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Exploring the use of risk assessment approach for climate change adaptation in Indonesia: Case study of flood risk and adaptation assessment in the South Sumatra province

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Abstract

According to the Assessment Report 4 of Working Group II of Inter-Governmental Panel on Climate Change (2007), there are five approaches in Climate Change Impact, Adaptation and Vulnerability (CCIAV) assessment. Notably, there has been shifting from research-driven approaches to assessments integrated toward policy-making, where decision-makers and stakeholder either participate in or drive the assessment (UNDP, 2005). Unlike the other four approaches which are more research oriented, the risk assessment approach has started to be applied in mainstreaming adaptation option into policy-making globally.

Since 2008, the Government of Indonesia has explored the use of risk assessment approach for climate change adaptation planning. Several case studies have been done including the preparation of a national document namely Indonesia Climate Change Sectoral Roadmap, Climate Change Risk and Adaptation Assessment in the Province of South Sumatra, the Province of Nusa Tenggara Barat, Greater Malang, and the City of Tarakan.

South Sumatra Province is one of the areas in Indonesia which tipped to be prone to the impact of climate change. In the face of climate change impact such as increased temperature, precipitation rate, and sea level, South Sumatra is very vulnerable due to its low-land areas that it may threat coastal, water, agriculture, and health sectors of the province. In terms of temperature, the analysis suggested that there was an increased trend for the last 25 years around 0.31°C in Palembang City and 0.67°C for the whole South Sumatra. In terms of precipitation rate in South Sumatra, the analysis showed that the climate hazard until 2030 will be dominated by climate uncertainty due to the inter-annual variability which could cause extreme precipitation. Based on projection, in the period of 2020 – 2030, the risk of extreme precipitation will actually increase compared to the period 1991 – 2000. Similarly, estimation of

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future sea level rise based on altimeter satellite, model, and tide gauge will be around 0.5 – 0.7 cm annually. As a result, the projection of sea level rise in 2030 will be 13.5±6.15 cm above the sea level in 2000.

The science basis data above then is to be used for flood hazards assessment, which then overlaid with vulnerability map to produce risk map. Based on the risk map, several adaptation options to Flood are identified as follows: Canalization, polder, retention pond, and infiltration measurement for Lowland areas; Detention basin and dam construction for Midland areas; Reforestation for Highland areas. The identified adaptation option above then is mainstreamed into development plans of South Sumatra Province.

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*Keywords:*Climate Change Adaptation, Risk Assessment, Flood

1. Introduction

1.1. Conceptual Background

Climate Change Adaptation (CCA) has recently become a significant development issue in Indonesia since the 13th Conference of the Parties of the UNFCCC in Bali in 1997. Several government documents related with CCA have been published including National Action Plan of Climate Change Mitigation and Adaptation (NAP-CCMA) in 2007 by Ministry of Environment (MOE), Indonesia Climate Change Sectoral Roadmap (ICCSR) by Bappenas (National Development Planning Agency) in 2010, and Indonesia Climate Change Adaptation Strategy by DNPI (National Council for Climate Change). Currently, the Bappenas has also begun the process of formulating the National Action Plan of Climate Change Adaptation (NAP-CCA) in Indonesia to be mainstreamed into the Next National Mid Term Plan (Rencana Pembangunan Jangka Menengah Nasional or RPJMN) of 2015-2019. Several Local Adaptation efforts have also been initiated such as Climate Change Risk and Adaptation Assessment (CCRAA) in the Province of South Sumatra, Lombok Island, Greater Malang and City of Tarakan.

According to the Assessment Report 4 of Working Group II of Inter-Governmental Panel on Climate Change [4], there are five approaches in Climate Change Impact, Adaptation and Vulnerability (CCIAV) assessment. Notably, there has been shifting from research-driven approaches to assessments integrated toward policy-making, where decision-makers and stakeholder either participate in or drive the assessment [5]. Unlike the other four approaches which are more research oriented, the Risk Assessment (RA) approach has started to be applied in mainstreaming adaptation option into policy-making globally. One of major differences of the RA is that the inclusion of the assessment into policy making.

Risk assessment approach has been well developed within the disaster communities and has been increasingly adopted within the Climate Change communities. The most recent special report of IPCC [5] with the title "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" also adopts the concept of RA. The evolution from VA to RA approaches can be traced from the definition of the IPCC Third Assessment Report [3], which defines Vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability (V) is a function of the character, magnitude, and rate of climate variation to which a system is exposed (E), its sensitivity (S), and its adaptive capacity" (AC). Based on this definition, vulnerability is schematized in pseudo-equation: V=ExS/AC. Under this approach, climate change, including climate variability and climate extremes, is included within the E (exposure). More than a decade later, the special report of IPCC [6] defines Vulnerability as "the propensity or predisposition to be adversely affected" and Exposure as "the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected". In conclusion, under IPCC 2012, risk approach has been applied in which climate change (especially weather and climate extreme events) is separated from vulnerability.

On the other hand, Risk Assessment Framework, based on Wisner [7], can be schematized as R=HxV. Under this approach, Hazards is "the natural events that may affect different places singly or in combination" which can be thought as "the manifestation of the agent that produces the loss". This paper derived Hazards from the climate change parameters such as increase of Temperature (T), change of Precipitation (P), Sea Level Rise (SLR) and extreme events (EE). As discussed in more detailed in chapter 2 below, for an example, for Flood Hazards Assessment, Change in Precipitation and EE are converted into flood hazards maps. Vulnerability refers to "the potential for casualty, destruction, damage, disruption or other form of loss in a particular element"[7]. Therefore, under this framework, hazards assessment caused by climate change is firstly done. Then it will be continued with vulnerability assessment. After that risk assessment is conducted. Finally, adaptation option is identified. In this paper, to demonstrate the use of RA for Flood risk and adaptation assessment, the risk approach is applied in the South Sumatra Province below.

1.2. Background to the Case Study of South Sumatra Province

Pattern of physical development in South Sumatra can be seen from the designation of several urban areas to play roles as National Activity Center, Regional Activity Center, and Local Activity Center. Palembang as the capital of South Sumatra Province is assigned as National Activity Center which functions as governmental as well as business center. Therefore, either single or multiple hazards of climate change occurred; for instance from coastal and flood, thus the negative impacts will be experienced by the Greater Palembang. In addition, South Sumatra also has nine Regional Activity Centers ; i.e. Prabumulih City, Lubuk Linggau City, Muara Enim urban area, Baturaja urban area, Lahat urban area, Indralaya urban area, Sekayu urban area, Kayu Agung urban area, and Sungsang urban area. These Regional Activity Centers will also be vulnerable to climate change hazards. Apart from that, strategic infrastructure such as transportation, water system, energy, telecommunication, and other social facilities including development of Tanjung Api-api International Seaport are also prone to the impact of flood and sea level rise.

In year 2010, according to the census, population numbers in South Sumatra Province was 7.446.401 people. The highest populated area was Palembang City, measured 1.452.840 inhabitants (19, 51% from total population). As the lowest one was Pagar Alam with only 161.814 inhabitants (only 1, 70% from total inhabitants). With its 91.806,36 km2 area, population density in South Sumatra Province in year 2010 was 78 people per km2. There were several districts and cities which have population density more than 100 inhabitants per km2; i.e. includes Ogan Komering Ulu Timur, Ogan Ilir, Palembang, Pagar Alam, Lubuk Linggau, and Prabumulih. The highest population density happened in Palembang city, approximately 3627 people/km2.

[1] reports that, in terms of precipitation rate in South Sumatra, the climate hazard until 2030 will be dominated by climate uncertainty due to the inter-annual variability which could cause extreme precipitation. Based on projection, in the period of 2020 – 2030, the risk of extreme precipitation, more than 100 mm/day, will not change compared to current situation. However, it will actually increase compared to the period 1991 – 2000. Similarly [2] estimates future sea level rise based on altimeter satellite, model, and tide gauge will be around 0.5 – 0.7 cm annually. The rate of increase is higher compared to current rate, which is around 0.41 cm annually. As a result, the projection of sea level rise in 2030 will be 13.5+6.15 cm above the sea level in 2000.

Extreme events will also influence the sea level rise, for instance, La-Nina phenomena in the Pacific Ocean may increase sea level around 15 cm compared to sea level at normal condition. In the future, La-Nina phenomena is predicted to be longer and will occur more often which cause in higher and faster speed of waves, and sea level rise. ENSO projection which incorporated El-Nino and La-Nina phenomena suggested that both of them will happen every year which interspersed by normal condition in year 2013/2014, 2021/2022, and 2027/2028. The science basis data above is used for flood hazards assessment. The major hazard is combination of intense rainfall, tidal, and sea level rise. The projection shows that the greatest risk will inundate 43.39% area of Ogan Ilir, 59.80% of Banyuasin, 60.57% of Palembang City. In combination with vulnerability assessment, the risk and adaptation assessment is done as follows.

2. Methods for Flood Risk and Adaptation Assessment

2.1. Flood Hazards Assessment

Flood hazard model is using the GSSHA (Gridded Surface Subsurface Hydrologic Analysis) method. The GSSHA is a grid-based two-dimensional hydrologic model. The model uses administrative map of South Sumatera Province, Digital Elevation Map (DEM), rainfall data, land use map, and geology map. Based on, Setiawan et.al. [6] the complete process is drawn in Figure 1.

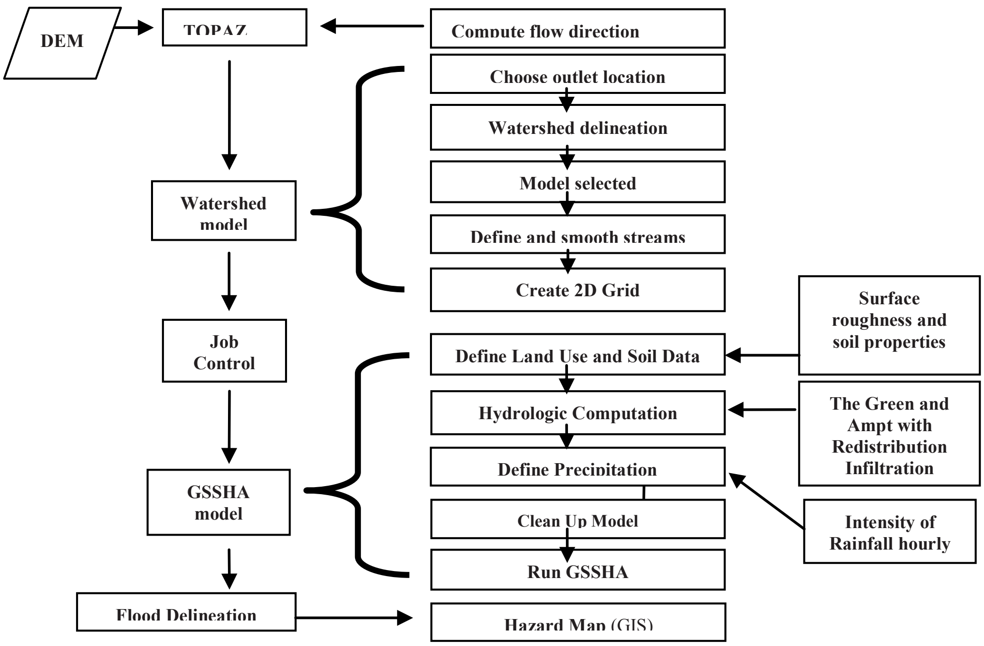


Fig. 1. Framework of flood hazard analysis

2.1.1 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.

2.1.2 GSSHA Model

- Define Land Use and Soil Data
  Surface roughness values are derived from land use type. The value of surface roughness reflects an infiltration capacity of land use type.
- Hydrologic Computation
  Hydrologic computation is an analysis for infiltration rate. This method is based on result from calculating surface roughness parameter of land use and soil properties parameter. The result of this analysis consists of land use grid map, soil type grid map and combine map of land use and soil type.
- Define Precipitation
  Parameters of precipitation are defined as hourly intensity of rainfall. Rainfall data is analyzed into two conditions of baseline and projection.
- Clean Up Model
  This step is intended for checking all of process parameters and hydrologic computation.
- Run The GSSHA Model

2.1.3 Flood Delineation

The result of the GSSHA *model* then is exported to GIS application to produce flood hazard map that covers inundation area, depth and duration of flood.

2.2. Method of Vulnerability Assessment

The indicators that are used to assess the vulnerability to flood hazards are population density, land-use, role of infrastructure, population welfare, and government program as shown in Table 1.

Table 1. Indicators and sources of data for flood vulnerability.

Indicators	Source of 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	Water Supply Company (PDAM) South Sumatra Province 2005 and Landuse 2008
Population Welfare	House type, Income/Capita (Field survey; National census, 2007)
Government Program	Infrastructures (Public Work Agency, South Sumatra Provinve, 2008)

2.3. Method of Risk Analysis

Following the definition of Risk (R) as function of Hazard (H) and Vulnerability (V) or R = f (H,V), risk is produced by overly hazards and vulnerability maps using GIS method.

3. Result

3.1. Hazard Analysis

Flood hazard is classified 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.

The hazard is made into baseline and projection condition. In the baseline condition, flood hazard model shows the depth of flood in range 0.01 m – 1.69 m and 48 hours of maximum duration of inundation. The depth of flood slightly increases in the projection condition to range 0.01 – 2.3 m and 51 hours of maximum duration of inundation. Most flood area is located in the Muara Enim District that has 4 levels of hazard. Inundation area has covered mostly agriculture land in baseline condition. In the projection condition, the flood will cover mostly plantations and agriculture land (see Figure 2).

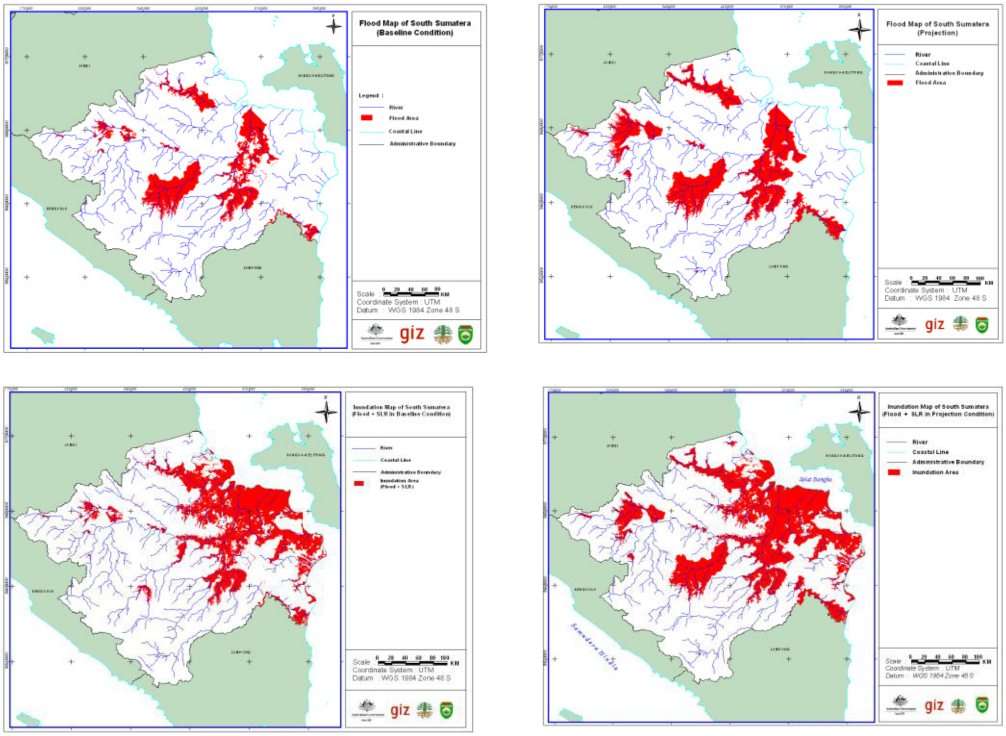


Fig. 2. Inundation (Flood + SLR) map of South Sumatera province

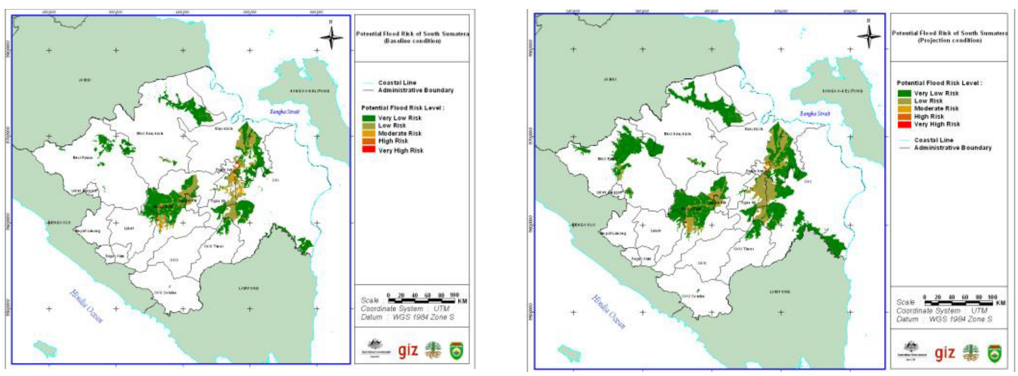
In the projection condition, flooding areas will increase slightly in some regencies and in the other places will increase sharply. The largest flooding area is located in the Ogan Komering Ilir Regency and Muara Enim Regency. The larger inundation could happen if the influence of tidal and sea level rise (SLR) is taken into consideration as seen in the Ogan Komering Regency with 73.28 Ha and the Banyuasin regency with 72.55 Ha are shown in Figure 3.1 and Table 2.

Table 2. Flood area of South Sumatera Province.

Regencies/ Cities	Flood				Flood + SLR (Inundation)			
	Baseline		Projection		Baseline		Projection	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
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
Muaraenim	27.97	31.78	29.91	33.99	31.06	35.29	31.17	35.42
MusiBanyuasin	13.87	9.59	20.57	14.22	17.59	12.16	22.11	15.29
MusiRawas	5.87	4.78	21.22	17.29	5.87	4.78	21.22	17.29
OganIlir	7.14	31.51	9.83	43.39	7.95	35.10	9.35	41.27
OganKomeringIlir	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

3.2. Flood Risk

In the baseline condition, based on percentage coverage of flood risk area, Prabumulih City has the highest flood risk. Meanwhile, in extreme event condition, the highest risk area will be located in Palembang City because 60.57 % of Palembang City area will be flooded. In the projection condition, the highest flood risk area will be located in Ogan Ilir Regency where 43.39 % of area submerged (see Figure 3 and Table 3).



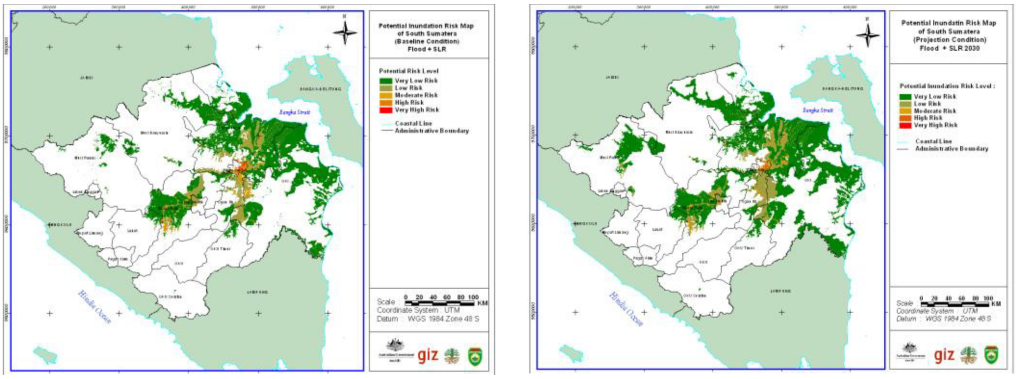


Fig. 3. Map of flood risk of South Sumatera

Table 3. Potential Risk Area of South Sumatera Province

Regencies/Cities	Flood		Flood + SLR (Inundation)	
	Baseline	Projection	Baseline	Projection
	%	%	%	%
OKU Selatan	0.13	0.28	0.13	0.28
Banyuasin	16.96	20.85	57.33	59.80
Muaraenim	31.78	33.99	35.29	35.42
MusiBanyuasin	9.59	14.22	12.16	15.29
MusiRawas	4.78	17.29	4.78	17.29
OganIlir	31.51	43.39	35.10	41.27
OganKomeringIlir	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

3.3 Adaptation Option

Adaptation options for flood risk in the South Sumatera are identified and classified to suite characteristics of the region: lowland, middle-land, and the highland (see Figure 4 and Table 4).

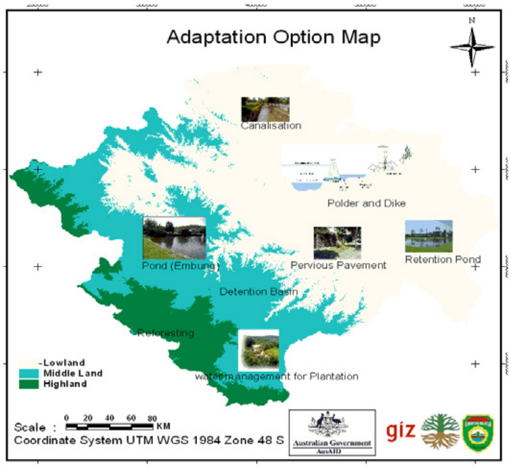


Fig. 4. Adaptation Option of South Sumatera Province

4. Conclusions

Unless adaptation planning decisions are well informed by an improved understanding of current vulnerabilities and the magnitude and timing of future change, the potential exists for insufficient action or mal-adaptation (actions that inadvertently increase vulnerability to climate change). Therefore, to avoid mal-adaptation, actions of adaptation need to be preceded with the risk/vulnerability assessment of climate change. Risk assessment approach provides framework for science based adaptation planning as well as integrating those chosen adaptation programs into the planning process at all level of government from national to local level.

The risk assessment approach has been applied so far in preparing Indonesia Climate Change Sectoral Roadmap (ICCSR) in 2009 which is intended to guide series of National Mid Term Plans (2010-2014, 2015-2019, 2020-2024, 2025-2029). As well as Climate Change Risk and Adaptation Assessment (CCRAA) in the Province of West Nusa Tenggara, South Sumatra and the Greater Malang and the City of Tarakan which are also intended to influence the provincial and local plans.

Therefore, it is arguably that the exploration of risk assessment for climate change adaptation in Indonesia has been successful. The strength of the approach includes primary on a systematic step by step process. However, it has also requires good historical data of climate and social economics aspects which are unfortunately not easily available in Indonesia. Application of risk assessment in the South Sumatra Province was able to delineate the flood risk maps. Based on the risk maps then adaptation option was identified. The next step which needs to be taken but not included in this paper is to prioritize the adaptation actions.

Acknowledgment

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