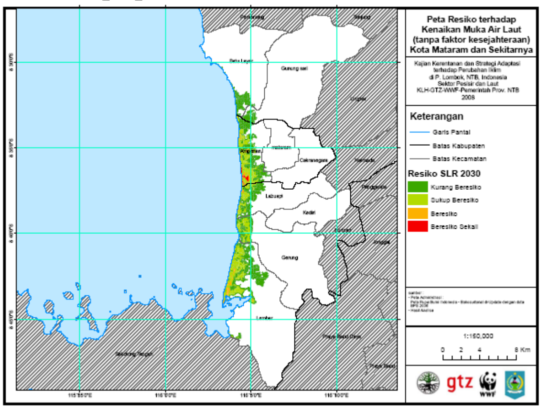
5.4.2. Risk Assessment of the Mataram City and its Surroundings

Figure 5.7 shows risk map of Mataram city and its surroundings without welfare factor, while Figure 5.8 shows risk map of this city with population welfare factor. Table 5.5 shows risk levels and the coverage areas with and without welfare factors. It can be seen that by including population welfare factors, medium and very high risk areas tend to be larger. This is caused by the level of welfare of coastal communities being very low, thus increasing the vulnerability, thereby increasing the extent of the areas that have very risky levels. From the analysis of vulnerability and risk, a very risky area is the district Ampenan, Mataram.

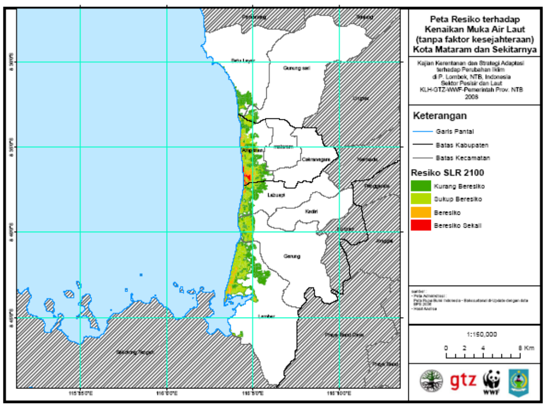
Figure 5.7 Risk maps of climate change projections for year 2030s (a), 2080s (b), and 2100s (c) in Mataram city and it's surrounding without population welfare factor



(a)



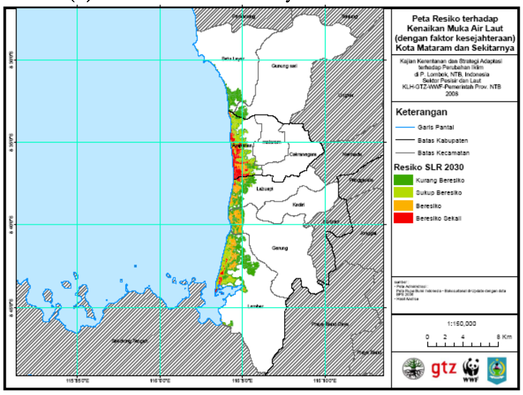
(b)



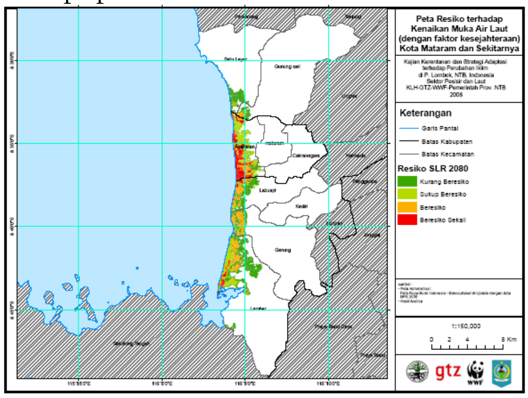
(c)

.

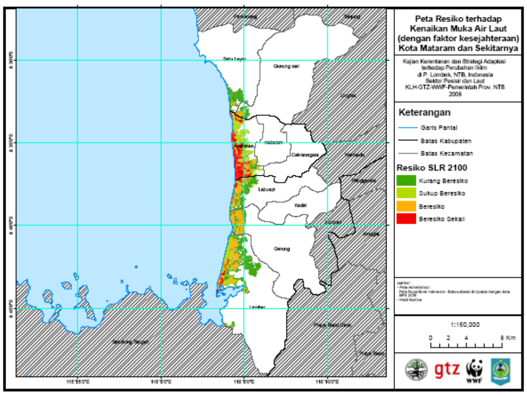
Figure 5.8 Risk maps of climate change projections for year 2030s (a), 2080s (b), and 2100s (c) in Mataram city and it's surrounding with population welfare factor.



(a)



(b)



(c)

Tabel 5.5 Coverage of Risk Level in Mataram with and without Welfare

No	Risk level	Coverage area (Hectares)					
		Without consideration of population welfare			Without consideration of population welfare		
		Year			Year		
		2030	2080	2100	2030	2080	2100
1	Very Low risk	2230.57	1931.37	1871.68	1767.82	1481.31	1422.2
2	Low risk	1613.44	1854.29	1816.74	976.4	979.91	933.17
3	Medium risk	218.31	258.38	348.91	762.82	928.32	958.88
4	High risk	65.37	83.64	90.36	620.65	738.15	813.44

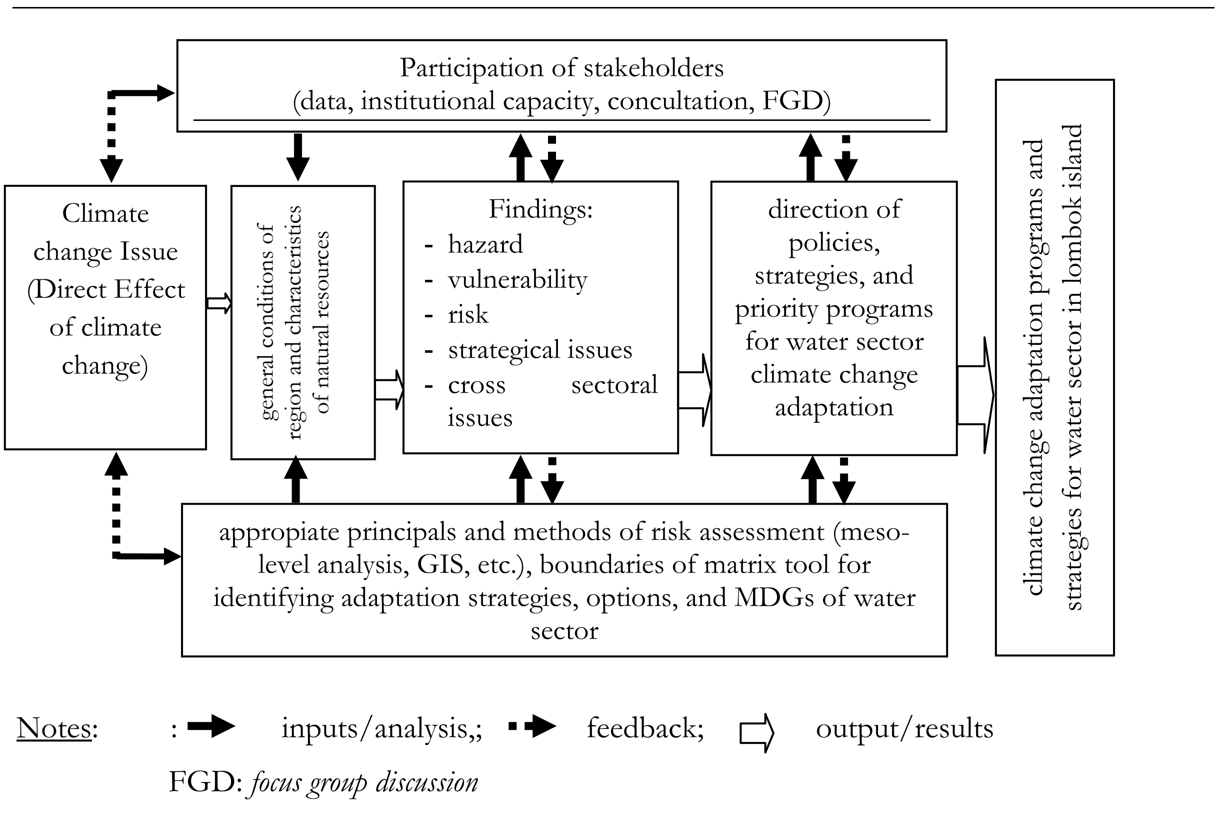
6

INTEGRATING ADAPTATION STRATEGY TO CLIMATE CHANGE INTO DEVELOPMENT PLANNING

6.1 Water Resource Sector

Having completed the vulnerability and risk assessment as presented in the previous chapters, it is considered that sufficient prerequisite for formulating adaptation strategy is present. This chapter presents adaptation strategy and program in water resources, agriculture, and coastal sectors to respond to climate change impact in the Lombok Island.

Figure 6.1. Scheme for strategy identification and adaptation program for climate change in water sector in Lombok Island.



Adaptation strategies and programs that have been identified are as follows:
1) Strategies for Data and Information Management are

Strategy 1: Increase the capacity for data and information collection and processing, institutions, capacity building, and regulations for the effective management of water resources to respond to climate change

a) Program 1: Increasing the capacity of data and information collection and processing as well as the research on climate change impacts on water resources sector at micro level

- Activity 1: Verify the data and information used in this study for a re-calculation of water resources balance involving variability and climate projections;
- Activity 2: Carry out studies on vulnerability and risks of climate change in the water sector at the micro-level;
- Activity 3: Study of the vulnerability and risks of climate change on the water sector in very vulnerable locations and/or strategic locations;

b) Program 2: Formalize regulatory policy for water resources and climate change impact management

- Activity 1: Develop regulation for river basin management, water resources, and response to climate change in the water sector
- Activity 2: Develop regulations for climate change adaptation in the water sector;
- Activity 3: Development of other regulations in the water sector and climate change adaptation;

c) Program 3: Socialization, training, campaigns on the impacts of climate change on the water sector, increasing community participation and involvement

- Activity 1: Socialization and campaigns on climate change adaptation in the water sector
- Activities 2; Training for climate change and water resource management

2) Strategies for adaptation to decreasing water supply and drought are as follows:

Strategy 1: Conserving water balance and providing equal access to clean water in rural and urban areas through rehabilitation and construction of water infrastructure and appropriate technologies for water resources development.

a) Program 1: Maintaining the water resources balance, prevention of climate change risks in the water sector, increasing the water infrastructure capacity;

- Activity 1: Rehabilitation and construction of check dams, *embung* (water storage), and other water reservoirs to support climate change adaptation
- Activity 2: Rehabilitation and construction of irrigation infrastructure to prepare for climate change impacts;
- Activity 3: Initiate water catchment campaigns so as to anticipate the impact of climate change on the water sector.

b) Program 2: Increase water supply in highly vulnerable areas through appropriate technology and the development of local water resources.

- Activity 1: The use of groundwater in water-lacking areas
- Activity 2: Provision of water and prevention of climate change impacts in dry areas with the application of rainwater harvesting technology[5].
- Activity 3: Provision of clean water and raw water in urban areas through the intermediate technology such as water purification or water recycle.

Strategy 2*:* Increase the capacity of watersheds and water conservation with a focus on sustainability of water availability for agriculture and water-based infrastructure through management of water catchment areas, adaptation to seasonal changes, the application of innovation or new technology, community participation[6], and the revitalization of culture and local wisdom[7].

---

[5] Rain water harvesting or, simply, "water harvesting" technology is one way of capturing, and storaging rain water in wet season and using it specially in dry season. Shortly, rain water harvesting is carried out with the following method: rain water from roof of a house is impounded by mean of a container that placed near the house. This water then can be used in dry season when water resources decreases.

[6] This can be gained, for an example, from the National Movement on Forest and Land Rehabilitation (= *GNRHL* or *Gerakan Nasional Rehabilitasi Hutan dan Lahan*).

[7] In Lombok, local wisdom includes: *Embung* (traditional pond), *Eras Geniut/Awig-awig* (penalty for cutting trees), *Nyowok* (penalty for damaging spring), and *hutan larangan* (forbidden forest).

a) Program 1: Enhancing the capacity of watershed areas, conservation of water resources, community participation, and local wisdom in anticipation of drought due to climate change

- Activity 1: Reforestation for water catchment areas.
- Activity 2: Development of water resource protection model and water catchment areas with cultural, local wisdom and community participation approach.

b) Program 2: Increased water supply for agriculture and water-based infrastructure operations

- Activity 1: Coordination of cultivation period: adjustment to water availability, seasonal and climate variability.
- Activity 2: develop new, innovative ways to conserve water, intensification of agriculture and anticipation of climate change impacts.

3) Adaptation Programs and activities in the area of flood risk reduction:

Strategy 1: Improve flood prevention and flood response capacity through spatial planning, watershed and river basin management, residential area arrangements, flood risk management, and community participation.

a) Program 1: Improving spatial planning and the management of river channels and flood-prone watershed area

- Activity 1: Implementation of integrated river management system concept, one river one management
- Activity 2: Evaluation and spatial restructuration with consideration for potential impacts of climate change
- Activity 3: Structuring the upstream watershed, river channel rehabilitation in flood-prone watershed areas involving the community.

b) Program 2: Improvement of the drainage in settlement areas, city infrastructure and flood prevention capacity

- Activity 1: Rehabilitation and improvement of the drainage in settlement areas in order to improve the flood prevention capacity.
- Activity 2: Rehabilitation of highway drainage infrastructure and development of flood avoidance infrastructure with intermediate technology.

- Activity 3: Development of urban community participation model in flood prevention.

4) Adaptation Programs and activities for other risks

Programs and special activities for adaptation to other risk require a quantitative vulnerability and risk assessment.

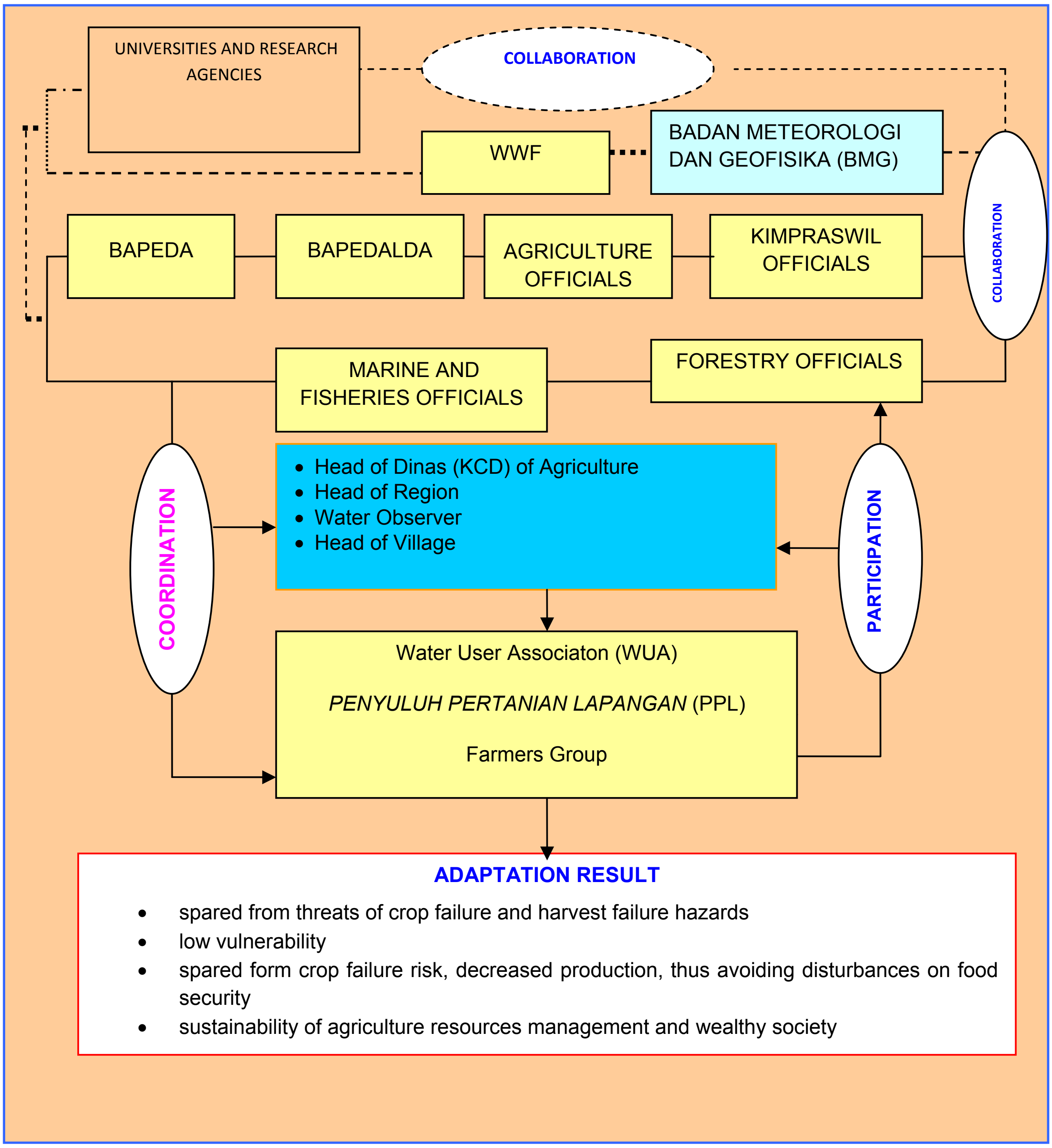
5) Integrated adaptation Programs and activities

Integrated adaptation programs and activities can be formulated by reviewing the proposed adaptation programs and activities that have been identified. Integrated programs and activities will be more comprehensive if they also involve mitigation measures.

6.2 Agricultural Sector

There are at least 8 (eight) principles that need to be taken into account: when implementing integrated mitigation and/or adaptation measures:: (1) Coordination, (2) Collaboration, (3) Participation/Involvement (willingness, ability, opportunity), (4)Representativeness, (5) Carrying Capacity, (6) Equity, (7) Priority Scale, (8) Sustainability of agricultural natural resources in the aspects of environment, social-culture, and economy. These principles can be seen in Figure 6.2.

Figure 6.2 Value chain of integrated adaptation on climate change impacts



6.2.1. Adaptation Strategies for Irrigated Rice Fields

Alternatives of adaptation strategies in the area of irrigated rice fields are as follows:

1) Program and activities for planting schedule and planting pattern

Strategy: Conduct coordinative and collaborative engagements of universities, research institutes, the Office of Agriculture, KIMPRASWIL (Public Works) and BMKG to formulate planting pattern and planting schedule for irrigated rice fields.

a) Sub-program 1: Conduct an intensive study (experiment) on planting schedules and planting patterns of irrigated rice fields that are not at risk due to climate forecast.

- Activity 1: Identify the common planting patterns and planting schedules in each district within the irrigation area that receive irrigation from Gebong, Jurang Sate and Batu Jai and Pengga dams. The responsible working unit for these activities is the Office of Agriculture.
- Activity 2: Conduct experiments by determining various alternatives of the planting schedules in October and / or November so as to the assessments of the vulnerability and risks of growing failure
- Activity 3: Conduct experiments on various alternatives of planting patterns to determine the optimum planting pattern in terms of water uses and water availability based on climate forecasting from BMKG.
- Activity 4: Assessments of vulnerability and risks of climate change in the agricultural sector for each irrigation area such as at mid- and downstream areas, which are predicted to be highly vulnerable to climate change.

b) Sub-program 2: Formalization of policy on planting schedules and planting patterns regulations for each irrigated area to support water resource management regulation in each of the irrigation sources, namely: Gebong, Jurang Sate irrigation and Batujai and Pengga dams

- Activity 1: Set the adaptive planting pattern to the impacts of climate change in order to prevent the hazard of reductions in production quality and quantity.
- Activity 2: Development of planting patterns and planting schedules for upstream, middle and downstream areas to increase the efficiency of water

resource utilization in the anticipation of climate change impacts on the agricultural sector.

- Activity 3: Development and enhancement for a climate change adaptation strategy for the agricultural sector conducted by related working units in coordinative and collaborative manner.

c) Sub-program 3: Dissemination of planting patterns, planting schedules and water distribution arrangements for upstream, middle and downstream irrigation areas.

- Activity 1: Dissemination and campaigns on planting patterns and planting schedules to achieve efficiency in irrigation water usage and to ensure fair and sufficient water distribution.
- Activity 2: Campaign (through training) for the benefits of planting patterns and schedule regulation to achieve efficient usage of water resources in dry season.
- Activity 3: Campaigns on the benefits of planting patterns and planting schedule against pests, disease attacks, and harvest failure s to decrease additional risk posed by climate change.
- Activity 4: Actions of command, supervision and control of planting pattern and schedule implementation in every agriculture area.

2) Programs and activities for the usage of rice commodity types and varieties

Strategy: Verifying the capacity of rice seeds and breeder, providing information on rice acreage planted in each season in anticipation of climate change through vulnerability assessment and planting pattern regulation.

a) Sub-program 1: Increasing the capacity of rice seeds breeder in Lombok Island to produce certified, superior quality seeds that are resistant to drought and pest diseases

- Activity 1: Verify data on the number of legal seed breeders with a capacity that has been permitted by BPSB (Office for Seeds Supervision and Certification) to prevent the emergence of illegal seed breeder that will produce bad quality seeds
- Activity 2: Study at multiple locations for every seed variety in accordance with its vulnerability to climate change, particularly drought.

- Activity 3: Search for superior varieties that are resistant to drought for drought-prone areas, and slouch-resistant varieties for the areas that are frequently hit by strong winds.

b) Sub-program 2: Provision of data and information on rice field areas, species and varieties which were planted in last planting season, provision of information of the varieties recommended by the Office of Agriculture

- Activity 1: Disseminate the use of certified rice seeds through activities of each PPL (Field Staff for Agriculture Extension) in every village.
- Activity 2: Provide authority and assign duties to each of PPL to conduct Plot Demonstration (Dem Plot) in each district.
- Activity 3: Campaign on the benefits of using quality superior seeds to prevent the risk of crop failure due to pest attacks and diseases due to climate change.
- Activity 4: Develop regulation on the use of rice varieties with superior quality.
- Activity 5: Subsidize superior quality seeds in a fair and equitable manner.

3) Adaptation programs and activities to prevent decreases of quantity and quality of rice production in rice fields that are vulnerable to high frequency and intensity of rainfall.

Strategy: Efficient land and crop management in areas prone to the reduction of productivity and rice production hazards.

a) Sub-program 1: Identify the total area of rice fields in each district in Lombok Island which are vulnerable to the hazards of increased frequency and intensity of high rainfall during grain maturation phase around the fourth week of February

- Activity 1: Assign each local PPL to conduct rice field data collection in every village that experienced growing failure during planting season last year.
- Activity 2: Assign the PPL to conduct focus group discussions (FGDs) in their respective area to define and agree on the time, variety types and planting pattern for each season.
- Activity 3: introduce a model of land and crop management in the rainy season (rice planting season).

4) Adaptation programs and activities for preventing deficit of river water discharge due to climate change (long drought)

Strategy: Preventing crop failure - especially in the middle and downstream areas due to river water flow deficit - through coordination between the Office of Agriculture and Water Resources Section of KIMPRASWIL (Settlement and Regional Infrastructures)

a) Sub-program 1: Establish planting schedule for each region in the upper, middle and downstream irrigation areas in each of the Gebong, Jurang Sate irrigation areas, and Batujai and Pengga dams. The purpose of this activity is to achieve effective and efficient water distribution for each region in a fair and equitable manner

- Activity 1: Share data and information related to water discharge, planting types and potential planted areas for each region.
- Activity 2: Develop planting and irrigation water distribution schedules for each irrigation area, facilitated by the Office of Agriculture and water resource section of KIMPRASWIL.
- Activity 3: Disseminate planting schedules for each irrigation area recommended by the Agricultural Office at district level.

b) Sub-program 2: Provide yearly information on the rainfall forecasts

- Activity 1: Activate the function of rainfall measurement stations by assigning a rainfall registrar officer to each station.
- Activity 2: Develop Field Schools on Climate

5) Programs and activities of processing of agricultural wastes into organic fertilizer and of preventing straw burning.

Strategy: Establish agricultural waste utilization for the production of organic fertilizer as one of the adaptation strategies that require technological innovation.

a) Sub-program 1: Introduction to appropriate technology for the processing of agricultural waste into useful products

- Activity 1: Training for farmers in the processing of straw into organic fertilizers by involving the Office of Industry, Agencies and Universities.

- Activity 2: Motivating research in Universities aimed to the assessment and discovery of new innovations in straw processing for fertilizer.
- Activity 3: Establishing a strict regulation on the ban of straw burning.

6) Programs and activities for equal and fair water distribution and for adaptation to flood.

Strategy: Prevention of late planting and unfair water distribution through construction of tertiary irrigation channels for the upstream, middle, and downstream areas'

a) Sub-program 1: Improve the arrangements of secondary, tertiary and quarterly irrigation channels for effective and efficient irrigation water distribution to middle and downstream areas, so that crop failure and harvest failure can be prevented.

- Activity 1: Identify areas that require tertiary and quarterly irrigation networks.
- Activity 2: Building new irrigation networks, repairing and maintaining current irrigation networks to anticipate droughts due to climate change.

b) Sub-program 2 : Improved arrangements for agricultural areas vulnerable to floods.

- Activity 1: Identify agricultural areas that are always exposed to flood hazard in each village and district.
- Activity 2: Building a drainage channel to overcome the hazard of flood in areas often exposed to potential flood hazards during incoming harvest.

6.2.2 Adaptation Strategies for Rainfed Rice Fields

There are two alternatives of adaptation strategies for areas with rice planting failure risk, which are:

1) Crop diversification programs and activities to ensure harvest certainty.

Strategy: Ensure crop harvest certainty by not relying on rice as the main crop.

a) Program 1: Use of alternative types of non-rice crops with high economic values

- Activity 1: Provide non-rice crops with high economic values which are also suited to the agroclimate region.
- Acivity 2: Develop rainwater storage by creating one-meter deep channel with a width of 50 cm around rice fields and/or in the middle of rice fields.
- Activity 3: Campaigns for and guidance to farmers about the economic benefits of non-rice crop cultivation as an effort of climate change adaptation on rainfed rice fields.

b) Program 2: Strengthening the implementation of rice farming systems through cost-effective "*Gogorancah Tanpa Olah Tanah* (TOT)" farming system with early yield (genjah) and superior varieties of rice.

- Activity 1: Dissemination of rice planting system of *Gogorancah Olah* without Land (TOT) for rainfed rice fields.
- Activity 2: Campaign for the benefits of the use of superior varieties and early yield (genjah) rice that can be resistant to drought.
- Activity 3: Research of early yield rice variety through networking with Laboratory of Rice Research *(Balai Besar Penelitian Padi-Padian)* to obtain a variety of genjah rice with superior quality and resistant to drought..

Alternatives of adaptation strategies for regions with the risk of crop failure:

1) Rain water storage programs and activities during rainy season.

Strategy: Ensure the availability of water in the rice field areas to irrigate crops when rain does not occur

- Activity 1: Facilitate and encourage farmers to make small water-pounds (*embung*) at the rice fields to store rain water (water harvesting) in the face of the relatively short period of the rainy season.
- Activity 2: Facilitate site visit (field trips) by farmers to villages that have implemented rain water harvesting by making *embung*.

2) Program and activities for the empowerment of poor farmers

Strategy: Improve the ability of poor communities to adapt to climate change

a) Program 1: Empowering the poor who are vulnerable to be able to adapt to climate change

- Activity 1: Assist the poor to improve their capacity for adaptive capacity to deal with climate change by providing material and / or financial assistances to create water storage (*embung*).
- Activity 2: Empower farming communities through poverty alleviation programs to increase economic capacity of society.

b) Program 2: Increase the capacity of current communities' *embung*

- Activity 1: Assist and facilitate farmers who already have *embung* to renovate their shallowing *embung*.
- Activity 2: Motivate farmers community through campaigns for the need of rain water harvesting by making *embungs* in their rice field

3) Adaptation programs and activities to adapt to rainfall uncertainty and relatively short period of rainfall through the use of superior quality and early yield (genjah) rice varieties.

Strategy: Prevention of crop failure due to lack of rainfall and short rainy season in rainfed areas.

a) Program 1: Ensuring rice crop certainty through improved understanding of the benefits of using "genjah" (early yield) rice varieties as climate change adaptation efforts for rainfed rice fields

- Activity 1: Motivating the seed breeders to produce *genjah* rice seed with superior quality.
- Activity 2: Provide assistance to subsidize farmers with *genjah* rice seed.

b) Program 2: Dissemination and campaigns for usage of various *genjah* and superior quality rice varieties as climate change adaptation

- Activity 1: Provide information and convince farmers about the benefits of superior *genjah* rice varieties with regards to the risk of crop failure due to climate change.

- Activity 2: Development of seed technology to find early yield rice varieties that are resistant to drought.

4) Programs and activities to implement raised bed (*bedeng*) farming systems to conserve water and soil in rainfed areas.

Strategy: Preventing farmers' loss due to crop failure by transforming production technology into raised beds farming system.

a) Program 1: Improve the productivity of rainfed land and income of farmers by implementing "raised beds" farming systems.

- Activity 1: Facilitate farmers to conduct crop and land management by the implementation of raised bed farming system.
- Activity 2: Introduce ACM (Aciar Cropping Model) and assist farmers in applying ACM on rainfed rice fields.

5) Programs and activities related to the optimization of the use of rainfed land with pumped irrigation water and forestry planting

Strategy: Increase the utilization of the capacity of rainfed land with development of pump system in rainfed areas in South Lombok such as Mujur and Setanggor villages in central Lombok

a) Program 1: Optimize the use of rainfed areas through legalized pumping of irrigation water from irrigation channels by pump engines

- Activity 1: To support farmers in building water storage in their rice fields in order to store the water that is pumped from irrigation channels.
- Activity 2: Facilitate farmers to legalize pumping of irrigation water from rivers/irrigation channels by pump engines.

b) Program 2: Promote intensively the plantation of Albasia plants (turi) in the dike fields and/or other plants with rich in nitrogen content (such as mango fruits) in rainfed areas as part of the land conservation program

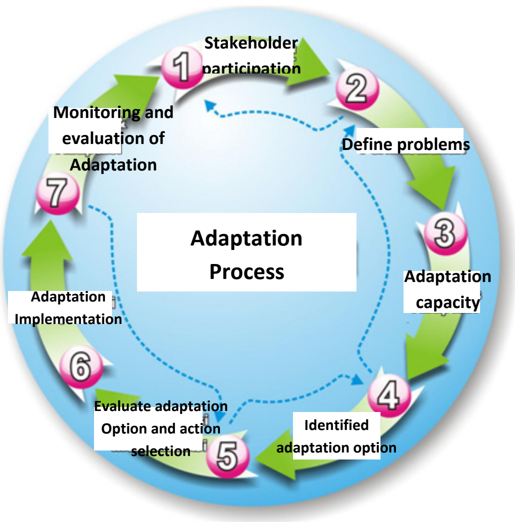
- Activity 1: Provision of Albasia seeds by the Office of Agriculture to be distributed to rainfed land farmers

- Activity 2: Carry out campaigns on how "to do" Albasia planting in rainfed rice fields areas

6.3 Coastal Sector

When considering the various potential impacts of climate change that have been described above it becomes evident that a long-term adaptation strategy is needed. In the coastal sector, the form of anticipation is manifested by adaptation, accompanied by mitigation. Conceptually, adaptation to climate change consists of a cycle of at least seven steps (Figure 6.3).

Figure 6.3 The sequence of seven steps in the process of adaptation to climate change (Diposaptono et al, 2009)



Adaptation strategies in the coastal sector can basically be grouped together under following themes:

(1) Physical adaptation in coastal areas and small islands
   a) Integrated physical management of coastal areas and small Islands.
   b) Environmentally view physical engineering (e.g., coastal structures with environmental consideration).
(2) Socio-demographic management
(3) Management of infrastructure and vital public facilities

(4) Management of potential coastal, marine and fisheries resources

   a) Management and commercialization of catched fisheries production.
   b) Management and commercialization of farmed fisheries production.
   c) Management of water resources.

(5) Integrated management of coastal and small islands ecosystems

(6) Development of of climate change adaptation policy and regulation

(7) Development of data and research inventories as well as of human resources

To apply these directions of adaptation strategy, it is necessary to arrange some priority programs that are described as follows:

Program-1: Strengthening capacities of research, monitoring, and study about the understanding of the phenomena, potential impacts, vulnerabilities, adaptation, and mitigation of climate changes

- Improve the data base and information system, by completion of the Marine and Coastal Resources Mapping and Planning (MCRMP) dataset of the West Nusa Tenggara Province.
- Improve the research and monitoring capacities.
- More detailed study of vulnerability and adaptation, especially for Mataram city and other important areas.

Program-2: Integrated planning and management of natural resources and ecosystems of coastal and small islands

- Strengthening capacity and adjustments of coastal zonation due to climate change.
- Strengthening human resources to manage climate change adaptation.
- Adjustment of spatial planning and zoning of coastal and sea areas to the potential hazards of sea water flood and storm waves.

Program-3: Development/adjustment of policy and regulation on climate change adaptation and mitigation on coastal and ocean areas

- Adjusting policy and regulation relevant to to climate change (such as: Act No. 26 of 2007, Act No. 27 of 2007).

- Strengthening the institution capacity for adaptation and mitigation through regulation adjustments.

Program-4: Adjustment of the levels and structures of buildings and vital facilities in coastal areas

- Identification of current conditions and future projections for the entire infrastructure in the coastal region.
- Adjustment of the levels and structures of the buildingss / and vital facilities at coastal areas.

Program-5: Management and protection of small islands

- Identification of current conditions and future projections for small islands such as the islands of Tiga Gili.
- Beach vegetation planting as well as sand dune and coral reef maintenances.
- Development of coastal protections and navigation safety facilities.
- Water resources management at the small islands.

Program-6: Integrated disaster management due to hazards of extreme weather and climate variability in coastal areas

- Improvement of risk reduction capacity in coastal- and ocean areas.
- Strengthening the capacities for transportation and lifeline inventory system at remote coastal areas.

Program-7: Integrated management of potential captured fishery resources

- Development of information systems and dynamic fishing ground mapping.
- Improvement of fishermen's capacity to reach off-shore fishing ground.
- Development of cold chain system from the ship to Fish Auction Location (TPI) and household-scale processing units.

Program-8: Management of potential farmed fisheries at sea water, brackish water and freshwater

- Development of sea water fisheries with low vulnerability to climate change (grouper fish, snapper fish, sea grass, red algae).
- Development of seeding season information system.
- Development of alternative natural sources of fish foods.
- Elevation and strengthening of current condition of pond walls.

7

LESSONS LEARNED FROM RISK AND ADAPTATION ASSESSMENT TO CLIMATE CHANGE IN LOMBOK ISLAND

"Mainstreaming climate change" means integrating the climate change adaptation strategies that have been formulated on the basis of the Vulnerability and Risk analysis into the regional development plans. The climate change assessment on the Island of Lombok timely coincided with the formulation of the Mid Term Development Plan (*Rencana Pembangunan Jangka Menengah Daerah*, RPJMD) of the West Nusa Tenggara Province (NTB) for 2009-2013 so that it was possible to integrate climate change issues into the RPJMD. As illustration, it is shown here the summary of the difference between the First Draft of RPJMD (without considering climate change study) and the Final Draft (considering the climate change study).

Draft RPJMD NTB without consideration of Climate Change Risk Study	Final Draft RPJMD NTB with consideration of Climate Change Risk Study
Chapter II. Overview **2.3 Hydrology and Climatology** • Potential water resources for NTB are 10.748,13 mcm (mega cubic meters), while the water needs are 6.826,22 mcm. • Rainy season (November - March) is dominated by western wind. August is dominated by eastern wind what leads to drought events in areas in southern coast of NTB. • Temperatures range between 22 ° C and 32 ° C, • The highest rainfall was 13.8 to 15.2 mm in the rainy season during March to April and from 158.1 to 130.3 mm during May to September. During the dry season, the	**Chapter II. Overview of Regional Condition** **2.6 Hydrology and Climatology** • Climate is an *economic driver* • During October to March, NTB is influenced by the west wind and high sea surface temperature (SST) that leads to to high rainfall in the month of November until February. In August, the east wind causes a dry season characterised by very low rainfall. • Potential fisheries catch occurs during July to September (east monsoon season) where SST is low and chlorophyl-a concentration is high. • SST decreases by 1°C to 1,5°C during El

Draft RPJMD NTB without consideration of Climate Change Risk Study	Final Draft RPJMD NTB with consideration of Climate Change Risk Study
highest rainfall reached 15.9 - mm in August.	Nino events, and increased by 1°C to 2°C during the biggest La Nina in 1999/2000. • Drastic increase or decrease of SST can cause damage to coastal ecosystem, especially coral reefs (coral bleaching) • SST increase based on satelite data is between? 0,2°C/century to 1,2°C/century • In the event of El Nino, sea level will be around 20 cm below normal, and during La Nina it will increase by 10 cm to 20 cm thereby increasing the risk of erosion, abrasion, sea water floods – especially during high rainfall period. • The Sea level is expected to rise by 3.5 mm/year in northern coast and 6.5 mm/year in southern coast.
Chapter IV. Analysis of Strategic Issues • Reduction of environmental quality is indicated by damage to ecosystems like forests, lands, coastal areas and sea, through land use conversion, clean water crises?? water pollution, increased size of critical land and climate change caused largely by human activities.	**Chapter IV. Analysis of Strategic Issues** • Reduction of environmental quality is indicated by damage to ecosystems like forests, lands, coastal areas and sea, through land use conversion, clean water crises, water pollution, increased size of critical land and climate change caused largely by human activities. • Gradual sea level rise caused by global warming is one of the most complex aspects of global warming effects. Sea level rise causes erosion, changing shorelines and reduces wetland areas along shorelines. In addition to those, sea level rise accelerates sea water intrusion to coastal aquifer areas. Sea level rise and sea surface temperature (SST) rise can also reduce catchment fisheries production. During El Nino in 1997/1998, SST around Lombok Island decreased drastically around 1°C to 1,5°C, and during strong La Nina in 1999/2000, SST has increased between 1.5°C to 2°C. This drastic change resulted in coral bleaching. The higher frequency of El Nino and La Nina results in a higher probability for high SST fluctuation with lowest temperature of 26°C and the highest 31°C annually, thus accelerating the

Draft RPJMD NTB without consideration of Climate Change Risk Study	Final Draft RPJMD NTB with consideration of Climate Change Risk Study
	damage to coral reefs and other coastal biotas. • High rate of forest- and critical land degradation, decreasing quantity and quality of water (surface and ground water), drought hazard in rice fields that cause cultivation failure and even crop failure will be worsened by climate change impacts.
Chapter VIII. Indication of Priority and Requirement Plan • Establisment of self-sufficient villages which are able to provide food for themselves. • Programs for the accelerated supply of irrigation- and clean water • Programs for the accelerated supply of electricity.	**Chapter VI Regional Development Strategy, Policy and Programs** • Establisment of self-sufficient villages so as to anticipate the impacts of climate change • Hydro-climatologybased technology for the accelerated supply of irrigation- and clean water programs • Programs for the accelerated supply of electricity, especially those with renewable resources. • Risk reduction and disaster recovery programs for geological, hydrometeorological and coastal disaster.

The Climate Change Risk and Adaptation Study on Lombok Island was used as the basis for the draft of the State Ministry of Environment Regulation on Climate Change Risk and Adaptation Study Guidelines (*Pedoman Kajian Risiko dan Adaptasi Perubahan Iklim, PKRAPI*), which are currently in its finalization stage.

The Climate Change Risk Assessment in the Lombok Island can be considered as the first Vulnerability and Adaptation Assessment to Climate Change in Indonesia which used the framework of risk assessment and multi-sectoral impacts approach. It means that the study in Lombok is a “policy driven study”, aiming to mainstream climate change issue into development policy.

This climate risk assessment is a meso level study at a province level and to assess impacts to related development sectors in the Lombok Island. The sectors which are considered as vulnerable to climate change in this study are water resources, agriculture and coastal sectors. This study also shows that, despite the various limitations of data and the lack of global climate models that can well represent Indonesia's dynamic climates characteristics, the analysis and projections of temperature increase, rainfall, sea level rise and extreme events have been successfully carried out for the Lombok Island. From this study also can be learned that the formulation of adaptation strategy to climate change will be more accurate if it is preceded by a study on risk and adaptation to climate change

Last but not least, the adaptation strategies that have been formulated for each sector should be integrated into the Strategic Planning of the offices (Dinas) for Water Resources, Agriculture, Marine and Fisheries, and also other related offices in the Province of NTB.

REFERENCES

1. Affeltranger,B. et al., **Living With Risk: A Global Review of Disaster Reduction Initiatives**, ISDR, 2006
2. Diposaptono, S., Budiman, F. Agung, **Menyiasati Perubahan Iklim di Wilayah Pesisir dan Pulau-Pulau Kecil**, Penerbit Buku Ilmiah Populer, cetakan I, Bogor, 2009
3. Downing, T.E. dan A. Patwardhan, **Assessing vulnerability for climate adaptation. Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures,** B. Lim, E. Spanger-Siegfried, I. Burton, E.Malone and S. Huq, Eds., Cambridge University Press, Cambridge and New York, 67-90, 2005
4. Hadi, Tri W., **Analisis dan Proyeksi Curah Hujan dan Temperatur**, Kajian Risiko dan Adaptasi Terhadap Perubahan Iklim di Pulau Lombok, 2009
5. IPCC, **Climate Change 2001: the Third Assessment Report of the Intergovernmental Panel on Climate Change,** 2001
6. IPCC, **Climate Change 2007: the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,** 2007
7. IPCC, Glossary of Climate Change, 2009.
8. Klein, R.J.T., **Approaches, Methods and Tools for Climate Change Impact, Vulnerability and Adaptation Assessment,** *Keynote lecture to the In-Session Workshop on Impacts of, and Vulnerability and Adaptation to, Climate Change*, 2004
9. Manyena, S.B., **The Concept of Resilience Revisited**. *Disasters*, Vol. 30, No. 4, 433-450, ISSN 0361-3666, 2006
10. Meehl, G.A., F. Zwiers, J. Evans, T. Knutson, L. Mearns, dan P. Whetton, **Trends in extreme weather and climate events : Issues related to modeling extremes in projections of future clmate change**, *Bull. Amer. Met. Soc.*, 81(3), 413-416, 2000
11. Messner, F., **Evaluation of Flood Damage and Flood Risk**, *Centre for Environmental Research Leipzig-Halle*, 2005
12. O'Brien, K., S. Eriksen, A. Schjolden dan L. Nygaard, **What's in a word? Conflicting interpretations of vulnerability in climate change research.**

Working Paper 2004:04, Centre for International Climate and Environmental Research Oslo, University of Oslo, Oslo, 2004

13. O'Brien, K. and C.H. Vogel, **Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies.** *Climate Res,* 2006
14. Peterson, L., and G. Haug, 2005 : Climate and the Collapse of Maya Civilization : A series of multi-year droughts helped to doom an ancient culture, Sigma Xi, The Scientific Research Society, diaskses tanggal 25 Februari 2009 dari situs
15. http://www.americanscientist.org/issues/num2/2005/4/climate-and-the-collapse-of-maya-civilization/1
16. Rayner, N. A., D. E. Parker, E. B. Horton, C. K. Folland, L. V. Alexander, dan D. P. Rowell, **Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century**, *J. Geph. Res.,* VOL. 108, NO. D14, 4407, 2003
17. Saaty, T.L., **The Analytic Hierarchy Process**, McGraw Hill, New York, USA, 1980
18. Schröter,D., C. Polsky dan A.G. Patt, **Assessing vulnerabilities to the effects of global change: an Eight-Step Approach.** *Mitig. Adapt. Strat. Glob. Change*, 2005.
19. Suroso, *Decentralised Vulnerability Assessment to Climate Change Assessment in Indonesia:Using Regional-Multi Sectoral Approach at Provincial Level,* 2008
20. Stern Review, **Economics of Climate Change**, 2008
21. Timmermann, A., M. Latif, A. Bacher, J. Oberhuber, E. Roeckner, **Increased El-Niño**, *Nature*, 398, 694-696, 1999
22. Turner, B.L., II, R.E.Kasperson, P.A.Matson, J.J.McCarthy, R.W. Corell, L. Christensen, N. Eckley, J.X. Kasperson, A. Luers, M.L. Martello, C. Polsky, A. Pulsipher dan A. Schiller, **A framework for vulnerability analysis in sustainability science.** *P. Natl. Acad. Sci.*, 2003
23. United Nation Development Programme, **Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures.** B. Lim, E. Spanger-Siegfried, I. Burton, E. Malone and S. Huq, Eds., Cambridge University Press, Cambridge and New York, 2005