Climate Change Risk and Adaptation Assessment

South Sumatera

Sectoral Report
Water

June 2012

Ministry of Environment

Climate Change Risk and Adaptation Assessment for the Water Sector – South Sumatera

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Climate Risk and Adaptation Assessment for the Water Sector - South Sumatera

Draft Final Report

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Table of Contents

Table of Figures

List of Tables

I. INTRODUCTION

1.1 Background

Indonesia is strongly exposed to climate change. With over 17.000 islands, the rising sea level, changes in precipitation and extreme climate events are a major issue. Climate projections indicate that the mean wet-season rainfall will increase across most of Indonesia, especially in regions located south of the equator such as Java and Bali. At the same time, the length of the dry season is expected to increase. Moreover, an increase in the intensity and frequency of extreme events like El Nino, which have caused major droughts and fires in Indonesia, is already noticeable in the Asian region. The risk of floods during the rainy season and drought in the dry season is therefore likely to increase. This will particularly impact water resources, agriculture and forestry, fishery as well as health and infrastructure. Land subsidence, sea level rise, floods, droughts, landslides and forest fires already cause considerable damage in Indonesia. Adaptive measures can mitigate damage and avoid aggravating impacts of natural disasters.

Therefore, the necessity for adaptation measures at national and local levels is rapidly emerging as central issue in the debate around policy responses to climate change. In order to prioritize, design and implement interventions to adapt to climate change, it is essential to adopt a coherent set of approach, framework and methodologies for examining vulnerability and adaptive capacity.

1.2 Problem Statement

Many vulnerability studies, while being effective in raising awareness to the possible effect of climate change on a general level, have limited effectiveness in providing local scale guidance on adaptation. Methods and tools for vulnerability studies at the provincial/local level are different from the ones used on national and global scales. To effectively formulate adaptation strategies at the province level, it is proposed to apply ”meso level-multi sectoral approach” (MsLMSA) which means assessing vulnerability at the meso-level but considering the multi sectoral impacts of climate change e.g. water, agriculture and coastal / marine sectors. An appropriate approach has been developed and applied on Lombok Island and is the first MsLMSA based vulnerability study in Indonesia. The study result is very promising and it is necessary to be replicated in other region in Indonesia.

Moreover, a shifting political system from centralized to decentralized structures urgently requires and challenges an increasing role of local (kabupaten/kota) governments to initiate local level activities in climate change adaptation. Therefore, the vulnerability assessment on climate change and integration of its result into local development planning also becomes essential. Thus, the MsLMSA based vulnerability study in Lombok Island was developed and conducted on provincial level (“meso level-multi sectoral approach” or MsLMSA). Mainstreaming of V-A into development policies can follow two approaches, the first one directly influencing the preparation of the local mid-term development plan (RPJM) and integration of the annual sectoral plans. Given that the preparation of the RPJM depends on the election cycle of the local governments, the project will prepare both the input for the *forthcoming* RPJMs and the annual sectoral plans as *immediate* contribution.

Furthermore, the new Indonesian environmental law has just been approved by the parlament and signed by the president (September/October 2009), which outlines the framework for climate change mitigation and adaptation issues, however the technical and operational guidelines still have to be developed. This project will develop the strategy and action and implementing it in the field, which can be taken as a model for technical and operational guideline development.

1.3 Objectives

The global objective of the project is to further develop and replicate the nationally approved V-A methodology, to develop adaptation strategies on local levels and to secure implementation by adequate budgeting and financing, including the development of innovative financing and policy instruments.

To achieve this global objective the following aims shall be achieved:

a. To enhance awareness on climate change impact and its management for regional/local government and stakeholders.
b. To further develop, replicate and apply methods and tools, which have been applied in Lombok Island (NTB Province) to South Sumatra province, South Sumatra City and Greater Malang in order to assess climate change vulnerability and design adaptation strategies as well as to integrate its result into regional/local development planning.
c. To mainstream adaptation to climate change into regional/local development planning.
d. To build capacity of stakeholders related to vulnerability and adaptation issues on the local level.
e. To streamline aspects of climate change adaptation and disaster preparedness

f. To support and provide input to national level policy maker and development planning, especially with a view to support local level adaptation strategies and planning.

g. To develop the capacity of local government in fiscal and financial areas and increase their capability in accessing national and international sources of fund. The financial mechanism should be developed in the context of the Indonesia Climate Change Trust Fund (ICCTF) investment window on adaptation and resilience, thereby providing the mechanism to the ICCTF, which local governments can use to access funds.

1.4 Scope of the Assessment

The scope of the assessment is vulnerability assessment (V-A) for the water sector in South Sumatera Province (Province) according to the “meso level-multi sectoral approach” (MsLMSA) and – on this basis – formulate an appropriate adaptation strategy with precise adaptation options which is endorsed by the local authorities.

The scope of the V-A for the water sector in more detail includes activities as follow:

a. Develop the conceptual framework and step by step easy to use methods for assessing climate risk on water sector and identification of data needs based on above methods to be completed for South Sumatera Province;

b. Collection, analysis and synthesis of the data for the water sector which cover surface water and groundwater, according to the methods mentioned above for South Sumatera;

c. Analysis of climate hazards and vulnerability of the water sector to the hazards for South Sumatera Province in collaboration with other experts within the scientific team;

d. Synthesis of climate risk for the water sector (in collaboration with the other experts within the scientific team) of South Sumatera Province;

e. Formulation of adaptation strategies on water sector in response to climate change for South Sumatera in collaboration with the local parliament, government and administration and other relevant stakeholders or institutions;

f. Facilitation of the mainstreaming process of the adaptation strategies into the local Development Policies for South Sumatera Province;

II. GENERAL DESCRIPTION, WATER SECTOR, AND CLIMATE CHANGE ISSUES OF SOUTH SUMATERA PROVINCE

2.1 Regional Descriptions

This section emphasized the general description of South Sumatera Province related to water sector. The description consists of location geographical and administrative information, population, climate, geology, land use, economy development, and spatial planning of the study area in brief. The data and information in this section become useful inputs for analysis, which will be explained in the next chapter. Data and information in this section with the next two section of chapter two are also used as basis for formulation of strategic issues of the study. This strategic issue is presented in the last section of the chapter two.

2.1.1 Location, Administrative, and Population

South Sumatera is located between 1 degree to 4 degree of south latitude and 102 degrees to 106 degrees of east longitude with a total area of 87.017,42 km^2. The boundaries are: the northern boundary of South Sumatera Province is Jambi Province, the southern boundary of South Sumatera is Lampung Province, the western boundary of South Sumatera is Bengkulu Province, and the eastern boundary of South Sumatera is Bangka Belitung Islands Province. Until the end of year 2008, the number of administrative regions in South Sumatera Province is eleven districts and four cities. The number of villages and sub-districts in South Sumatera in 2007 was 2685 and 364. And the number of sub-districts was 212.

Table 2. 1 Number of villages and wards by District/Province in South Sumatera Province

No	Regencies/Municipalities	The Number of		
		Districts	Villages	Wards
1	Ogan Komering Ulu	12	140	10
2	Ogan Komering Ilir	18	299	11
3	Muara Enim	22	305	16
4	Lahat	21	359	17
5	Musi Rawas	21	242	19
6	Musi Banyuasin	11	209	9
7	Banyuasin	15	272	16
8	OKU Selatan	18	252	7

No	Regencies/Municipalities	The Number of		
		Districts	Villages	Wards
9	OKU Timur	20	272	14
10	Ogan Ilir	16	227	13
11	Empat Lawang	7	154	2
12	Palembang	16	0	107
13	Prabumulih	6	15	22
14	Pagar Alam	5	0	35
15	Lubuk Linggau	8	0	72

Source: BPS – Statistics of South Sumatera Province, 2009

Figure 2. 1 Map of Districts/Cities of South Sumatera Province

Total population and its distribution, density and growth in one region are ones of the most important parameter in the water sector assessment. The total population of South Sumatera Province in 2009 amounted to 7,121,790 inhabitants with a population density of 81.84 people/km^2 (Table 2.2. and Figure 2.3).

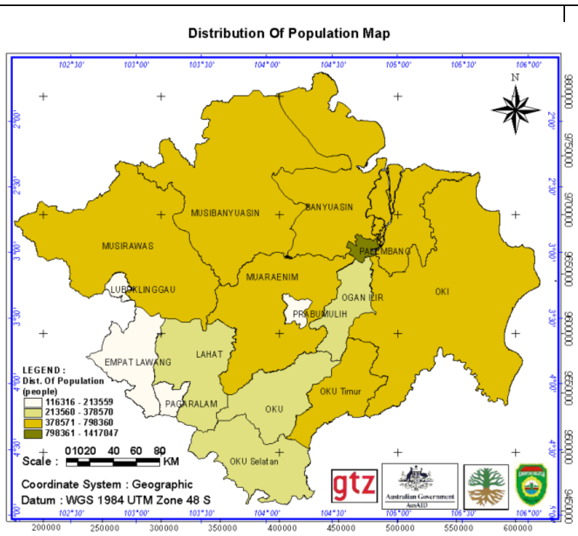
Table 2.2 Population Distribution and Density

District/Province	*Total Area* (Km^2)	*Number of Population*	*Density of Population*
(1)	(2)	(3)	(4)

District/Province	*Total Area* (Km²)	*Number of Population*	*Density of Population*
(1)	(2)	(3)	(4)
Ogan Komering Ulu	4.797,06	323.420	67.42
Ogan Komering Ilir	18.359,04	726.659	39.58
Muara Enim	9.223,90	717.717	77.81
Lahat	5.311,74	370.146	69.68
Musi Rawas	12.358,65	524.919	42.47
Musi Banyuasin	14.266,26	562.584	39.43
Banyuasin	11.832,99	749.107	63.31
OKU Selatan	3.370	609.715	180.92
OKU Timur	5.493,94	318.345	57.94
Ogan Ilir	2.666,07	380.861	142.85
Empat Lawang	2.256,44	220.694	97.81
Palembang	400,61	1.452.840	3626.57
Prabumulih	434,50	161.814	372.41
Pagar Alam	633,66	126.363	199.42
Lubuk Linggau	401,5	201.217	501.16
Jumlah / *Total*	**91.806,36**	**7.446.401**	81.11

Source: BPS – Statistic of South Sumatera Province

The distribution of the population is mostly located in the Province Capital of Palembang with 1,452,840 people or 19.51 % of the total distribution of people in South Sumatera Province. The lowest distribution of people is located in Pagar Alam City with 126,363 people or 1.70 % of the total distribution of people in South Sumatera Province. As it is shown in Table 2.2, the highest population density of South Sumatera Province is found in Palembang city with 3,626.57 people in a km^2 (*jiwa/km^2*) and the lowest density is in district of Musi Banyuasin with 39.43 people in a km^2 (*jiwa/km^2*).



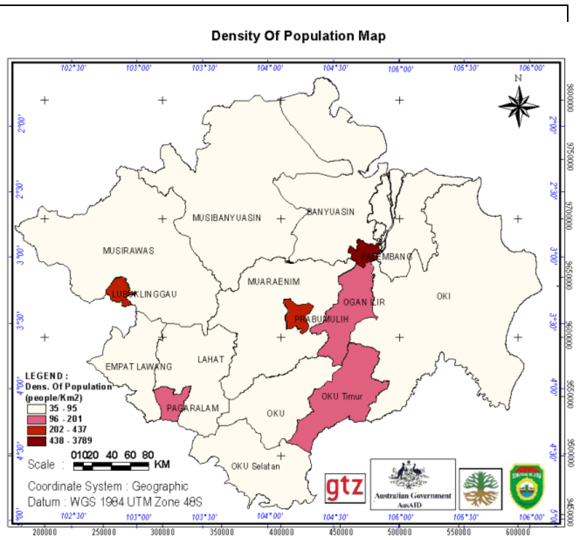


Figure 2.2 Map of Population Distribution and Density of Sumatera Selatan Province

2.1.2 Climate

2.1.2.1 Temperature

Temperatures of South Sumatera in year 2008 showed a variation between 26.4 to 27.8 degrees of Celsius. While humidity varies between 80 and 88 Rh. based on data BWS VIII, South Sumatera has 62 climatology stations (Appendix A)

Based on globally gridded temperature data obtained from the University of Delaware (UDEL), The Science Basic Expert calculated the temperature trend at Singapore (nearest grid) and all South Sumatra (area averaged) and presented the results in Figure 2.3. It can be seen that the gross feature of the temperature variations for Palembang and Singapore are quite similar, especially from the first decade of the 20th century until 1950s. Moreover, these results could clarify that the positive trend during the last 25 years is of regional scale. The Science Basic Team estimated that the regional temperature trend did not exceed 0.3 ° C during the last 25 years. It should also be noted that large peaks of surface temperature increase, such as that of 1997, mark the years of El Nino events. However, the increase of surface temperature during the last 25 years seem to be more related to the so called "Climate Shift" phenomenon that occurred in the middle of 1970s. The origin of the phenomenon is still a matter of debate but IPCC scientists suspect the anthropogenic global warming was the main cause.

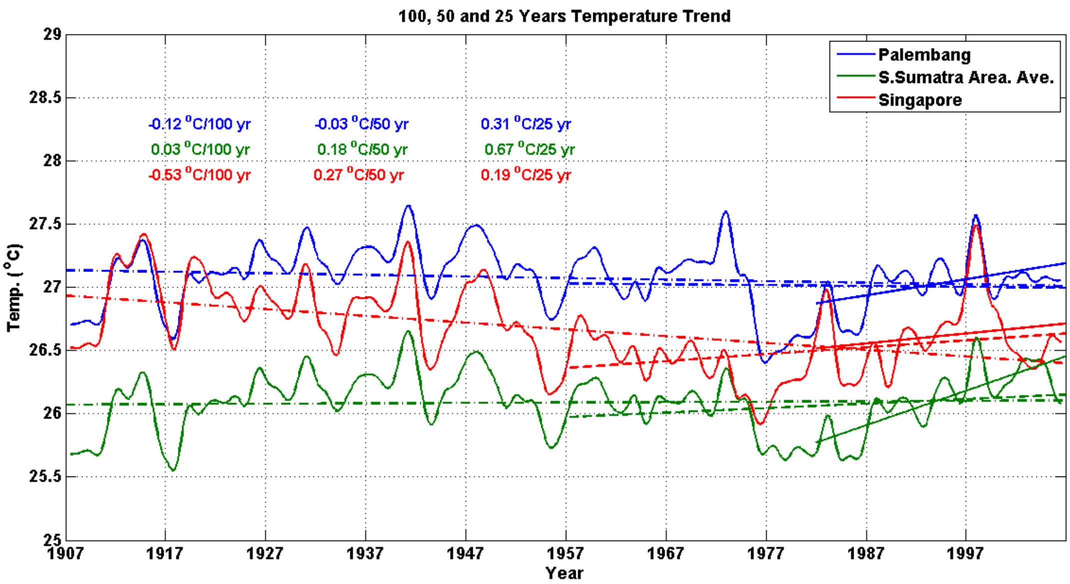


Figure 2. 3 Temperature fluctuations and linear trends calculated from UDEL temperature data for Singapore (nearest grid; red line), and all South Sumatra (area averaged).

The calculated mounthly surface temperature trend usually varies. The month-to-month variations of surface temperature trends for Palembang, Singapore, and South-Sumatra are shown in Table 2.3. It can be seen that the temperature trends are more consistent for Singapore with negative values for the last 100 years but positive for the last 50 and 25 years. More significant variations of temperature trends are found for Palembang and South Sumatra region.

Table 2. 3 Values of linear trends in surface temperature changes of the last 100, 50, and 25 years for Palembang, Singapore, and all South Sumatra area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Trend (°C/100 yr)	-0.50	-0.31	-0.25	-0.03	0.01	0.10	-0.08	-0.11	-0.21	-0.10	-0.33	-0.42	**Palembang**
	-0.32	-0.23	-0.14	0.08	0.12	0.21	0.10	0.02	-0.05	0.00	-0.20	-0.29	**S.Sumatra A.Ave**
	-0.50	-0.60	-0.59	-0.50	-0.41	-0.34	-0.55	-0.60	-0.63	-0.44	-0.84	-0.80	**Singapore**
Trend (°C/50yr)	-0.20	-0.20	-0.03	0.06	-0.07	0.11	0.29	0.31	0.07	-0.15	-0.36	-0.05	**Palembang**
	0.09	0.09	0.14	0.18	0.12	0.22	0.35	0.41	0.12	0.05	-0.06	0.05	**S.Sumatra A.Ave**
	0.43	0.26	0.39	0.25	0.47	0.36	0.32	0.42	0.23	0.31	0.25	0.40	**Singapore**
Trend (°C/25yr)	0.51	0.07	0.49	0.24	0.42	-0.01	0.69	0.31	1.03	0.51	0.32	0.27	**Palembang**
	0.70	0.42	0.73	0.57	0.65	0.43	0.76	0.70	1.12	0.78	0.64	0.74	**S.Sumatra A.Ave**
	0.71	0.39	0.44	0.27	0.75	0.05	0.21	0.03	0.53	0.41	0.47	0.69	**Singapore**

2.1.2.2 Rainfall

South Sumatera has a tropical climate and wet with rainfall variation between 23.9/11 – 634.3/22 mm during the year 2008. November was the month with highest rainfall. In the tropical region, rainfall variations at inter-annual time scale are known to be largely affected by global climatic phenomena known as *El Niño Southern Oscillation* (ENSO) and *Indian Ocean Dipole* (IOD). These phenomena are related to the dynamical behaviour of the Pacific and Indian Ocean, which are manifested as temporal and spatial variations in Sea Surface Temperature (SST). Indices that represent the climatic events associated with ENSO and IOD have been developed based on SST measurements.

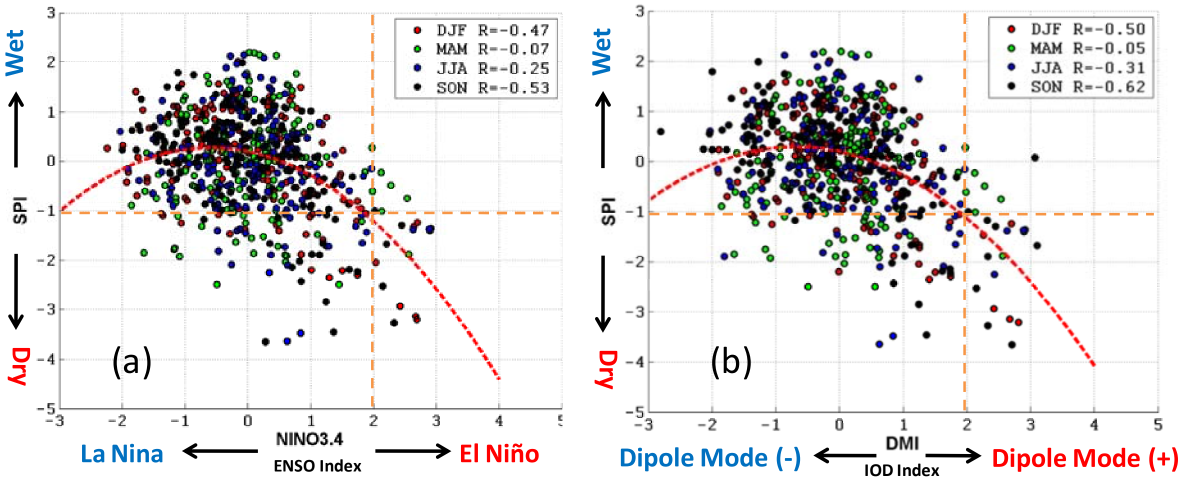


Figure 2. 4 Correlation between 6-monthly Standardized Precipitation Index (SPI) calculated from rainfall of South Sumatra (area averaged) and Dipole Mode Index (DMI)(left) as well as ENSO index (Nino3.4 sea surface anomaly)(right).

The drought events in South Sumatra are correlated with strong El Niño and Dipole Mode (+) events. Correlation between ENSO/Dipole Mode indices and SPI is highest for the September-October-November (SON) period but the SPI calculation includes data of five other earlier months. This result indicates that impact of ENSO/Dipole Mode on drought in South Sumatra is most significant in dry season and dry to rainy transition months.

2.1.2.3 Rainfall Projection

Outputs of seven GCMs contributed for the IPCC AR-4 (the 4th Assessment Report) are used in this study to obtain projections of rainfall in Palembang and South Sumatra.

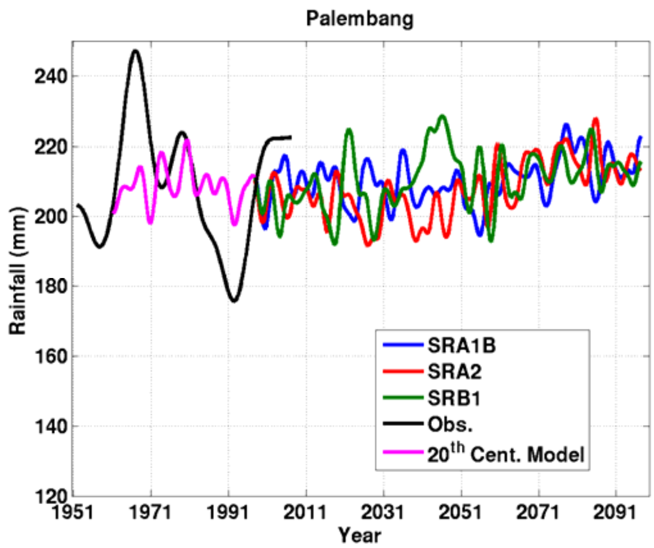


Figure 2. 5 The projected rainfall variations of Palembang in the 21st century based on GCM output. Blue, green, and red lines respectively represent the results of B1, A1B, and A2 SRES

scenarios with extension back to 1951 (20th century; magenta line). Smoothing by moving average was applied to the monthly time series before plotting.

(Note: data is refered to results of analysis from climate team. Palembang location is selected as a sample of projection condition in South Sumatera. Complete data available at report of climate team)

The increase of rainfall during the last decade was obtained from the results from A1B and A2 scenarios. In general, results from these two scenarios produce similar rainfall variations at least until early 2030s. Rainfall projection is produced for spatial grids over South Sumatra region. The spatial patterns of the projected rainfall were validated by means of "testing data". It is found that the model produced better spatial correlation for dry season, especially September, while the worst correlation is obtained for the month of December, as illustrated in Figure 2.6

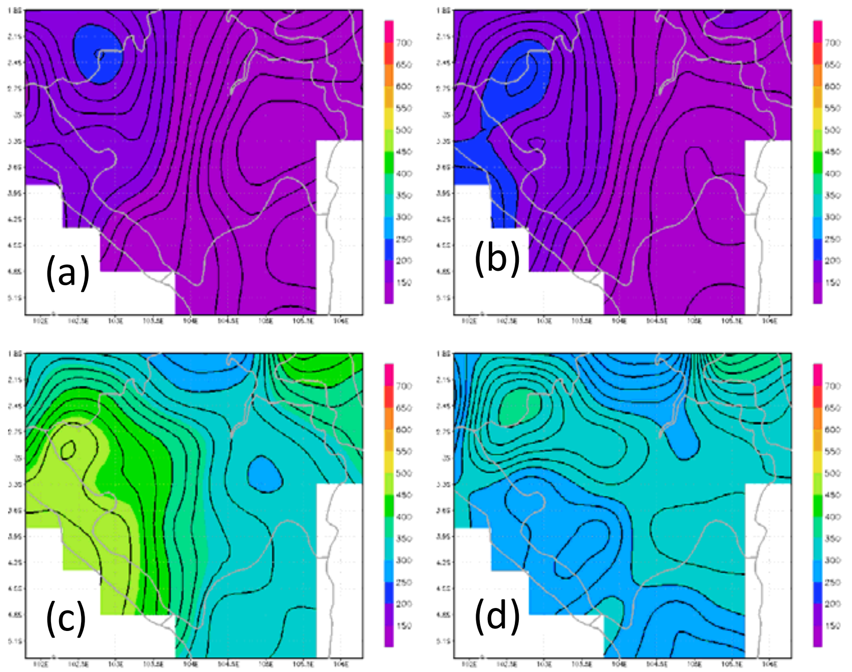


Figure 2. 6 Comparisons of spatial patterns between observed ((a) and (c)) and projected ((b) and (d)) rainfall over South Sumatra region. Samples represent data of September ((a) and (c)) and December ((b) and (d)) averaged over the 2000 to 2008 period.
(Source: Climate Team Study Analysis Result)

2.1.2.4 Temperature Projection

Temperature projection has also been made based on GCM output using methods to that of rainfall. The trend of temperature increase during the last 25 years as depicted by the model seems to be quite comparable with the regional trend detected from observational data. The projected temperatures indicate an almost uniform increase of temperature from 1990s to

2030 for all scenarios. After 2030 the trend splits between B1 (low emission) and other (A1B and A2) scenarios. This result, is in general, agree with the global trend of temperature for the tropical region.

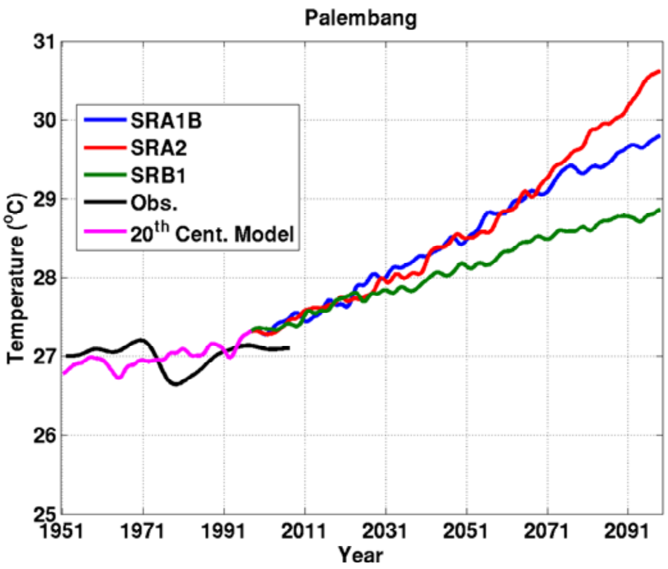


Figure 2. 7 The GCM out based projected temperature of Palembang for the 21st century with an extension back to 1951 (20th century). Data has been smoothed to show only the long-term trend.

2.1.2.5 Extreme Events

Science Basics sector calculated the probability of occurrence of daily rainfall larger than the threshold of 90th, 95th, and 98th percentiles in each month corresponding to classes of monthly rainfall. The extreme rainfall events in South Sumatra mostly occurred when monthly rainfall was in the range of 200-400 mm. They suspect that this class of monthly rainfall mainly occurs during transition months of March-April-May (MAM) and September-October-November (SON) periods.

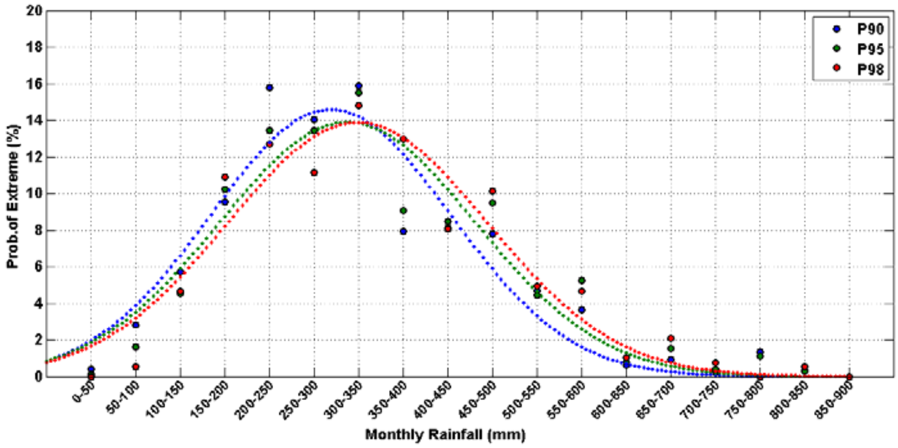


Figure 2. 8 Curves that represents the relationships between the probability of occurrence of extreme rainfall (values exceeding the threshold of 90th percentile) as a function of classes of monthly rainfall.

The model (with A1B scenario) projected an increase in the probability of extreme rainfall indicator (the selected classes of monthly rainfall) by about 3 to 5 %. Only rainfall in the range of 350 -400 mm is projected to decrease in the probability of occurrence. It should be noted, however, that models tend to produce more moderate monthly rainfall compared to observations. Therefore, this result is subject to further validation and should be used cautiously when analysing the projected extreme rainfall events.

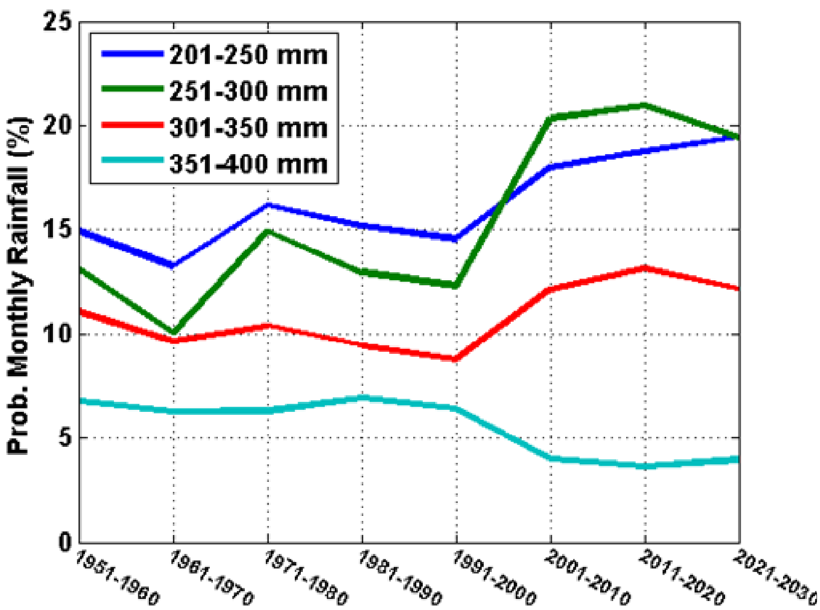


Figure 2. 9 Changes in projected probability of monthly rainfall in the range of strongest correlation with extreme daily rainfall in South Sumatra.

2.1.3 Land Use

The land use will affect water resources, pattern of water usage, and water budget in a region. Physically, changes in land use from natural area into built up area which often found in urban region will reduce the capacity of infiltration of surface water into the ground. This changing in land use also will be accompanied with increase in water demand and the balance of water budget becomes greater in demand side. Such change of land use also will increase flood events. It also cas extent the present of degraded area caused by erosion which impact to increase river sedimentation. Hence the existing land use and the prediction of its change in the future have to be considered in the assessment.

According to the data of RTRW (Table 2.3), South Sumatera Province, year of 2010, land use of South Sumatera region are divided into twenty-one groups. These twenty-one groups of the land use are: 1) airport/port 2) primary dry land forest 3) secondary dry land forest 4) secondary mangrove forest 5) primary swamp forest 6) secondary swamp forest 7) plantation forest; 8) open land; 9) plantation 10) settlement; 11) mining; 12) dry land agriculture; 13) mixed shrub of dry land farming; 14) swamp; 15) savannah; 16) *wet rice field*; 17) bush, 18) bush swamp; 19) pond; 20) transmigration; 21) body of water. The pattern of existing land use in South Sumatra Province is dominated by dry land farming of 3,509,121.849 Ha (33.236%). These lands are scattered in almost every district/city in South Sumatra province.

Settlement is separated into urban settlement and rural settlement. Urban settlement includes towns or centers of sub districts. Rural settlement has spread relatively and evenly distributed in the area around the highway between the centers of sub districts. Projections show a significant increase in the population. Settlement demand will also increase water demand.

Table 2.4 Area of Existing Land Use in South Sumatra Province in 2010

No.	Land Use Types	Area (Ha)	%
1	Airport	274,12	0,003

No.	Land Use Types	Area (Ha)	%
2	Primary Dry land Forest	372.060,96	4,053
3	Secondary Dry land Forest	230.782,82	2,514
4	Secondary Mangrove Forest	172.957,66	1,884
5	Primary Swamp Forest	108.568,57	1,183
6	Secondary Swamp Forest	95.629,41	1,042
7	Plantation Forest	187.503,46	2,042
8	Open Land	77.684,74	0,846
9	Plantation	1.525.014,48	16,612
10	Settlement	181.646,43	1,979
11	Mining	33.146,56	0,361
12	Dry Land Agriculture	322.351,50	3,511
13	Mixed shrub of Dry Land Farming	3.072.712,20	33,47
14	Swamp	91.478,30	0,996
15	Savannah	144.331,25	1,572
16	Wet rice field	441.761,20	4,812
17	Bush	593.836,74	6,469
18	Bush Swamp	1.322.570,58	14,407
19	Pond	105.693,63	1,151
20	Transmigration	71.175,26	0,775
21	Body of water	29.180,12	0,318
Total		9.180.636,00	100,000

Sumber : RTRW Prov Sumatera Selatan 2010-2030

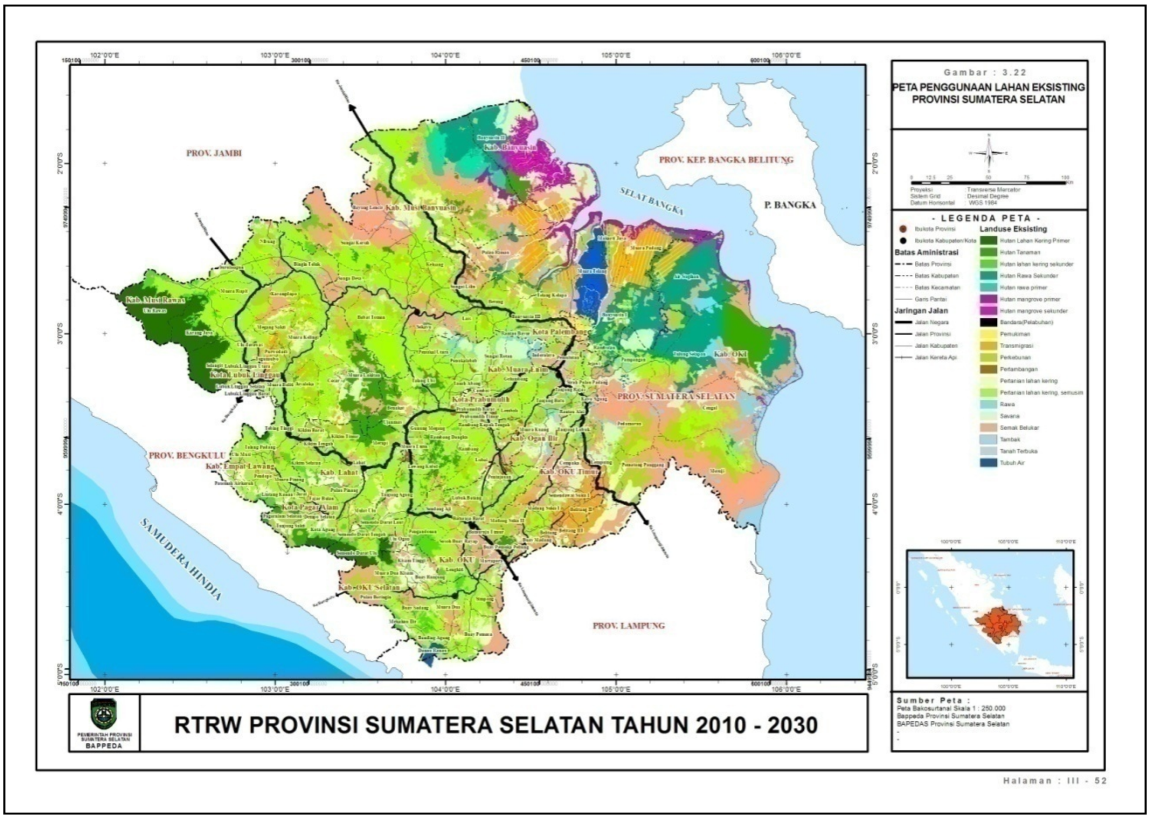


Figure 2. 10 Map of Land use of South Sumatera Province (*Source: Bappeda of Sumsel)*

2.1.4 Economy, Development, and Spatial Plan

The economic structure of South Sumatra Province is dominated by three consecutive sectors: mining, agriculture, and industry. Mining and quarrying sector is the sector with the largest contribution to the GDP of South Sumatra Province. However, the development contribution of this sector tends to decline during the period of 2003-2008. The amount of revenue from the mining sector is supported by revenues from oil and gas sub-sector that is equal to 19.26% of the total GDP of South Sumatra province in 2008. Furthermore, the second sector which contributes most to the GDP of South Sumatra Province is agriculture (19.92%). The amount of revenue from this sector is supported by income from crops sub sector that is equal to 9.34% and sub-sectors of food for 4.77% of total GDP of South Sumatra Province. This is followed by the industrial and the manufacturing sector that is 17.45% in 2008.

South Sumatra Province plays an important role in the national scale, both in terms of industry, transportation, mining, and agriculture. South Sumatra was declared as the national barns. Barns programs nationwide have the understanding that South Sumatra as food producers and providers of national food reserves, as the center of agribusiness development and agro-industry sub-sectors of food crops and horticulture, plantation, livestock, fisheries and forestry. (See Table 2.4)

South Sumatera Province, by the President of the Republic of Indonesia on November 9th, 2004, was also declared as the National Energy Granary Province. It means that South Sumatra Province is a provider and supplier of energy derived from fossil fuels and non-fossil for the needs of various industrial sectors such as commercial, transportation, and households in South Sumatra Province, National, and for the export of primary and secondary energy. There are around 24179.98 BSCF gas reserves in South Sumatra province or ±13.01% of the total reserves of natural gas in Indonesia. Besides that, the South Sumatra province has coal reserves of about ±38.44% of the total coal reserves of the National or 22240.47 million tons, while oil reserves in South Sumatra province of ± 8.78% of total oil reserves of the National or 757.60 MMSTB.

To maintain the functions of South Sumatra and its fast development, a mature and comprehensive plan is needed. This plan should take into account all aspects of planning, especially climate change that is currently a major challenge for Indonesia as an archipelagic country. Below is the plan map and the table at spatial pattern drawn up to support the functions of South Sumatra Province.

Table 2.5 Spatial Plan Map of South Sumatera Province in 2030

No.	Land Use Types	Area (Ha)	%
A	**Protected Forest**		
1	**Sub Types of Protected Forest**	**1.233.099,48**	**13,43**
	a. Area of Protected Forest	584.940,84	6,37
	b. Peat	617.415,00	6,73
	c. Mangrove	30.743,64	0,33
2	**Conservative Area, Nature Preserve, and Cultural Heritage**	**726.920,61**	**7,92**
3	**Local Protected Area**	**204.060,92**	**2,22**
	a. Beach Area	-	-
	b. River Border	203.640,55	2,22
	c. Lake	420,37	0,00
	d. Spring	Tentative	
4	**Kawasan Rawan Bencana***	**3.640.184,30**	**39,65**
	a. Earthquake*	300.812,39	3,28
	b. Landslide*	958.469,61	10,44
	c. Flood*	1.001.838,30	10,91
	d. Restricted Area of Mt. Dempo*	36.850,00	0,40
	e. Areas Prone to Forest Fires	1.342.214	14,62
Total		**2.164.081,01**	**23,57**
B	**Cultivation Zone**		
1.	**Forest**	**2.093.876,04**	**22,81**
	a. Fix Production Forest	1.619.025,47	17,64

No.	Land Use Types	Area (Ha)	%
	b. Limited Production Forest	229.929,70	2,50
	c. Converse Production Forest	244.920,87	2,67
2.	**Agriculture**	**1.470.398,69**	**16,02**
	a. Wet Field Agriculture	909.254,42	9,90
	b. Dry Field Agriculture	561.144,27	6,11
3.	**Plantation**	**2.990.372,26**	**32,57**
4.	**Fishery**	**11.377,68**	**0,12**
	a. Aquaculture	11.377,68	0,12
	b. Fisheries	Tentative	
5.	**Non-Agriculture Cultivation Zone**	**3.213.030,93**	**35,00**
	a. Settlement Area	437.530,33	4,77
	b. Mining Area*	2.719.500,60	29,62
	c.Tanjung Api-api Area	13.000,00	0,14
	d. Tourism Area	Tentative	
	e. Military Area (Omiba)	43.000,00	0,47
	f. Geothermal	Tentative	
Total		**7.016.555,00**	**76,43**

Source: Result, 2010.

*Notes: *)not included in total because it is on other regions (overlapping).*

***)included inside the area of protected forests.*

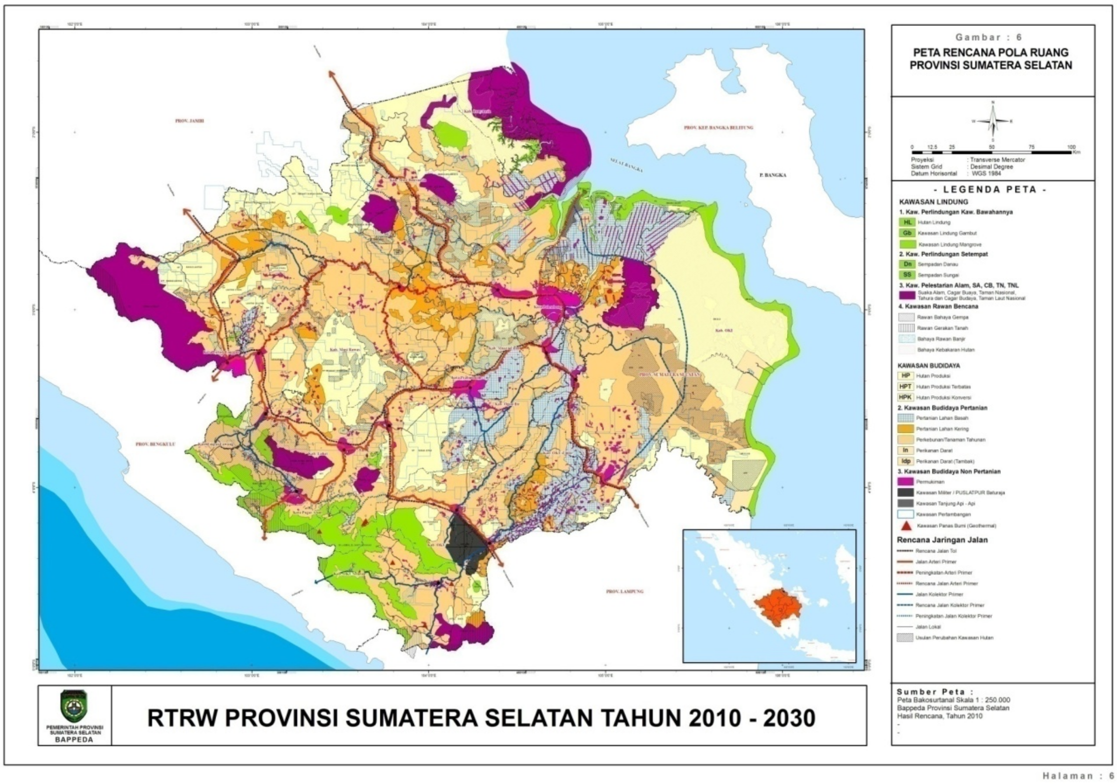


Figure 2.11 Spatial Map of South Sumatera Province (*Source: Bappeda of South Sumatra Province)*

2.2 General Description of Water Sector

Description of the existing water sector is important to know the availability of water resources including its quantity and quality; distribution of water resources spatially, as well as temporally; utilization of water resources; and water budget. Also, it is needed in formulating the problem of water resources, including current hazards and their impact and vulnerability; and the strategic issues on water sector.

This description of the water sector and its management in South Sumatera is conducted on the basis of field observation data and the results of previous studies (secondary data). The data from field observation is used to update the secondary data. The previous studies concerning water sector of South Sumatera Province are:

- Inland Waterways Project, 1995
- Tanjung Api Api Port and Coal Terminal, 1997
- The study on Comprehensive Water Management of River Musi Basin, 2002 – 2003

The scope of work of field checks are plotting the location of water resources including spring, dug well, bore hole, reservoir (*embung*) and dam; observation of flood locations; observation of river sedimentation; and water supply facilities. The field work also includes observation of water table in dug wells and bore holes, hydrodynamic of groundwater, and water sampling for chemical and physical analysis of groundwater.

Based on the data from previous studies and updating the data from field observation, the description of water sector of South Sumatera Province includes surface water, groundwater, and utilization of water resources.

2.2.1 Surface Water

Quality of river water is good enough and it can be consumed after treated using activated carbon and filtering. All local governments are using water river as sources of pipe water (Table 2.9) Based on the data of BWS VIII, some rivers have a discharge measurement station. Musi River has 895.56 m^3/s – 3935.08 m^3/s, Komering River with 25.38 – 493.83 m^3/s, and Kelingi River with 29.71 – 445.87 m^3/s.

Beside rivers, South Sumatera Province has swamp areas that based on public work data, it has over 1.3 million Ha of coastal swamp area which about 320 673 Ha (24.7%) had been reclaimed, and 278 000 Ha (32.4%) had been used for agriculture and residential of transmigration. The swamp area is located in 7 regencies/city that are Palembang City, Musi Banyuasin, Banyuasin, Ogan Komering Ilir, Ogan Ilir, Ogan Komering Ulu, and Muara Enim District. Swamps located in the lowlands store a noticeable quantity of water. The quality of this water is acid so it is not suitable for source of drinking water.

2.2.2 Groundwater

In the Barisan Mountain Range, an unknown but presumably substantial potential groundwater exists for new and extended schemes exploiting spring sources and shallow aquifers. An additional potential relying on deep fracture zones to be verified in terms of quality and quantity.

Detailed survey should be directed towards spring sources and shallow aquifers. Deep aquifers are less likely to bear any major potential for groundwater explanation. The Pre-Pleistocene Peneplains including the surroundings of Palembang are generally not suited for groundwater exploitation from deep formations due to poor aquifer characteristics in term of both quantity and quality. In this area the major potential for groundwater abstraction is limited to shallow aquifers exploitable by shallow drilled and hand dug wells.

In the Pleistocene Peneplains the groundwater prospects are generally good for shallow as well as for deep aquifers. In the tidal lowlands of the Coastal Plain the shallow formations have poor aquifer characteristics. Acidic, saline, and brackish condition prevails over large areas.

Prospective aquifers may be present at deeper levels, either in older alluvial deposits or in the upper Palembang formation. Any opportunities have to be investigated by intensive receptivity prospecting, followed by drilling and through testing of test production wells.

2.3 Current Hazards and Vulnerabilities of Water Sector

2.3.1 River's Morphological Condition

(1) Musi River Basin

The Musi River Basin is in the southern part of Sumatera Island. The Musi main stream and most of the major tributaries originate in the Barisan Range. The Musi River collects flow from the tributaries and finally pours into the Bangka Strait. The Musi river length is approximately 640 km and the total catchment area is approximately 59,942 km^2.

Catchment areas of major rivers in the Musi River basin are as follows:

(i) Musi River : 17 833 km^2

(ii) Harileko River : 3 765 km^2

(iii) Rawas River : 6 026 km^2

(iv) Lakitan River : 2 763 km^2

(v) Kelingi River : 1 928 km^2

(vi) Semangus River : 2 146 km^2

(vii) Lematang River : 7 340 km^2

(viii) Ogan River : 8 233 km^2

(ix) Komering River : 9 908 km^2

The elevation in the upper part of the Lematang catchments reaches up to 3,200 m at Gunung Dempo in the Barisan Range, and the elevation of the upper catchments of the Musi Rawas reaches 2,202 m. The average slopes of the Musi River range from 5 to 6 per mill in the upper reaches, to 0.1 per mill in the lower reaches upstream of Palembang. In Palembang the Musi River crosses a Miocene anticline and flows downstream through the Coastal Plain, which has a very mild slope of about 0.05 per mill.

(2) River Characteristics

The Musi River Basin consists of the upper, middle and lower reaches of rivers. The middle reaches are braided and gradually change to meandering river toward the lower reaches of deltaic formation. The meandering and the sand bars are found in many places in the middle and lower reaches of the rivers.

The slopes of longitudinal profile of the Musi River and its tributaries become milder in the downstream. The average bed slopes range from 5 to 6 m per km in the lower reaches.

Bifurcations are found along the Komering River such as Randu and Jambu as natural diversion rivers between the Komering and the Ogan Rivers.

Riverbeds of almost all the lower reaches have been silted up due to the deposition of sediment caused mainly by erosion in the upper catchments, and geological conditions (anticline). The rise of riverbed results not only in the reduction of discharge capacity and causing floods, but also in the extension of back swamp areas.

(3) Conditions and Problems

Conditions and main problems of the respective river basins are summarized below.

(a) The Komering River

River channel of the Komering is wide and shallow with sand bars and low sinuosity. Sediment discharge is mainly bed load. The upper watershed is covered by sandy soils produced by landslide and sheet erosion due to deforestation. In the upper reaches the erosion is still going on, and no sediment control measures has been taken yet.

In the middle reaches the Komering diverges toward the Ogan River with various diversion channels such as Randu, Arisan, Jambu, Sigonang, and Anyar. At the downstream of the Randu diversion, the riverbed becomes very mild, about 10 m for 50 km, and the river is almost left dry in the dry season. The river becomes braided, with numerous sand bars and the riverbed is rising due to the sediment deposition.

(b) The Ogan River

River channel of the Ogan River is meandering with a narrow and deep channel. Sediment discharge is mostly suspended load.

In the middle reaches, elevation of the Ogan floodplain is 10 m lower than Komering floodplain due to difference of sedimentation. The greater part of the Komering river discharge diverges to the Ogan River through Randu diversion. The road between Payama and Muara Kuang is submerged and cut by over spilling, and the urban and food crop areas are inundated during the rainy season.

In the lower reaches, the river discharge increases fast specially through the channel built during the Dutch colonial era. The river is clearly enlarging its bed by straightening and widening the channel with numerous stream bank cuttings. Between Kayu Agung and Palembang, there is lots of swamp areas flooded for several months a year.

(c) The Lematang River

The main problem of the Lematang River is inundation due to over spilling mainly over the left bank. In the middle reaches, the areas between Lubuk Mompo and Modong are flooded during the rainy season.

The Enim River of the Lematang River system is suffering from bank erosion and inundation due to over spilling. The riverbank erosion threatens the road and the erosion is still progressing at several places. In the river reaches between Penyandingan and Tanjung Karangan, overtopping of flood flow occurs over the natural banks every rainy season.

(d) The Rawas, Lakitan, and Kelingi Rivers

The main problems of the Rawas, the Lakitan and the Kelingi Rivers are inundation due to over spilling and riverbank erosion which threatens the urban areas. At Muara Lakitan, Muara Rupit, Bingin Teluk, Muara Kelingi and other places, the damages still continue.

2.3.2 Floods

The study area is drained by the Musi River mainstream and its tributaries; namely, Komering, Ogan, Lematang, Semangus, Kelingi, Lakitan, Rawas, and Harileko. To have clearer idea on the river system, the Musi River Basin is divided into three areas; namely, Mountain Area, Flood Plain Area, Coastal Plain Area, as described below.

(a) Mountain Area

The Musi River flows down for approximately 640 km from the Barisan mountain range to the Bangka Strait, passing through Sekayu and Palembang City. The origin in the Barisan mountain range is south west of the study area at the elevation of about 1 300 MSL and about 40 km west of Lubuk Linggau. Its tributaries also originate in this mountain range.

At the upstream of the Komering River, the Ranau Lake is situated with the discharge control gate to the downstream of Komering River. The design water surface level of this lake has been decided at 517.4 m in another study.

(b) Floodplain Area

(i) Upstream of Sekayu

The area at the upstream of Sekayu City is drained by the Musi River and its tributaries; namely, Rawas, Lakitan, Semangus and Kelingi.

Near Muara Kelingi City, the Kelingi River joins the Musi River from the west and the stream flow changes its direction from north to northeast. The Musi River further flows down and is joined again from the east by the Semangus River at 30 km downstream of the Kelingi River. The Musi River runs near Muara Lakitan City where the Lakitan River is located. Of the tributaries in the study area, the Lakitan and Kelingi rivers in the coastal plain area have gentle slopes.

Further downstream, the Musi River runs for 30 km from Muara Lakitan City to the junction of the Rawas River. After the junction, the Musi River changes its flow direction again from northeast to east and runs for 90 km to Sekayu City.

(ii) From Sekayu to Palembang

In the stretch from Sekayu to Palembang, the Musi River is joined by three rivers; namely, Harileko River, Lematang River and Ogan River. The Harileko River has a gentle slope as compared with the other tributaries.

The Musi River further flows down to the east and merges with the Lematang River that comes from the south. After merging, the Musi River becomes twice as wide as the upstream stretches and the meandering becomes more significant as the river flows downstream. According to the report of the Musi River Basin in 1989, the Lematang River Basin is inundated due to over-spilling mainly over the left bank, and the middle reaches of this river is usually inundated during the wet season.

Moreover, the Ogan and Komering rivers also join from the south around Palembang. The Ogan River meanders with high sinuosity and has narrow and deep channels, while the Komering River has a low sinuosity and the channel is wide and shallow with sandbars. Additionally, braiding of the Komering River has developed due to the rise of riverbed caused by the sediment deposits generated from the easily erosive banks or basin, such as sandy materials with little vegetation protection.

At the middle reached of the Komering-Ogan River the flow is diverted toward the Ogan River through the diversion channels of Randu, Jambu, Bengkudo, Muara Baru and Ampar due to tectonic movement. As of October 2002, the water flow toward the Komering River has been interrupted due to collapse of the left bank and the weirs at the Randu that direct the flow to the Ogan River.

(c) Coastal Plain Area (Downstream of Palembang)

The river bifurcates at 25 km downstream from Palembang and the left river is commonly called the Musi River, while the right one is the Padang River, as for the river width, the Musi River becomes remarkably wider starting from the downstream of Palembang; i.e., three or four times wider than the stretch upstream of Palembang. The river width after Palembang reaches 1000 m on the averages and about 3000 m at the river mouth.

2.3.3 Inundation of Sea Level Rise

(1) Objective of Inundation Analysis

To identify the probable flood inundation area at present and future conditions, the inundation analysis was carried out at Palembang. Additionally, the basic hydrological boundary or parameters, which were set up during the establishment of the simulation model for the inundation analysis, made use of the drainage plan of Palembang.

(2) Inundation Regime

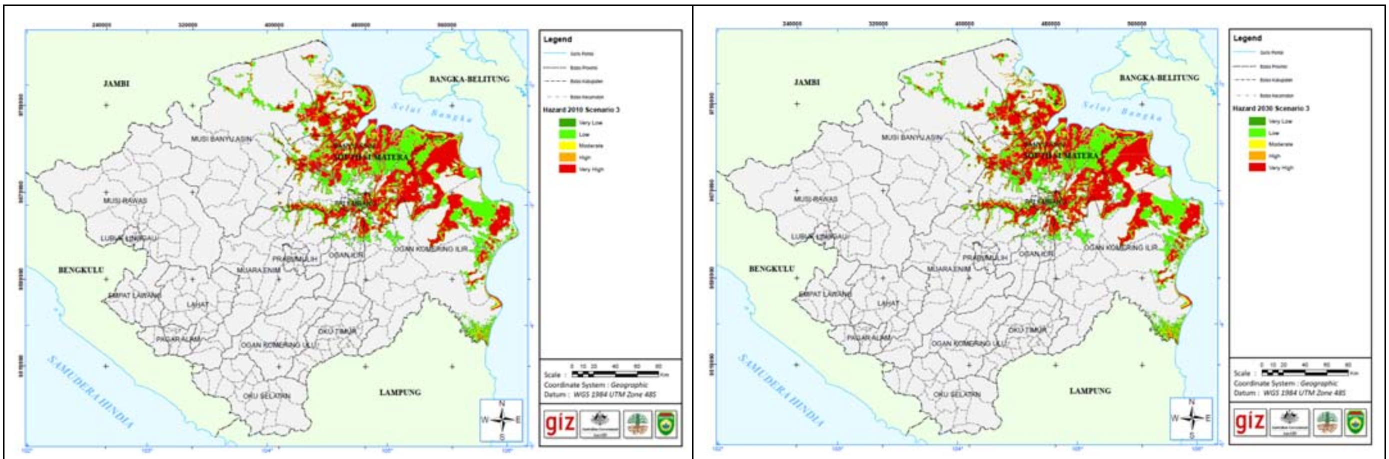
Around 10 years ago, inundation happened frequently spreading from the drainage channel. The width and insufficient capacity of the channel, as well as high tide, has been the primary causes of the inundation. Nowadays, the probable inundation area is smaller so that the people in Palembang do not recognize the inundation as a disaster because of the effect of the drainage improvement done so far. Until now, however, spot inundations routinely take place at 59 areas when rainfall intensity becomes higher. The duration at the probable inundation area with 126.9 km^2 is 4.6 hours and the average inundation depth is 0.3 m.

Table 2.6 Outline of Inundation Area

No.	Sub-Basin	CA (km^2)	IA (ha)	Depth (m)	Duration (hour)
1	Gandus	23.95	-	-	-
2	Gasing	52.11	1.5	0.25	4
3	Lambidaro	50.52	7	0.25	5
4	Boang	8.67	8.5	0.18	3
5	Sekanak	11.4	16.73	0.25	3.29
6	Bendung	19.19	14.62	0.38	5.43
7	Lawang Kidul	2.34	-	-	-
8	Buah	10.42	6.3	0.3	2.5
9	Juaro	6.86	13.5	0.4	12
10	Batang	5.59	0.8	0.25	4
11	Sungai Lincah	4.83	-	-	-
12	Borang	71.21	8.26	0.15	5.21
13	Sungai Nyiur	22.85	-	-	-
14	Sriguna	4.91	13.75	0.18	4.13
15	Aur	6.58	9.5	0.18	3.40
16	Kedukan	9.32	3.9	0.21	6.25

No.	Sub-Basin	CA (km^2)	IA (ha)	Depth (m)	Duration (hour)
17	Jaka Baring	37.61	3.17	0.15	4.70
18	Kertapati	25.09	15	0.20	6
19	Keramasan	30.09	-	-	-

Based on Climate Risk and Adaptation Assessment on Coastal Report in The South Sumatera Province, the flooding or inundation hazard due to sea-level rises give large impacts on both penetration distance from shoreline and inundation area. Large scale impacts could be forced to locations in several coastal sub-districts. There are Banyuasin, Musi banyuasin, Ogan Komering ILir, Palembang City, Ogan Ilir and Muara Enim. Inundation hazard considers five elements of climatic hazards: global sea level rise, La Nina, and storm surges. Inundation hazard in South Sumatera Province based on scenario of extreme and La-Nina and surges conditions (Scenario-3). It represents the condition of when combination of overall climate-related hazards such as tidal, wave climate, La nina, and sea level rise that occur in the same time.



Inundation Map of Scenario-3 on 2010	Inundation Map of Scenario-3 on 2030

Figure 2. 12 Inundation Map (Coastal flooding) of South Sumatera Province

2.3.4 Erosion and Sedimentation

(1) Erosion Rate

According to the critical land inventory done by Directorate General of Land Rehabilitation, Ministry of Forestry, 1985, the critical land of the Musi River basin is approximately

1,510,000 ha, which is about 30 % of total forest area 5,251,000 ha. This critical land condition will continue become worse if sustainable mitigation measures against the damage will not be taken properly and intensively.

Erosion in the Central Plain at the foot of the Barisan Range is mostly produced by the infiltration of water. The soil loss dissolution is estimated at 180 ton/year/km^2.

The erosion rate is 719 ton/year/km^2 in the Komering River. In the Lematang upper catchments, erosion rate is 507 ton/year/km^2.

The erosion rate of the Komering River basin is relatively larger than those of the other river basin.

River bank erosion has occurred at many locations in Musi River system. The riverbank erosion is described in 2.3.2 River Flooding.

Since 2007, BPDAS Musi has been controlling sedimentation rate in some sub watersheds such as Kungku (upstream musi), Malus (Lakitan), Gambu (Lematang), Kelampaian (upstream Musi), Lintang Kiri (upstream Musi), Selabung (Komering), and Kisau (Komering). Sedimentation data from BPDAS Musi showed the highest sedimentation occurs in upstream Musi river with 173.98 ton/ha/year and 99.35 ton/ha/year.

Table 2. 7 Sedimetation Rate in some sub-watersheds

sub-watershed	Sedimentasi (ton/ha/year)			
	2007	2008	2009	2010
Kungku	15 - 60	45.14	20.39	5.43
Malus	60 - 180	46.84	13.74	43.05
Gambu	15 - 60	24.16	11.26	3.04
Kelampaian	15 - 60	173.98	0.91	n/a
Lintang Kiri	15 - 60	31.29	99.35	n/a
Selabung	n/a	44.5	2.1	26.5
Kisau	n/a	71.03	47.36	18.75

(2) Sedimentation Problems

There is serious sedimentation problem in the middle and lower reach of the Komering River. River flow of downstream of Perjaya dam is not stable by sedimentation caused by divergence of the Komering River. Riverbed between Menanga and Cempaka is raised by sedimentation and no water flow during dry season.

The riverbed rises and water level rises also during flooding. Difference elevation between the Komering River and the Ogan River is about 10 m. Therefore, the Randu channel slope is very steep. The Randu channel was washed out. Width of the Randu channel became about 100 m after the flood, which width was 5 m before the flood. Scoring due to the flood broke stilling basin of the regulating dam of the Randu.

Almost whole discharge of the Komering River flowed into the Randu channel after enlargement of the Randu channel. Therefore, sedimentation increased at downstream of Randu in the Komering River.

2.3.5 Drought

In the middle reaches of the Komering River, river course meandering is active and shortage of water occurred along the old river courses. Discharge volume of the connection river from the Komering River to the Ogan River is increasing and the downstream side of the Komering River suffers from water shortage.

In the dry season, whole water flows into Randu channel. Drought occurs at the area from Randu up to Kayu Agung and upper Randu (Minanga, Adu Manis, Sukanegri, Kangkung, Ulak Baru, G. Jati Campang Tiga, Kuripan, Sukaraja, and Negeri Sakti).

The natural trans-basin channels from Komering River to the Ogan River, namely the Randu, Arisan, Jambu, Sigonang and Anyar channels, cause the drought problem in the downstream of the Komering River. In order to solve the drought problems, the control structure was built across the Randu channel, but unfortunately this structure does not effectively solve the above problems. Coping with the problems, in the middle of year 2000, a program was released to handle the Randu channel with weir development and dredging the sediment along the Komering River about 8 km from Sukabumi village, OKU district to downstream.

Dinas PU Pengairan, South Sumatera Province dredged the channel from Randu up to 8 km downstream. Bottom width of the channel is 8 m and upper width is 20 m. elevation of bottom of channel is + 27 m above mean sea level. Gabion dam shall be constructed at year of 2020 across the Randu channel. Width of the dam is about 100 m and crown elevation is + 29.5 m above mean sea level. Randu regulating dam of Gabion shall be reconstructed temporary. The width is 10 m and crown elevation is + 29.5 m above mean sea level.

2.4 Strategic Issues of Water Sector, Climate Change, and Development

The following identification of strategic issues of water sector will be the next main focus of this study. These strategic issues are derived based on the results of regional description, general description of water resources, and current hazard and vulnerability of water sector which includes secondary data of water resources in South Sumatera as presented in previous section.

Based on the previous study and the latest FGD on this study, a few problems or sectorial issues occurred in Sumatera Selatan, which is: (1) imbalance and conflicts between upstream – downstream, different sectors, etc; (2) flood and inundation damages; (3) infrastructure and facilities for water use (irrigation, domestic, industrial, etc.) are lacking and deteriorated, (4) destruction of forests is progressing, (5) water quality deterioration is in progress by erosion, wastewater discharge, disposal of domestic wastes; and (6) capacity of the relevant institution is low and low coordination between organizations (7) some occurrence of landslide in several regions. Based on general description of current hazards and vulnerabilities of water sector in South Sumatera as in previous sub section, it's also found that a few problems on water sector are: flood in several watersheds, inundation of sea level rise, erosion and sedimentation. Meanwhile, from climate team analysis on this study, it is obtained temperature rise data and rainfall decrease on a few projection periods, including period 2011-2030, on several locations in province of Sumatera Selatan.

From above identifications, issues of water sector is already analyzed and discussed in relation with climate change and development in Province of Sumatera Selatan in presents day and beyond. Those issues are:

1) Water shortage or decreasing of water supply caused by climate driven such as decrease on rainfall, or by non-climate driven such as increase on water use. Knowing amount and dispersion of water shortage hazard, vulnerability, and risk

encountered on space and time and amount of it is a challenge on this research. Then, adaptation method need to be defined to reduce risk of water shortage.

2) Flood already frequently happened in several locations in Province of Sumatera Selatan. Flood risk become important issue. This is related with possibly increasing vulnerability because non-climate factors such as change on land use, then increasing risk of flood.
3) Landslide. A few of landslide events already happened in Sumatera Selatan region. Related with increase of rainfall on future periods, landslide hazard become apparent issue in Province of Sumatera Selatan. By this mean, it is necessary to identify location of landslide hazards.

III. METHODOLOGY OF ASSESSMENT

3.1 Framework of the Assessment

In this sub-chapter, we express in short the context of methodology and general framework used in the Climate Risk and Adaptation Assessment for Water Sector, in South Sumatra Province. However, apart from the explanation of methodology and general framework below, general assumptions applied are also discussed.

For the analysis of water shortage, GIS analysis has been done since the beginning of this study. The main framework of this study is shown in Figure 3.1.

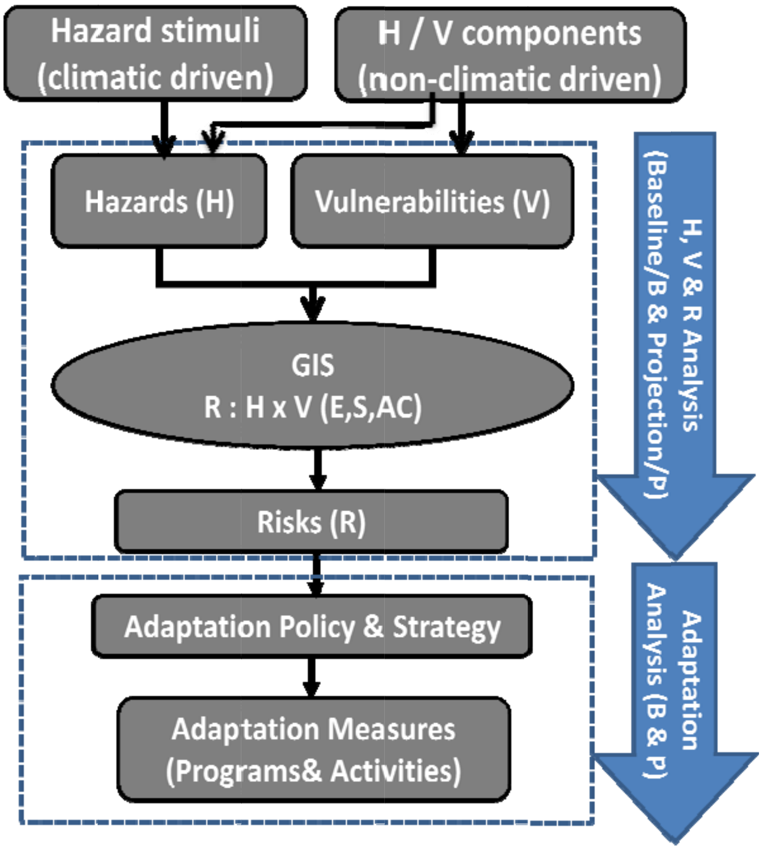


Figure 3. 1 Main framework in the climate risk and adaptation assessment of this study.

Note: Main hazard stimuli (climatic drivers) are temperature increase and precipitation variability. H or V (H/V) is components of non-climatic drivers, i.e population, and land-use. R is risk, H is hazard, V is vulnerability, E is exposure, S is sensitivity, AC is adaptive capacity; GIS is geographic information system. R is function of H and V; while V is function of E and S where E and S multiple the vulnerabilty, while AC decreases the vulnerability. Weighting is used to rank the value of H, V and R.

Assumptions about future trends are needed to show how the driving force on water sector is assumed to happen on the projection period. Thus, there are two assumptions, climatic drivers and non-climatic drivers. Assumptions about future trends in climatic driver are needed to limit the main stimuli from the climatic components affecting future water sector. As stated in the AR4, assumptions about future trends in non-climatic drivers are necessary in order to assess the vulnerability of freshwater systems to climate change, and to compare the relative importance of climate change impacts and impacts due to changes in non-climatic drivers.

3.2 Assumptions about future trends

3.2.1 Climatic drivers

As stated in the AR4, the most dominant climatic drivers for water availability are precipitation, temperature, and evaporative demand. The three drivers are also valid for the water condition of South Sumatra. Precipitation involved in the climate change impact projection to water sector in South Sumatra is the monthly precipitation. But, for several cases, if the data is available, daily precipitation is also used.

The temperature stimulus is also assumed important in determining the future water condition on South Sumatra. The temperature data is obtained from the climate sector study; in this context it is also assumed to include sea level rise impact. The evaporative demand, due to the unavailability of ground level solar radiation data, atmospheric humidity, and wind speed, is assumed could be approached by only using temperature data. Another assumption is that for all of South Sumatra Island, there is only one climatic data (Temperature T; and Precipitation CH) which comes from one observational station located on the island. In other words, it is assumed that there is no spatial variation in the temperature and precipitation of South Sumatra Island.

This study takes SRA1B as the scenario of climate change due to global warming. The next climate data and information used in this discussion are the T and CH from climate analysis results of scenario SRA1B.

Geographically, the projection of increasing surface temperature (T) of 0.5ºC is assumed equal for South Sumatra because the available climate data comes from only one climate observational station. Temperature increase of 0.5ºC is lower than the global temperature rise projection where by the end of the 21st century, the most likely increases are 3 to 4ºC for the A2 emissions scenario and around 2ºC for B1 (AR4, 2009). However, temperature rise of 0.5ºC in 2030 is higher from the trend of temperature rise during the 20th century in the region.

It is assumed that evaporative demand will increase on South Sumatra during the projection condition. In this study, evaporative demand is calculated by using Tornwhite formula in the water balance analysis.

The decreasing interdecadal condition from 1990-2010 to 2010-2030 is smaller than the decreasing interdecadal in 1961-1970 to 1951-1960. But, the projection model may result in higher decreasing precipitation as in the 1961-1970. The precipitation variability in the projection period is in accordance with one of the results of global climate projection. The increasing temperature and decreasing precipitation are further assumed to cause decreases of total runoff (TRO), which causes decreasing water availability.

3.2.2 Non-climatic drivers

As stated by the IPCC in AR4, water resources, both in quantity and quality, are influenced by land-use change, the construction and management of reservoirs, pollutant emissions, and water and wastewater treatment. Also, as stated in the AR4, water use is driven by changes in population, food consumption, economic policy (including water pricing), technology, lifestyle, and society's views of the value of freshwater ecosystems. In short, the availability and functions of water are very influenced by non-climatic drivers.

For South Sumatra, based on the consideration of temporal and spatial data availability, thereare nine non-climatic drivers involved on the water sector in this vulnerability analysis: *population density, land-use, water demandor water sources; water quality; PDAM services (*PDAM : Perusahaan Daerah Air Minum*) or regional company for drinking water; role of infrastructures, governmental program, and society's welfare*. All those non-climatic drivers are especially involved in the analysis of vulnerability to water sector hazards, in baseline and projection periods, except for water demand and land-use where both are used in the hazard analysis as well as in the vulnerability analysis.The nine non-climatic drivers are described shortly as follows:

(1) Population

Data of total population, population density, and population growth per district in South Sumatra is assumed as data from the 2010 survey. Furthermore, it is important to calculate the population of each house to gain the spatial population density distribution in a more reliable condition in the baseline period. In this assessment, the population of each house is obtained based on the following assumptions: 1) population of each house is the same in a village; and 2) a house is a building with an area less than 500 m^2.

In the projection condition (2030), the general assumption is that population distribution will be distributed following the development of regions. The development can be indicated by road planning and is limited by the settlement planning. The development assumptions are: 1) population growth only happened in regions of settlement planning; 2) the existence of roads shows that the settlement is ready to be developed; and 3) population growth level is determined by the current population density. Using these assumptions on the simulation, the population density in 2030 is obtained.

(2) Land-use

Land-use type strongly influences the level of risk. Current land-use as a baseline is based on the 2008 land-use from the BAPPEDA of South Sumatra Province. Meanwhile, the 2030 land-use condition is assumed as the 2030 Spatial Planning of South Sumatra Province.

(3) Water demand

The performance of water supply gets worse by higher water demand. The higher water demand can lead to shortage of water supply. Hence, water demand is an indicator which will be used to analyze the vulnerability and hazard of water shortage.

Water demand is analyzed from two components, they are population or domestic water needs and industrial' water needs. Based on the standard of WHO, domestic water needs is 144 liter/person/day and industrial water needs is around 0.3-0.8 liter/second/ha or 25.92-69.12 m^3/day/ha (*Kementrian PU*, Ministry of Public Works). This standard is used in the baseline or current water needs because no others standard is available for the South Sumatra water needs.

It is also difficult to predict the water demand in 2030 because of, among others, difficulty in establishing the projection of future industries built in South Sumatra Province. But based on the 2030 Spatial Planning of South Sumatra Province, the location of industries has been clearly depicted. The areas of industries in the 2030 Spatial Planning are assumed to be the areasof industries in 2030.

To project the water demand in 2030 period, we also need the standard of water needs both for domestic and industrial. In this study, standard of domestic water needs is relatively unchanged from the current condition. Meanwhile, the standard of other water needs in the 2030 period are grouped based on land-use. This last standard assumed as a reliable approach in determining the water need in projection period.

(4) Water Resources

The impact of climate change to water availability will be felt by people according to the amount of water sources utilized. The higher the dependence of the water sources to climate, the bigger the impact of climate change felt. Water source, especially surface water and shallow groundwater of unconfined aquifer are sensitive to temperature rise and precipitation variability.

Water sources information used by the local people is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Based on the data, there are 10 water sources utilized by the population of South Sumatra: *1)rain water, 2) river water, 3) unprotected spring, 4) protected spring, 5) unprotected well, 6) protected well, 7) drilled well, 8) retailed piped water, 9) piped water (PDAM services), and 10) bottled water.* Those water sources are assumed as the signifinact water sources for South Sumatra Province in the baseline or current period.

In the projection condition, it is assumed that 90% of South Sumatra Province will be served by PDAM network. This assumption is based on the Masterplan of PDAM. Thus, it is assumed that in the period of 2030, the Masterplan of PDAM is achieved so the assumption that 90% of South Sumatra Province will be served by PDAM network is valid.

(5) Role of infrastructures

Natural disasters or impact of climate change often cause great collateral damage. This happened if there are important infrastructures. The amount of this damage is difficult to measure but very real. As an example, if a landslide occurred on a road, then every activity on the road, such as public transportation and economy, cannot be continued.

Current infrastructure distribution can be seen from the current infrastructure data of PDAM. Future infrastructure condition is difficult to calculate, but can be assumed based on the 2030 Spatial Planning. The infrastructure classes are uniformed by using the type of infrastructures in the 2030 Spatial Planning.

(6) Social welfare

Other than government programs, society also plays a role in minimizing the impact of disasters or impact of climate change. This is what we address as adaptive capacity that will reduce the vulnerability. But the involvement of adaptive capacity of society really depends on the ability or capacity of society itself. This ability or capacity of society is assumed could be approached from analysis of the social welfare condition.

In this study, assumption for social welfare is that its value can be considered from two sides, house types and society's income. With this assumption, the social welfare can be counted temporally (baseline and projection conditions) and drawn spatially. Currently, house types and society's income are based on the existing data. In the projection, social welfare is not included due to government program that assumed has the performance of maximum condition.

3.3 Method of Hazards Analysis

3.3.1 Method of water shortage hazard analysis

The hazard of shortage of water availability, or in simply, water shortage hazard (WS hazard) is analyzed based on direct climate change impact and physical potential hazard. The direct impact is the analysis results of climate scientific basis. The results consist of projection of temperature and precipitation. The physical potential hazards are water demand and quantity of water in watershed unit.

Water availability is the amount of available water that can be utilized. Water availability in nature is affected by climate variability and climate change. On the other hand, water availability in nature is also affected by human activities. Even sometimes, human activities have a great deal in the decreasing water availability. Based on these facts, water shortage can be interpreted as “the decreasing amount of water both naturally or due to human utilization”.

Water potential can be approached by using the method from F.J. Mock. This method is developed based on hydrological cycle with the concept of water balance. The general form of water balance equation is: $\mathbf{P = Ea + \Delta GS + TRO}$

Precipitation (P) will be used for evapotranspiration (Ea), surface run off (TRO), and then stored in the ground (**ΔGS).** The amount of water utilized directly by society is the surface run off or often called total runoff (TRO). Total runoff consists of Direct Runoff (DRO) which is directly flowed on the surface when raining, base flow which becomes the run off of river bed through springs and storm run off which is a run off on the unsaturated zone.

The evapotranspiration in the formula mentioned above is calculated using Thornwhite formula with modification. The formula based only on temperature (T) data. The formula with modification is taken because of the available data, for calculating evapotranspiration, spatially and temporally, is only temperature data.

Water balance calculation is best used in the watershed unit and monthly time series. The hazard analysis is based on the water availability data in a watershed. The surface water availability in a watershed is seen from the total runoff (TRO) value. Meanwhile, the current water shortage can be seen based on the changing value of TRO cumulative probability 50

% in current period ($TRO_{CDF50\%,\ current}$) to the condition of TRO cumulative probability 50 % in the baseline period ($TRO_{CDF50\%,\ baseline}$). Meanwhile, the value of water shortage in the projection is the decreasing total runoff cumulative probability 50 % in the projection ($TRO_{CDF50\%,\ projection}$) to the value of $TRO_{CDF50\%,\ baseline}$. The baseline condition is defined as the condition of 1960 – 1990, current condition 1990 – 2020, and projection condition is the condition of 2000 – 2030.

In this study, WS hazard is defined as decreasing water availability (DoWA) plus the value of water demand (WD) and divided by total water availability in baseline condition ($Q_{Baseline}$ or $Q_{1960\text{-}1990}$) in watershed unit as expressed in the following formulation:

$$Water\ Shortage\ Hazard\ (WS\ Hazard) = \frac{(DoWA + WD)}{Q_{Baseline}}$$

The DoWA (decreasing water availability) and total water availability in baseline condition ($Q_{Baseline}$) are calculated using the method of water balance analysis. The TRO here is an important tool for calculating the DoWA and $Q_{Baseline}$. Cumulative distribution frequency (CDF) analysis, as illustrated in Figure 3.5, is used to further calculate the total runoff (TRO) data which is obtained from the water balance analysis. By application of the CDF method it is possible to determine value of TRO which can generate the water shortage as the TRO below 50% on CDF graphic (see sample on Figure 3.3) denote the value.

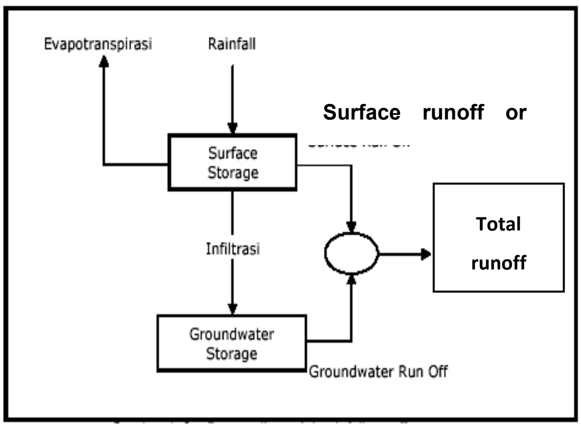


Figure 3. 2 Conceptual framework of water balance analysis. The total run off or TRO = direct run off (DRO or surface run off + groundwater run off

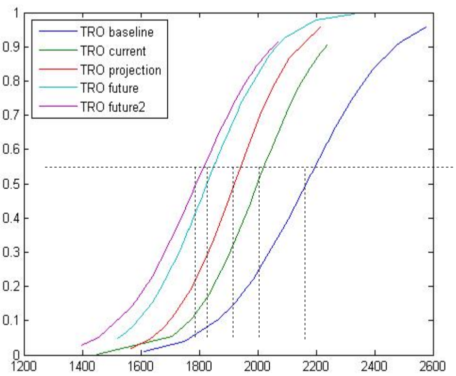


Figure 3. 3 Illustration of CDF 50% for TRO in baseline (1960-1990), current (1991-2020), projection (2010-2030), future1 (2031-2060) & future2 (2061-2090)

Furthermore, the DoWA (decreasing of water availability) is formulated as the probability of water decrease compared to normal condition (baseline condition, or 1960-1990). The value of 50% TRO is taken as reference, while the value below 50% TRO indicates decreasing water availability. Hence, the DoWA in the formula mentioned above is:

(1) the difference between TRO of baseline condition ($TRO_{Baseline}$) and TRO of current condition ($TRO_{current}$), or $DoWA_{current} = TRO_{Baseline} - TRO_{current}$ for current condition; and

(2) the difference between TRO of baseline condition ($TRO_{Baseline}$) and TRO of projection condition, or $DoWA_{projection} = TRO_{Baseline} - TRO_{projection}$ for projection condition.

Finally, the DoWA is also influenced by water demand (WD). The higher the water demand, the bigger the magnitude of the hazard. The WD is calculated spatially based on the total population and industry for the baseline period; and based on population and type of land-use for the projection period. WD analysis uses standard water demand for each component of water user and assumptions as mentioned in section 3.1 and presented in Table 3.2 and Table 3.3 below. From the formula of WS hazard, it is clear that the unit of WS hazard is watershed or water catchment area.

Table 3. 1 Standard of water need for domestic use

Total population (household)	Connection to House	Connection to Public Facility	Water Demand in Average (m^3/day/person)
>1000	0.21	0.30	0.174
500 – 1000	0.17	0.30	0.170
100 – 500	0.15	0.30	0.126
20 – 100	0.90	0.30	0.78
0 – 20	0.60	0.30	0.54

Table 3. 2 Standard water needs in 2030 based on land-use

Land-use Types	Water Demand (m^3/day/ha)
Industries	50
Trades and services	40
Airports	40
Hospitals	30
Governmental offices	25
Religious places	25

3.3.2 Method for Flood Hazard Analysis

Flood hazard model is using GSSHA method. GSSHA (Gridded Surface Subsurface Hydrologic Analysis) is a grid-based two-dimensional hydrologic model. Features include 2D overland flow, 1D stream flow, 1D infiltration, 2D groundwater, and full coupling between the groundwater, vadoze zone, streams, and overland flow.

Flood hazard model uses administrative of South Sumatera Province map, DEM, rainfall data, land use map, and geology map.

3.3.2.1 Watersheds Delineation

The watershed is delineated from the DEM and based on calculations from *TOPAZ.* The *TOPAZ* model also determines the stream network from the DEM data. The watershed model is based on extreme event (flood) that occurs in the watershed, such as Lematang watershed. Distributed models are used over a wide range of grid sizes. The selection of the grid size will determine the total number of grid cells which is used to describe the watershed size. The geometric of river parameters, such as stream type, depth and width of stream, and slope, will be used as input to 2D grid watershed model.

3.3.2.2 GSSHA Model

- Define Land Use and Soil Data

  Surface roughness values are based on land use type that has typical range in 0.01 – 0.5. Overland roughness coefficients must be assigned to every cell in the active grid. The value of surface roughness represents an infiltration capacity of land use type which specifies Manning/Strickler n values for the overland flow domain.

  Soil type has to be determined based on geological map. Soil properties include organic matter content, texture and structure of soil, porosity, bulk density, saturated hydraulic conductivity, initial soil moisture content and saturated moisture content.

- Hydrologic Computation

  Hydrologic computation is analysis for infiltration. Infiltration analysis is using the Green and Ampt with redistribution infiltration method. This method based on result from calculating surface roughness parameter of land use and soil properties parameter (Table 3.3).

Table 3.3 The Green and Ampt with Redistribution Infiltration Method Parameters.

Parameter	Units	Typical Range

Ks (Saturated Hydraulic Conductivity)	cm/hr	0.01 – 2.0
ψf (Capillary Suction Head)	cm	10 – 100
θs (Porosity)	m^3/m^3	0.25 – 0.6
λ (Pore Index Value)	none	1.0 – 4.0
θr (Residual Saturation)	m^3/m^3	0.01 – 0.1
θf (Field Capacity)	m^3/m^3	0.01 – 0.3
θwp (Wilting Point)	none	0.03 – 0.25
θi (Initial Soil Moisture)	m^3/m^3	θr-θs

This analysis will result in 3 types of 2D grid map: land use grid map, soil type grid map and combine map of land use and soil type. An overall analysis in the GSSHA model will result in flood hazard map that shows inundation area, depth and duration of flood.

- Define Precipitation

Precipitation parameters are hourly intensity of rainfall that distributed per grid. Rainfall data is analyzed into two conditions of baseline and projection. Based on the existing rainfall data, it shows extreme rainfalls are mostly located in highland to middle land such of occurance in the year of 2005. Extreme daily rainfall in the Middle and highland zones was 199 mm with the amount of maximum rainy day was 19 days, meanwhile maximum monthly rainfall was more than 660 mm, such as in the Komering watershed.

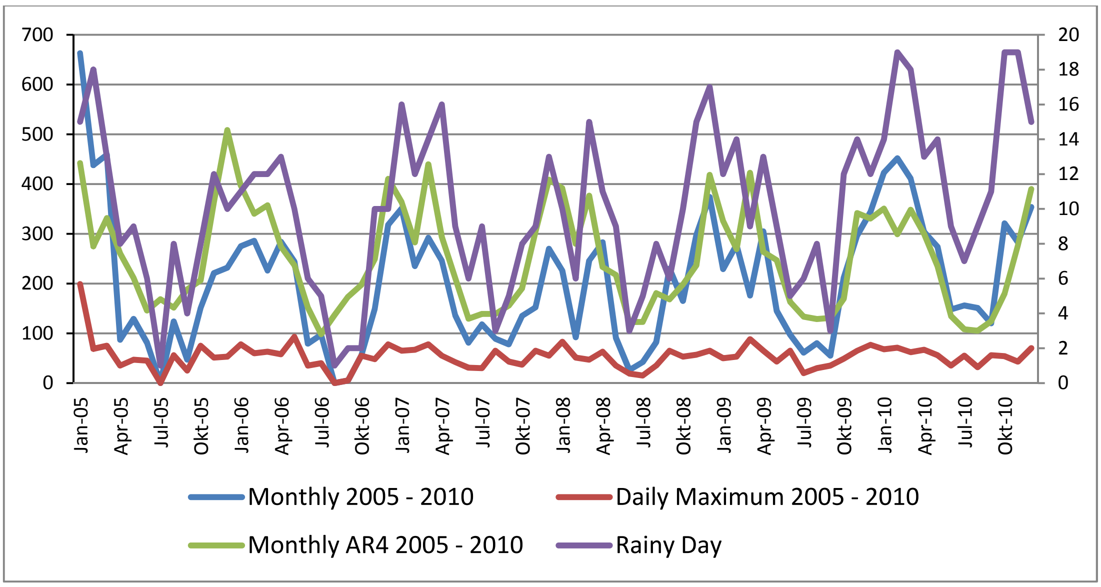


Figure 3. 4 Rainfall of Komering watershed in Baseline Condition

There has different value between observation (>660 mm) and AR4 baseline (508 mm) data that has more than 100 mm. In the Lowland area, extreme daily rainfall was 172 mm with the maximum rainy day was 29 days. Meanwhile extreme monthly rainfall was more than 650 mm (rainfall data of SMB II rainfall station gauge). Extreme rainfall occurred in July 2002.

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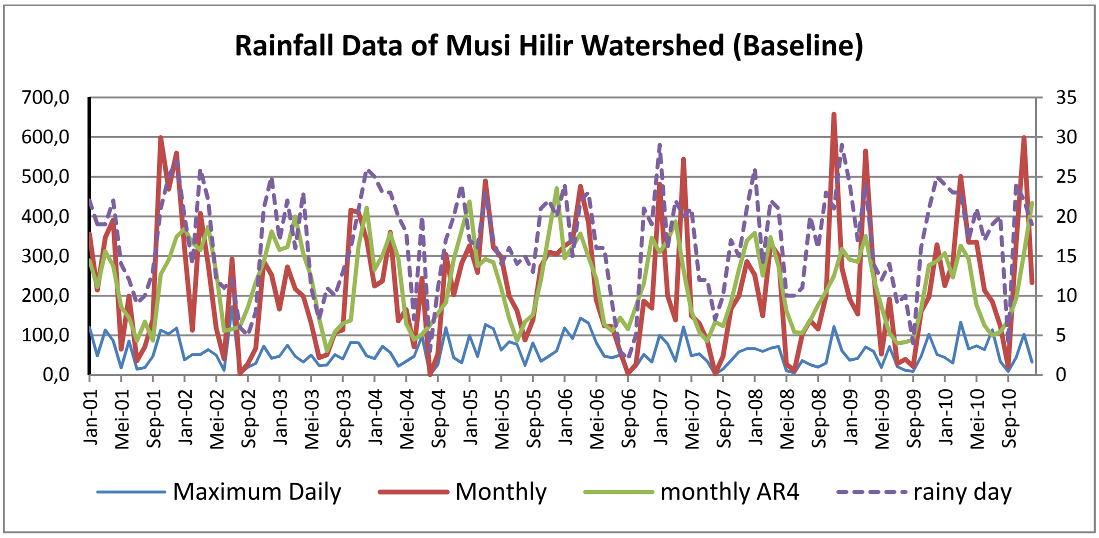


Figure 3. 5 Rainfall data of Musi Hilir watershed (Palembang) in Baseline Condition

In the projection condition, the precioitation analysis will be using SRA1B scenario, the rainfall data will increase around 12 % – 60% than the baseline condition. It will occur in the Mesuji watershed (Figure 3.5). Generally, most of watersheds will increase 20 % than the baseline condition.

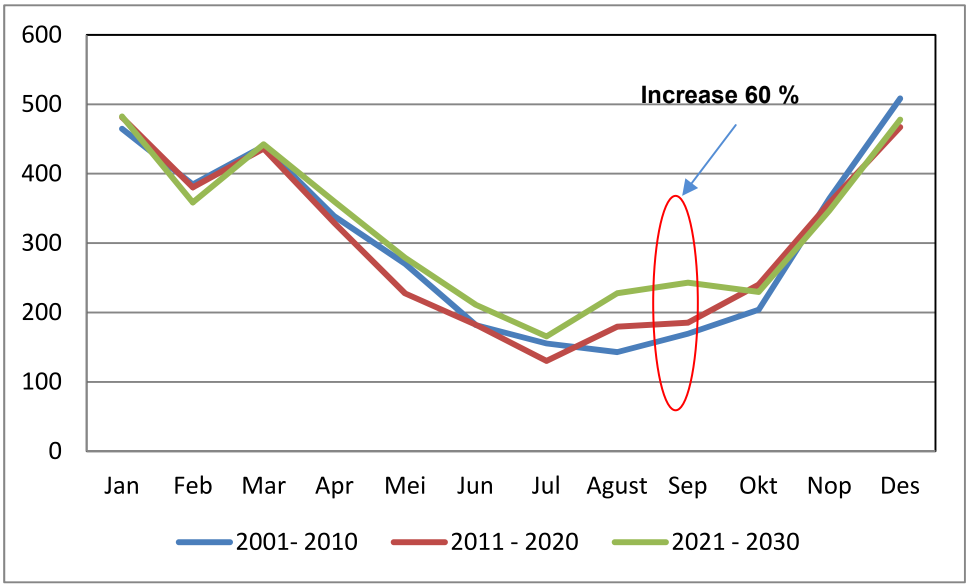


Figure 3. 6 Rainfall of Mesuji Watershed in Baseline and Projection Condition

- Clean Up Model

  This step will be checking all of process parameters and computation of hydrologic. If there are errors, the analysis process can nott be continued.

- Run The GSSHA Model

  GSSHA outputs are multiple solution files including an outlet hydrograph file, a summary file, and solution data sets. Over all of analysis in the GSSHA model will be distributed into flood hazard map that shows inundation area, depth and duration of flood.

3.3.2.3 Flood Delineation

The result of GSSHA has to be exported to GIS application to produce the flood hazard map. According to availability and accuracy data, the flood hazard assessment will be analyzed into 2 scales that are watershed (sub-basin) and provincial scales. And the flood hazard will be modelled into baseline and projection condition due to rainfall data scenarios. The scales of analysis have different accuracy of results which the watershed (sub-basin) has the highest accuracy than provincial scale because the provincial scale analysis is generated based on the result of watershed (sub-basin).

In the watershed (sub-basin) scale, the hazard level will be divided into 5 levels i.e. very low, low, moderate, high, and very high. These levels represent the depth of inundation. While in the provincial scale, the hazard will be divided into 2 levels which are hazard and no hazard.

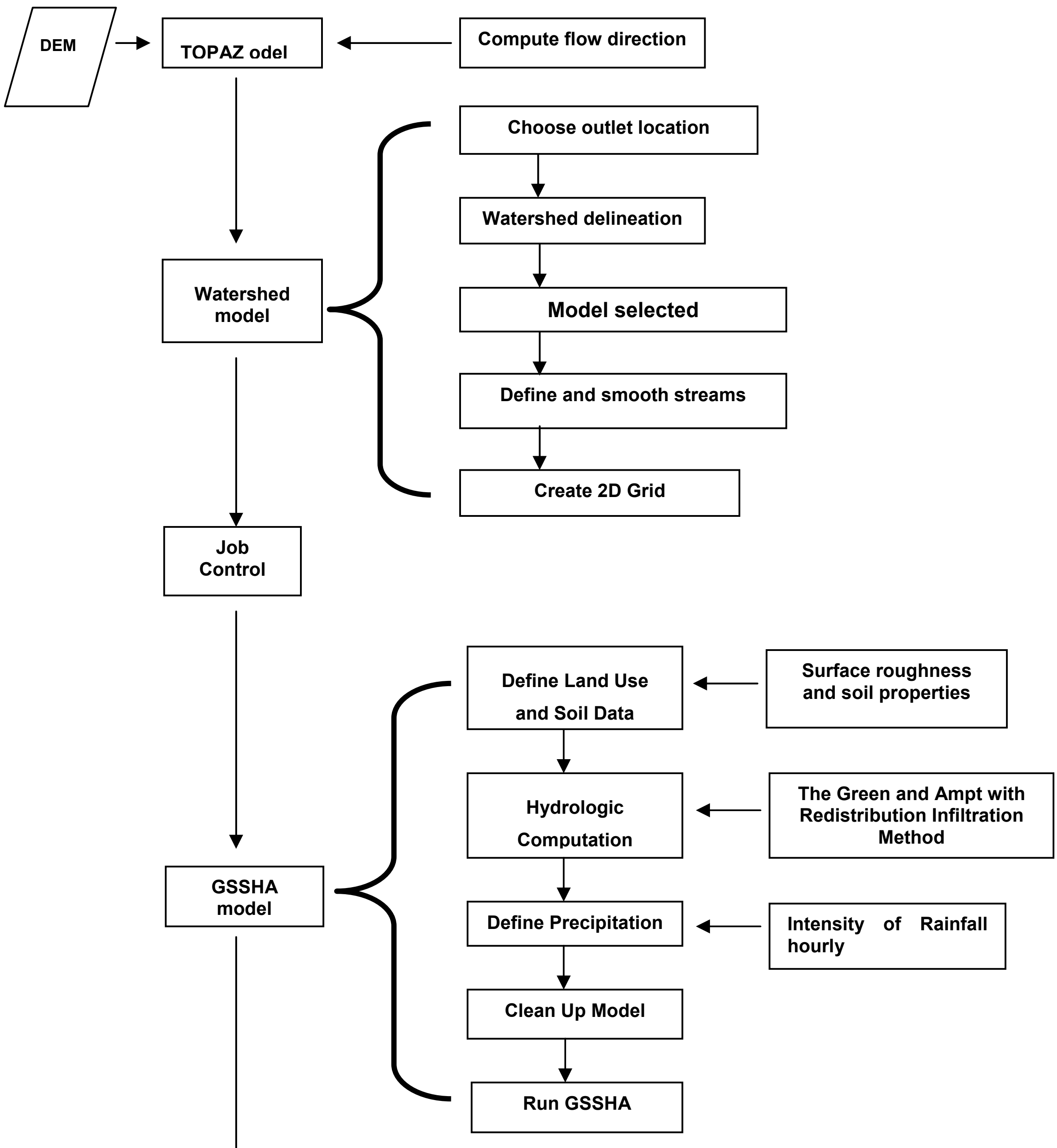


Figure 3. 7 Framework of Flood Hazard Analysis

3.3.3 Method for Landslide Hazard Analysis

Landslide hazard is usually trigerred by rainfalls as a climatic driven factor, as well as geology, soil type, and slope. Several methods have been used to integrate the characteristics of extreme rainfall into the slope stability analysis. Climate change indicates trend of rainfall change that is one of landslide triggering factors. Landslide hazard assessment is analyzed by Geographical Information Systems (GIS) method. The assessment techniques used are deterministic and statistical approaches. Deterministic approaches based on stability model that analyzed by Geostudio application, while statistical approach is used for weighting of landslide trigger factors. The method of statistical analysis to generate landslide hazard show at figure 3.8 below.

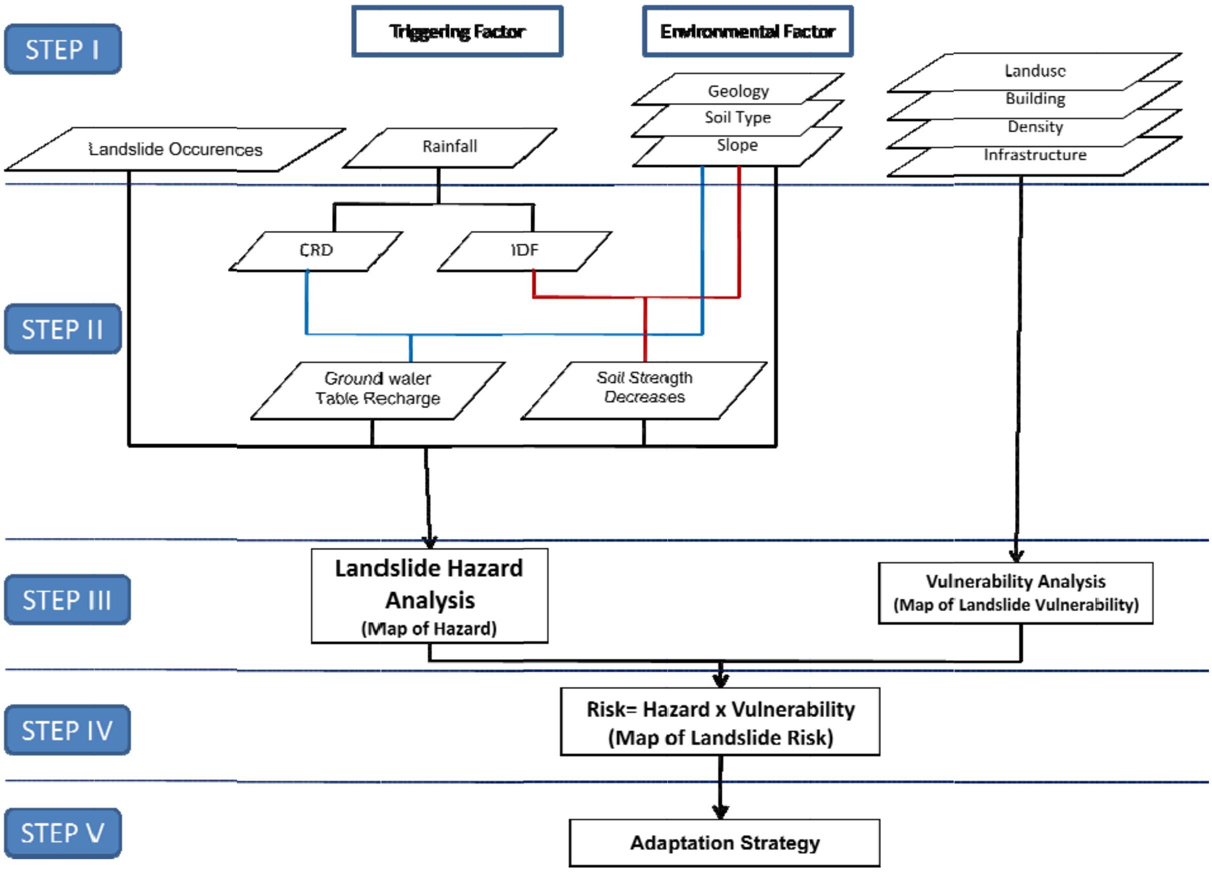


Figure 3. 8 Framework of landslide risk assessment

1. Landslide Occurrences Analysis

The historical landslide occurrence is one of landslide hazard assessment indicators which will be analyzed by using deterministic approach. The landslide hazard will be assessed by using slope stability analysis which calculated a safety factor.

The slope condition will be considered as technically safe if index of safety factor > 1.5, while the construction will be declared as unsafe if index of safety factor < 1.5. Landslide will occur if the safety factor < 1. The safety factors of exsisting landslide occurrences will be weighted as a baseline condition of landslide hazard.

In the projection condition, safety factor index will be influenced by ground water table recharge and soil strength decreases factors. The ground water table recharge will be analyzed by using Cumulative Rainfall Departure method which is strongly influenced by rainfall and specific yield of soil, while the soil strength decreases will be calculated by Intensity Duration Frequency analysis.

a. Ground Water Table Recharge Analysis

The cumulative rainfall departure (CRD) method, based on the water-balance principle, is often used for assessing water level fluctuations. Because of its simplicity and minimal requirement of spatial data, the CRD method has been applied widely for estimating either effective recharge or aquifer storability. The CRD value has a linier relationship with a monthly water level change. Ground water table recharge is analyzed for baseline and projection condition. The baseline condition is determined as 1980 – 2011 period, and the projection is as the period of 2012 – 2030.

The result of ground water table recharge analysis will be divided into 7 levels that representing ground water table recharge scales which have probability to trigger landslide occurrence. The highest level of GWT is identified the highest probability to trigger landslide hazard.

b. Soil Strength Decrease Analysis

The soil strength decrease analysis identified intensity and duration of rainfall that affecting cohesion decrease. The analysis is using relation curve between intensity duration frequency of rainfall, hydraulic conductivity function, and soil water character curve. Based on the result of soil strength decrease analysis, in the one of landslide location, Waturejo village of Kasembon sub-district, the landslide will be occurred if the soil cohesion decreases when the intensity of rainfall has 21.38 mm/hour of > 1 hour duration rainfall. Based on it, in the projection condition, the landslide occurrences will be the worst.

2. The Environment Trigger Analysis

Besides rainfall factor, landslide hazard is also triggered by geological and slope factors. Geological type can be triggering landslide occurrence due to the physical and structure of geology. Based on it, the lithology is divided into 5 levels due to erosion rate that are very high, high, moderate, low, and very low.

Furthermore, the slope is the highest factor of landslide trigger. Based on digital elevation model (DEM), the slope map is divided into 6 classes which the highest class will represent the highest slope.

3. Landslide Hazard Assessment

The result of landslide occurrences and the environment trigger analysis have to be exported to GIS. Landslide hazard is divided into 5 levels that are very low, low, moderate, high, and very high. The landslide hazard assessment will be producing 2 maps for the baseline and projection conditions. The landslide hazard baseline map represents existing landslide hazard while the projection map is a combination weighting of all of landslide trigger factors i.e. landslide occurrence, potential landslide occurrence, geology, and slope factors.

3.4 Method of Vulnerability Analysis

Vulnerability is defined as a function of the character, magnitude, and rate of climate change as well as the degree of variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC AR-3). Thus, the components of vulnerability consist of exposure (E), sensitivity (S), and adaptive capacity (AC). The function initially is a multiplication between E with S factors and divided by AC factor as in the following formula: $V = (E \times S)/AC$. The formula means vulnerability to a certain hazard is strengthened by its exposure and its sensitivity and decreased by its adaptive capacity. In this assessment, the function of $V = (E \times S)/AC$ is *pseudo* multiplication, because, in practice, the vulnerability (V) is gained from addition between the exposure (E) component with the sensitivity (S) component and reduced by adaptive capacity (AC) component.

Several sub-sections below explain the method of vulnerability assessment in facing hazard used in this study. The hazard which has been identified in the previous chapters are water shortage, floods, and landslides. Hence, there are three types of vulnerabilities: vulnerability to water shortage hazard, vulnerability to flood hazard, and vulnerability to landslide hazard. The scopes of the explanation including method of identification and selection of vulnerability components as well as indicators of each component, method of assessment of water shortage vulnerability as well as method of flood vulnerability assessment and landslide vulnerability assessment; and method of analyzing and weighting each component of vulnerability.

In this study, we also implement dynamic vulnerability. Meaning, indicators of each vulnerability components are dynamic. To obtain the vulnerability results in a more reliable projection condition, an analysis of change of vulnerability indicators from baseline condition to projection condition is needed both its number and distribution. Several analysis methods are needed to approach this dynamic vulnerability.

3.4.1 Method of identification and selection of vulnerability components

In this step, we identify the vulnerability components E, S, and AC through each of its indicators for every hazard. Sources of identification are some related IPCC's publications, and previous study results in Indonesia, and discussions between experts in this VA study, also the results of focus group discussions with stakeholders from the government of the South Sumatra Province.

Next, we select from the identification results based on certain criteria to determine final vulnerability indicators and components. The criteria are:

(1) The level of significant relation between indictors and hazards reviewed where the strongest significance will be chosen;

(2) Indicators have enough availability of data, both temporal (baseline and projection) and spatial; and

(3) Indicators are not yet include in the analysis of hazard.

The next step is to map the indicators into one of the components of vulnerability: exposure, sensitivity, and adaptive capacity. Then it is followed by calculating the quantity, mapping the distribution, and weighting the vulnerability components based on its indicators in the baseline and projection period.

3.4.2 Method of assessment of water shortage vulnerability

Based on the benchmarking to literature studies (AR4 IPCC, ICCSR, VA Lombok, etc.) we obtained that indicators with strongest relation with the water shortage hazard are water availability, water demand, water sources as a part of water availability, water quality, population welfare, PDAM network as community's access to clean water source, local government's policies and programs on water management, initiatives and role of local community on water conservation, landslides, water sources damages, etc.

Based on the three criteria that have been mentioned above, we identify the vulnerability indicators for water shortage hazard, which are: population, land use, water demand, water resources used by inhabitant people, role of infrastucture and social welfare. These indicators wil be fixed in Chapter V of this study with each data sources presented in Table 3.4 below.

Table 3. 4 Indicators and sources of data for water shortage vulnerability

Indicators	Data
Water Demand	• Population Census of South Sumatra , 2010 • Landuse 2008 • *Rencana Tata Ruang* South Sumatra, 2030
Water sources	• National Census, 2007
Population Welfare	• House type, Capital Income (Field survey, National Census, 2007)

Based on Table 3.5, methods used in the assessment of water shortage vulnerability are:

1) Calculating and mapping of water demand

Water demand (WD) is calculated based on the water needs of every water user, they are society, industries, etc. The difference of WD used as vulnerability components with WD in the hazard analysis is that the WD in the vulnerability is calculated per grid or distribution per grid with grid area = 100 m x 100 m or 1 hectare; while the WD in the hazard analysis is calculated per watershed unit.

Society's WD is calculated based on the current population for the baseline and based on 2030 population for the projection condition. At first, water needs standard used is 144 liter/person/day for the baseline condition. After processed based on the classification of total households, the standard is modified into as in Table 3.2. For the projection condition, society's WD is calculated based on the projection of 2030 population. Population growth here uses values from the BPS. Meanwhile, the water needs standard of the projection is assumed the same with the standard of baseline period (Table 3.2).

Society's WD calculation per grid with grid area of 1 hectare, needs an approach to estimate the distribution of population density more reliably for both baseline and projection period. For the baseline period, we need the calculation of population distribution per every household in each village and the number of houses per grid area. In the projection periods, we need data on 2030 spatial plan to calculate population development and its distribution in the same grid area. Thus, we use assumptions as discussed in sub-section 3.1.2 1) above, for both the baseline and projection periods..

Calculation and mapping of industries' and other's WD is based on the approach of land=use condition and standard water needs for every land-use. In the baseline condition, the number and distribution of land-use is obtained from the land-use map of South Sumatra Provinve of 2008, while the standard water needs per land-use unit is as shown in Table 3.3.

In the projection period, the land-use condition is determined by 2030 land-use derived from 2030 Spatial Planning of South Sumatra Province. The standard of water needs per land-use unit for the projection period is assumed as the same with the standard water needs for every type of land-use in the baseline period (Table 3.3).

2) Calculating and mapping of water sources

Water sources are various sources of water that are used by population in South Sumatra Provinve for the baseline and projection periods. For the baseline, the calculation and mapping of water sources data is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Report of the survey consists of the data of each source of water used by people and its distribution in village as unit of distribution.

In the projection condition, based on the assumption that 90% of South Sumatra Provinve will be served by PDAM network, it is clear that 90% of water sources in every village are taken from PDAM service. Hence, map of this water source will follow the map of PDAM service networking. Here, the contribution of the others sources, which are 10% of total water source in the projection are neglected.

3) Calculating and mapping of water quality

Based on literature studies, swamp water on Kalimantan and its surrounding has a bad quality because possibly it contains iron or has a high acidity. Based on the data of water sources used by public, in South Sumatra, there are still people using river water, wells, and springs for its daily use. In the regions near swamps or regions which are previously swamps there are possibilities that the water quality from those three sources is contaminated by low quality swamp water. Meanwhile, in the projection period where there will be a decrease of water supply, swamp water may likely used by the public as a source of water.

The next method of this water quality vulnerability indicators study begins with extracting samples or checking other secondary sources of water. These water samples then tested at a laboratory to ensure its level of quality. The next step after the quality of water is obtained, is determining the source of water which fulfills the criteria to be an indicator of vulnerability component.

The final step is to calculate the spatial distribution of these selected sources of water. To determine the distribution of swamp area, for instance, we can use an observational method with the help of Landsat ETM7 images of 2003 with the assumptions mentioned in the previous sub chapter. Other significant sources to water quality may also be calculated and mapped based on its distribution. In the projection period we assume that water quality is not significant as a vulnerability indicator because in 2030 it is assumed that PDAM's water services has reached 90% of the total population, and the 10% left can be ignored.

4) Calculating and mapping of PDAM's service network

Based on data availability, the reliable method to calculate and map PDAM's service network is by using the approach of population served by PDAM. Thus, we calculate the population percentage served by PDAM with its service network map in the baseline or current condition (2010) and projection period (2030).

5) Calculating and mapping of social welfare

As assumed before, social welfare is measured by two sub-indicators, they are type of house and population income. Hence, the calculation method of house type is based on the house type in every village through field surveys. Meanwhile, the calculation method of population income is done by analyzing data from the 2007 National Census. With these two methods, house type and population income can be calculated and mapped for each village unit. The two methods are calculation and mapping of social welfare for the baseline period (2010).

For the projection period, this social welfare is assumed as not it does contribute in reducing the vulnerability. It is because the government program to mitigate water shotage is assumed in maximum condition that is 90% PDAM service target is achieved.

3.4.3 Method of flood vulnerability assessment

Based on the existing literature references, we obtain a number of alternative indicators with strong relation to floods hazard. These indicators are: population density, land-use, watershed degradation, slope, rock type and its ability to absorb water, role of infrastructure, population welfare, and government program.

Based on the same criterions that have been applied in selecting the indicators of water shortage vulnerability, we can identify vulnerability indicators to floods hazard: population, density, land-use, role of infrastructure, population welfare, and government program as shown in Table 3.5. These will be fixed in Chapter V.

Table 3. 5 Indicators and sources of data for flood vulnerability

Indicators	Data
Population Density	Population Census of Govt. of South Sumatra Province 2010
Land-use	Land-use 2008 (South Sumatra Province with modification)
Role of Infrastructure	PDAM South Sumatra Province 2005 and Landuse 2008
Population Welfare	House type, Income/Capital (Field survey; National census, 2007)
Government Program	Infrastructures (Public Work Agency, South Sumatra Provinve, 2008)

Based on Table 3.5, two of the indicators are the same with the indicators previously used in the assessment of water shortage vulnerability, such as: population density (used in the calculation of water needs), and population welfare. Below are the assessment methods in detail for the floods hazard indicators.

1) Calculating and mapping of population density

The population density data used as the indicator of floods vulnerability is the same with the population density data calculated in the analysis of water needs in the assessment of water shortage vulnerability. The method has been discussed in the explanation of water demand indicator.

2) Calculating and mapping of land-use

To calculate and map the land-use type, we acquire sufficient data from the local government. The data includes: the 2008 land-use from the BAPPEDA of South Sumatra Provinve for the baseline period and 2030 land-use of the Spatial Planning of South Sumatra Provinve for 2030 with the assumption as been mentioned in the sub-sub chapter. The next needed study is to assess the data further to group the land-use based on the uniform land-use unit between baseline and projection period. This step is needed considering the different classified between 2008 land-use and 2030 land-use.

3) Calculating and mapping of role of infrastructure

Role of infrastructure here, as mentioned in the assumptions, is infrastructures wich is useful in preventing floods or overcoming impacts of floods. An example of this role is reservoirs used as floods reducer besides its function as water storage, and which is useful as clean water supplies for society suffered from the flood. Data used includes: current infrastructure data of PDAM's service and 2008 land-use map for the baseline period. For the projection period the same assessment will be done using the 2030 Spatial Planning.

4) Calculating and mapping of government program

As stated in the assumption about future trends, the government programs are any treatment from the government to handlefloods to government facilities and important infrastructures which suffered from floods. Those government programs are for the baseline period. Hence, the methods that will be done here are assessing the location of government program related to floods that has been implemented or planned to be acted in the next couple of years and drawing their magnitude and distribution on the map.

Meanwhile, for the projection period, it is assumed that the role of government program in the projection is in the maximum condition. It means that government program in anticipating flood in the projection period will cover all areas of South Sumatra Provinve. Being in this assumption, the method for calculating and mapping the government program for the projection period can easily be done by tracing the location of the floods in the projection period.

5) Calculating and mapping of social welfare

The social welfare indicator for floods is as the social welfare indicator for the water shortage vulnerability. Hence, the method used to calculate and map the social welfare in this floods vulnerability is the same with the method of study of the social welfare in the water shortage vulnerability.

3.4.4 Method of landslide vulnerability assessment

Using the same method as in benchmarking the alternative indicators to water shortage and flood vulnerability, for vulnerability to landslides, there are several possible vulnerability indicators: population, density, land-use, watershed's critical level, slope, rock type and its ability to filtrate water, ground water surface, roads position to hills, role of infrastructure, settlement distribution, population welfare, government program, etc.

Based on the criteria used, we can identify indicators for landslides vulnerability as population, density, land-use, role of infrastructure, population welfare, and government program (Table 3.6).

Table 3. 6 Indicator and sources of their data for landslide vulnerability

Indicator	Data
Population Density	Population Census Govt.South Sumatra Province 2010
Landuse	Landuse 2008 (Government of South Sumatra Province, with modification)

Role of Infrastructure	PDAM South Sumatra Province 2005 and Landuse 2008
Population Welfare	House type; Capital Income (Field survey, National census, 2007)
Government Program	Roads (Public Work Agency, South Sumatra Province, 2008)

Vulnerability indicators to landslides and its sources (Table 3.6) are the same with the indicators and its sources used in the assessment method of flood vulnerability as in Table 3.5. This is due to data availability which prevents landslides vulnerability indicators to acquire more complete data.

Based on the comparison of Table 3.5 and Table 3.6, methods used in the vulnerability assessment to landslides are the same as the calculation and mapping methods of vulnerability to floods.

3.4.5 Method of vulnerability weighting

The indicator weighting method in this study uses AHP (Analytic Hierarchy Process), that is a method founded by Saaty in 1980 and became a popular and widely used method for multi-criteria decision making.

The Basic Principal of AHP Method

As often stated in many references of the AHP, this method was designed for formalizing decision making where there are a limited number of choices but each has a number of attributes and it is difficult to formalize some of those attributes. This method allows the use of qualitative, as well as quantitative criteria in evaluation.

The basic principle in AHP is to develop a hierarchy of decision criteria and define the alternative courses of actions. Shortly, it is said that AHP algorithm is basically composed of two steps: 1) determine the relative weights of the decision criteria; 2) determine the relative rankings (priority) of alternatives. Both qualitative and quantitative information can be compared using informed judgments to derive weights and priorities.

3.5 Method of Risk Analysis

Following the definition of Risk (R) as function of Hazard (H) and Vulnerability (V) or R = f (H,V), risk analysis conducted after hazards and vulnerability have been identified by using GIS method.

IV. ANALYSIS OF HAZARD DUE TO CLIMATE CHANGE

4.1 Direct impact of climate change related to water sector

The variability of rainfall and air temperature rise as direct impacts of climate change has influenced on water availability. Temperature has an effect on the amount of evaporated water in the evapotranspiration process, which in turn could decrease on water availability.

Based on analysis of climate team in this study, projection of air temperature for the South Sumatera shows an indication of increasing temperature reaching up to 0.5°C until year 2030, as shown in Figure 4.1.

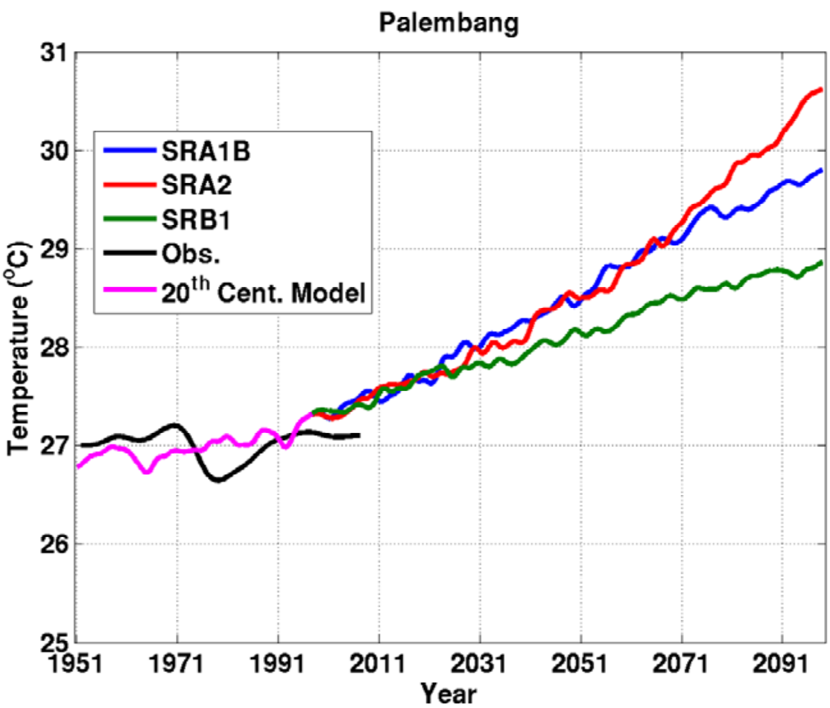


Figure 4. 1 Average surface temperature increase pattern on South Sumatera in 1951–2010

, observation (black) and 20th century model (pink); SRA1B (2011-2091) scenario (blue), SRA2 (red), and SRB1 (green) from climate analysis (Hadi et al, 2011). Temperature T during the projection period experiences an increase in all scenarios. Climate projection results until 2030s show tendency of increasing average temperature as high as 0.5ºC for all scenarios (B1, A1B, and A2). *Source*: Hadi et all, 2011)

In this study, evaporative demand is calculated by using the Blaney-Criddle formula for water balance analysis. The significant temperature rise will trigger significant evapotranspiration rise. This rise will be followed by decreasing TRO – caused by non-climatic factor –, which will effect on water shortage hazard.

Meanwhile, the monthly average precipitation (CHavm) on the projection is varying but in general it shows a decreasing trend in the period of 2011-2030. As in the scientific basis analysis, CHavm in the projection period of 2011-2030 actually experiences variability or up and down in the period of 5 to 10 years. However, the general trend of CHavm in the projection period of 2011-2030 is decreasing.

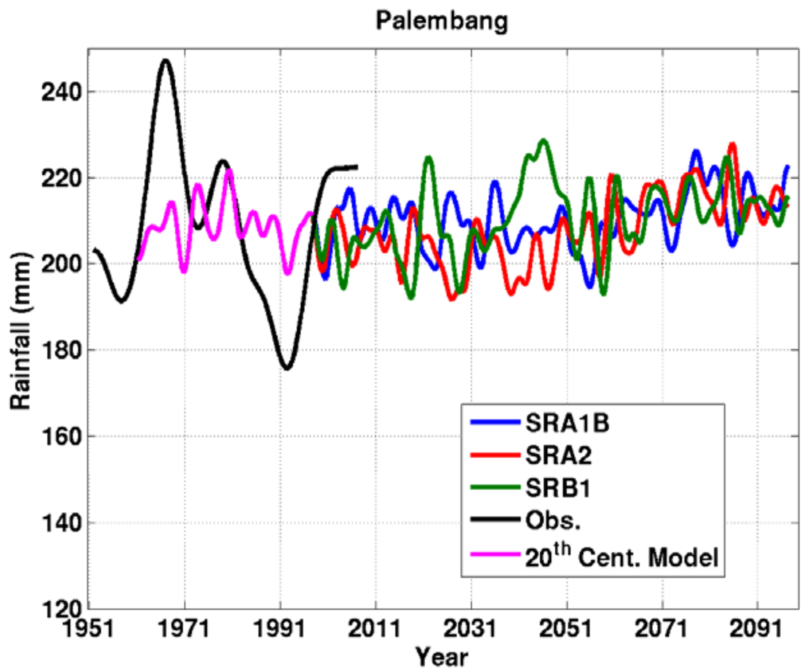


Figure 4.2 Average rainfall increase pattern on South Sumatera in 1951–2010, observation (black) and 20th century model (pink); SRA1B (2011-2091) scenario (blue), SRA2 (red), and SRB1 (green) from climate analysis (Hadi et al, 2011). In the box, 2011–2030 projection shows precipitation variability with general trend of decrease, consistent for all scenarios with the lowest decrease in scenario SRB1 of 2021-2030 period. There is a trend of interdecadal decrease in 2011-2020 and 2021-2030 although the decrease is not as low as the 1961-1970 period.

4.2 Water Shortage Hazard

Indication of the water decrease in the South Sumatera until year 2030 had been identified through the decrease of rainfall and the rise of air temperature. Based on the framework of the assessment method, water shortage hazard is formulated as the probability of decreasing water supply in the normal condition, stressed by the condition of water demand, compared to the water supply of normal condition. The normal condition is assumed as the condition of 1960-1990 or baseline condition.

The main indication of water shortage hazard is the tendency of decreasing precipitation as stated by the results of climate analysis, where 1960-2030 precipitation fluctuated, but had a decreasing trend in 2011-2032 (see Figure 4.2). The consistent temperature rises since the baseline period is predicted to increase potential evapotranpiration (ET). This increase on ET will contribute for water hazard as shortage on water availability that driven by climate.

Beside an influence from the climate factor, the rise from amount of water need is water shortage hazard of non-climate driven. An increase of water need has a correlation with increasing population and change of land use. For this study, the most significant of non-climate driven to water sector hazard is landuse change. Other factors of non-climate driven to water sector hazard is water need per watershed.

4.2.1 Climatic drivers of water shortage hazard

Based on the climate data in Appendix 3.1, we analyze Potential Evapotranspiration (ET) and water balance which produced Total Run Off (TRO), Base Flow (BF), Direct Run Off (DRO) and Storm Run Off (SRO) data in mm/year from 1960-2090. The analysis results are shown in Figure 4.3 and 4.4.

An actual evapotranspiration is a decreasing factor of water shortage, which occured as a result of re-evaporation process to atmosphere. Climate data analysis in the periods of 1961-2100 shows actual evapotranspiration, South Sumatera has a tendency to rise linearly with a gradient 6.2 a year (Figure 4.4). This mean, the value of an actual evapotranspiration is 1,721 mm/year with minimum number 1,380 mm/year on 1965 and maximum number 2,233 mm/year in 2091.

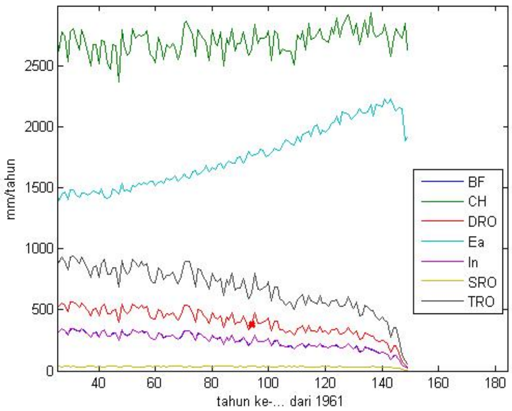


Figure 4.3 Plot of rainfall, Total Run Off (TRO), potential Evapotranspiration (ET), Infiltration (IF), Base Flow, Direct Run Off, and Storm Run Off. In 1961-2100 all parameters are decreasing except ET.

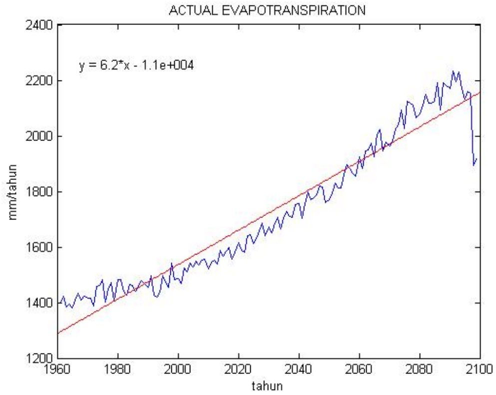


Figure 4.4 Blue: magnification of Ea (mm/year) vs time (1960-2100). Red: linier regression of Ea vs year, with equation y = 6.2x + 1.1 * 10^4

From Figure 4.3 we can see that the decreasing trend is greater along with time (year) for the following variables: Total Runoff (TRO, green), infiltration (IF, tosca green), Direct Runoff (DRO, red), and Base Flow (BF, blue) from 1960 to 2100. Decreasing variables of TRO, IF, DRO, and BF are the indicators of water shortage. These curves are a proves of future water shortage hazard, beside the decreasing CH trend and temperature rise.

Figure 4.4 is a magnified graphic of actual evapotranspiration (EA). This figure show a trend of increasing EA from year 1960 to year 2100. The linier line formulation (y = 6.2*x + 1.1e+004 or y = 6.2x + 1.1 * 10^4) is the linier regression from the actual evapotranspiration (EA) curve, where y is the actual evapotranspiration in mm/year and x is year (from 1960 to 2100). The actual evapotraspiration is the amount of water evaporates from South Sumatera from 1960 to 2100. Meanwhile, increasing trend of actual evapotranspiration means decreasing of water supply.

Rainfall is one of main component supply of water availability in South Sumatera. However, because of the evapotranspiration process evaporate 60% of this rainfall, thus the water supply from rainfall become only 40% left. This trend will continue and tend to rise in projection period.

Shortage of water availability analyzed using *Cumulative Distribution Function* (CDF) against value of *Total Run Off* (TRO). The CDF analysis is used to correlate the TRO value to certain numbers from the percentage CDF. The value of TRO that corelated to value of CDF 50% assumed as normal condition of water availability, thus the water shortage condition assumed as TRO that corelated to value of CDF below 50%. The value TRO is calculated from the result of water balance analysis. This study calculates TRO from three different periods, which are Baseline (1960-1990), current period (1991-2020), and Projection (2010-2030). Figure 4.5 shows graph of CDF analysis of three periods above with additional of two periods of Future (2031-2060) and Future 2 (2061-2090).

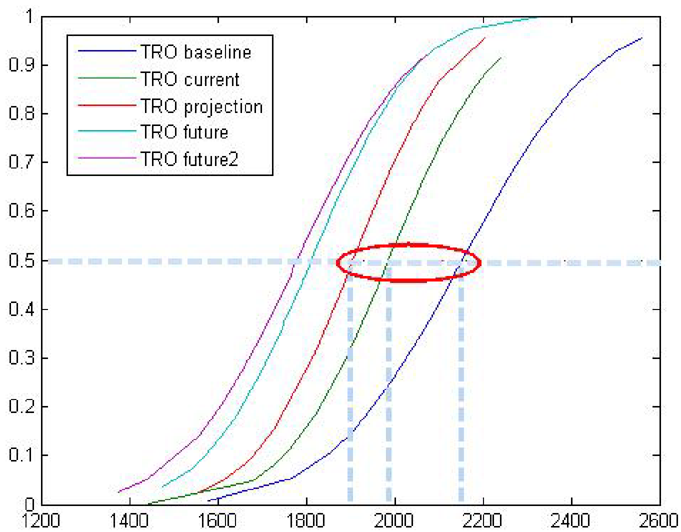


Figure 4.5. Schematic of CDF analysis (Y axis, maximum = 1 or 100%) vs TRO (X axis, mm/year). Drastic decrease occurred in 1960-1990 (Baseline) to 2010-2030 (projection).

Water availability analyzed by multiplication of sum Total Runoff (TRO) with area of watershed or water catchment (in *bahasa*, DAS = *daerah aliran sungai*). As shown in figure 4.6 the water catchment area in South Sumatera divided into six main catchment area (watershed) these are Sugihan, Banyuasin, Musi, Mesuji, and the two small one that belong to main watershed of Bengkulu province. Using digital elevation model (DEM) analysis, it is found that six watersheds are consisted of 70 sub-watersheds.

These six watersheds or 70 sub-watersheds have hierarchy (order) levels. These orders levels in this study are analyzed using flow accumulation calculation based on DEM data. As a result, there are eight levels order of water catchment area. Numbers of order level of water catchment area are determined from upstream to downstream using descendant numbers. Hence, the water catchment areas with order level 1 are areas with all rivers inside estuary to sea; catchment areas with order level 2 are areas which all rivers inside estuary to catchment areas with orders level 1; catchment areas with order level 3 are areas which all rivers inside estuary to catchment area with orders level 2 and so on. Therefore, catchment area of order level 8 at upstream is where all the rivers inside are originated and estuary into water catchment area of order level 7. These order levels of catchment area are presented in Figure 4.6 and 4.7 and are used further to analyze the decreasing of water availability in South Sumatera.

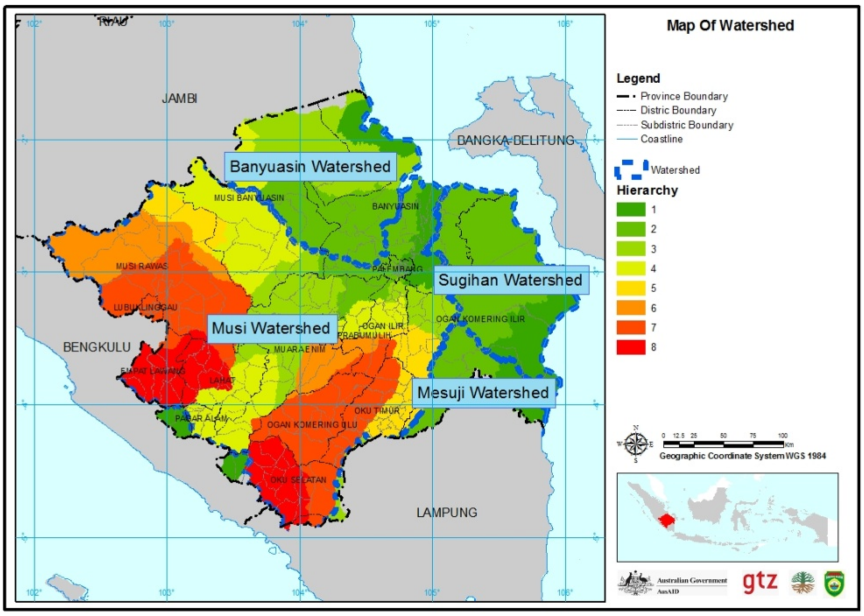


Figure 4. 6 Map of South Sumatera Watershed which consists of 70 sub-watersheds are divided into eight levels of watershed orders or hierarchies (from green color which is order level 1 to red color which is order level 8).

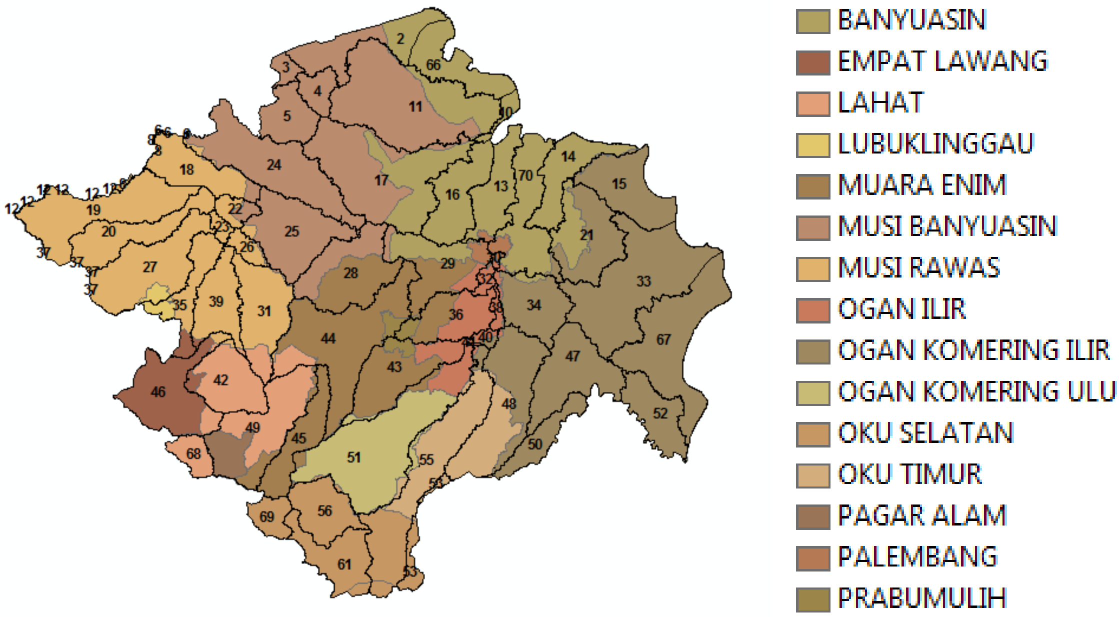


Figure 4. 7 *Overlay* of heirarchy distribution of water area catchment South Sumatera with administration district/city area 2010.

Condition of water availability is decreasing from baseline condition, current, until projection as shown in Table 4.1. From Table 4.1, it is calculated the decrease of water availability for every watershed from baseline to current condition and from current to projection condition as presented in Table 4.2.

By using CDF analysis, it is found that Decreasing of Water Availability (DoWA) at baseline condition in average is 7.42%. Meanwhile, DoWA at projection condition in average is -8.83%. Maximum decrease on water availability at baseline condition happened in sub-watershed number 10 (Table 4.2, Object ID no. 10). This is corelated with order level 1 of watersheds, which partially cover region of Banyuasin, Palembang, Ogan Ilir, and Ogan Komering Ilir (Table 4.2, column 2 and 3). This maximum decrease could reach up to 585,600,000 m^3/year. Meanwhile, minimum decrease of water availability in baseline condition is 717,700 m^3/year, which happened in sub-watershed 14 and level order of catchment area is number 1 that covered area of OKU Selatan Regency (Table 4.2, Object ID no. 14). In other hand, the maximum percentage of water availability decrease in current condition compared to baseline condition is 10.48%, which happened at Musi Rawas and Lubuk Linggau, order level VII (Table 4.2, Object ID no. 35).

Table 4. 1 Water availability per sub-watershed, level order of watershed, and regency in baseline to projection condition.

OBJECTID	*Hierarchy of DAS/watershed*	***District/ City Area***	*WATER AVAILABILITY (X1,000 m^3/year)*		
			baseline	Current	projection
10	I	Banyuasin, Palembang, Ogan Ilir, Ogan Komering Ilir	7,422,110,208.00	6,836,510,208.00	6,738,619,904.00
16	I	Banyuasin	81,854,200.00	74,409,904.00	69,684,704.00
13	I	Ogan Komering Ilir	264,040,992.00	254,691,008.00	250,708,000.00
70	I	Lahat	87,932,400.00	84,767,504.00	86,652,304.00
14	I	OKU Selatan	59,565,900.00	58,848,200.00	59,868,000.00
33	II	Banyuasin	144,336,992.00	134,125,000.00	129,476,000.00
52	II	Banyuasin, Palembang	112,691,000.00	104,213,000.00	99,464,304.00
66	II	Banyuasin	370,318,016.00	339,776,992.00	329,536,000.00
67	II	Ogan Komering Ilir	330,756,000.00	311,710,016.00	306,531,008.00
68	II	Musi Banyuasin, Banyuasin	411,896,000.00	381,267,008.00	369,470,016.00
69	II	Muara Enim, Banyuasin, Musi Banyuasin, Ogan Ilir, Palembang	4,915,999,744.00	4,488,569,856.00	4,416,880,128.00
11	II	Palembang, Ogan Ilir, Banyuasin	2,377,520,128.00	2,229,789,952.00	2,209,200,128.00
17	II	Ogan Komering Ilir,	185,920,000.00	170,303,008.00	165,383,008.00

OBJECTID	Hierarchy of DAS/watershed	District/ City Area	WATER AVAILABILITY (X1,000 m^3/year)		
			baseline	Current	projection
		Banyuasin			
29	II	Ogan Komering Ilir	107,613,000.00	98,914,000.00	96,494,896.00
30	II	Ogan Komering Ilir	225,155,008.00	210,780,992.00	206,435,008.00
21	II	Ogan Komering Ilir	212,770,000.00	196,802,000.00	193,687,008.00
15	II	Ogan Komering Ilir	572,003,008.00	536,804,000.00	532,312,000.00
47	II	Ogan Komering Ilir	882,976,000.00	843,966,016.00	843,857,984.00
50	III	Banyuasin	1,268,150,016.00	1,157,699,968.00	1,113,260,032.00
2	III	Musi Banyuasin, Banyuasin	860,771,968.00	780,835,968.00	748,136,000.00
4	III	Musi Banyuasin, Banyuasin	160,154,000.00	145,588,992.00	136,344,000.00
28	III	Musi Banyuasin	367,457,984.00	333,870,016.00	327,241,984.00
44	III	Muara Enim, Musi Banyuasin	3,677,129,984.00	3,333,769,984.00	3,273,120,000.00
32	III	Muara Enim, Lahat	1,036,339,968.00	966,846,976.00	960,278,976.00
34	IV	Ogan Ilir, Palembang	2,219,109,888.00	2,084,589,952.00	2,067,010,048.00
53	IV	Ogan Komering Ilir, Banyuasin, Ogan Ilir	153,435,008.00	140,636,000.00	137,808,992.00
3	IV	OKU Selatan, OKU Timur	551,976,000.00	507,012,992.00	507,051,008.00
5	IV	Musi Banyuasin	173,583,008.00	156,104,992.00	154,339,008.00
24	IV	Musi Banyuasin	145,299,008.00	133,063,000.00	130,413,000.00
25	IV	Musi Banyuasin, Musi Rawas	391,255,008.00	353,180,000.00	347,185,984.00
49	IV	Musi Banyuasin, Musi Rawas	3,020,600,064.00	2,739,460,096.00	2,690,160,128.00
45	IV	Lahat, Pagar Alam, Muara Enim	410,559,008.00	391,100,992.00	394,308,000.00
36	IV	Muara Enim	189,035,008.00	180,524,000.00	180,451,008.00
38	IV	Ogan Ilir, Muara Enim, Prabumulih	153,580,000.00	141,608,992.00	138,476,000.00
18	IV	Ogan Ilir	2,047,059,968.00	1,926,009,984.00	1,912,039,936.00

OBJECTID	Hierarchy of DAS/watershed	District/ City Area	WATER AVAILABILITY (X1,000 m^3/year)		
			baseline	Current	projection
22	V	Musi Rawas, Musi Banyuasin	870,910,016.00	792,779,008.00	783,254,976.00
40	V	Musi Rawas, Musi Banyuasin	1,892,829,952.00	1,716,300,032.00	1,685,159,936.00
48	V	Ogan Ilir, Ogan Komering Ilir	1,704,300,032.00	1,610,099,968.00	1,601,200,000.00
19	V	OKU Timur, Ogan Komering Ilir	326,796,992.00	301,303,008.00	296,587,008.00
20	VI	Musi Rawas	445,126,016.00	409,703,008.00	407,119,008.00
23	VI	Musi Rawas	233,140,000.00	211,268,992.00	209,020,992.00
26	VI	Musi Rawas	657,747,008.00	590,216,000.00	580,712,000.00
43	VI	Musi Rawas	1,189,040,000.00	1,085,280,000.00	1,066,169,984.00
41	VI	Muara Enim, Prabumulih, Ogan Ilir	232,760,000.00	214,058,000.00	210,100,992.00
27	VII	Ogan Ilir	1,456,220,032.00	1,381,880,064.00	1,377,240,064.00
35	VII	Musi Rawas, Lubuk Linggau	345,171,008.00	308,980,992.00	305,264,992.00
39	VII	Musi Rawas, Lubuk Linggau, Empat Lawang	291,671,008.00	262,735,008.00	258,080,000.00
31	VII	Musi Rawas, Lahat, Empat Lawang	917,857,984.00	843,166,976.00	833,942,976.00
51	VII	Musi Rawas, Lubuk Linggau	232,154,000.00	207,372,992.00	199,366,000.00
55	VIII	OKU Selatan	743,283,008.00	693,059,968.00	681,328,000.00
46	VIII	Empat Lawang, Lahat, Musi Rawas	544,678,976.00	505,806,016.00	505,974,016.00
42	VIII	Lahat, Empat Lawang, Musi Rawas	210,055,008.00	191,616,992.00	188,820,000.00
56	VIII	OKU Selatan	206,971,008.00	202,258,000.00	203,204,992.00
61	VIII	OKU Selatan	250,455,008.00	244,211,008.00	245,851,008.00
	SOUTH SUMATERA		77,445,636,920.80	109,060,679,387.52	51,860,594,596.00

Futhermore, based on Table 4.2 the maximum decrease of water availability (DoWA) in the projection period is 683,489,984 m^3/year, which will occurr in region of Banyuasin, Palembang, Ogan Ilir, Ogan Komering Ilir (Table 4.2, Object ID 10). Meanwhile, minimum DoWA will occur at Lahat region with 1,280,100 m^3/year (Table 4.2, Object ID 70). While some parts of South OKU region with order level no. 1 have negative DoWA or increase in water availability with 302,100 m^3/year in the projection period compared with baseline condition (Table 4.2, ID 14). While minimum DoWA or maximum water availability percentage at projected condition is 14.87%, which will happen at Banyuasin (Table 4.2, Object ID no. 16) and Musi Banyuasin-Banyuasin (Table 4.2, Object ID no. 4).

Table 4. 2 Water shortage per watershed in baseline and projection period.

OBJECTID	Hierarchy of DAS/watershed	District/City Area	DoWA_baseline	DoWA_proj
10	I	Banyuasin, Palembang, Ogan Ilir, Ogan Komering Ilir	(585,600,000.00)	(683,489,984.00)
16	I	Banyuasin	(7,444,300.00)	(12,169,500.00)
13	I	Ogan Komering Ilir	(9,349,980.00)	(13,333,000.00)
70	I	Lahat	(3,164,900.00)	(1,280,100.00)
14	I	OKU Selatan	(717,700.00)	302,100.00
33	II	Banyuasin	(10,212,000.00)	(14,861,000.00)
52	II	Banyuasin, Palembang	(8,478,000.00)	(13,226,700.00)
66	II	Banyuasin	(30,541,000.00)	(40,782,000.00)
67	II	Ogan Komering Ilir	(19,046,000.00)	(24,225,000.00)
68	II	Musi Banyuasin, Banyuasin	(30,629,000.00)	(42,426,000.00)
69	II	Muara Enim, Banyuasin, Musi Banyuasin, Ogan Ilir, Palembang	(427,430,016.00)	(499,120,000.00)
11	II	Palembang, Ogan Ilir, Banyuasin	(147,730,000.00)	(168,320,000.00)
17	II	Ogan Komering Ilir, Banyuasin	(15,617,000.00)	(20,537,000.00)

OBJECTID	Hierarchy of DAS/watershed	District/City Area	DoWA_baseline	DoWA_proj
29	II	Ogan Komering Ilir	(8,699,000.00)	(11,118,100.00)
30	II	Ogan Komering Ilir	(14,374,000.00)	(18,720,000.00)
21	II	Ogan Komering Ilir	(15,968,000.00)	(19,083,000.00)
15	II	Ogan Komering Ilir	(35,199,000.00)	(39,691,000.00)
47	II	Ogan Komering Ilir	(39,010,000.00)	(39,118,000.00)
50	III	Banyuasin	(110,450,000.00)	(154,890,000.00)
2	III	Musi Banyuasin, Banyuasin	(79,936,000.00)	(112,636,000.00)
4	III	Musi Banyuasin, Banyuasin	(14,565,000.00)	(23,810,000.00)
28	III	Musi Banyuasin	(33,588,000.00)	(40,216,000.00)
44	III	Muara Enim, Musi Banyuasin	(343,360,000.00)	(404,009,984.00)
32	III	Muara Enim, Lahat	(69,493,000.00)	(76,061,000.00)
34	IV	Ogan Ilir, Palembang	(134,520,000.00)	(152,100,000.00)
53	IV	Ogan Komering Ilir, Banyuasin, Ogan Ilir	(12,799,000.00)	(15,626,000.00)
3	IV	OKU Selatan, OKU Timur	(44,963,000.00)	(44,925,000.00)
5	IV	Musi Banyuasin	(17,478,000.00)	(19,244,000.00)
24	IV	Musi Banyuasin	(12,236,000.00)	(14,886,000.00)
25	IV	Musi Banyuasin, Musi Rawas	(38,075,000.00)	(44,069,000.00)
49	IV	Musi Banyuasin, Musi Rawas	(281,140,000.00)	(330,440,000.00)
45	IV	Lahat, Pagar Alam, Muara Enim	(19,458,000.00)	(16,251,000.00)
36	IV	Muara Enim	(8,511,010.00)	(8,584,000.00)

OBJECTID	Hierarchy of DAS/watershed	District/City Area	DoWA_baseline	DoWA_proj
38	IV	Ogan Ilir, Muara Enim, Prabumulih	(11,971,000.00)	(15,104,000.00)
18	IV	Ogan Ilir	(121,050,000.00)	(135,020,000.00)
22	V	Musi Rawas, Musi Banyuasin	(78,131,000.00)	(87,655,000.00)
40	V	Musi Rawas, Musi Banyuasin	(176,530,000.00)	(207,670,000.00)
48	V	Ogan Ilir, Ogan Komering Ilir	(94,200,096.00)	(103,100,000.00)
19	V	OKU Timur, Ogan Komering Ilir	(25,494,000.00)	(30,210,000.00)
20	VI	Musi Rawas	(35,423,000.00)	(38,007,000.00)
23	VI	Musi Rawas	(21,871,000.00)	(24,119,000.00)
26	VI	Musi Rawas	(67,531,000.00)	(77,035,000.00)
43	VI	Musi Rawas	(103,760,000.00)	(122,870,000.00)
41	VI	Muara Enim, Prabumulih, Ogan Ilir	(18,702,000.00)	(22,659,000.00)
27	VII	Ogan Ilir	(74,340,000.00)	(78,980,000.00)
35	VII	Musi Rawas, Lubuk Linggau	(36,190,000.00)	(39,906,000.00)
39	VII	Musi Rawas, Lubuk Linggau, Empat Lawang	(28,936,000.00)	(33,591,000.00)
31	VII	Musi Rawas, Lahat, Empat Lawang	(74,691,000.00)	(83,915,000.00)
51	VII	Musi Rawas, Lubuk Linggau	(24,781,000.00)	(32,788,000.00)
55	VIII	OKU Selatan	(50,223,000.00)	(61,955,000.00)
46	VIII	Empat Lawang, Lahat, Musi Rawas	(38,873,000.00)	(38,705,000.00)
42	VIII	Lahat, Empat Lawang, Musi Rawas	(18,438,000.00)	(21,235,000.00)
56	VIII	OKU Selatan	(4,713,010.00)	(3,766,020.00)

OBJECTID	Hierarchy of DAS/watershed	District/City Area	DoWA_baseline	DoWA_proj
61	VIII	OKU Selatan	(6,244,000.00)	(4,604,000.00)
SOUTH SUMATERA			(4,036,442,012.00)	(4,707,092,288.00)

4.2.2 Non-climatic drivers of water shortage hazard

The non-climatic drivers affecting water shortage hazard is water demand. The water demand in South Sumatera consists of domestic and non-domestic demand. The domestic demand is household need to clean water. The total water domestic demand is calculated based on population number multiplied by standard domestic water need (Table 4.3). The non-domestic demand is limited only of water need for agriculture and plantation area. The total of non domestic demand is calculated based on total agriculture and plantation area multiplied by standard water need for each use (Table 4.3).

Table 4. 3 Standard for clean water demand

Need		Jumlah	Unit	Referensi
Domestic	Population	150	litre/people/days	World Health Organization (WHO)
Non-domestic	Wet land agriculture	700	mm/total growing period	Food and Agriculture Organization (FAO)
	Dry land agriculture	800	mm/total growing period	Food and Agriculture Organization (FAO)
	Palm tree Plantation	2000	mm/year	Reddy, et.al (2001)

Hence, this study has calculated the water needs or water demands table for each district in South Sumatra, as shown in Table 4.4.

Table 4. 4 Water demand of South Sumatera per watershed.

OBJECTID	Hierarchy of DAS/watershed	County/City Area	Water Demand (m^3/year)	
			baseline	projection
10	I	Banyuasin, Palembang, Ogan Ilir,	1,894,074,641.04	2,731,480,134.78

OBJECTID	Hierarchy of DAS/watershed	County/City Area	Water Demand (m³/year)	
			baseline	projection
		Ogan Komering Ilir		
16	I	Banyuasin	-	29,637,911.87
13	I	Ogan Komering Ilir	1,376,165,994.19	1,634,002,621.73
70	I	Lahat	384,065,127.87	491,978,555.03
14	I	OKU Selatan	352,375,243.56	338,168,817.70
33	II	Banyuasin	1,229,554,181.68	2,586,349,332.79
52	II	Banyuasin, Palembang	1,061,558,197.01	1,954,791,401.91
66	II	Banyuasin	1,236,313,715.52	1,344,497,810.57
67	II	Ogan Komering Ilir	3,596,200,974.98	2,961,616,674.15
68	II	Musi Banyuasin, Banyuasin	3,970,999,492.02	5,611,409,232.67
69	II	Muara Enim, Banyuasin, Musi Banyuasin, Ogan Ilir, Palembang	1,789,705,431.70	2,668,086,331.07
11	II	Palembang, Ogan Ilir, Banyuasin	62,650,198.02	115,154,283.64
17	II	Ogan Komering Ilir, Banyuasin	1,989,595,324.01	1,310,079,367.67
29	II	Ogan Komering Ilir	1,860,338,410.76	1,034,184,558.08
30	II	Ogan Komering Ilir	2,203,105,589.58	3,215,029,824.94
21	II	Ogan Komering Ilir	1,005,063,512.75	1,168,147,786.97
15	II	Ogan Komering Ilir	3,848,528,078.33	6,345,802,877.33
47	II	Ogan Komering Ilir	3,247,431,632.41	5,114,896,927.75
50	III	Banyuasin	-	2,848,658.79
2	III	Musi Banyuasin, Banyuasin	3,280,835,530.20	4,593,890,425.62
4	III	Musi Banyuasin, Banyuasin	561,476,058.94	843,539,492.89
28	III	Musi Banyuasin	494,297,825.15	576,279,439.31
44	III	Muara Enim, Musi Banyuasin	2,063,365,490.01	3,735,514,337.52
32	III	Muara Enim, Lahat	3,862,185,070.02	4,860,210,708.46
34	IV	Ogan Ilir, Palembang	69,096,111.51	371,142,949.24
53	IV	Ogan Komering Ilir, Banyuasin, Ogan Ilir	792,258,289.88	2,597,255,630.03
3	IV	OKU Selatan, OKU Timur	367,753,270.84	347,948,210.25
5	IV	Musi Banyuasin	274,380,687.76	416,673,457.86
24	IV	Musi Banyuasin	800,515,143.00	773,056,026.21
25	IV	Musi Banyuasin, Musi Rawas	2,259,523,418.85	2,505,260,224.68
49	IV	Musi Banyuasin, Musi Rawas	2,120,091,802.88	3,938,457,339.25
45	IV	Lahat, Pagar Alam, Muara Enim	2,253,737,631.41	3,744,946,290.33

OBJECTID	Hierarchy of DAS/watershed	County/City Area	Water Demand (m^3/year)	
			baseline	projection
36	IV	Muara Enim	1,132,120,794.32	1,663,349,483.10
38	IV	Ogan Ilir, Muara Enim, Prabumulih	1,543,874,647.84	2,169,035,877.34
18	IV	Ogan Ilir	132,552,492.10	239,054,346.82
22	V	Musi Rawas, Musi Banyuasin	1,495,704,260.88	2,119,440,582.69
40	V	Musi Rawas, Musi Banyuasin	240,658,520.27	790,407,120.48
48	V	Ogan Ilir, Ogan Komering Ilir	83,389,867.03	157,137,918.66
19	V	OKU Timur, Ogan Komering Ilir	3,710,419,751.11	4,667,114,296.01
20	VI	Musi Rawas	1,871,377,131.63	2,482,089,321.75
23	VI	Musi Rawas	1,186,433,429.22	1,510,696,711.83
26	VI	Musi Rawas	222,089,303.15	343,757,686.27
43	VI	Musi Rawas	389,903,575.98	534,816,689.15
41	VI	Muara Enim, Prabumulih, Ogan Ilir	2,060,275,836.72	2,269,472,983.57
27	VII	Ogan Ilir	1,975,706.86	10,845,006.46
35	VII	Musi Rawas, Lubuk Linggau	2,406,861,073.21	3,278,070,870.35
39	VII	Musi Rawas, Lubuk Linggau, Empat Lawang	1,392,888,309.75	1,971,900,200.21
31	VII	Musi Rawas, Lahat, Empat Lawang	1,656,456,655.11	2,196,655,213.46
51	VII	Musi Rawas, Lubuk Linggau	1,528,957,104.16	1,835,861,424.45
55	VIII	OKU Selatan	417,713,461.66	1,194,793,876.59
46	VIII	Empat Lawang, Lahat, Musi Rawas	2,065,488,833.30	3,253,455,759.71
42	VIII	Lahat, Empat Lawang, Musi Rawas	1,542,703,960.47	2,417,440,295.52
56	VIII	OKU Selatan	985,551,599.02	1,911,884,961.36
61	VIII	OKU Selatan	1,008,774,733.05	2,017,683,769.96
SOUTH SUMATERA			77,445,636,920.80	109,060,679,387.52

The highest water demand for domestic use for the whole South Sumatra is located in Palembang City, which is 178,403,313 m^3/year for baseline period and 296,880,278.73 m^3/year for projection period. Meanwhile, the highest water demand for non-domestic use for the whole South Sumatra is located in Musi Banyuasin Regency, which is 53,439,331,490.82 m^3/year for the baseline period and 72,507,416,969.27 m^3/year for the projection period. The highest contributor for high number of water demand of non-domestic use is the plantation landuse. Meanwhile, the largest total of domestic and no-domestic water demand for South Sumatra is located in Musi Banyuasin Regency, which is

53,580,668.51 m^3/year for the baseline period and 72,755,750.49 m^3/year for the projection period.

Based on this result, maps of water demand per watershed for baseline and projection periods are produced (Figure 4.8 and Figure 4.9). In these maps, water demand is classified into five groups, which varies from low (green color, demand of water < 0.5 million m^3/year/km^2) to high (red color, demand of water > 2.0 million m^3/year/km^2).

Using clasification of water demand then overlayed with each area of sub-district, Its found that region with the highest water demand (> 2.0 million m^3/year/km^2) at baseline period located at 34 sub-districts. Those location spread in: Palembang, Banyuasin, and Musi Rawas (Figure 4.8). The distict with highest water demand is northeast part of Ogan Ilir regency and Palembang city with total 8,719,485 m^3/year.

By using the same analysis, the region with the highest water demand (> 2 million m^3/year/km^2) in projection period is covering 146 sub-districts that spread in all region in South Sumatera, except in Pagar Alam regency (Figure 4.9). This number is increasing from 34 sub-districts in the baseline period mention above. The highest water demand with 1,155,387,003.15 m^3/year is located in sub-districts that belong to the Banyuasin District.

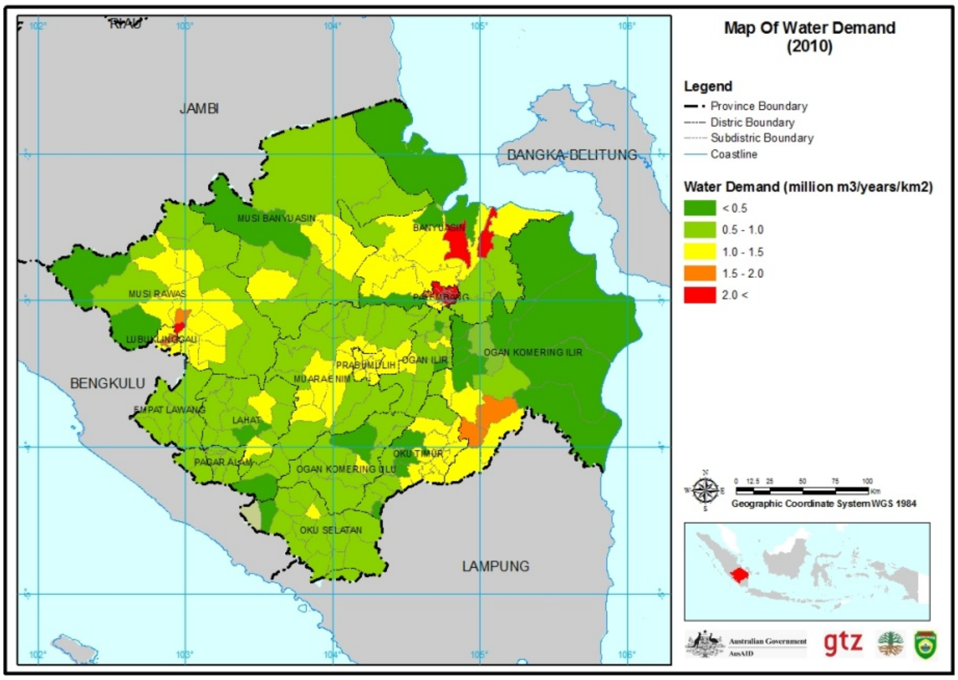


Figure 4. 8 Map of water demand for the baseline period.

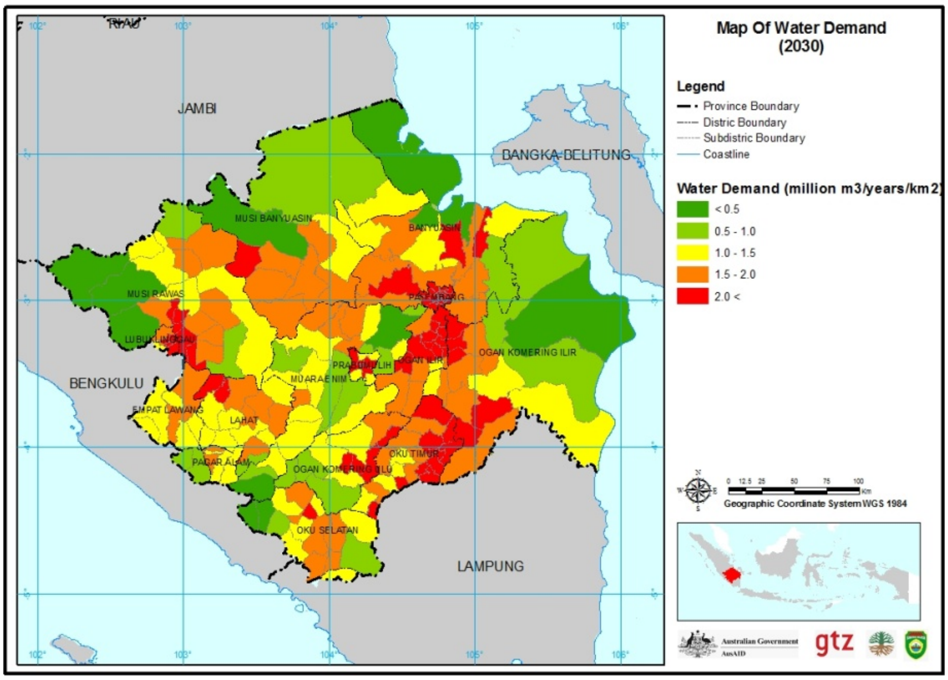


Figure 4. 9 Map of water demand for the projection period.

4.2.3 Figure of water shortage hazard

As in Chapter 3, water shortage hazard or hazard of decreasing water supply in this study is formulated as the probability of decreasing water amount from the normal condition which will be worsen by the water demand condition. The probability is approached by the analysis of CDF to TRO in the 50% CDF. The CDF analysis has shown that the TRO 50% CDF tendency to decrease consistently from the baseline (1960-1990), current (1991-2020), and projection (2010-2030), even continued to future (year 2090) as presented in Figure 4.6.

To find out the quantity and distribution of water shortage hazard, the amount of decreasing of water availability (DoWA) and water demand (WD) per district are compared to the number of water availability (WA) of normal condition. In this study, WA of normal condition is assumed as WA of baseline period (1960-1990) and stated as $Q_{Baseline,1960-1990}$. Based on concept and assumption above, the number of water shortage hazard (WSH) and its distribution is obtained from overlaying the DoWA with the WD and compared to the WA in the baseline period ($Q_{Baseline,1960-1990}$). Mathematically, it can be formulated with WSH = [(DoWA + WD)/ $Q_{Baseline,1960-1990}$]. Hence, the WSH in baseline period is defined as $WSH_{baseline}$ = [($DoWA_{baseline}$ + $WD_{baseline}$)/ $Q_{Baseline,1960-1990}$], while WSH in projection period is defined as

$WSH_{projection} = [(DoWA_{projection} + WD_{projection}) / Q_{Baseline,1960\text{-}1990}]$. Using this approach with the data on DoWA resulted from section 4.2.1 (Table 4.1) and water demand data resulted from section 4.2.2 (Table 4.4, Figure 4.8, and Figure 4.9), this study has created the map of water shortage hazard as shown in Figure 4.10 and Figure 4.11 below.

In these maps, the value of water shortage hazard is clasified into five levels of the hazard. Those level are: very low (< 0.2% water shortage), low (0.2-0.4% water shortage), moderate (0.4-0.6% water shortage), high (0.6-0.8% water shortage), and very high (> 0.8% water shortage). It can be seen quite clearly from both figures above that the water shortage hazard increases from the current to projection periods.

Based on Figure 4.10 and 4.11, the regions with very high water shortage hazard in baseline period are located in the eastern part of South Sumatera, especially Palembang City, eastern part of Musi Banyuasin District, western part of Banyuasin Regency, and western part of Ogan Komering Ilir District. The level of the hazard in those areas in the projection period will increase along with the decreasing natural water supply due to decreasing precipitation, increasing of evapotranspiration, and increasing of water needs. Other areas in the South Sumatera will also experience increasing level of the hazard in the projection period.

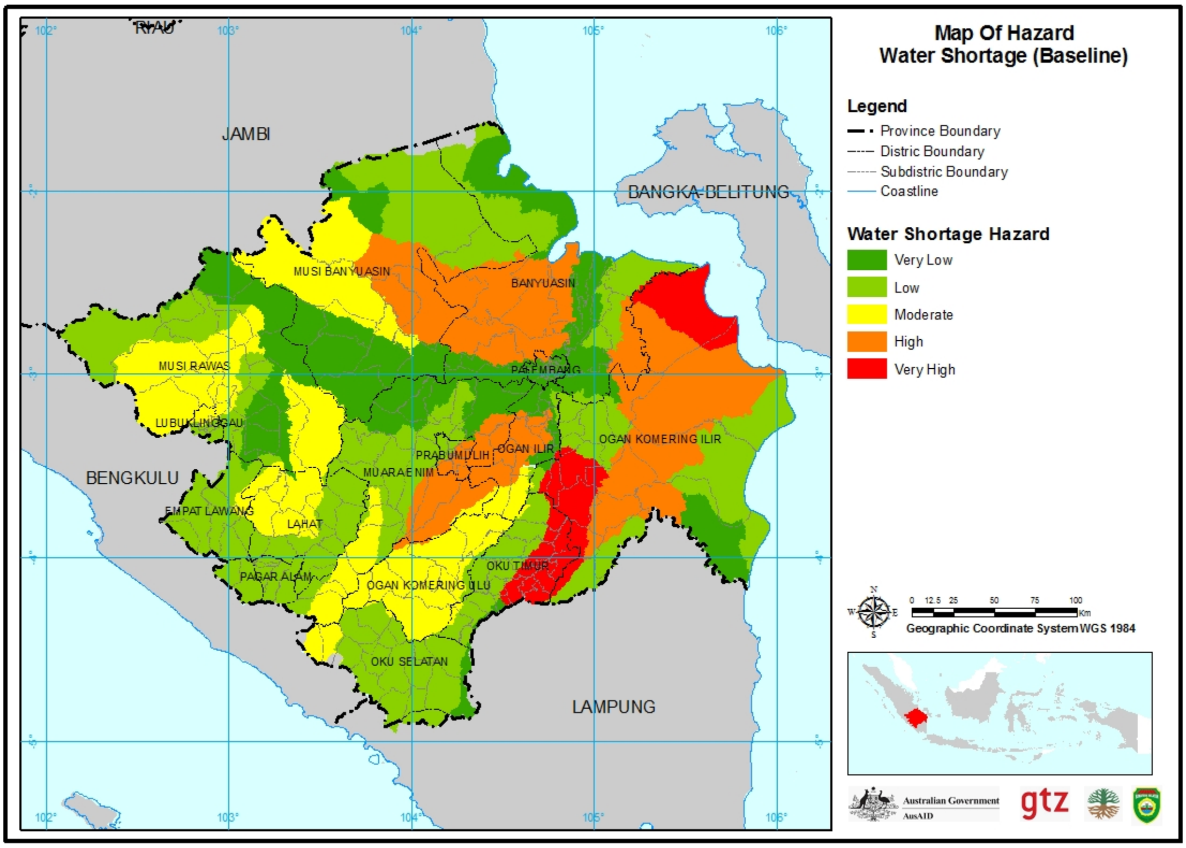


Figure 4. 10 Map of water shortage hazard for baseline period, 1990-2020.

The overlay result between map of decreasing water availability with map of water needs for every watershed with 5 hazard classes: very high (red), high (orange), moderate (yellow), low (light green), and very low (green).

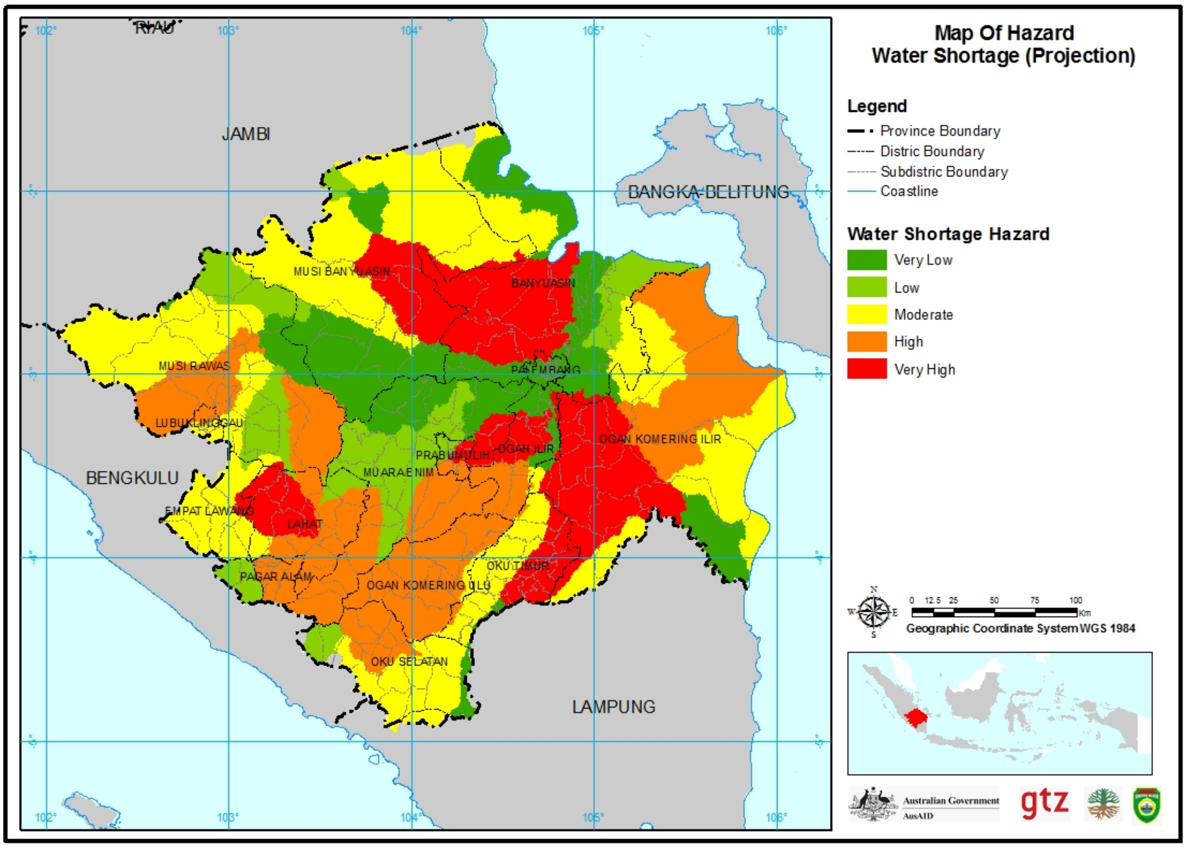


Figure 4. 11 Map of water shortage hazard for projection period, 2010-2030.

The overlay result between map of decreasing water availability with map of water needs for every watershed with 5 hazard classes: very high (red), high (orange), moderate (yellow), low (light green), and very low (green).

Table 4.5 below summarizes the level of water shortage hazard and its distribution in the baseline period and projection period.

Table 4. 5 Water shortage hazard and its distribution in the watershed for current period and projection period

Level of	Current (baseline), 2010

WS[1)] Hazard	DoWA[2)] current-baseline (x10^6 m^3/years)	WD[3)] 2010 (x10^6 m^3/years)	WA_{2010} (x10^6 m^3/years)	% WS	Watershed	District
Very High	35.2-94.2	83.4-3,848.5	536.8-1,610	3.4	II, V	Ogan Komering Ilir, Ogan Ilir
High	7.4-103.8	0-3,247.4	74.4-1,085.3	5.4	I, II, IV, VI	Ogan Komering Ilir, Banyuasin, Muara Enim, Musi Rawas
Moderate	12.2-427.4	0.1-2,253.7	133.1-4,488.6	21.4	II, III, IV, VI, VII, VIII	Musi Banyuasin, Lahat, Pagar Alam, Muara Enim, Musi Rawas, Ogan Ilir, Empat Lawang, Lubuk Linggau, Banyuasin, Palembang
Low	0.7-343.4	0-3,971.0	58.8-3,333.8	33.9	I, II, III, IV, V, VII, VIII	Kecuali Pagar Alam, Prabumulih
Very Low	3.2-585.6	132.6-3,862.2	84.8-6,836.5	36.0	I, II, III, IV, V, VI	Meliputi seluruh wilayah administrasi Sumatera Selatan
Level of WS[1)] Hazard	Projection, 2030					
	DoWA[2)] projection-baseline	WD[3)] 2030 (x10^6 m^3/years)	WA_{2030}	% WS	Watershed	District
Very High	8.58-152.1	29.6-5,114.9	69.7-2,067.0	8.5	I, II, IV, V, VIII	Banyuasin, Palembang, Ogan Komering Ilir, Ogan Ilir, Prabumulih, Lahat, Empat Lawang, Musi Rawas, Muara Enim
High	3.8-330.4	10.8-6,345.8	129.5-2,690.2	16.3	II, IV, VI, VII, VIII	Banyuasin, Ogan Komering Ilir, Ogan Ilir, Muara Enim, OKU Selatan, Lahat, Musi Rawas, Lubuk Linggau
Moderate	4.6-168.3	0.1-4,667.1	130.4-2,209.2	18.5	II, III, IV, V, VI, VII, VIII,	Musi Banyuasin, Ogan Komering Ilir, Musi Rawas, Palembang, Ogan Ilir, Banyuasin, Musi Rawas, OKU Timur, Lubuk Linggau, OKU Selatan, Empat Lawang, Lahat
Low	0.3-499.1	239.1-5,611.4	59.9-4,416.9	25.8	I, II, III, IV, VII	Ogan Ilir, Musi Rawas, Lubuk Linggau, Empat Lawang, OKU Selatan, Musi Banyuasin, Banyuasin, Muara Enim, Palembang, OKU Timur
Very Low	1.3-683.5	343.8-4,860.2	86.7-6,738.6	30.9	I, II, III, IV	Banyuasin, Palembang, Ogan Komering Ilir, OKU Selatan, Musi Rawas, Musi Banyuasin, Muara Enim, Ogan Ilir, Lahat, Prabumulih

Note:
[1)]WS : water shortage
[2)]DoWa : decreasing water availability or supply, m^3/year
[3)]WD : water demand in m^3/year

As shown in Figure 4.10 and 4.11 and also Table 4.5, the most dominant water shortage hazard is the very low level both in baseline and projection period. This level of water shortage hazard is covering area from 30.9% in baseline period and 30.6% in projection period of total area of South Sumatera. In projection period the area of high level and very high level of water shortage hazard (24.8% of total area of South Sumatera) is increasing compared to the area with the same levels of the hazard of baseline period (8.8% of total area of South Sumatera).

4.3 Flood Hazard

The topography of South Sumatera Province can be divided into 3 zones. Based on its elevation, there are highland, middle land, and lowland. The highland is around the Barisan Range with elevation > 500 m msl, the Middle land has elevation 50 m – 500 m msl, and the lowland is located along the coast with elevation < 50 m msl.

Flood hazard model analyzed by WMS 8.3 application. The model had validated with historical flood hazard events. Based on data availability, in some watersheds, there occured flood every year. Inundation of flood mostly occured in riverine and intersection river area. Flooding was occurred in the upstream and downstream areas. According to the result of flood hazard model, it is known the location of flooding that is located in the narrowing of the river channel areas. It was occurred in the upstream of Komering watershed, Rawas watershed and Lakitan watershed. In the lowland areas, the flood events is strongly influenced by tidal and sea level rise.

The hazard analysis will be detailed in watershed (sub-basin) scale analysis due to data availability, such as Lematang watershed. The watershed (sub-basin) scale analysis was modelled with a grid-based two-dimensional hydrologic model that strongly influenced by precipitation (rainfall) and land use. Furthermore, the hazard model would be analyzed in two conditions that are baseline and projection condition. In the baseline condition, the hazard model of watershed (sub-basin) is analyzed with rainfall observation data with a long series data (minimum in 10 years). According to availability data of hazard model, the watershed scale model had been analyzed in the Lematang watershed because there have the most comprehensive of rainfall series data in the South Sumatera province. Flood hazard will be divided in 5 levels that are Very Low, Low, Moderate, High and Very High. Lematang watershed has 7461.63 km^2 catchment areas, in year of 2010, the flood had been inundated 7 districts in Lahat and Muara Enim District. The most part of Lematang watershed area is located in Pagar Alam, Lahat and Muara Enim District (Figure4.12).

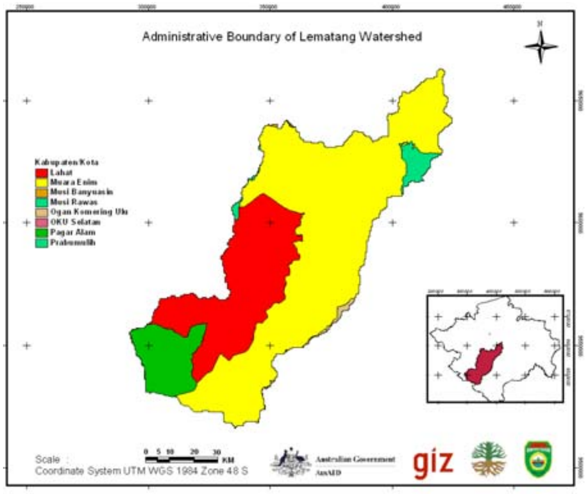


Figure 4. 12 Administrative Boundary of Lematang watershed

The flood hazard analysis is done for Baseline and Projection condition. The result of flood model shows majority of inundation area in the middle land zone (Figure 4.2). Inundation area mostly occurs at intersections of river. Flood hazard is divided into 5 levels of hazard; Very Low Hazard with < 0.07 m depth of flood, Low Hazard with 0.07 m – 0.24 m depth of flood, Moderate Hazard with 0.24 m – 0.58 m depth of flood, High Hazard with 0,58 m – 1.09 m depth of flood, and Very High Hazard with > 1.09 m depth of flood.

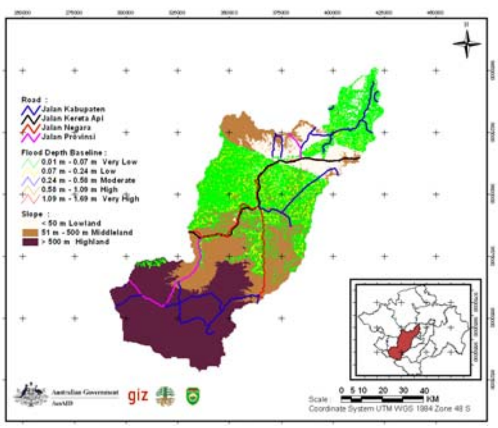
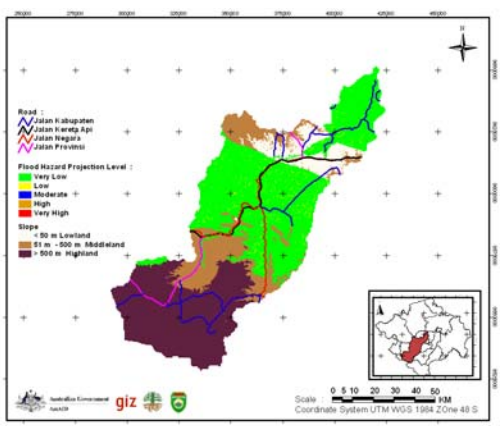
Baseline	Projection 2030
	

Figure 4. 13 Inundation Area of Lematang watershed

In the baseline condition, flood hazard model shows the depth of flood in range 0.01 m – 1.69 m and 48 hours maximum duration of inundation. The depth of flood slightly increases in projection condition to range 0.01 – 2.3 m in 51 hours of maximum duration of inundation. Most of flood area is located in Muara Enim District that has 4 levels of hazard (Table 4.1). Inundation area has covered mostly agriculture land in baseline condition, but in the projection condition, it will cover mostly plantations and agriculture land (Figure 4.14).

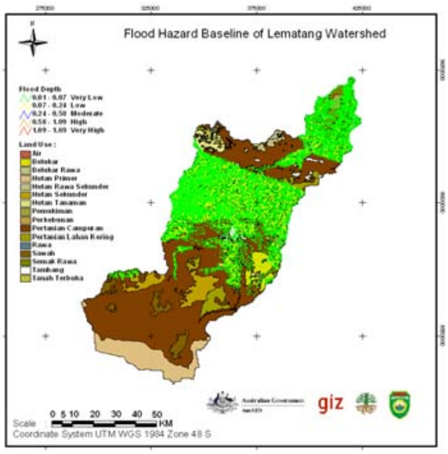
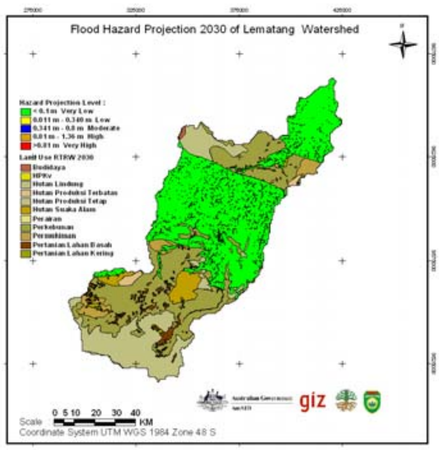
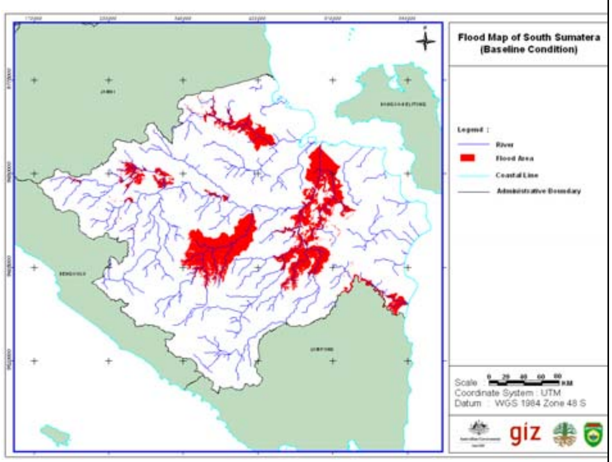
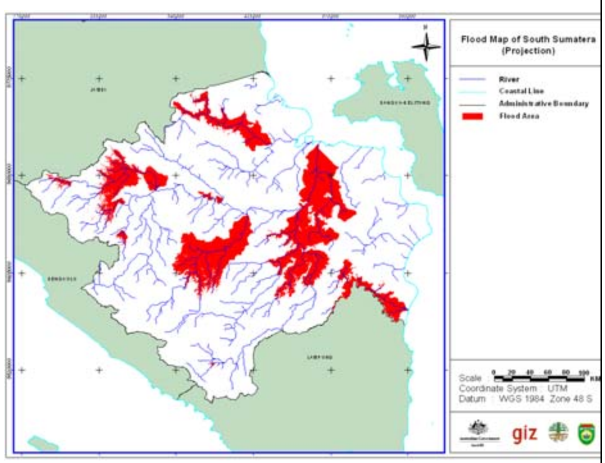
Baseline	Projection
	

Figure 4. 14 Flood Hazard Area to Land Use Existing and RTRW 2030

According to the result of flood hazard analysis, the flooding of Lematang watershed inundate the national road that connected 2 provinces that are South Sumatera and Bengkulu province (Figure 4.15).

Furthermore, the flood hazard will be analyzed to provincial scale which generated from the result of watershed (sub-basin) scale because of lack of data in the others watershed. In this scale, the hazard level will be divided in two classes that are no hazard and hazard area. The result of provincial scale analysis has low accuracy because in this scale only provided the area of flooding.





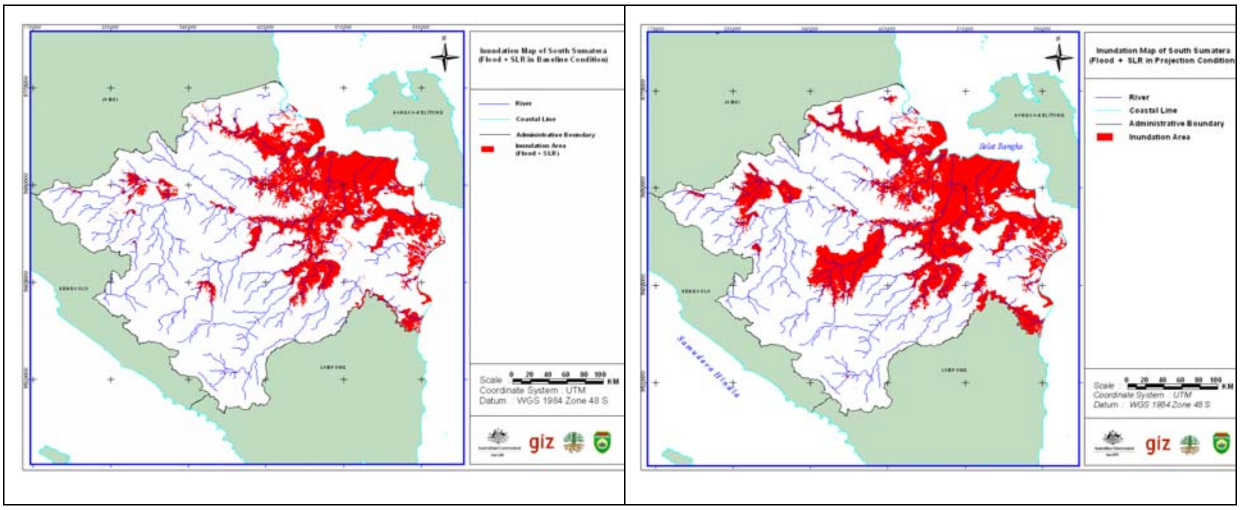


Figure 4. 15 Inundation (Flood + SLR) Map of South Sumatera Province

In the baseline condition, flood hazard isinundated 1,015,612.22 ha or 11.7 % of South Sumatera Province areas. It's flooding 11 districts/cities that are Oku Selatan, Banyuasin, Musi Banyuasin, Muara Enim, Musi Rawas, Ogan Ilir, Ogan Komering ilir, OKU Timur, Lahat, Prabumulih and Palembang City. The largest flooding area is located in Muara Enim and Banyuasin district with 27.97 Ha and 20.57 Ha. Inundation area will be extreme when the flood influenced by tidal and Sea Level Rise. The districts in coastal area have a larger inundation area, such as Banyuasin and Ogan Komering Ilir district.

In the projection condition, flooding area will be increased slightly in some district, but in other district/city will be increased sharply. The largest flooding area is located in Ogan Komering Ilir and Muara Enim district. The extreme inundation that influenced by tidal and sea level rise will be located in Ogan Komering district with 73.28 Ha and Banyuasin district with 72.55 Ha that are coastal area.

Table 4. 6 Flood Area of South Sumatera Province

Regencies /Cities	Flood				Flood + SLR (Inundation)			
	Baseline		Projection		Baseline		Projection	
	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area
OKU Selatan	0.06	0.13	0.13	0.28	0.06	0.13	0.13	0.28
Banyuasin	20.57	16.96	25.30	20.85	69.55	57.33	72.55	59.80
Muara enim	27.97	31.78	29.91	33.99	31.06	35.29	31.17	35.42
Musi Banyuasin	13.87	9.59	20.57	14.22	17.59	12.16	22.11	15.29

Regencies /Cities	Flood				Flood + SLR (Inundation)			
	Baseline		Projection		Baseline		Projection	
	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area	Area (Ha)	% of District/city area
Musi Rawas	5.87	4.78	21.22	17.29	5.87	4.78	21.22	17.29
Ogan Ilir	7.14	31.51	9.83	43.39	7.95	35.10	9.35	41.27
Ogan Komering Ilir	18.44	10.83	32.67	19.19	62.88	36.93	73.28	43.03
OKU Timur	2.76	8.23	3.75	11.18	2.76	8.23	3.75	11.18
Palembang	0.53	14.55	0.64	17.39	2.18	59.36	2.23	60.57
Prabumulih	1.54	33.82	1.54	33.82	1.54	33.82	1.54	33.82
Lahat	2.79	6.53	3.49	8.15	2.79	6.53	3.49	8.15

Table 4. 7 The Flood Hazard Levels of District in Lematang watershed

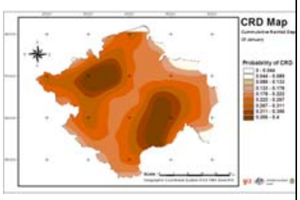
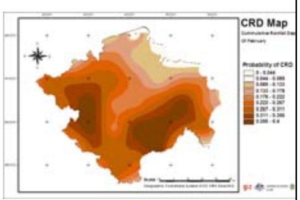
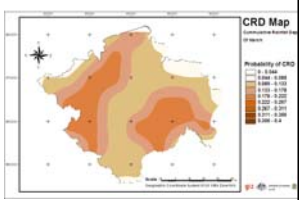
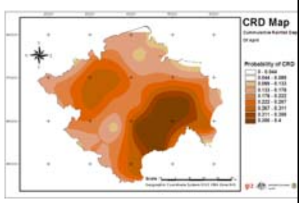
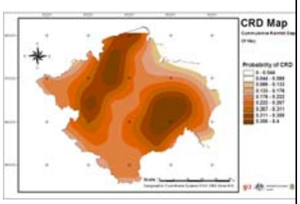
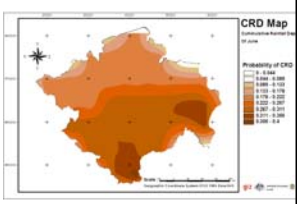
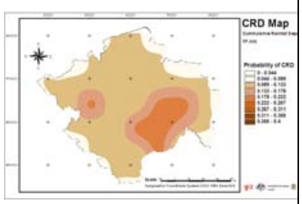
Muara Enim			Prabumulih			Lahat			Musi Rawas			OKU		
Hazard Level	**2010 (km^2)**	**2030 (km^2)**	**Hazard Level**	**2010 (km^2)**	**2030 (km^2)**	**Hazard Level**	**2010 (km^2)**	**2030 (km^2)**	**Hazard Level**	**2010 (km^2)**	**2030 (km^2)**	**Hazard Level**	**2010 (km^2)**	**2030 (km^2)**
VL	1519.63	4655.1	VL	62.64	86.78	VL	431.55	707.45	VL	20.50	25.07	VL	5.20	18.77
L	56.25	2489.76	L	1.55	3.78	L	12.06	14.85	L	0.32	0.45			
M	0.77	74.79												
H	0.11	0.52												
VH	0.02	0.07												

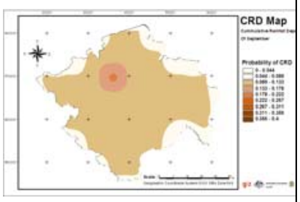
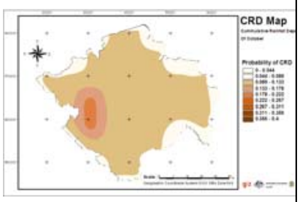
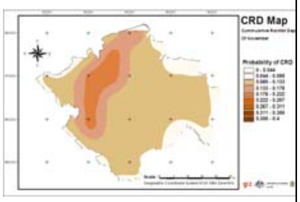
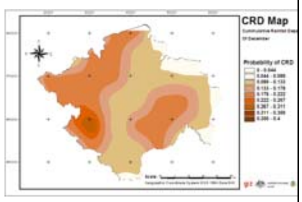
4.4 Landslide Hazard

Landslide hazard map is generated based on the observation data and it analyzed using Geographical Information System (GIS) approach. Those observation data i.e. landslide existing, slope, lithology and groundwater table need to be modified as layers in GIS analysis. Each layer is a parameter that caused landslide, but because each layer provide a different effect on the landslide, the weighting process is required.

Decrease in slope stability as the cause of landslide affected by rising groundwater as result of infiltration. The rate of infiltration would be depends on duration, frequency and intensity of rainfall. In this research, change the groundwater table due to precipitation is modeled by using the Cumulative Rainfall Departure (CRD) Method. CRD as climate driven modeling in climate change is to use rainfall data on baseline condition (1980-2011) and projection condition (2012-2030) that is taken from the result of science basis modeling. To provide the impact of climate change on landslide hazard, that is rainfall variability in the projection, the changing of groundwater table is generated by using CRD method as shown in Table 4.8.

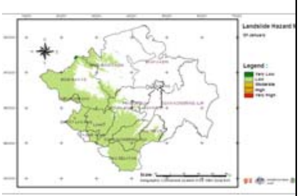
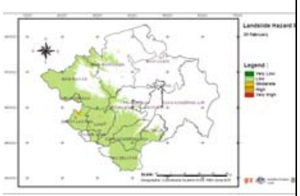
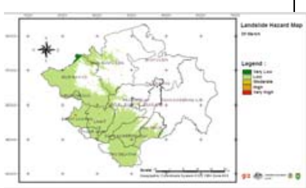
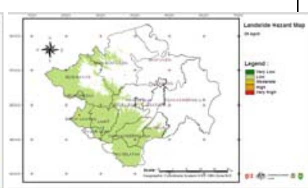
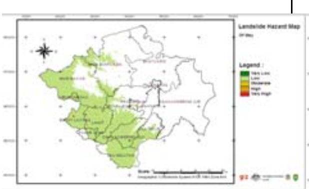
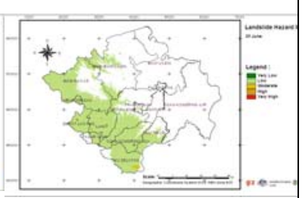
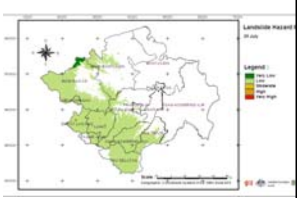
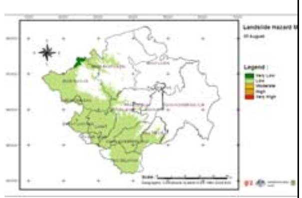
Table 4. 8 Monthly ground water table recharge of South Sumatera Province

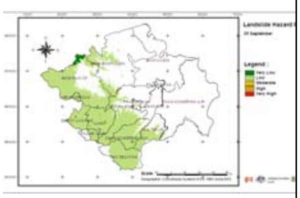
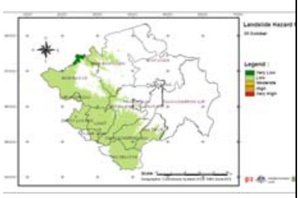
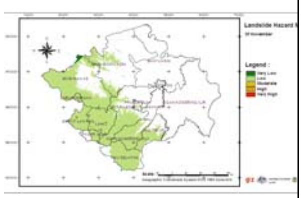
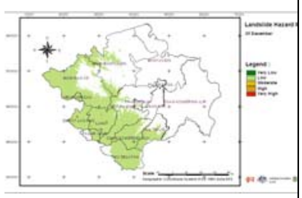
January	February	March	April
			
May	June	July	August
			
September	October	November	December

As seen on Table 4.8, the periods of high ground water table change are in December to June and the periods of low ground water table change are in July to November. The ground water table change controlled the landslide occurrence as shown in Table 4.9. The level of hazard is estimated by using quartile of probability range of ground water table change. The level can be divided in to 5 levels that are very low, low, moderate, high and very high. The area of landslide hazard level shown in Table 4.9

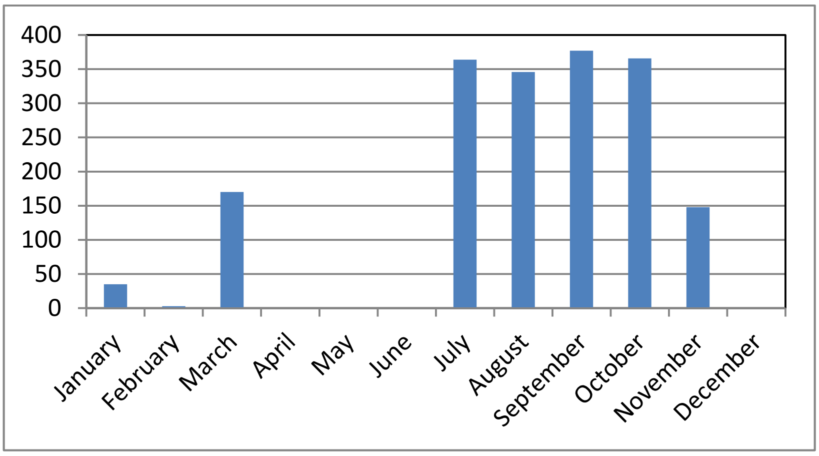
Table 4. 9 Monthly landslide hazard of South Sumatera Province

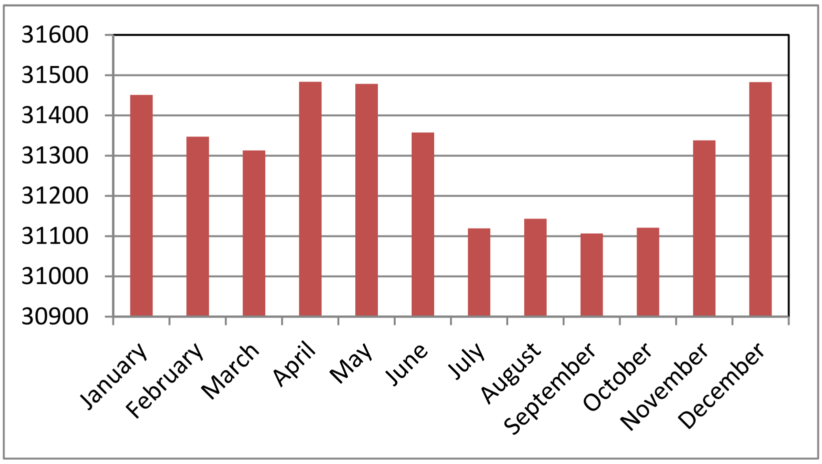
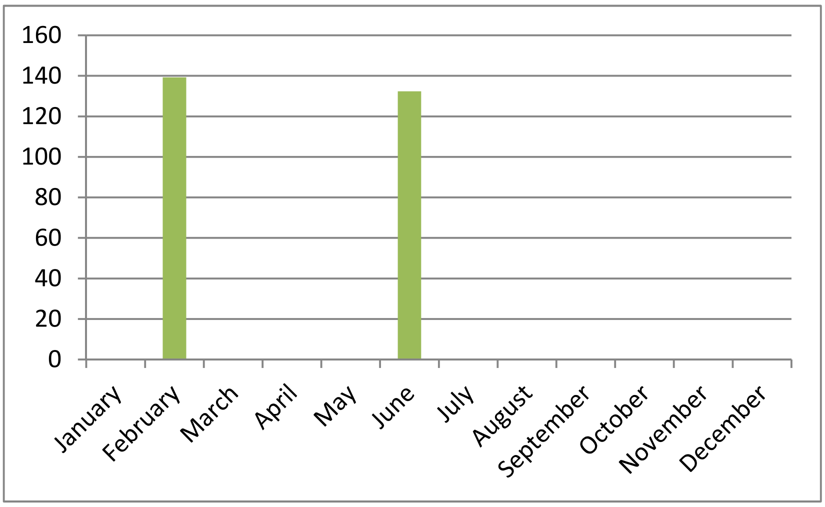
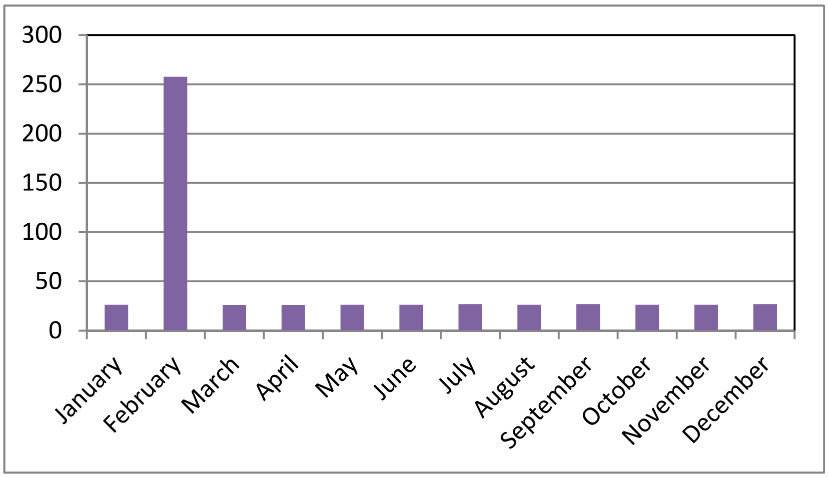
January	February	March	April
			
May	June	July	August
			
September	October	November	December

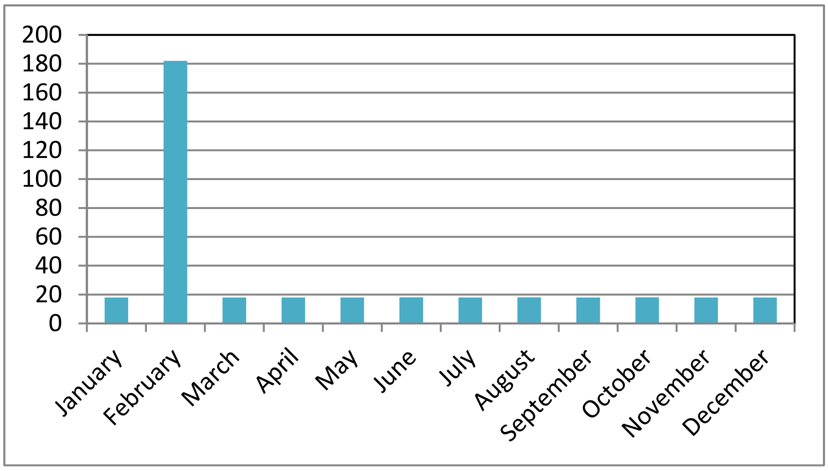
			

The total of hazard areas in each month doesn't have significant differences then it can be seen in the hazard level area which the largest very low level area is occurred on October with 366 km^2, the largest low level area on April with 31484 km^2, and the others level area is occured on February sequentially with 139 km^2, 258 km^2 and 182 km^2. According to the result of landslide hazard analysis, the largest hazard areas will be occurred in February with 31929 km^2. But the month of June has the highest landslide hazard probability.

Table 4. 10 Monthly level of landslide hazard of South Sumatera Province

Hazard Level	Area (km^2)
Very Low	

Hazard Level	Area (km^2)
Low	
Moderate	
High	

Hazard Level	Area (km^2)
Very High	

Based on hazard analysis, June has the highest probability of landslide hazard which the detailed explaination is shown in Figure 4.16 It showed the landslide hazard area where the largest hazard area on the low level with 31357 km^2 then followed by moderate, high, and very high level.

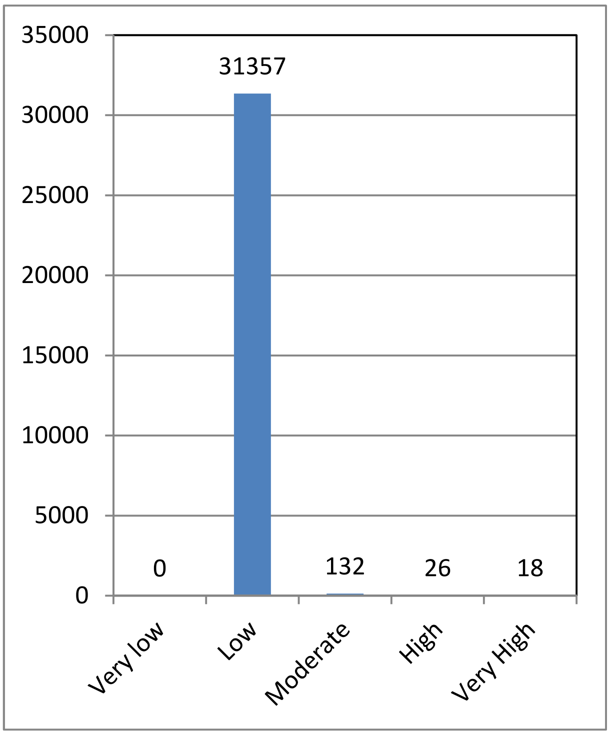
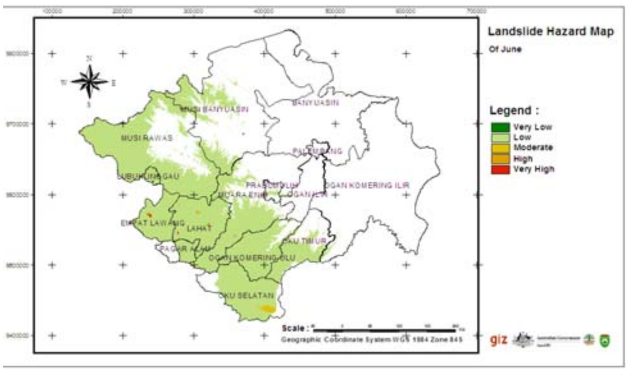
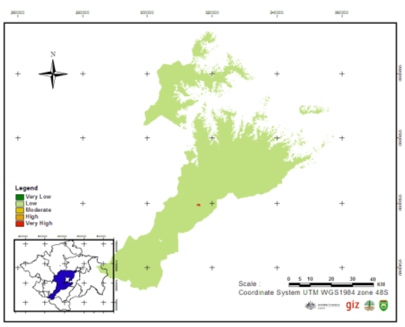
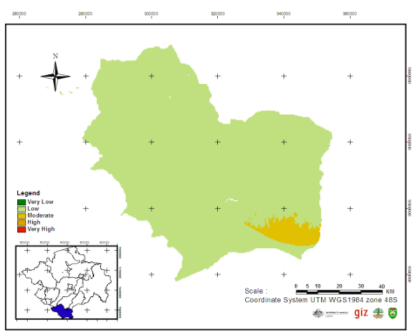
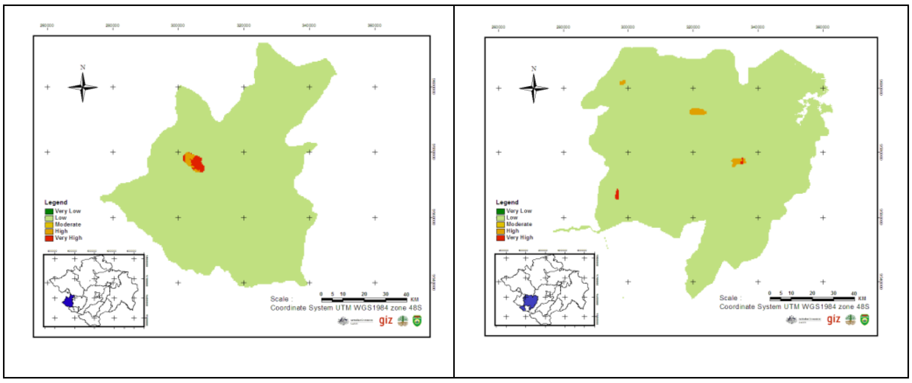


Figure 4. 16 The landslide hazard area on June

Furthermore, the result of hazard analysis is cross-checked to administrative map of South Sumatera province. It is shown the location of landslide hazard where occurred in middle and highland region.

Table 4. 11 South Sumatera landslide hazard map on June

<table>
<tr><td colspan="2">Landslide hazard map of South Sumatera Province</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Muara Enim District</td><td>OKU Selatan District</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Empat Lawang District</td><td>Lahat District</td></tr>
</table>



As seen on Table 4.11, the landslide hazard probability occurrence is spotted in 10 districts where the 3 of upper level of hazard (very high, high, and moderate) are located in 4 districts those are Muara Enim, OKU Selatan, Empat Lawang, and Lahat districts. The total hazard area is 31547 km2 which the moderate is 132.9 km2, 26.37 km2 of high level area, and 18.09 km2 of very high level area. While the low level occurred in 10 districts those are Pagar Alam, Empat Lawang, Lahat, OKU Selatan, Muara Enim, Ogan Komering Ulu, OKU Timur, Musi Rawas, Musi Banyuasin, and Prabumulih district which covered 31357 km2 of hazard area.

V. ANALYSIS OF VULNERABILITIES TO CLIMATE CHANGE

5.1 Identification of Vulnerability Component

The overall vulnerability in water sector of South Sumatera has been analyzed using the GIS method. There are six primary components of vulnerability based on their significant to the hazard and availability of data. The six primary components are described in the following sections.

5.1.1 Population Density

Population density in a location of hazard determines its level of vulnerability. South Sumatera has a relatively medium population density with uneven distribution. In 2008, total population of South Sumatera was 7,544,362 people and the average of population density is 786 person/km^2. Its population growth in the 2005-2010 periods was about 1.58% per year; meanwhile the projection of population growth for 2020-2025 periods is 1.18% per year (BPS, 2011). The high population density as in the Palembang city increases vulnerability to climate change.

The population density analysis in the current condition is based on data of population per sub-district. This data refered to data of village potency from *Pondes*, 2008. Meanwhile, the analysis of population density in the projection condition is based on the population growth as in the Sumsel's spatial plan (*RTRW*) year 2030. The growth ratio assumed similar for all sub-districts each district. Figure 5.1 and Figure 5.2 show the population density on the current condition and projection condition.

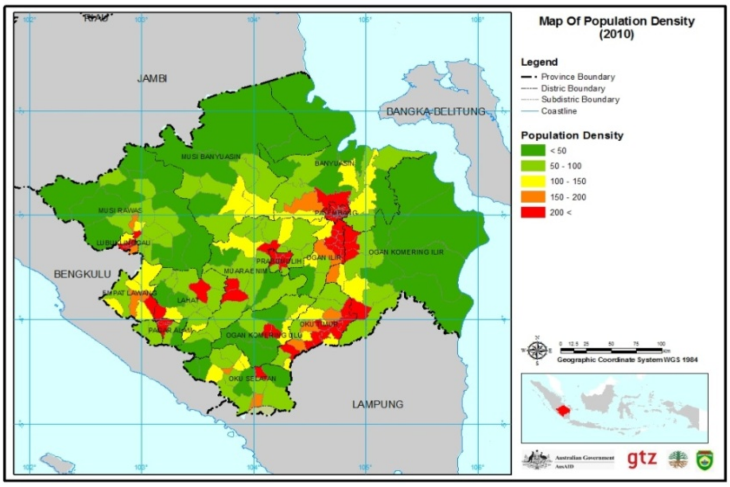


Figure 5. 1 Population Density at Baseline Condition.

Population density reaches limit of maximum value at 200 persons/km^2. If it is more than 200 persons/km^2, it will be assumed to reach the maximum value.

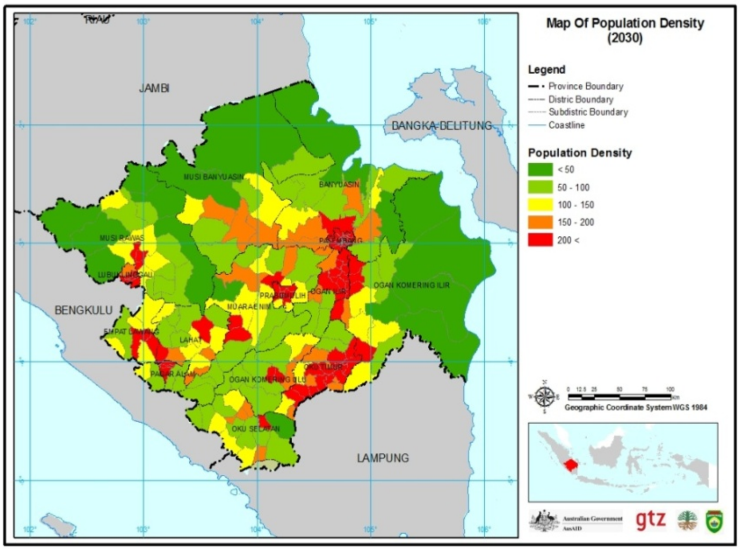


Figure 5. 2 Population density at projection condition

For every values were given linear weighting. This analysis applied for floods and landslides hazards. Meanwhile, for analysis of water shortage hazard, the value of population density is converted into value of water needs.

5.1.2 Landuse

The level of risk is also influenced by the landuse type. Current land use is based on 2008 Landuse, while the projection condition uses the 2030 Spatial Planning. Land use data is obtained from the BAPPEDA. To maintain consistency of the data, landuse is seen from its economic value during floods and landslides and from its water needs for water shortage. Assumptions of each economy value is presented in Table 5.1 below.

Table 5. 1 Landuse types and assumptions of its value for calculating the vulnerability of landuse to climate change in water sector (for flood and landslide hazard), baseline condition (2008)

Landuse 2008	Landuse Value (Million per m^2)
Settlement	1.00
Mining	0.75
Transmigration area	0.75
Fish pond	0.50
Paddy field	0.25
Pertanian campuran **(unclassified farming)**	0.10
Dry land agriculture	0.10
Oil palm plantation	0.25
Rubber plantation	0.25
Oil/rubber plantation	0.25
Plantation	0.05

Plantation on peat land	0.05
Sugar plantation	0.05
Peat land forrest	0.01
Dry land forrest	0.01

Table 5. 2 Landuse types and assumptions of its value for calculating the vulnerability of landuse to climate change in water sector (for flood and landslide hazard), baseline condition (2008) - *continued*

Landuse 2008	Landuse Value (Million per m^2)
Bush	0.00
Swamp bush	0.00
Primary mangrove forrest	0.00
Secondary mangrove forrest	0.00
Primary forrest	0.00
Primary swamp forrest	0.00
Secondary swamp forrest	0.00
Secondary forrest	0.00
Swamp	0.00
Swamp bush	0.00
Moor	0.00

Table 5. 3 Landuse types and assumptions of its value for caculating the vulnerability of landuse to climate change in water sector (for flood and landslide), projection condition (2030).

Landuse 2008	Group of Landuse	Landuse Value (Million per m^2)
Settlement	Settlement	1.00
Cultivation	**Cultivation**	0.75
Aquaculture	**Aquaculture**	0.50
Wet land agriculture	**Wet land agriculture**	0.25
Dry land agriculture	**Dry land agriculture**	0.10
Plantation	**Plantation**	0.25
Permanent production forrest	**Production forrest**	0.10
Temporer production forrest	**Production forrest**	0.10
Limited production forrest	**Production forrest**	0.10
Tanjungapi-api area	**Non-cultivation**	0.00
Protected forrest	**Non-cultivation**	0.00
Conservation forrest	**Non-cultivation**	0.00
Water body	**Non-cultivation**	0.00

The maximum value of landuse is Rp 1 Million/m^2. These values will also be normalized according to the maximum value.

Based on the criterias, data, and assumptions in Table 5.1 and 5.2, we can create weighting for landuse vulnerability for the current baseline condition and projection condition for floods and landslides, as shown in Figure 5.3 and Figure 5.4.

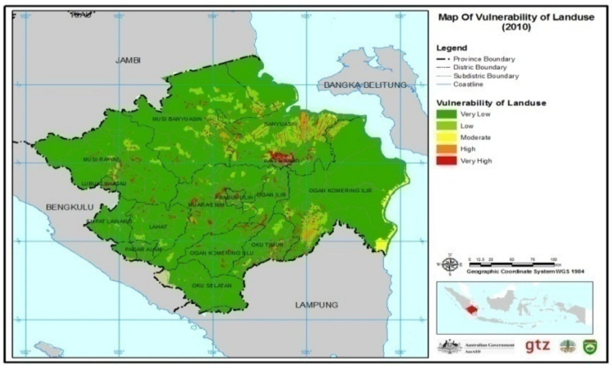
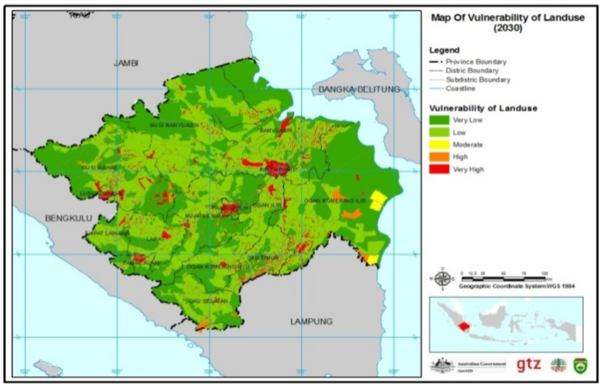


Figure 5. 3 Vulnerability of landuse at baseline condition

Figure 5. 4 Vulnerability of landuse at projection condition



5.1.3 Role of Infrastructures

Hazard often caused great collateral damages or risks for vulnerable area, especially if it occured in important infrastructures. For example, if a landslide occurred on a road, then every activity on the road cannot be conducted.

Road network is the important infrastructure which determines the level of vulnerability to climate change. The source of road data includes: (1) *Dinas Kehutanan* of Sumatera Selatan (*peta jalan Dishut*); (2) map of roads from *Dinas Kehutanan* of Sumsel in the form of map of Earth's surface from Bakosurtanal (*peta jalan Dishut-RB*); and (3) map of roads in the RTRW for the baseline (2010) and projection (2030). Each map has its own characteristics:

1) *Peta jalan Dishut*: does not have any road function attributes;

2) *Peta jalan Dishut-RB*: does have road function attributes, but different from the ones on the RTRW
3) Map of roads for RTRW: for the baseline condition, the map represents the existing function of road; while for the projection condition the map is assumed as road infrastructures for the 2030.

Roads also have larger role for opening access from one location to another. Thus, the weighting role of the infrastructure can also be based on each function of the roads (Table 5.4).

Table 5. 4 Values for each road for the weighting component of infrastructure vulnerability

Type of Road	Value
Rail Roads	3 x roads length each grid (1km^2)
Arterial Roads	3 x roads length each grid (1km^2)
Collector Roads	2 x roads length each grid (1km^2)
Local Roads	1 x roads length each grid (1km^2)
Plantation road	¼ x roads length each grid (1 km^2)

Based on the data and approach, also from the above assumptions, we obtain the map of road infrastructures for the baseline and projection conditions as shown in Figure 5.5.

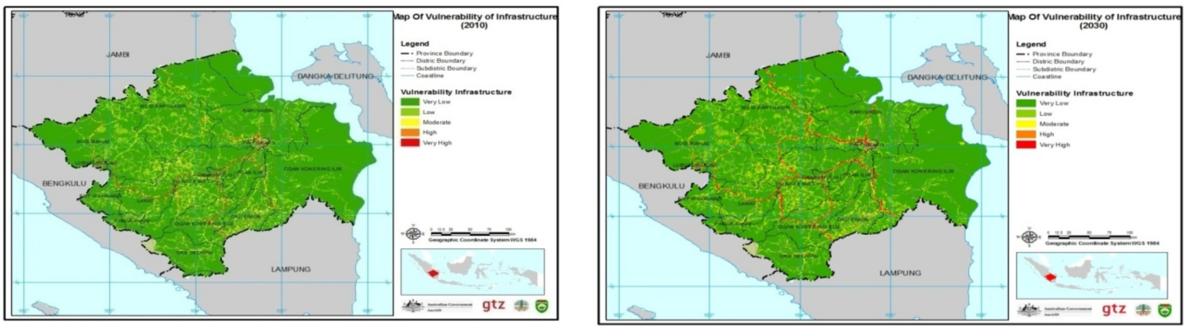


Table 5. 5 Map of infrastructure in South Sumatra at baseline (2010) condition (*left*) and projection (2030) condition (*right*)

5.1.4 Water Demand

On this analysis of water demand vulnerability, water demand is calculated based on administrative unit. Meanwhile, water demand on analysis of water shortage hazard is calculated based on watershed or sub-watershed unit.

Water demand is an indicator used to analyze water shortage. Water shortage will be worsen by the increase of water demand. The level of water demand is analyzed based on the two components: people or domestic water need and landuse water need. Based on the standard of WHO, people's water need is 150 liter/person/day or 0.15 m^3/person/day. The landuse water need is divided into four groups of water need (Table 5.4). Water need for the landuse is the water need assumed to be fulfilled by the irrigation system. Meanwhile, the forest landuse is assumed that it does not have any water need from the irrigation system.

Table 5. 6 Water demand assumption depend on landuse

Landuse types	Water demand (m^3/ha/year)
Rice field	14.000
Oil palm plantation	15.000
Rubber plantation	15.000
Dry land agriculture	8.000
Forest	-*)

Source: FAO, 2010

In this study, water need for industries is not involved, considered as it is not significant. Another consideration is because the areas distribution of industries is only concentrated in palembang and its surrounding, therefore it gives an uneven result in the GIS analysis. Based on the above assumptions, the water demand distribution obtained for South Sumatra in baseline and projection period as presented in Figure 5.5 and 5.6.

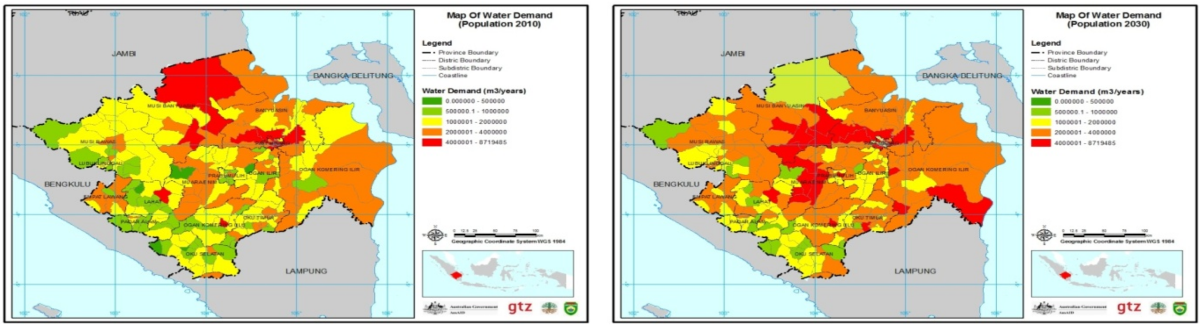


Figure 5. 5 Map of population's water need and its distribution in South Sumatera for the baseline (left) and projection (right)

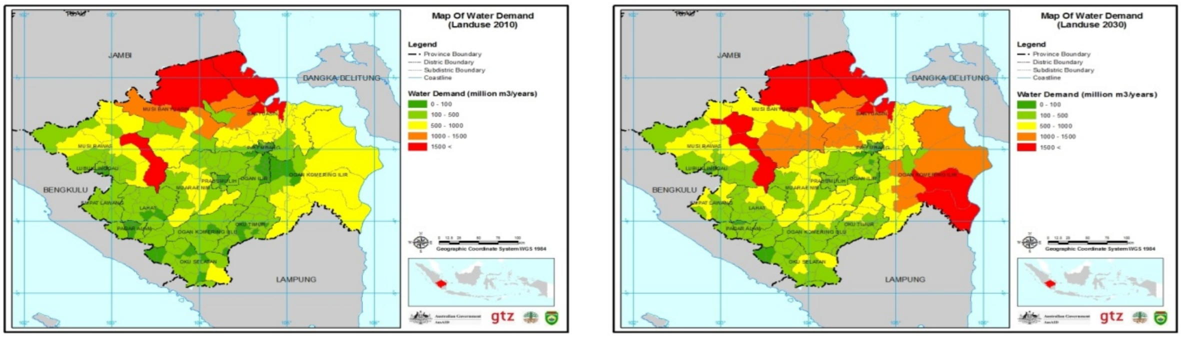


Figure 5. 6 Map of landuse's water need and its distribution in South Sumatera for the baseline (left) and projection (right)

5.1.5 Water Sources

The impact of climate change to water availability depends on the amount of water sources utilized. The higher the dependence of water sources to climate, the bigger the impact of climate change. So, the water sources are a part of vulnerability component to the hazard of climatic change, especially water shortage hazard.

Data of utilized water sources is obtained from 2008 Village Potential data (*National Census, 2008*). Based on this reference, there are 7 water sources utilized in South Sumatera as follows:

1) Instalation water or bottling/packing water,

2) Pumping water

3) Well

4) Spring

5) river/lake

6) Rain water

7) Others.

To obtain the weighting values for the water sources, along with its spatial distribution for the baseline and projection, we use the following assumptions:

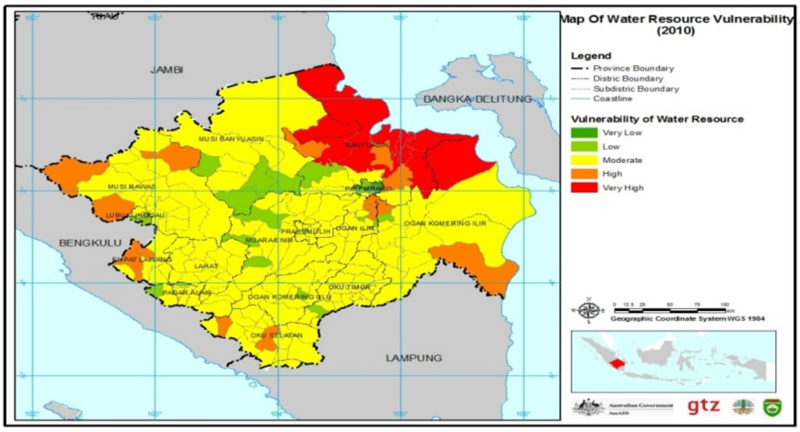
- Unit of weighting is sub-distric (*kecamatan*) where water resource of each sub district is averaged from the village's water source;
- Each vulnerability weighting is shown as in Table 5.5;
- On the projection conditions (2030), it is assumed that all water sources in South Sumatera are in the form of installation water or bottling/packing water (water from PAM or bottled water). This means that the weight value of water source is assummed to be 1 or the maximum value (the lowest vulnearbility).

Table 5. 7 Each weighting value for each water source

Type of Water Source	Weighting of Water Source
Instalation water or bottling/packing water	1
pumping water	2
Well	3
Spring	4
River/lake	5
Rain water	6
Others	7

Based on the assumptions and weighting above, we obtain the picture of vulnerability level of water sources and its spatial distribution in South Sumatera. Figure 5.8 shows the level of vulnerability of water sources and its distribution in the baseline condition.

Figure 5. 7 Vulnerability of water source at baseline condition

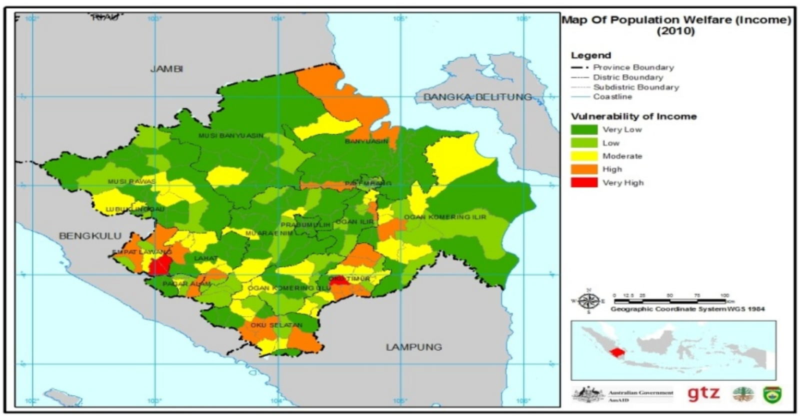


5.1.6 Population Welfare

Population welfare or social welfare is used to represent the participation of society in minimizing impacts of disasters. In this study, it is measured based on the income/capita indicator. The income data is obtained from the 2007 National Census. In the analysis, the data is then averaged from Rp 200,000 to Rp 8,000. Several assumptions used in the analysis are:

- As the income become lower, the vulnerability to climate change become larger;
- In the projection condition, it is assumed that the population welfare in 2030 can minimize the impact of climate change in optimal way. Hence, the vulnerability of welfare component is on the lowest condition or value 1 (Figure 5.9)

Figure 5. 8 Vulnerability of population welfare at baseline condition



5.2 Overview of Water Sector Vulnerability

As stated in Chapter 3, vulnerability in this study is defined as a function of character, magnitude, and velocity of climate change hazards and a variation of exposure, sensitivity, and adaptive capacity from the system to the hazards. There are two affecting factors for vulnerability: climate change identified hazard type; and the components of vulnerability based on the hazard.

Based on the identified hazard, there are three vulnerabilities of water sector to climate change in this study. These vulnerabilities are: vulnerability to water shortage, vulnerability to floods, and vulnerability to landslides. Furthermore, each vulnerability component is analyzed based on its population density, landuse, role of infrastructure, water demand, water source, and population welfare.

5.2.1 Vulnerability to water shortage

Vulnerability to water shortage is defined as vulnerability from the combination of its vulnerability components to water shortage hazard. Water shortage hazard has been identified in Chapter 3. The vulnerability to water shortage consists of three indicators, each indicates different vulnerability components: water demand as indicator of its exposure component, water sources as indicator of its sensitivity components, and population welfare as indicator of its adaptive capacity component. Each indicator consist one or more sub-indicators. Table 5.8 shows the vulnerability components to water shortage along with its indicators, sub-indicators, and weighting in the GIS analysis.

The weighting values in Table 5.6 are concluded from the AHP calculation. The calculation method of AHP is seen in sub chapter 3.4.5. This AHP calculation was based on survey result from the four experts. Based on this survey, it is concluded four weighting value for each indicators. The weighting value for each indicator then averaged into one weight numbers for every indicator as shown in Table 5.8.

Table 5. 8 Components and its indicator of vulnerability to water shortage

Components	Indicators	Sub Indicators	Weighting

Components	Indicators	Sub Indicators	Weighting
Exposure	Water Demand	Population water demand	0.5
		Landuse water demand	
Sensitivity	Water Resource	Instalation water; or bottling or packing water; pumping water, well, spring; river/lake, rain water; others water resources.	0.32
Adaptive Capacity	Population Welfare	Society's income	0.18

Based on the previous analyses on water demand, water sources, and population welfare with GIS analysis (framework in Table 5.8), the map of vulnerability to water shortage hazard for the baseline and projection periods produced in Figure 5.10 and 5.11.

In general, the vulnerability condition of South Sumatera to water shortage hazard is increasing from the baseline to the projection period. By looking at the map of watersheds as in Chapter 4, the regions experiencing significant increase of vulnerability from the baseline to the projection period for each watershed is shown in Table 5.9.

Table 5. 9 Vulnerability change to water shortage hazard from the baseline (2010) to the projection (2030) period

No.	Watershed	Districts/Cities	Vulnerability Level Change	
			Baseline Condition	Projection Condition
1	Musi watershed	A part of Middle part of Banyuasin	Mostly low vulnerability (v), & moderat to high v in the middle section	Mostly high v., some section are very high v and moderate v.
		Small part of upper OKI	Mostly low. A smal part is very low v.	Mostly high v, with very high v in a small part
		OKU Timur	Very low to low v. Som parts are moderate v.	Mostly high v. Some parts are very high v and moderate v
		OKU Selatan	Mostly low v, some part is very low v; a small part in the east is moderate v	Mostly high v. Some parts are moderate to low v
		OKU	Very low to low v	Low to high v.
		Ogan Ilir	Very low to low v.. A very small part in the east is moderate v	Mostly high v. in The middle are become veri high v and a very small part in the middle area bocome moderate v
		Palembang	Low to moderate v.	High to very high v.
		Prabumulih	Low v	Moderate to very high v.

No.	Watershed	Districts/Cities	Vulnerability Level Change	
			Baseline Condition	Projection Condition
		Muara Enim	Very low to low v	Mostly moderate v. Some parts are low and high v. A small section in the northeast is very high v
		Pagar Alam	Very low to low v	Low to high v.
		Lahat	Very low to low v	Moderate to high v
		Empat Lawang	low to moderate v., a small part in the southwest is very low v	Mostly high v. A small part in the southwest is moderate v
		Lubuk Linggau	Low v	Mostly is high v.
		Musi Rawas	Mostly low v. A significant area in the west is very low v & a small part in the middle and the south are moderate v.	Mostly moderet to high v. The very low v area in the baseline become low v. A small part in the south is very high v.
		Upper part of Musi Banyu Asin	Very low to low v.	Mostly high v. Some parts are low to moderate v
2	Sugihan watershed	A small part of east Bayu Asin	Low to moderate v.	Moderate to high v.
		Arround 60% of OKI region	Very low to low v	From north to south area: low to high v.
3	Mesuji watershed*)	Around 30% of OKI region, south of OKI	Low to moderate v	Moderate to high v and a small part in the south is very high v.
5	Banyuasin watershed	East or midle to lower Musi Banyu Asin	From north to south : Very low to low v in th southwest & moderate v in the southeast	From north to south : Low to moderate in th southwest & high v in the southeast
		Northeast part (around 30%) of Banyu Asin	Low v	Moderate v

Note: v = vulnerability; Watershed: is the main watershed which consists of some small watersheds

As shown in Figure 5.9 and 5.10, generally, the vulnerability of South Sumatera to water shortage hazard is varying from very low to very high in both periods. Here, the most dominant component that contributes for high level of vulnerability is water demand component. Since it has the biggest weighting on component on its indicator of vurnerability to water shortage.

(1) The baseline condition of water shortage vulnerability

In the baseline condition, the most vulnerable area to water shortage is in the middle of Banyu Asin. This includes the edge of Musi watershed to the northeastern coastal areas which is bordering with OKI region. This area is classified as having a very high vulnerable level that surrounded by wide areas of moderate vulnerable. Another very high vulnerability region is a small part of southern Palembang. The largest contributed components to this vulnerability are exposure (landuse or water demand) and sensitivity (water resources).

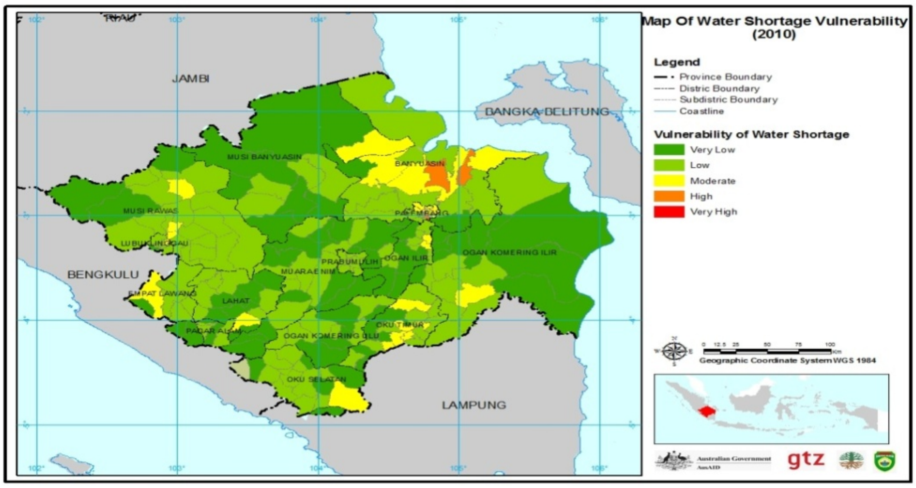


Figure 5. 9 Vulnerability to water shortage hazard at baseline condition (2010)

Regions with moderate level of vulnerability are distributed in several districts such as middle Banyuasin, and northeastern coastal areas; southeastern Musi Banyu Asin; and Palembang. These regions are a part of three large watersheds, which is: Banyuasin Watershed, Musi hilir Watershed, and Sugihan Watershed. Other regions of moderate vulnerability are southern OKI which is inside the Mesuji Watershed; and the middle of OKI Timur and southeastern OKU Selatan. The two regions are a part of Musi Watershed in South East – middle to upper Musi Watershed, southeast section. Moderate vulnerability regions also include: a small part of eastern Ogan Ilir and southeastern Lahat; a medium part of middle western Empat Lawang; and a small part of southern Musi Rawas, near Lubuk Linggau; and in the middle of Musi Rawas.

Aside from the high and moderate vulnerability regions, the rest is low and very low vulnerable regions. The low and very low regions have the largest vulnerability level regions. There are districts/cities that located in the low and very low level, they are: OKU, Muara Enim, Prabu Mulih, and Pagar Alam.

The vulnerability condition is based only on three vulnerability components: water demand, water sources, and population welfare (translated as income per capita). There are some other vulnerability components which are not involved in the analysis due to unavailability of data, there are: water quality and water infrastructures.

(2) The projection condition of water shortage vulnerability

The vulnerability condition of the projection period (2030) is very different compared to the baseline condition (2010). As shown in Table 5. 9, in general, the vulnerability is changing to be higher vulnerability. There are three patterns of change from the baseline to the projection, which are: (1) change from a level into one higher level of vulnerability, (2) change into two levels higher, and (3) change into three levels higher.

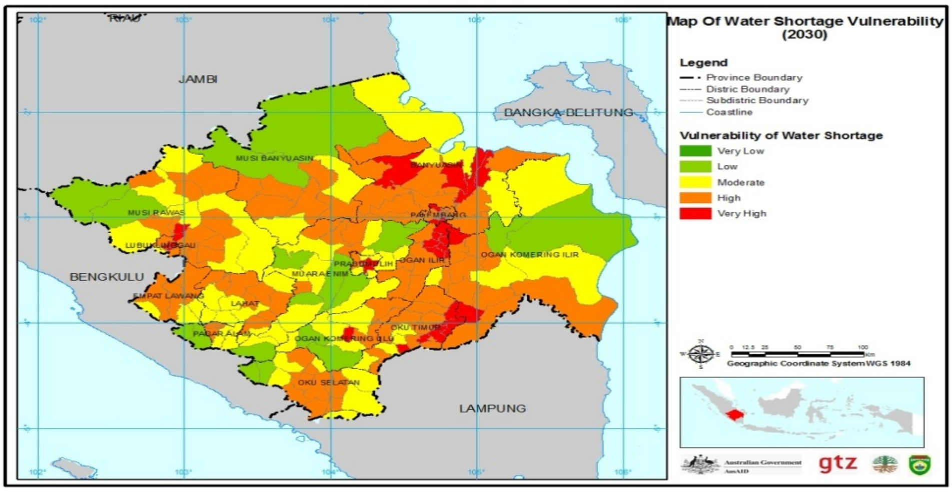


Figure 5. 10 Vulnerability to water shortage hazard at projection condition (2030)

In the first pattern that is vulnerability change become one higher level, there are 4 categories of regions:

1) **High** vulnerability regions change into **very high** vulnerability regions, in example: around middle Banyuasin in the Musi watershed; and southern Palembang.
2) **Moderate** vulnerability regions change into **high** vulnerability regions, such as: northeastern Musi Banyuasin which spread to its neighboring Banyuasin; eastern coasts of Banyuasin; eastern Ogan Ilir, in the southeastern Lahat; mid-western Empat Lawang; and a small region in the southern and middle Musi Rawas.
3) **Low** vulnerability regions change into **moderate** vulnerability regions. For example: northeastern coasts of Banyuasin (*Taman Nasional Sembilang*); northeastern OKI and a little of Banyuasin; a wide area in Muara Enim, Lubuk Linggau, Musi Rawas; and several other districts.
4) **Very low** vulnerability change into **low** vulnerability regions, for example: middle OKI; and a wide area of Musi Banyuasin from the middle to the northern area.

For the second pattern, vulnerability change become two higher levels, there are three categories:

1) **Moderate** vulnerability level change into **very high**. For example: mid-western Banyuasin, in the northern Palembang; eastern Ogan Ilir; a small part of OKU Timur and the southern part, bordering with Lubuk Linggau from Musi Rawas.
2) **Low** vulnerability level change into **high** vulnerability. In example: southwestern OKI; several small parts of OKU Timur, OKU, Lahat, Pagar Alam, and Lubuk Linggau; and a wide area of mid-western OKU Selatan, mid-southern Musi Rawas, and mid-southern Musi Banyuasin.
3) **Very low** vulnerability level change into **moderate** vulnerability. In example: mid-southern OKI; several wide areas of OKU Timur, OKU, OKU Selatan, Ogan Ilir, Prabumulih, Lahat, Empat Lawang, Pagar Alam, and Muara Enim; and southern Musi Rawas, Musi Banyu Asin, Banyu Asin.

For the third pattern, ulnerability change into three higher levels, there are two categories:

1) **Low** vulnerability regions change into **very high** vulnerability, for example: the middle of Prabumulih and a small area of mid-OKU.
2) **Very low** vulnerability regions change into **high** vulnerability, such as: most southern part of OKI until the border of Lampung Province; several small to medium parts of OKU Timur, Ogan Ilir, OKU, Lahat, Muara Enim, and Musi Banyu Asin

Regions that need to be focus on in reference to adaptation based on the distribution of high vulnerability level and its changes are: 1) the centre of Banyu Asin-Palembang-Ogan Ilir until the southern areas in OKI and eastern OKU; 2) southern OKU; 3) the centre of Empat Lawang-Lubuk Linggau; 4) the centre of Prabumulih to the northwestern Musi Banyuasin and the centre of Prabumulih to eastern Banyuasin.

As in the baseline condition, the vulnerability analysis for the projection period did not involve other vulnerability components (such as water quality and water infrastructures) due to shortage in projection data. The vulnerability condition will be different and will worsen several regions if the water quality and infrastructures are involved.

5.2.2 Vulnerability to floods

The vulnerability to floods consists of 3 components and 4 indicators: population and land use as indicators of the exposure component, role of infrastructure as indicator of the sensitivity components, and population welfare as indicator of the adaptive capacity component. The Table 5.8 shows the vulnerability components along with the indicators and weighting from the GIS analysis.

The weighting values in Table 5.8 were concluded from the AHP calculation. Calculation method of AHP is described in sub-chapter 3.4.5. This AHP calculation was based on the judgment by four experts.

Table 5. 10 Components and its indicators of vulnerability to flood

Components	Indicators	Sub-indicators	Weighting
Exposure	Population density	Population and population growth per sub-district	0.53
	Landuse	Landuse as in regional planning	0.23
Sensitivity	Role of infrastructure	Road infrastructure	0.18
Adaptive Capacity	Population Welfare	Population's income	0.06

Based on previous analyses on vulnerability components to floods, with the GIS analysis refering to the framework as seen in Table 5.8 above, maps of water vulnerability to floods are produced for the baseline period and projection period, shown in Figure 5.12 and 5.13.

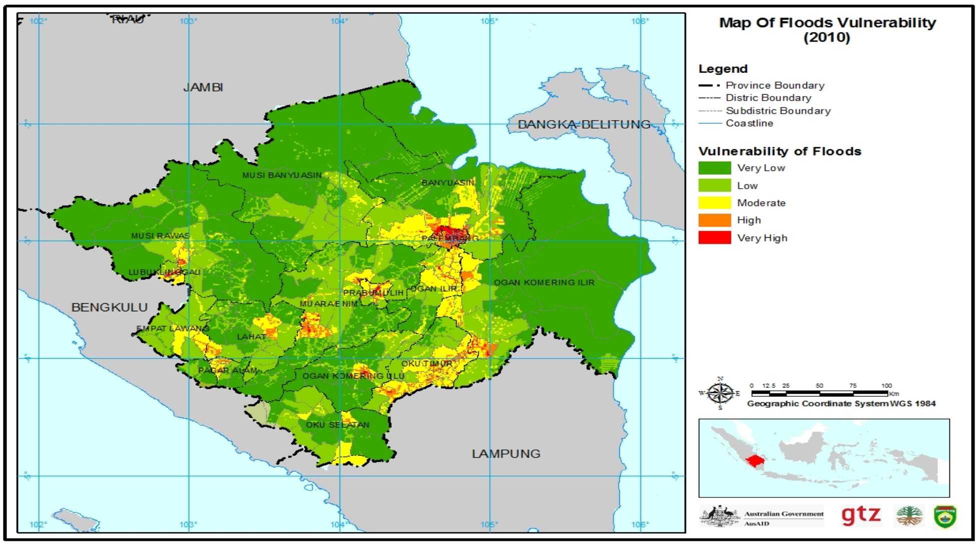


Figure 5. 11 Vulnerability to flood hazard at baseline condition (2010)

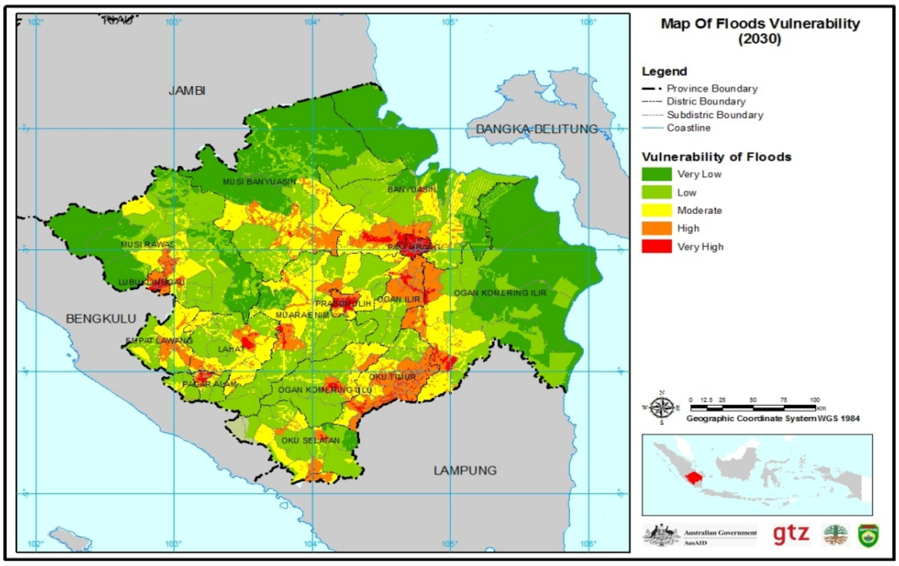


Figure 5. 12 Vulnerability to flood hazard at projection condition (2030)

Generally, the vulnerability condition of South Sumatera to floods increases from the baseline (2010) condition to the projection (2030) condition. By refering to the map of watersheds as in Chapter 4, the regions which experience significant increase of vulnerability level in every watersheds are presented in Table 5.9.

Table 5. 11 Vulnerability change to floods hazard from the baseline to the projection condition

No	Watershed that is	Districts/Cities	Change on Vulnerability Level

	vulnerable to change		Baseline Condition	Projection Condition
1	Musi watershed	South part of Banyuasin	Mostly moderate vulnerability (v)	Mostly high v.
		Middle to east part of Banyu Asin	Some significant areas of moderate v plotted with high v area	Respectively, the area of moderate and high v become wider
		West part of OKI	Some scattered areas of moderate v to high v	The scattered areas become high v to very high v
		South part of OKI	Some spotted of moderate v	Moderate v with some spotted area of high v
		OKU Timur	Mostly moderate v with scattered high v area	Mostly high v scattered with area of very high v.
		OKU Selatan	Moderate to high v in small part in the south and in the north area	Respectively the areas become high v
		OKU	Moderate to high v in some small part in the middle area	The small parts in the middle area become high to very high v. Some moderate v appear in the north
		Ogan Ilir	Moderate v in the middle to the north area	The area of moderate v in the baseline become high to very high v
		Palembang	High to very high v.	Very high v
		Prabumulih	Mostly moderate v & high v in some parts	Very high v to high v in almost all regions
		Muara Enim	High to moderate c in some small parts in the middle area	Mostly moderate v and the area with high v become wider
		Pagar Alam	Small part is moderate v to high v	The area with high v become wider
		Lahat	High to moderate v in a small part in the middle area	The area with high v become wider; some moderate v in the south
		Empat Lawang	A small part is moderate v	The moderate v become high v; & some others moderate v
		Lubuk Linggau	A small part of moderate to high v	Almost all region is high v
		Musi Rawas	A small part of moderate to high v in the south which is border on Lubuk Linggau	The moderate to high v area become wider. An area of moderate v in the north
		Lower part of Musi Banyu Asin	Low v with plotted of moderate v area	Respectively become moderte to high v
2	Mesuji watershed	A significant area in the south of OKI	Mostly low v with scattered of moderate to high v	Mostly moderate v with some parts of high v
5	Banyuasin watershed	Lower part of Musi Banyu Asin	Low v with plotted area of moderate v	Respectively the area become moderate to high v

5.2.3 Vulnerability to landslides

Vulnerability to landslides can be defined as the vulnerability produced from the combination of function of its vulnerability components to landslides hazard. Landslides hazard has been identified in Chapter 4. The vulnerability components along with its indicators and weighting as shown in Table 5.10.

The weighting values in Table 5.10 ware concluded from the AHP calculation. Calculation method of AHP is described in sub chapter 3.4.5. This AHP calculation was based on the judgement by four experts.

Table 5. 12 Components and its indicators of vulnerability to landslides

Components	Indicators	Sub-indicators	Weighting
Exposure	Population density	Population and population growth per sub-district	0.54
	Landuse	Landuse as in regional planning	0.22
Sensitivity	Role of infrastructure	Road infrastructure	0.18
Adaptive Capacity	Population Welfare	Population's income	0.06

The vulnerability indicators of landslides are identical with the indicators of floods. Hence, the weighting can also be identical. Based on the previous analysis, the following maps of vulnerability to landslides in the baseline and projection periods are produced in Figure 5.14 and 5.15.

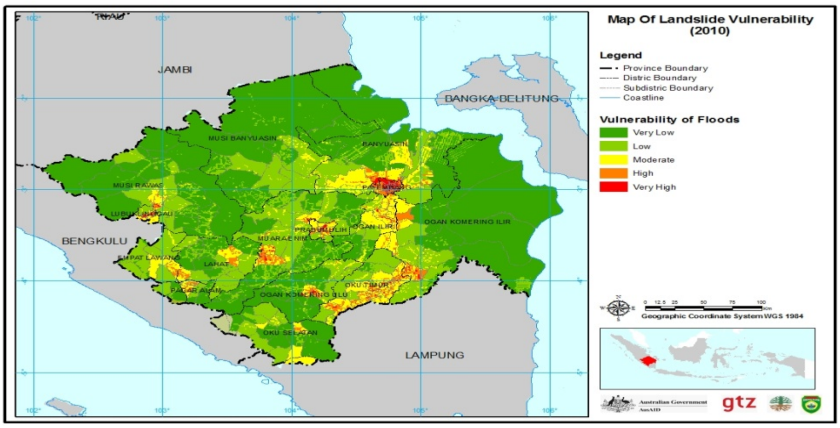


Figure 5. 13 Vulnerability to landslide hazard at baseline condition (2010)

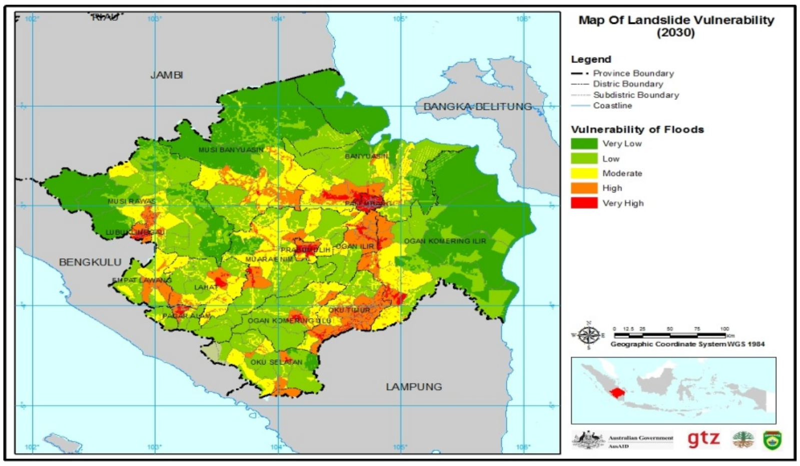


Figure 5. 14 Vulnerability to landslide hazard at projection condition (2030)

Due to the identical vulnerability indicators between landslides and floods, the vulnerability level of landslides and its distribution are also identical with the floods. As well as its vulnerability condition in the baseline and projection periods.

VI. ASSESSMENT OF RISK TO CLIMATE CHANGE

6.1 Identification of Climate Change Risk on Water Sector

This study assesses the risks of each hazard identified before: water shortage, floods, and landslides. As stated in the assessment method (Chapter 3), risk is a function of hazard and vulnerability (Affeltranger, et.al, 2006).

The risk is drawn in a map to see its distribution for minimum of two periods, baseline and projection. Risk level is classified into 5 levels; very low risk, low risk, moderate risk, high risk, and very high risk.

6.1.1 Water shortage risk

Water shortage risk is a function of water shortage hazard and vulnerability. Water shortage hazard consists of natural water supply component and increasing water needs per district unit (Figure 4.9 and Figure 4.10).

Meanwhile, the vulnerability consists of water demand component per grid area of 100 x 100 m^2, water sources, and social welfare as presented in Chapter V. The map of risk of water shortage, as the result of the GIS team analysis, is presented in Figure 6.1 and 6.2.

Generally, a risk for decrease in water availability for the baseline condition in South Sumatera is low rate. High risk is found in sub-district Muara Telang, Banyuasin Regency. While moderate risk already found in 22 sub-districts in 7 (seven) districts/cities, namely Palembang, Banyuasin, Musi Banyuasin, Musi Rawas, Ogan Komering ILir, Ogan Ilir, and OKU Timur.

Based on the Figure 6.1 and 6.2, the water shortage risk in South Sumatera is relatively low for the baseline period and slightly increases for the projection period. In the projection period, there is a slight increase of low to high risks and an increase of area of moderate and high risks, compared with previous period.

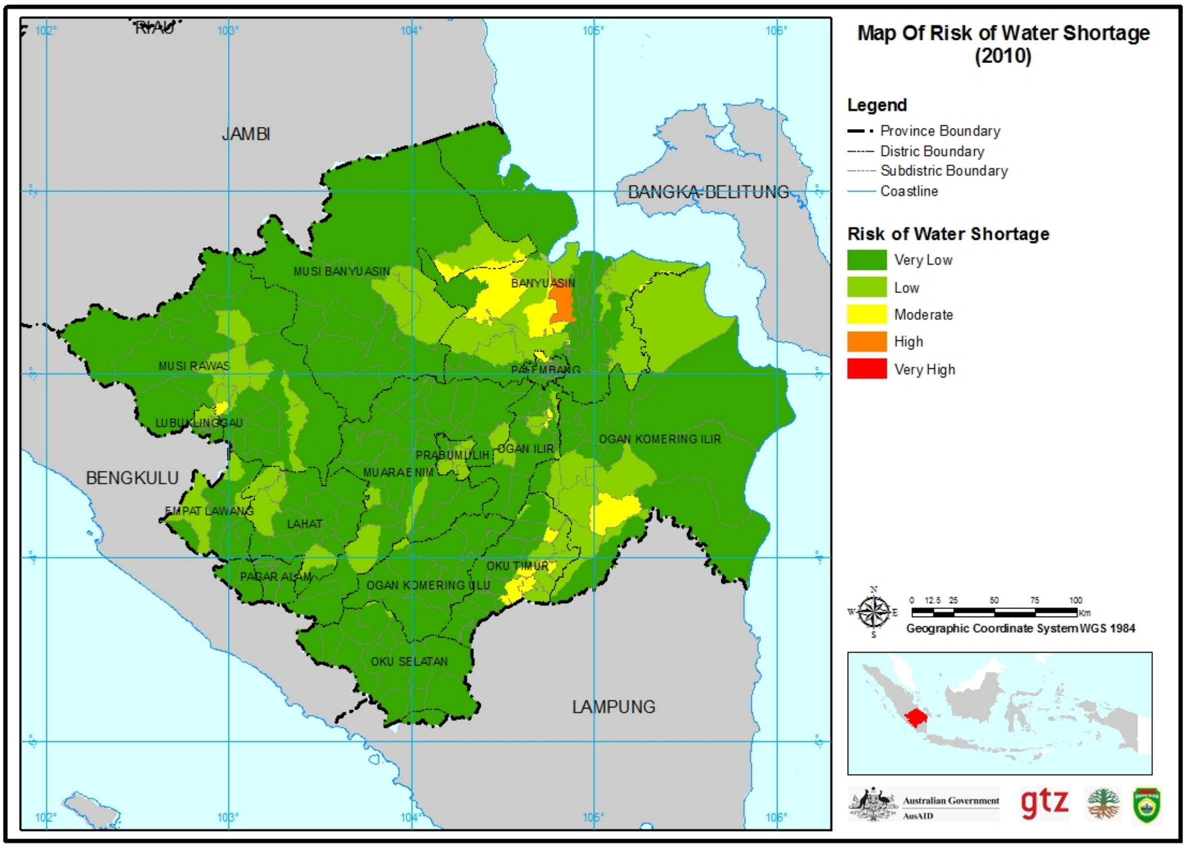


Figure 6.1. Map of water shortage risk, for the baseline/current period, 1990-2020.

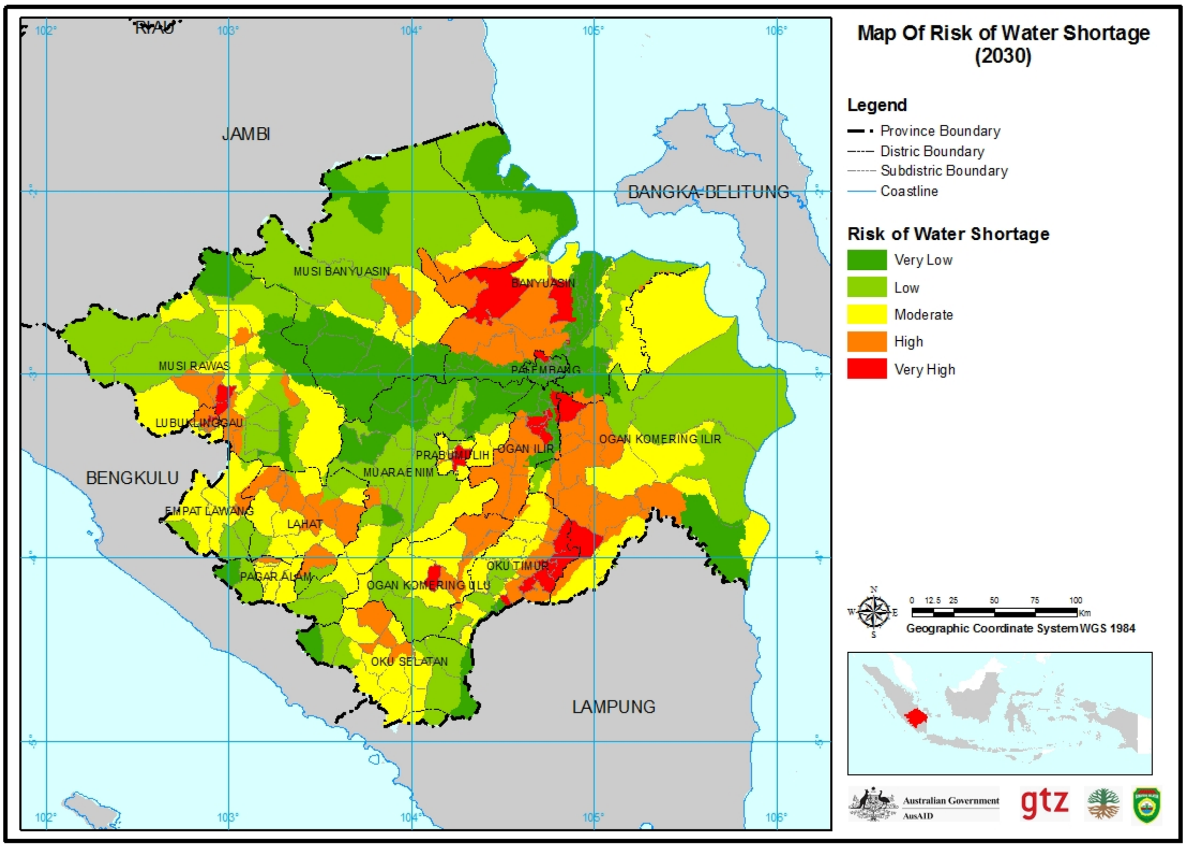


Figure 6. 2 Map of water shortage risk, for the projection period of 2010-2030.

At the baseline condition, high risk of water shortage is located at region with an area of 431.524 km^2 in sub-district Muara Telang, Banyuasin District. Moderate risk of water shortage located around sub-district Pulau Rimau and sub-district Tanjung Lago in the District of Banyuasin, sub-district Mesuji Raya in the District of Ogan Komering Ilir, and also sub-district Buay Madang and sub-district Belitang Jaya in the District of Ogan Komering Ulu Timur.

At the projection condition, change in risk level with increase of high-risk rate and to be very high risk rate at previous location, which is sub-district Muara Telang, sub-district Pulau Rimau, and sub-district Tanjung Lago in the District of Banyuasin District. A few region in north of Palembang city also has very high risk rate of water shortage. A southwest region of the Ogan Komering Ilir District and southeast region of the District of Ogan Komering Ulu Timur also increase to very high risk rate. The City of Lubuk Linggau also has very high risk rate of water shortage at the projection condition.

The characteristics of each risk level in the baseline period are shown in Table 6.1 below. Meanwhile in the projection period, the condition of water shortage risk and its risk levels are shown in Table 6.2.

Table 6.1 Water shortage (WS) risks and their distribution in each watershed in baseline period (1991-2010)

Level of WS[1)] Risk	Regency	Area (km^2)	Description of the Risk
Very High	-	-	There's no significant very high risk
High	Banyuasin	128,748.34	Dominant contribution as a cause of water demand for plantation
Medium	Ogan Komering Ilir, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Timur, Ogan Ilir, Palembang	5,213,585.10	Dominant contribution as a cause of water demand for plantation
Low	Ogan Komering Ilir, Ogan Komering Ulu, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Timur, Ogan Ilir, Palembang, Prabumulih, Lubuk Linggau, Muara Enim, Empat Lawang, Lahat	26,395,616.62	There's no signifiacant risk
Very Low	Ogan Komering Ilir, Ogan Komering Ulu, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Timur, Ogan Ilir, Palembang, Prabumulih, Lubuk Linggau, Muara Enim, Empat Lawang, Pagar Alam	98,803,956.31	There's no significant risk

Table 6.2 Water shortage (WS) risks and their distribution in each watershed in projection period (2010-2030)

Level of WS[1)] Risk	Regency	Area (km^2)	Description of the Risk
Very High	Ogan Komering Ulu, Ogan Komering Ilir, Musi Rawas, Banyuasin, OKU Timur, Ogan Ilir, Palembang, Prabumulih, Lubuk Linggau	7,483,479.86	• Dominant contribution as a cause of water demand for plantation • Water availability driven by climate is decrease
High	Ogan Komering Ulu, Ogan Komering Ilir, Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Selatan, OKU Timur, Ogan Ilir, Empat Lawang, Palembang, Prabumulih, Pagar Alam, Lubuk Linggau	27,447,142.83	• Dominant contribution as a cause of water demand for plantation • Water availability driven by climate is decrease
Medium	Ogan Komering Ulu, Ogan Komering Ilir, Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Selatan, OKU Timur, Ogan Ilir, Empat Lawang, Palembang, Prabumulih, Pagar Alam, Lubuk Linggau	40,787,550.61	• Dominant contribution as a cause of water demand for plantation • Water availability driven by climate is decrease
Low	Ogan Komering Ulu, Ogan Komering Ilir, Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Selatan, OKU Timur, Ogan Ilir, Empat Lawang, Palembang, Prabumulih, Pagar Alam, Lubuk Linggau	30,909,273.63	
Very Low	Ogan Komering Ilir, Muara Enim, Lahat, Musi Rawas, Musi Banyuasin, Banyuasin, OKU Selatan, OKU Timur, Ogan Ilir, Empat Lawang, Palembang, Prabumulih, Lubuk Linggau	23,914,459.43	

Generally, the risk area of projection period is wider than in the baseline period. The distribution includes new areas which previously are not in risk. The increasing risk is caused by the decreasing water supply due to decreasing precipitation trend and increasing evapo-transpiration and water needs.

6.1.2 Flood Risk

Risk level map is resulted from the 2 Dimensional Table analysis between hazard level and vulnerability level by ILWIS application (Figure 6.1). By using the same procedure as in the hazard analysis, risk analysis begins with an analysis on a watershed scale that is in Lematang Watershed, then generated into the provincial scale.

2-Dimensional Table "Risk_Lematang_Base" - ILWIS

	Very Low	Low	Moderate	High	Very High
Very Low	Very Low	Very Low	Low	Low	Moderate
Low	Very Low	Low	Low	Moderate	High
Moderate	Low	Low	Moderate	High	High
High	High	Moderate	High	High	Very High
Very High	Moderate	High	High	Very High	Very High

Figure 6. 3 2-Dimensional Table of Risk Level

Flood risk assessment is divided into 5 levels. There are Very Low Risk, Low Risk, Moderate Risk, High Risk, and Very High Risk.

The flood risk is analyzed in 2 conditions that are baseline and projection. Both of conditions will be brokendown into watershed (sub-basin) and provincial scale which have different level of accuracy. The watershed (sub-basin) has a higher accuracy than the provincial scale. The watershed (sub-basin) scale analysis follows the approach of hazard analysis which was analyzed in the Lematang watershed.

In the watershed (sub-basin) scale of the baseline condition, the Lematang watershed has 5 levels of risk: very low, low, moderate, high, and very high. These levels covered most of residential area in the Muara Enim District, Lahat District, and Prabumulih City. Meanwhile in the projection condition, the levels of risk will decrease to 4 levels due to land use conversion of the spatial planning of 2030 of South Sumatera Province. (See Table 6. 5).

In the provincial scale, the levels of risk will consist of 5 levels that are very low, low, moderate, high, and very high. According to the percentage of flood risk area to district areas, the baseline condition shows the highest potential flood risk area is located in the Prabumulih City because of 33.82% of city areas maybe inundated. Meanwhile the largest potential flood risk area is spread in the Muara Enim district which inundates 276687.59 ha of areas. But if the flood events is influenced by tidal and sea level rise then the highest risk of district will be located in the Palembang City and Banyuasin district because of 59.36% of Palembang City area and 57.33% of Banyuasin district area will be flooded.

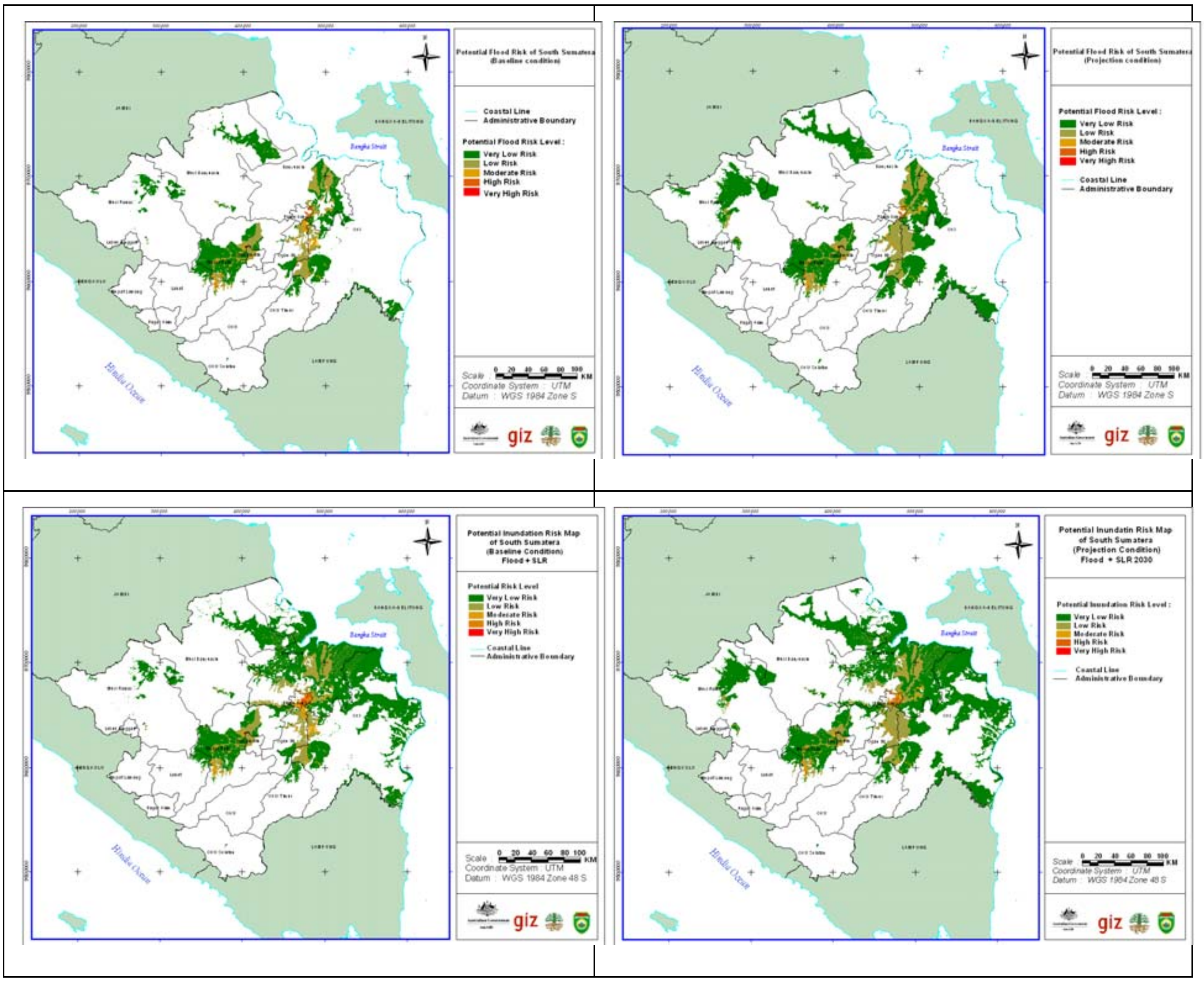


Figure 6. 4 Potential Risk map of South Sumatera

In the projection condition, the highest potential flood risk area will be located in the Ogan Ilir District where 43.39 % of district area submerged. Meanwhile in extreme event condition, the highest potential risk area will be located in the Palembang City because 60.57 % of Palembang City area will be flooded.

Table 6. 3 Potential Risk Area of South Sumatera Province

Regencies/Cities	Flood (% of District/city area)		Flood + SLR (Inundation) (% of District/city area)	
	Baseline	Projection	Baseline	Projection
	%	%	%	%
OKU Selatan	0.13	0.28	0.13	0.28
Banyuasin	16.96	20.85	57.33	59.80
Muara enim	31.78	33.99	35.29	35.42

Regencies/Cities	Flood (% of District/city area)		Flood + SLR (Inundation) (% of District/city area)	
	Baseline	Projection	Baseline	Projection
	%	%	%	%
Musi Banyuasin	9.59	14.22	12.16	15.29
Musi Rawas	4.78	17.29	4.78	17.29
Ogan Ilir	31.51	43.39	35.10	41.27
Ogan Komering Ilir	10.83	19.19	36.93	43.03
OKU Timur	8.23	11.18	8.23	11.18
Palembang	14.55	17.39	59.36	60.57
Prabumulih	33.82	33.82	33.82	33.82
Lahat	6.53	8.15	6.53	8.15

Table 6. 4 Risk Levels of Lematang Watershed to Land Use Area in Baseline and Projection Condition

Very Low Risk				Low Risk				Moderate Risk				High Risk				Very High Risk			
2010		2030		2010		2030		2010		2030		2010		2030		2010		2030	
Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)	Land Use	Area (km2)
Water body	23.03	Budidaya	0.81	Air	0.60	Budidaya	0.00	Water body	0.09	Green forest	0.10	Residential	0.09	Production Forest	0.03	Residential	0.02	-	-
shrubs	73.42	HPKv	99.65	shrubs	0.83	HPKv	0.78	Residential	0.29	Production Forest	0.13	Tanah Terbuka	0.02	Agriculture land	0.01				
Swamp shrubs	39.97	Green Forest	14.36	Swamp shrubs	0.22	Green Forest	0.32	Moors	0.23	Perairan	0.07	Total	0.11	Total	0.04				
Secondary swamp forest	19.25	Limited Production Forest	16.23	Secondary swamp forest	0.46	Limited Production Forest	1.04	Tanah Terbuka	0.10	Perkebunan	0.08								
Secondary forest	0.94	Production Forest	1149.27	Secondary forest	0.06	Production Forest	27.49			Agriculture land	0.07								
Industry Forest	285.60	Protected Forest	43.14	Industry Forest	1.69	Protected forest	0.55	total	0.71	Total	0.45								
Residential	109.95	Perairan	31.49	Residential	6.87	Perairan	0.83												
Plantation	11.38	Perkebunan	1700.40	moors	38.34	Perkebunan	38.27												
Total	563.54	Total	3055.36	Agriculture land	6.68	residential	4.02												
				Paddy field	0.09	Wet agriculture	0.30												

Very Low Risk		Low Risk				Moderate Risk		High Risk		Very High Risk	
2010	2030	2010		2030		2010	2030	2010	2030	2010	2030
				land							
		Total	55.83	Total	73.62						

Table 6. 5 Hazard, Vulnerability and Risk Levels Matrix of Lematang Watershed

Districts	HAZARD										VULNERABILITY										RISK									
	VL		L		M		H		VH		VL		L		M		H		VH		VL		L		M		H		VH	
	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P	B	P
Lahat					-	-	-	-	-	-									-	-							-		-	-
Muara Enim										-									-	-									-	
Musi Banyuasin	-	-	-	-	-	-	-	-	-	-					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Musi Rawas					-	-	-	-	-	-					-	-	-	-	-	-			-		-	-	-	-	-	-
OKU			-	-	-	-	-	-	-	-					-	-	-	-	-	-			-		-	-	-	-	-	-
OKU Selatan	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pagar Alam	-	-	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prabumulih					-	-	-	-	-	-									-	-							-		-	-

VL

L

M

H

VH

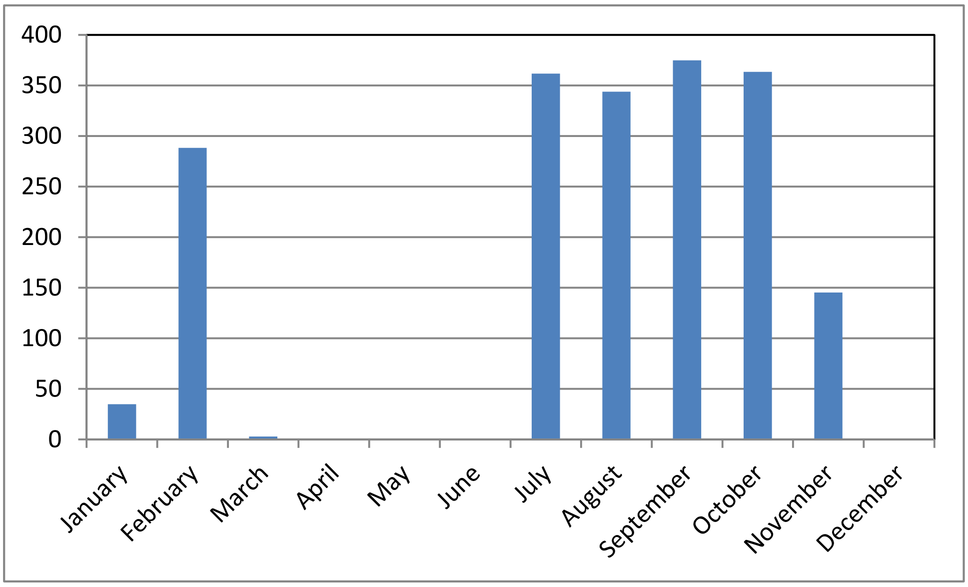
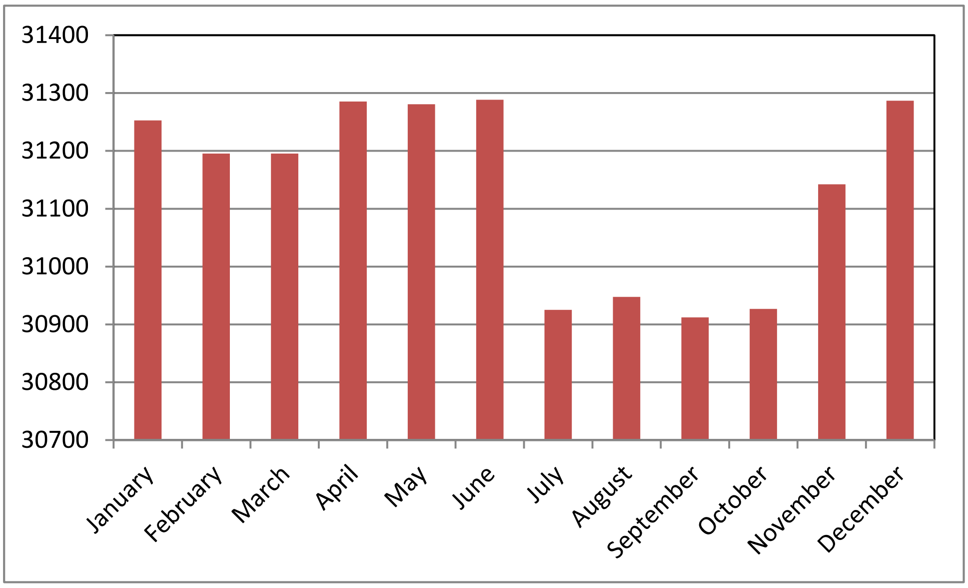
B = Baseline

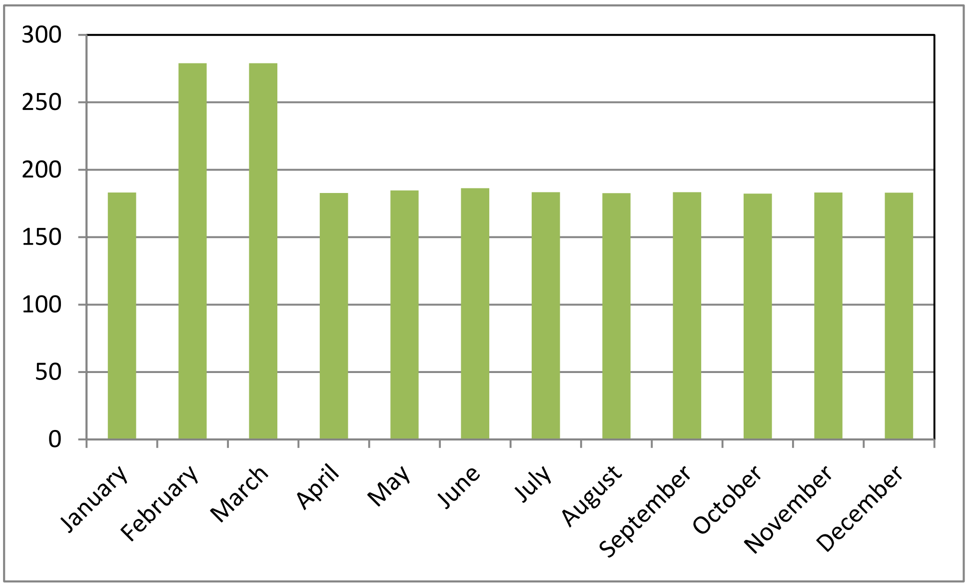
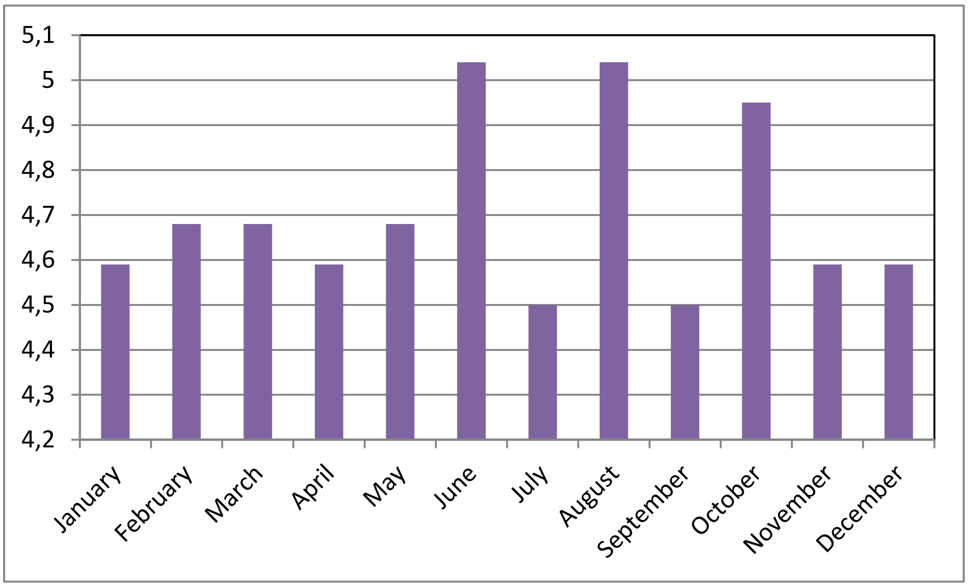
P = Projection

6.1.3 Landslide Risk

Landslide risk analysis includes the cross-correlation of the hazard analysis which triggered by existing historical landslide, slope, geology, and ground water table recharge, and the vulnerability analysis which indicated by population density, land use, role of infrastructure, and population welfare. The landslide risk is analyzed into 2 conditions that are baseline which will be brokendown to monthly analysis, and projection conditions. It is divided into 5 levels that area very low, low, moderate, high and very high

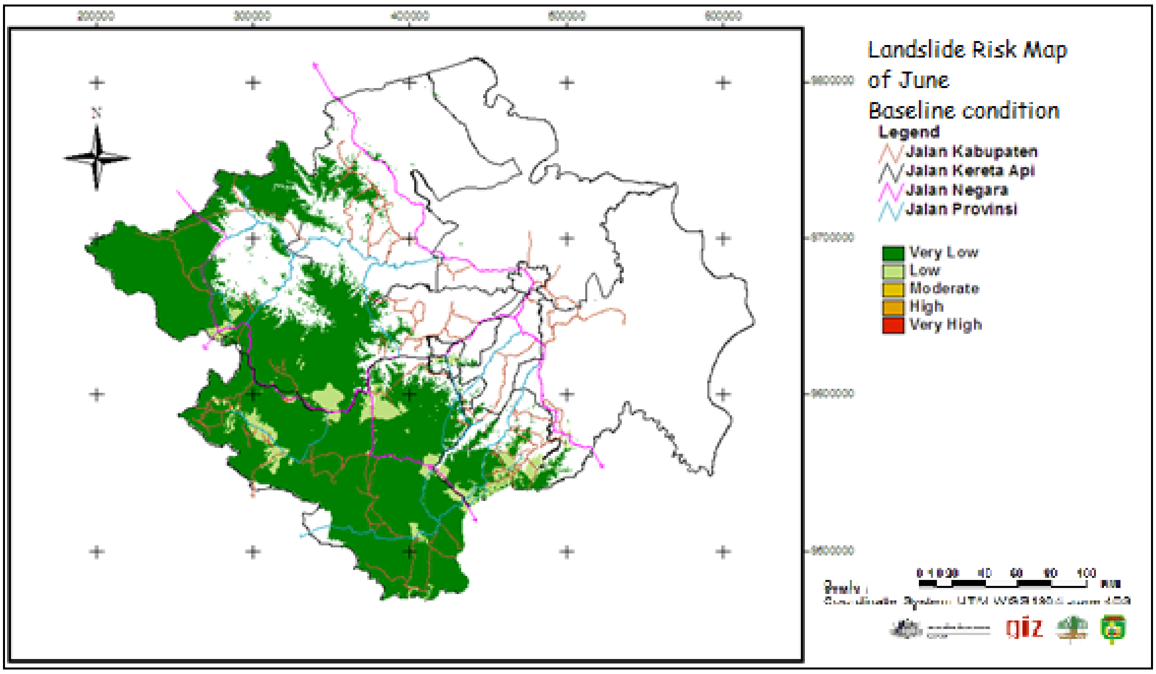
Table 6. 6 Monthly landslide risk of South Sumatera Province

Risk Level	Area (km^2)
Very Low	
Low	

Risk Level	Area (km^2)
Moderate	
High	

Based on the result of monthly analysis of landslide risk in the baseline condition, the highest probability of risk is occurred on the month of June that furthermore will be analyzed in the projection condition. The largest landslide hazard area is arised on the month of February of 31767.41 km^2; on the contrary the smallest landslide hazard area is occurred on May with 31469.94 km^2 area.

Baseline condition



Projection condition

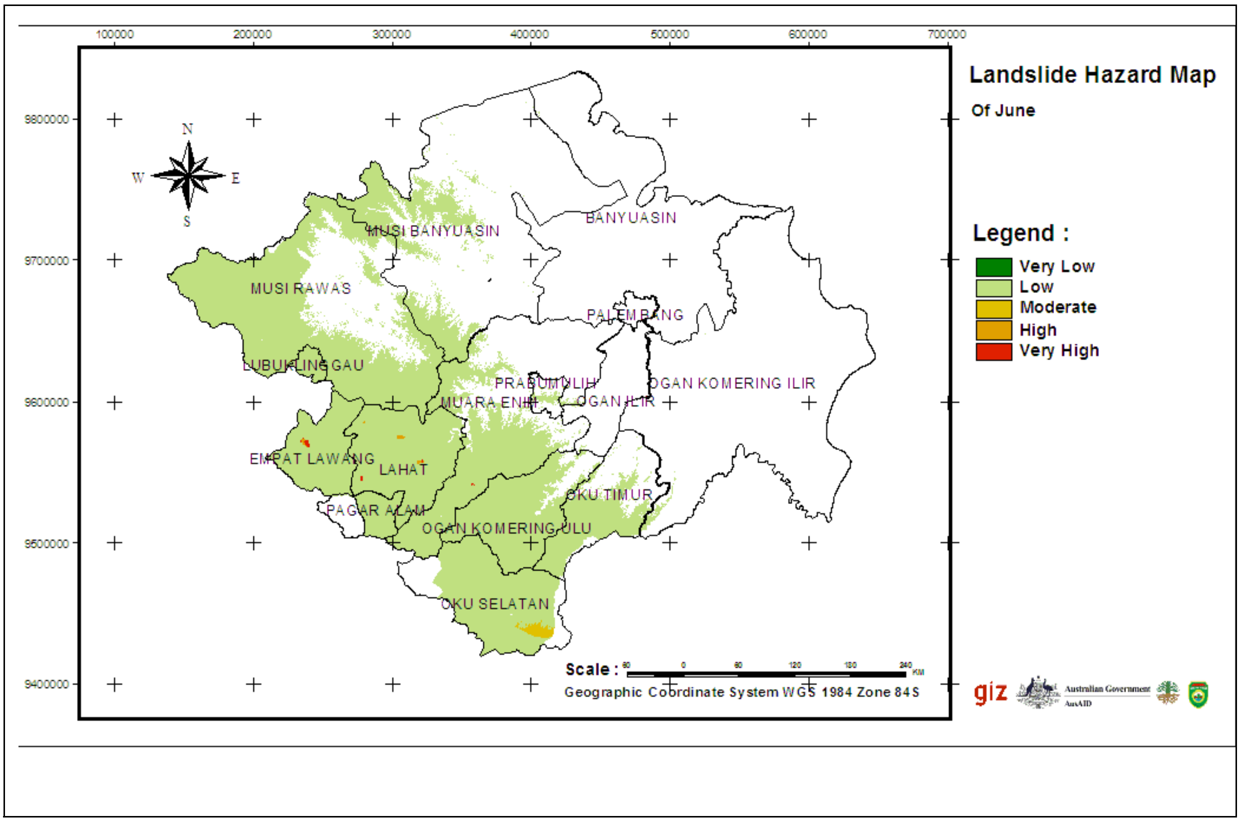


Figure 6. 5 Landslide risk map of South Sumatera Province

According the result of June risk analysis in the projection condition, the risk area will be sharply decreased in the very low, high and very high level while the low and moderate level will be increased significantly than the baseline condition. This condition was caused by land use converstion.

Table 6. 7 Risk map area for baseline and Projection of South Sumatera Province

Risk Level	Area (m^2)	
	Baseline	Projection
very low	29919.78	0,0
low	2798.64	31288.5
moderate	0,0	186.3
high	33.57	5.04
very high	900	0,0

Based on the result of risk analysis in the projection condition that is cross-checked to the administrative map of South Sumatera province, the risk area will be spread into 6 districts that are Muara Enim, Ogan Komering Ulu, Empat Lawang, Oku Selatan, Pagar Alam, and OKU Timur (Figure 6 .6 below).

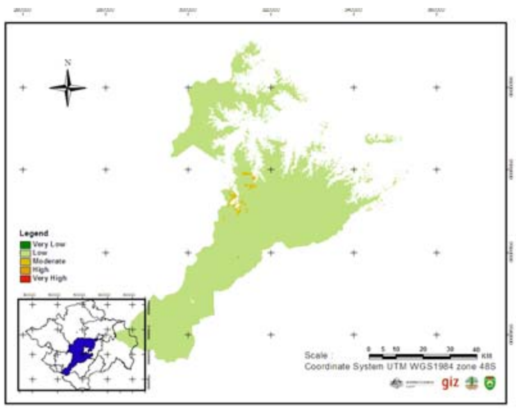
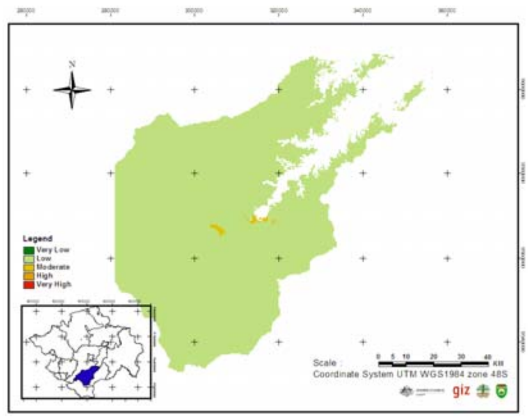
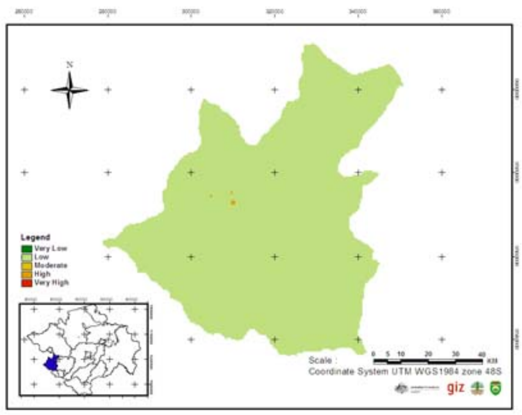
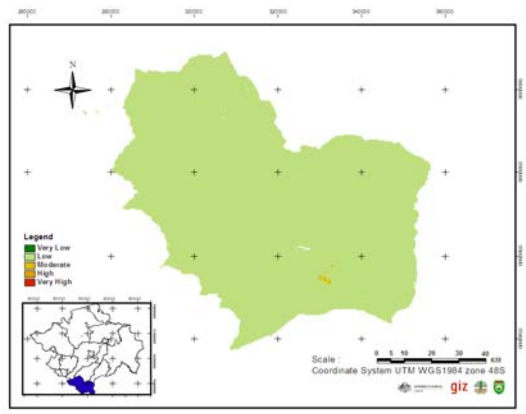
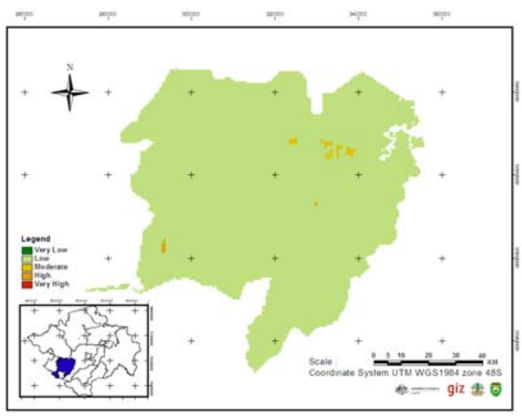
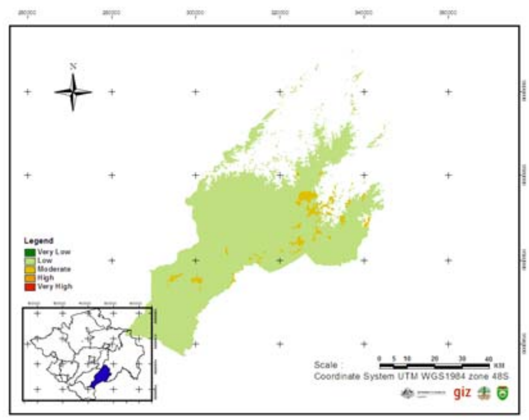
Muara Enim District	Ogan Komering District
	
Empat Lawang District	**OKU Selatan District**
	
Pagaralam District	**OKU Timur District**
	

Figure 6. 6 Landslide risk map (a) Muara Enim, (b) Ogan Komering, (c) Empat Lawang, (d) OKU Selatan, (e) Pagaralam, (f) OKU Timur

According to the result of risk analysis, most of potential landslide area will be spread into 6 districts (Figure 6 .7) where most of the high level of risk will be located in Pagaralam, Empat Lawang, Lahat, and Muara enim districts.

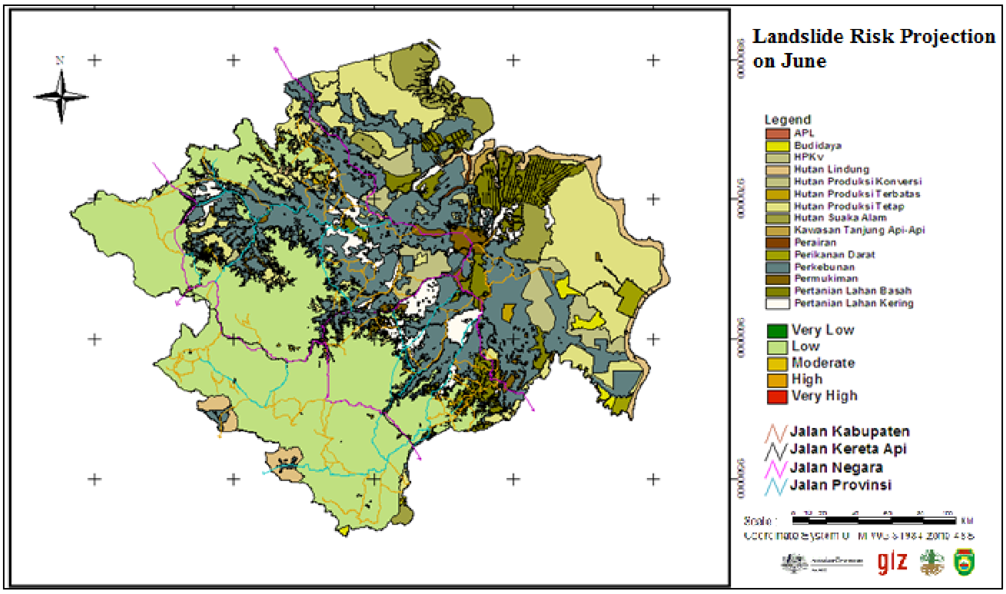


Figure 6. 7 Overlay Landslide risk map to Landuse 2030

Furthermore the result of analysis will be cross-checked to the spatial planning of 2030 of South Sumatera province, the low risk level will cover most of plantation area, forest and agriculture land, while the moderate and high levels will be spread mostly to residential area (Table 6.8)

Table 6. 8 Landslide risk in spatial planning

Landuse	luas (km^2)		
	Low	Moderate	High
APL	0.049		
cultivation	253.53		
HPKv	65.38		
Protected Forest	3268.075	0.42	
Limited Production Forest	1926.29	0.06	
Production Forest	4954.49	14.83	
Green forest	3615.097	0.70	
Waters	62.99	0.41	0.034
Plantation	90579.64	29.36	4.17

Landuse	luas (km^2)		
	Low	Moderate	High
Residential area	1110.10	100.47	0.08
Wetland agriculture	773.51	27.13	0.20
Moors	1094.22	3.74	

VII. ADAPTATION STRATEGY ON WATER SECTOR

7.1 Context for Adaptation

Adaptation to water risk must be a part of Integrated Water Resources Management (IWRM). In this adaptation, climate change supposes to be one of the basic considerations in managing water, as in developing water supply infrastructures, etc. As stated in the AR4, IWRM should be an instrument to explore adaptation measures to climate change. The indicators of the IWMR as stated in the AR4 are: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems, consideration of climate change, and omitting the impediments to the flow of information.

To implement the IWRM in South Sumatra as well as in many regions in Indonesia there are still many constraints. The constraints are unavailability of data, uninvolvement of local government, and the partial authority of central government. For example, the duty and authority of The Ministry of Public Work do not include the maintenance of water sources and water infiltration zones. Some adaptation options from the AR4 are presented in Table 7.1, while Table 7.2 is an example of adaptation technologies for water supplies from the UNFCCC.

Table 7. 1 Some adaptation options for water supply and demand (*Source*: the AR4)

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

Supply-side	Demand-side
	metering and pricing to encourage water conservation

Table 7. 2 Example of adaptation technologies for water supplies (*Source*: UNFCCC, 2006)

Use category		Supply side	Demand side
Municipal or domestic		• Increase reservoir capacity • Desalinate • Make inter-basin transfers	• Use “grey” water • Reduce leakage • Use non-water-based sanitation • Enforce water standards
Industrial cooling		• Use lower-grade water	• Increase efficiency and recycling
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Alter ship size & frequency of sailings
Pollution control		• Enhance treatment works	• Reduce effluent volumes
		• Reuse and reclaim materials	• Promote alternatives to chemicals
Flood management		• Build reservoirs and levees	• Improve flood warnings
		• Protect and restore wetlands	• Curb floodplain development
Agri-cultur	• Rain-fed	• Improve soil conservation	• Use drought-tolerant crops
	• Irrigated	• Change tilling practices	• Increase irrigation efficiency
		• Harvest rainwater	• Change irrigation water pricing

Adaptation options in the tables can be grouped into two types of adaptation, hard adaptation and soft adaptation. Hard adaptation is physical adaptation, such as building reservoirs and other physical structures to adapt. Soft adaptation is intangible adaptation such as development of regulations, early warning system for floods, capturing society’s views, etc.

The followings are recommended adaptation options for South Sumatra which divided according to its risk. Most of those recommendations are physical adaptations.

7.2 Adaptation for water shortage risk

Most of the high-risk zones for water shortage supply in the South Sumatera are located in plantation areas (Figure 6.2 above). Locally, high risk area in Palembang is caused by the increase of population within the degradation of ground water quality.

Water shortage in the South Sumatera is mostly caused by the increase of water need in the plantation areas. Therefore, adaptation options are proposed to maintain the water supply stability so it could cover the increase of the need of water. Those efforts cover the water supply regulation, water resources conservation, dam infrastructure development, rainfall utilization optimization, water surface utilization optimization, water company optimization, and ground water optimization.

Hence, there are 5 adaptation zones related to the water shortage risk in the South Sumatera:

1. Zone I is the Musi river watershed from upstream to downstream as the major river. This zone has all varieties of activities on using water, so the adaptation concept that is proposed as all adaptation of conservation, services, and optimization. The division of zone I into 9 sub-zones is based on the main function of each watershed area in relation to main development activity within each district/city.
2. Zone II is planned to be production forest, plantation, irrigated farming and mangrove forest. Main adaptation option is conservation through regulation and land conservation.
3. Zone III is planned to be non-irrigated farming area, plantation, production forest and settlement. The adaptation option is through regulation, infrastructure, optimization of water company services and water resources conservation.
4. Zone IV is planned to be forest conservation, production forest, farming, plantation, and mangrove forest. The conversion of forest into plantation area is the main factor of hazard level enhancement. Adaptation option is through all the option of optimization of water company services, infrastructure, regulation, and water resources conservation.
5. Zone V is planned to be protected forest. The adaptation option is through water resources conservation.

Table 7. 3 Adaptation zoning of water shortage risk in the South Sumatera Province

ZONE	District/City	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK (R) IN PROJECTION PERIOD	ADAPTATION STRATEGY
I –Musi watershed	• Banyu-asin District • Palem-bang city • Musi Banyu-asin District • Lahat District	Divided into 9 sub-zones. Except zone I-1, other 8 sub-zones are dominated by upland areas. • Zone I-1 from upstream land to downstream land is forestry, plantation, farming, residence and swamp area. The vulnerable zone is high in upstream land of Banyuasin district, caused by the increasing of water need for plantation. While the increasing of population locally happened in Lahat district, Musi Banyuasin district and Palembang city. The degradation of water quality is a particular factor for Palembang city.	- Area of high-hazard zone is wider and hazard level increases into very high level. - Vulnerability is dominated with plantation water need. - High risk is in the Palembang city and downstream of Zone I of Banyuasin district	The adaptation option in lowland through conservation and services, such as: • Water supply regulation for plantation activity • Enhancement of water company services • Utilization of ground water with deep artesian aquifer well development • Water resources conservation Adaptation option in upland through conservation and optimization, as: • Utilization of water surface from river through dam development or hydraulic technology. • Reforestation and other plant conservation • Rainfall harvesting
	▪ Musi Banyu-asin District	• Zone I-2 is Batangharileko projected as dry-farming area, plantation, production forest, protected forest and mining area.	- Medium-level hazard - Vulnerability is dominated with water need enhancement for plantation - Medium-risk is in the south.	Adaptation option is conservation through: • Water supply regulation • Water resources conservation
	▪ District Musi Rawas	• Zone I-3 is Rawas and it is plantation and mining areas and an icrease of population is in the Musi Rawas district.	- An uplift of hazard level into medium. - Vulnerability is dominated with water needs enhancement for plantation. - High-risk is in the Southeast plantation	Adaptation options are optimization, conservation and services such as: • Water company enhancement of services • Land and vegetation

ZONE	District/City	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK (R) IN PROJECTION PERIOD	ADAPTATION STRATEGY
			and mining areas.	conservation for maintaining water resources. • Regulation for water supply by Plantation and Mining Companies • Utilization of ground water and rainfall harvesting • Dam development
	▪ Musi Rawas District	Zone I-4 Lakitan is plantation and mining areas, with population growth as buffer for the Lubuk Linggau city.	- The hazard level up to very high. - Vulnerability is dominated with water needs increase for plantation and effect of population growth. - High-risk is in the area near to Lubuk Linggau city.	Adaptation options are optimization, conservation and services such as: • Water company enhancement of services • Land and plant conservation for water resources maintenance. • Plantation and mining company regulation in water supply • Utilization of ground water and rainfall harvest • Dam development
	▪ Lubuk Linggau city	Zone I-5 Kelingi is a growth city with population growth in the Lubuk Linggau city.	- Hazard level is up to medium level - Vulnerability is dominated with a rising of water need caused by population growth - High-risk is in the Lubuk Linggau city.	Adaptation option are optimization, conservation and services such as: • Water company enhancement of services • Water infrastructure enhancement for farming • Plantation and mining company regulation on water supply • Dam development
	▪ Musi Rawas District ▪ Musi Banyu-asin District	Zone I-6 Semangus is planned to be farming, forest and plantation area. A high vulnerability is in the southeast of Musi Rawas District	- Hazard level is up to high level in Musi Rawas district. - Vulnerability is dominated with a rising of water need for irrigated-farming area and an	Adaptation option are optimization, conservation and services such as: • Water company enhancement of services • Water infrastructure

ZONE	District/City	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK (R) IN PROJECTION PERIOD	ADAPTATION STRATEGY
		as effect of population growth. Also caused by the increasing of irrigated farming area.	increasing of irrigated-farming area. - Medium risk is in Musi Rawas district.	enhancement for farming • Plantation and mining company regulation on water supply • Dam development
	▪ Muara Enim District ▪ Lahat District ▪ Pagar Alam District.	Zone I-7 Lematang is projected as farming, forest, and swamp. This zone has a high-risk in the upstream of Lahat district.	- An uplift of two hazard level into very high in Lahat district. - Vulnerability is dominated with a rising of water need as an effect of population growth. - High-risk is in Lahat District.	Adaptation option are optimization, conservation and services such as: • Regulation of water supply by Plantation Company • Increasing The services of water company • Increasing of the Irrigation infrastructure • Land conservation or reforestation and forest conservation
	▪ Ogan Kome-ring Ulu District ▪ Muara Enim District ▪ Prabu-mulih City ▪ Ogan Ilir District.	Zone I-8 Ogan is planned to be protected and production forest, farming and plantation area. This zone has a high risk as effect of water need rising that is caused by population growth in Ogan Komering Ulu District, Prabumulih city and Ogan Ilir District.	- Very high hazard level uplift in the boundary of Prabumulih and Ogan Ilir district. - Vulnerability is dominated by a rising of water needs as an effect of population growth - High-risk is in the center of city activity of OKU district, Prabumulih and Ogan Ilir district.	Adaptation option are optimization, conservation and services such as: • Regulation of water supply by Plantation Company • Increasing the services of water company • Utilization of ground water and dam development
	▪ South OKU district ▪ East OKU district	Zone I-9 Komering is planned to be protected and production forest, plantation, irrigated-farming and military area. This zone highly risk as an effect of the increase water need for	- An uplift of hazard level, high hazard zone is in the southeast of the East OKU district - Vulnerability is dominated with the increase water need for plantation - High risk is in the southeast of the	Adaptation option are optimization, conservation and services such as: • Regulation of water supply for Plantation company • Increasing the services of water company

ZONE	District/City	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK (R) IN PROJECTION PERIOD	ADAPTATION STRATEGY
		plantation in southeast of the East OKU district.	East OKU.	• Utilization of ground water and dam development • Land conservation or reforestation and forest conservation
II –Sugihan watershed	▪ Ogan Kome-ring Ilir District	This area is planned to be farming, plantation and swamp. A very high hazard zone covered Ogan Komering Ilir district because of a high water need for plantation.	- A very high hazard zone is move from coastal to the west of Zone II - Vulnerability is dominated with a rising of water need for plantation - High risk is in area near to the Palembang city.	• Land conservation and water resources • Regulation of water supply for Plantation company
III – Mesuji watershed	▪ Ogan Kome-ring Ilir District	This area is planned to be farming, forest and shrubbery. Very high hazard zones cover the Ogan Komering Ilir district because of a high water need for plantation.	- Expansion and increasing of hazard level to very high level. - Vulnerability is dominated with a high water need for plantation - High risk area is in the east boundary of East OKU district.	• Regulation of water supply for Plantation company • Irrigation infrastructure development for irrigated farming land • Sustainability of land conservation, forest conservation and reforestation
IV – Banyuasin watershed	▪ Banyu-asin District ▪ Musi Banyu-asin District	The area is planned to be plantation, farming, shrub and swamp. A very high hazard zone covering Musi Banyuasin and Banyuasin District as effect of a high water need for plantation.	- An uplift of hazard level to very high level. - Vulnerability is dominated with a rising of water need for plantation - High risk is in downstream of the Banyuasin District of Zone II.	• Increasing the services of water company • Irrigation infrastructure development • Regulation of water supply for Plantation company • Sustainability of land conservation, forest conservation and reforestation for quantity and the quality of water supply.
V –Bengkulu Bagian Atas watershed	▪ Pagar Alam District ▪ East OKU district	This area is dominated with forest. This zone cover Pagar Alam	- Water supply degradation risk is very low.	Sustainability of land conservation, forest conservation and reforestation for quantity

ZONE	District/City	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK (R) IN PROJECTION PERIOD	ADAPTATION STRATEGY
		District and East OKU district.		and quality of water supply.

Based on adaptation option which is suitable for each zone characteristics above, the implementation criteria is arranged this way (Table 7.4.):

Table 7. 4 Adaptation Implementation Rank of climate changes in South Sumatera Province (Priority scale 1-9)

No	Criteria	East OKU District	Ogan Ilir District	Banyuasin District	Prabumulih City	Ogan Komering Ilir District	Musirawas District	Lubuk Linggau City	Ogan Komering Ulu District	Palembang City	Priority strategy adaptation
1	Large area factor that has a high risk only	1	2	3	4	5	6	7	8	9	Services, Optimization and Conservation
2	Large area factor that has a high to very high risk + water needs factor	1	2	3	5	4					Focus on water resources conservation through water supply regulation for plantation area
3	Large area factor that has a high to very high risk + water supply factor		9	5			4	3	2	1	Focus on services and water supply services in activities center area

7.3 Adaptation for flood risk

Adaptation options for risk flood in South Sumatera assessment are divided into 3 areas based on slope area (Figure 7.1).

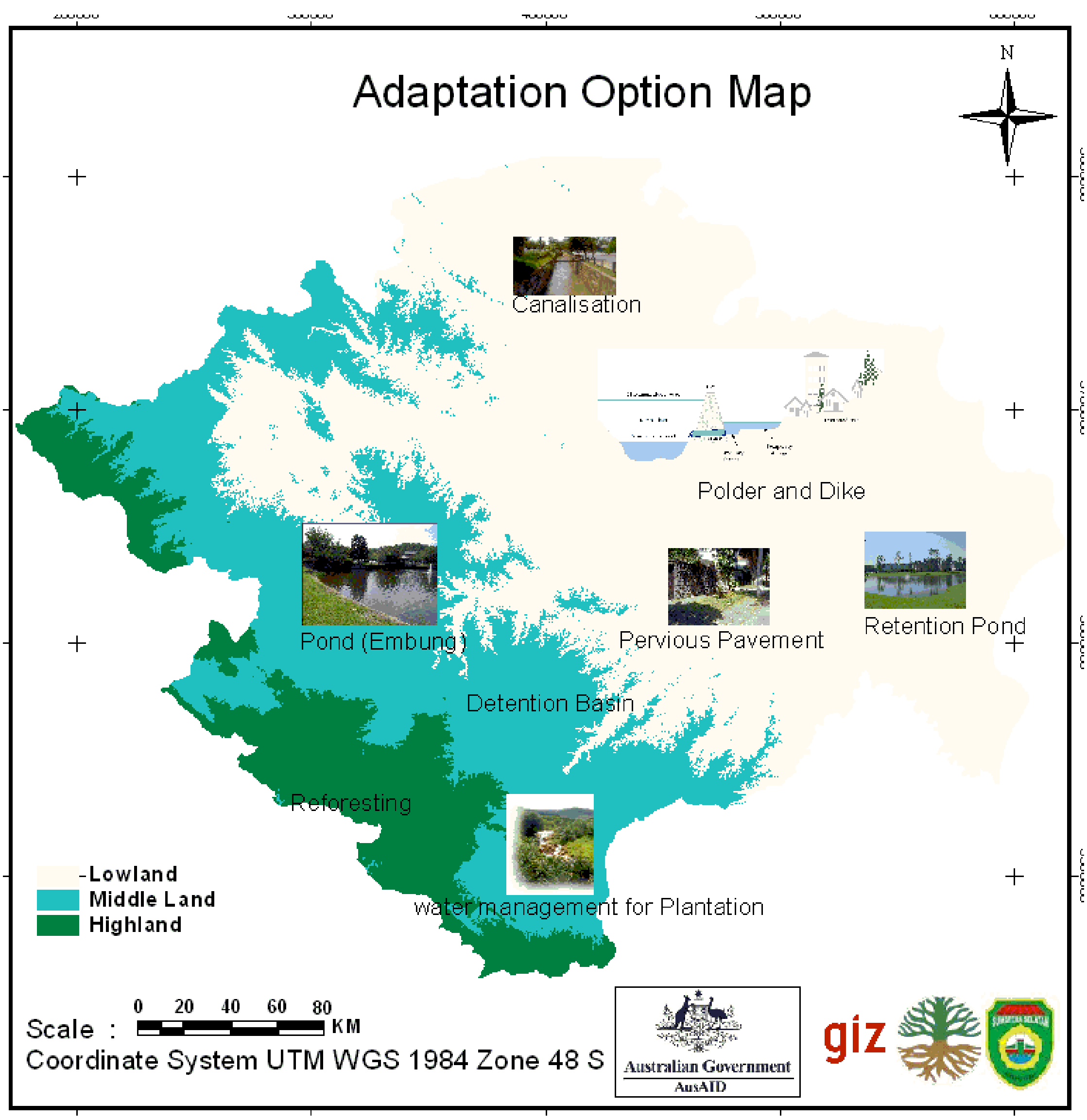


Figure 7. 1 Adaptation Option of South Sumatera Province

a. Lowland

Most of South Sumatera is lying in the lowland area which greatly influenced by sea level rise. Based on this situation, the adaptation options for this area consists of **canalisation, polder and dikes, retention pond, and infiltration measures**.

- Canalisation

Canalisation is the most traditional measure in drainage works. It is obtained by removing obstructions from riverbed, straightening river course and fixing river banks, resulting in an increased conveyance. This option suggested for cities in the lowland area.

- Polder and Dikes

The conception of a polder allows protecting a riverine area from the main river flooding, by constructing a dike alongside the channel. Inside the protected area, it needs a temporary storage basin and an auxiliary channel to convey local waters to this reservoir. Ussually, flap gates are responsible for discharging this reservoir when main river water level falls below temporary inside storage water level. Another possibility lays on the use of pumping stations to complement flap gates discharge capacity.

- Retention Pond

Retention pond is designed to control storm water runoff on a site—and, in some cases, to remove pollutants from the retained water. Storm water control strategies include ditches, swales, ponds, tanks, and vaults. These generally function by capturing, storing, treating, and slowly releasing storm water downstream or allowing infiltration into the ground. A retention (or infiltration) pond collects water as a final storage destination, where water is held until it either evaporates or infiltrates the soil. Detention ponds are designed to temporarily store accumulated water before it slowly drains off downstream.

- Infiltration Measures

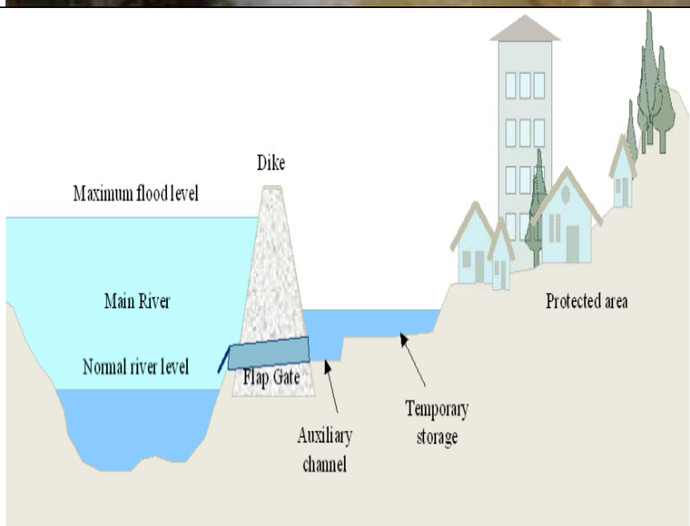
Infiltration measures allow to partially recovering the natural catchment hydrologic behaviour. Infiltration measures may be divided into some different categories. There are Infiltration trenches, Vegetated surfaces, Rain gardens, Porous or permeable pavements.

Infiltration trenches, which are very common infiltration devices, are linear excavations backfilled with stones or gravel. The infiltration trench store the diverted runoff for a sufficient period of time, in order to have this volume infiltrated in the soil. Vegetated surfaces are other type of infiltration measure. Two common types of this kind of structure refer to swales and filter strips. Swales are shallow grassed channels used for the conveyance, storage, infiltration and treatment of storm water. The runoff is either stored and infiltrated or filtered and conveyed back to the sewer system. Filter strips are very similar, but with very low slopes and designed to promote sheet flow. Rain gardens are an especial type of garden designed to increase infiltration potential, presenting also a landscape function. Porous or permeable pavements are a type of infiltration measure where superficial flow is derived though a pervious surface inside a ground reservoir, filled with gravel. Porous pavement upper layer consists of a paved area constructed from open structured material such as concrete units filled with gravel, stone or porous asphalt. Another possibility refers on concrete units separated by grass.

Soil infiltration rates and clogging over time will interfere with the effectiveness of this type of device.

A summary of adaptation options for flood risk is shown in table 7.5 below.

Table 7. 5 Adaptation Strategy of Flood Risk in the Lowland Area in the South Sumatera Province

<table>
<tr><th>Region</th><th>Adaptation Strategy</th><th>District</th><th>Photo</th></tr>
<tr><td rowspan="2">Lowland</td><td>Canalisation</td><td>Banyuasin
Palembang
Ogan Komering Ilir</td><td></td></tr>
<tr><td>Polder and Dikes</td><td>Along the River area in Muara Enim, Prabumulih, Ogan Ilir, Ogan Komering Ilir, Banyuasin, and Musi Banyuasin districts.</td><td>
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Region	Adaptation Strategy	District	Photo
	Retention Pond	Palembang Banyuasin Ogan Ilir	
	Infiltration Measures	Palembang Banyuasin	

b. Middle land

Based on flood hazard model, the inundation area located in around boundary between Middle land and Lowland area. The adaptation options for middle land area are detention basin, ponds, and water management for Plantation.

- Detention Basin

Flood damping is an effective measure to redistribute discharges over time. Increased volumes of runoff, which are resultant from urbanisation, are not diminished, in fact, but flood peaks are reduced. Damping process works storing water and controlling outflow with a limited discharge structure.

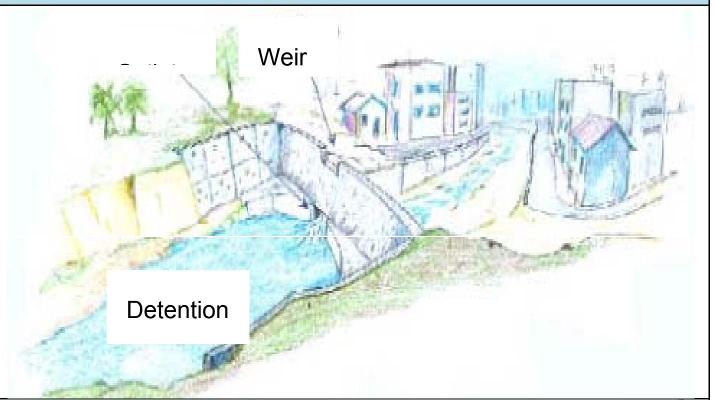
There are several possibilities of application of this kind of measure. Detention ponds may be placed in line with rivers, controlling great portions of the basin, upstream the urbanized area, where occupation is lower and there is more free space to set larger reservoirs. Public parks and squares, as well as riverine areas may be used as detention ponds, opening the possibility to construct multifunctional landscapes.

- Ponds

The Pond provides two primary services. First, the pond has function as a basin that is designed to catch runoff water from higher elevation areas, and retains the runoff before releasing it into streams. Second, the pond will be used as water storage that will have to supply as water source. The pond should be built in near of middle stream area.

A summary of adaptation options for flood risk is shown in table 7.6 below.

Table 7. 6 Adaptation Strategy of Flood Risk in the Middle Land Area in the South Sumatera Province

Region	Adaptation Strategy	District	Photo
Middle Land	Detention Basin	Lahat Muara Enim The western of Musi Banyuasin Ogan Komering Ulu OKU Timur	
	Pond		

c. Highland

Actually in highland no historical flood events that had ever been occur in this area. Adaptation option for this area is reforestation.

Reforestation prevents soil erosion, retains topsoil and favours infiltration. Runoff volumes are reduced and drainage structures keep working efficiently, once a minor quantity of sediments arrives at the system. Renewing a forest cover may be achieved by the artificial planting of seeds or young trees.

A summary of adaptation options for flood risk is shown in table 7.7 below.

Table 7. 7 Adaptation Strategy of Flood Risk in the Highland Area in the South Sumatera Province

Region	Adaptation Strategy	District	Photo
Highland	Forestation	Pagar Alam Empat Lawang Musi Rawas OKU Selatan	

7.4 Adaptation for landslide risk

The area of landslide, divided into two main area, with different types of area, for settlement and non settlement area. Based on landslide historical data from PU Jasa Marga and Departement of Mining and Energy in South Sumatera, there are about thirty four (34) landslided occured along the road.

There are two main adaptation strategies of the climate change impact on landslide at South Sumatera, based on the landuse projection, in non-population area and area with population. In principle, stabilizations are about reducing driving forces and resisting forces, the ilustrations are shown below.

Factor of Safety:

$$Fd = \int_s S_d (W) ds$$

$$Fr = \int_s \tau_r (\mu_w, c', \varphi') ds$$

$$FS = \frac{Fr}{Fd}$$

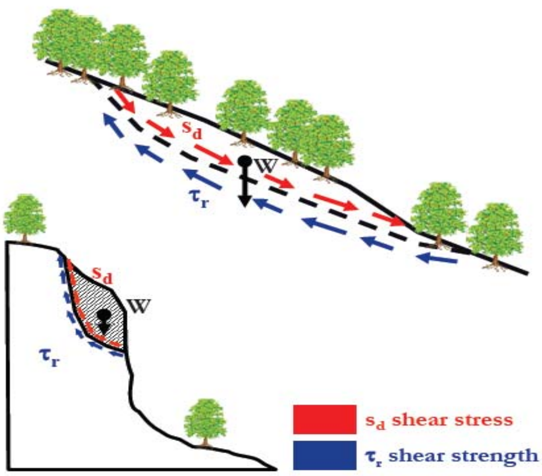


Figure 7. 2 Phylosophy of landslide

The adaptation that considered to be taken in non-population area is reforestation/ a forestation, to cover land with vegetation, the root systems support the soil and provide a stabilizing effect. In area with population, it requires engineering works.

a. Reforestation/ A Forestation

The vegetation (forests, bushes) allows increasing evapo-transpiration and therefore limits infiltration, this is one of efforts to avoid ground water table recharge and soil strength decrease, due to infiltrate of water. Bush and tree vegetation, by its roots, insures a certain superficial stability, but over a limited depth. The effect of interception by the leaves reduces the erosion generated by the rain. In the other cases vegetation has no impact on slope stability, in particular for deep slides.

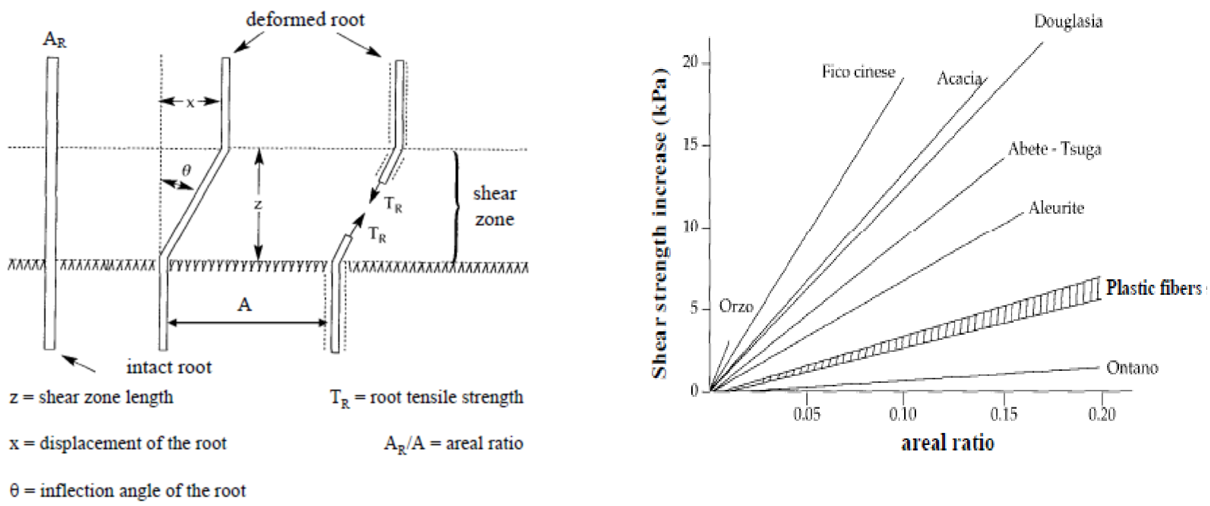


Figure 7. 3 left; shear strength of soil-root system, right; shear strength increase induce by root (Puglisi, 1999)

Figure 7.3 shows shear strength of soil-root system in stabilization, but the roots have a limited stabilizing effect to a few meters depth, if the slide is deeper the forest can bear important movements and even survive.

b. Engineering works

In area with population, meaning in building area there is no more space to take forestation as adaptation action, it requires engineering works. Its adaptation needs a prediction of landslide processes, the choice of strategies and actions to be implemented is a function of economic, social, environmental, cultural, legal, technical and political indicators.

Slow landslides frequently involve huge soil volumes and show velocities from slow to moderate, independently from the stage. Due to both the involved volumes and kinematic characteristics of slow landslides, stabilization works are more suitable than mitigation ones. Particularly, the design of stabilization works can often rely on data coming from monitoring that enhances the modeling of short and long term behavior of the landslides. Rapid landslides are first failure phenomena characterized by the almost lack of premonitory signs and high velocities during the propagation stage. Both stabilization and mitigation works are possible but their design needs a detailed modeling of landslides behavior based on the prevision of the potential occurrence without the help of any monitoring system.

The landslide size, as well as its mechanism, plays an important role in the determination of its sensitivity to climatic conditions, for large slides the movements may appear to be nearly constant whatever the rainfall variations. Whatever the rainfall variations the effect of size is also related to the slide depth for which the hydrogeological conditions have to be determined, for small slides a good correlation between movement and rainfall can often be observed. Deep-seated landslides generally display a fairly continuous movement that is hardly affected by increased seasonal variations. In some cases debris flows in streams flowing on the landslide may show an increased activity. Due to the summer increase of temperature, the evapotranspiration will increase and thus reduce infiltration. There are some engineering works that can be done in South Sumatra, there are stabilization by mass movements, stabilization using anchor, drainage solutions.

To unload the top part of the slope, or to place fill on the toe of slide, the aim is to reduce slope angle. There are buildings of a rigid or semi-rigid structure, if possible with draining capacity, to maintain the unstable mass (gabions, reinforced earth structure, cross-draining masses), and build a structure that avoids erosion at the toe of the slide (also useful for protection against the effects of floods). But, the excavation of the soil cover above the landslide mass may accelerate rainfall infiltration and increase the movements of the sliding mass.

But, the excavation of the soil cover above the landslide mass may accelerate rainfall infiltration and increase the movements of the sliding mass. There is need covered on opened area to avoid water infiltration that causes ground water table recharge as we know, it is one of landslide causes.

In some cases, reducing slope is considered unsuitable at that area, there are other alternatives such as installing passive anchors (bolts or bars set in tension as a consequence of the movements), prestressed anchors, with single or repeated tensioning (in order to compensate the tension losses). The piles or micropiles working in compression may be assimilated to this technique. They can be combined with anchors to avoid the displacement of their head, this method is generally costly with respect to a drainage scheme, but it apparently gives more guarantees (except if the grouted zone is still located in the landslide mass.

Drainage is the most adaptable in many different type of landslide, for any type of landslides (from small to large). Possibility to improve the drainage system in respect to the slope response. The aims of drainage are:

1. To lower the ground water level in the landslide mass
2. To reduce the pressure at the level of the slip surface
3. To reduce the flow affecting the landslide mass

In many cases in which the ground water conditions depend on direct infiltration, the interception of surface run-off as well as sub-surface flow may be useful to reduce the ground water level. However such works have a limited effect on rainfall or snow melt critical conditions that trigger crises in the landslide movements. Type of drainage as follows:

1. Surface drains and ditches
2. Shallow or deep trenches
3. Buttress-counterforts of coarse-grained materials
4. Vertical boreholes with pumping or delf draining
5. Vertical wells
6. Subhorizontal boreholes
7. Drainage galleries or tunnels
8. Vacuum dewatering (wellpoints)
9. Drainage by syphoning

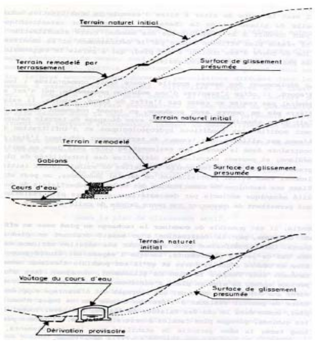
This type of drainage have been used in many countries (Italy, France, Canada, Switzerland)

Based on the historical landslide data from the office Public Work of South Sumatrea Province and The Ministry of Energy and Mineral Resources, there were 34 occurencies along the road network, and most of them were the rockfall type (Figure 7.4)

Figure 7. 4 Rockfall at one of road

Falls are abrupt movements of masses of geologic materials, such as rocks and boulders. A fall starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement take place. The material then descends mainly through the air by falling, bouncing, or rolling. Separation occurs along discontinuities such as fractures, joints, and bedding planes and movement occurs by free-fall, bouncing, and rolling. Falls occur in almost all types of rocks, especially along bedding planes, joints or local fault areas, or fault planes. There are no reliable methods for calculating the stability of a slope with respect to falls. There are several adaptation strategies that can be taken, by messing or netting the slope and boulder fences.

Table 7. 8 Adaptation Options for landslide Risk In the aSouth Sumatera Province

Area	District	Adaptation Option	Photo
1	Empat Lawang, OKU Selatan, Musi Banyuasin, Prabumulih Musi Rawas	Reorestation/ A Forestation	
2	Lahat Muara Enim OKU OKU Timur Lubuk Linggau	Reforestation and engineering works (Scaling, splitting, and removal of unstable rocks removal rocks, Slope regrading, Cut back, Toe weighting; Anchored wall; Appropriate drainage and type of subsurface and deep drainage; Messing and boulder fence)	  

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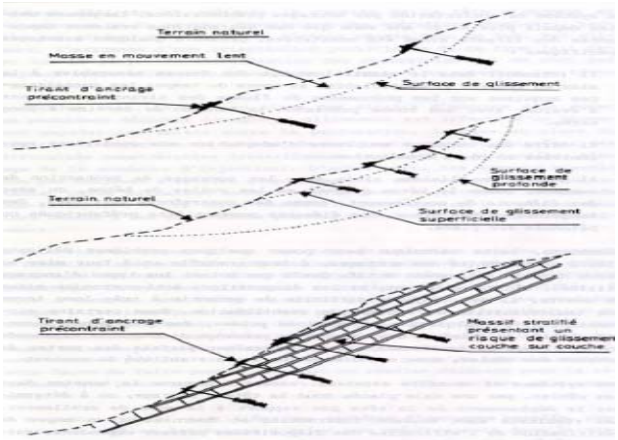
<tr><th>Area</th><th>District</th><th>Adaptation Option</th><th>Photo</th></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>
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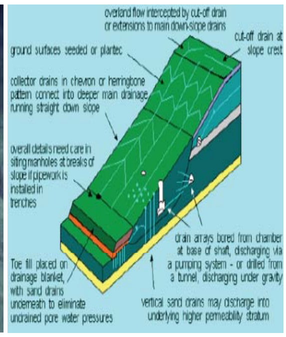
<tr><td> 
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The integrated implementation of landslide stabilization are needed to take the large scale of impact of climate change to landslide, and the potential impact of climate change represents a major cause in the evolution of some landslides. We need detailed knowledge on geological, hydrogeological, and geomechanical condition of sand parameters.

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