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Climate change impacts related flood hazard to communities around Bantimurung Bulusaraung National Park, Indonesia

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Climate change impacts related flood hazard to communities around Bantimurung Bulusaraung National Park, Indonesia

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Abstract. Climate variability in a region leads to the increased rainfall intensity during the rainy season and the increasing number of days of the dry season. This condition is happening in most of Indonesia, especially in the South Sulawesi province where it has a quite complex characteristic of the ecosystem. One of them is Bantimurung-Bulusaraung National Park with a special characteristic of the landscape in the form of karst area and the people in the buffer villages located in Maros, Pangkajene Kepulauan and Bone Regions depend on their livelihoods in the park. One of the impacts of climate changes happening around the National Park area is the increasing potential of the flood. The flood mostly occurs due to the high rainfall in the rainy season supported by the characteristics of the land in the form of karst area that very quickly passes the water. Flood hazard analysis in Bantimurung-Bulusaraung National Park area was assessed by using Soil and Water Assessment Tools (SWAT) model on actual condition (climate period 2004-2013) and projection of climate change in the 2030s using scenario RCP 4.5 (rainfall scenario tend to decrease) and RCP 6.0 (rainfall scenario tend to increase). Based on the SWAT model analysis results, it is known that there are areas of the buffer villages of Bantimurung-Bulusaraung National Park, which has a very high level of flood, which the actual condition of the affected area is 10,380.31 ha and on climate change projection of scenario RCP 4.5 covering 9,061.99 ha and RCP 6.0 scenario covering 24,188.26 ha.

1. Introduction

The extreme climate changes raise a variety of issues worsening the anthropogenic factors such as the increasing trend of disasters and other negative impacts on each aspect of human life. The EM-DAT International Disaster Database, Centre for Research on the Epidemiology of Disasters (CRED) (http://www.emdat.be/database) releases that the occurrence of most disastrous events during the period of 1900 - 2015 is related to climate change (related meteorological disasters) is a flood that then other disasters such as drought and landslides. Flood is a flow of river water flow that is relatively larger than normal conditions, due to rain down in the upstream or a certain place continuously. So that cannot be accommodated by the existing river flow, then the water overflows out and inundates the surrounding area [1].The hazard level of a flood affected area can be identified from trend analysis of incident data

[2,3], or by analyzing the character of its territory such as landform, the condition of the left-right slope of the river, type meandering river, and the presence or absence of flood control buildings.

Flooding occurs when rainwater is high enough and falls uniformly throughout the catchment area, then turns into rapidly collected surface runoff at an outlet. Natural water catchment factors such as morphological characteristics of watersheds are factors that affect the speed of surface runoff from all catchments to be collected together at the output points. According to the morphological phenomenon, where each form of land can provide information about the level of flood vulnerability and its characteristic. These characteristics include frequency, extent, and duration of flooded puddles as well as sources of causes of flooding [4]. Climate variability in a region leads to the increased rainfall intensity during the rainy season and the increasing number of days of the dry season. This condition is happening in most parts of Indonesia, including in the South Sulawesi province where it has a quite complex characteristic of the ecosystem. One of them is Bantimurung-Bulusaraung National Park with a special characteristic of landform in the form of karts area. In this area, several villages become buffer zone located in Maros regency administration, Pangkajene Islands and Bone. The buffer village, a community that relies heavily on the existence of Bantimurung-Bulusaraung National Park. So that the natural dynamics that occur in the region is strongly influenced and affect the lives of the community in the buffer villages.

The impact that is often felt by the public is the occurrence of natural disaster phenomena such as floods, which cause harm to the community who live around Bantimurung-Bulusaraung National Park. Therefore, a study related to flood vulnerability analysis in buffer villages around Bantimurung-Bulusaraung National Park is necessary to know the impact of disasters on the community in the buffer villages. The survey of the impacts of climate change on floods around Bantimurung Bulusaraung National Park is the result of the Research and Development Centre of "Natural Heritage, Biodiversity and Climate Change", LP2M of Hasanuddin University. This activity is coordinated by the Ministry of Environment and Forestry and is funded by the United Nations Development Program. This activity is part of the preparation of the Third National Communications, as the Government of Indonesia's commitment to reduce emissions. This impact assessment is expected to illustrate the potential "problems" facing a region for climate change events. As part of the objective of this study is to develop climate change scenarios through several models; assess the hazards of flooding in study areas affected by climate change and affect villages downstream of the river basin in Bantimurung Bulusaraung National Park, mainly associated with karst area which is one of the characteristics of this area.

2. Study Area

Bantimurung Bulusaraung National Park is a conservation area established under the Decree of the Minister of Forestry Number398/Menhut-II/2004. Bantimurung Bulusaraung National Park is divided into 7 (seven) zones. Zone division is the cornerstone of the national park management to divide the territory within the park area which is distinguished according to the ecological, social, economic and cultural functions and conditions of the community. Zoning national park is a process of arrangement of space within the national park into zones, which includes preparatory activities, data collection, and analysis, drafting, public consultation, design, boundary and determination, using analysis of ecological, social, economic and community culture. The division of zones is a process of arrangement of space within the national park into zones that have different designation functions. The zoning of Bantimurung Bulusaraung National Park can be seen in figure 1.

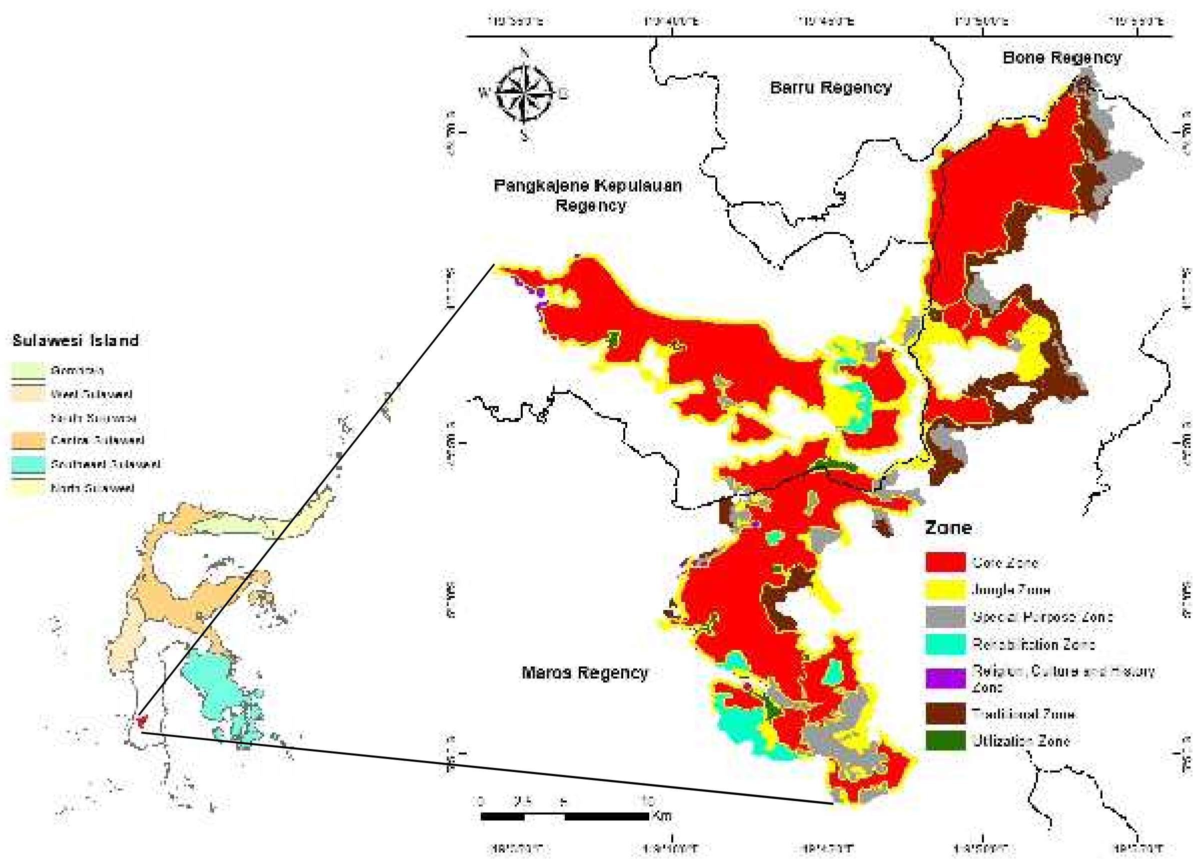

Figure 1. Zoning Map of Bantimurung Bulusaraung National Park

Based on the results of the agreement on the improvement of zonation revision, distribution of zonation of Bantimurung Bulusaraung National Park can be seen in table 1 [5].

Table 1. Zoning of Bantimurung Bulusaraung National Park

No.	Zone	Area	
		(ha)	(%)
1.	Core Zone	22,849.73	52.23
2.	Jungle Zone	10,435.84	23.85
3.	Utilization Zone	374.43	0.86
4.	Traditional Zone	4,374.05	10.00
5.	Rehabilitation Zone	1,331.38	3.04
6.	Religion, Culture and History Zone	191.49	0.44
7.	Special Purpose Zone	4,193.08	9.58
	Total	43,433.85	100.00

Both in figure 1 and table 1 can be observed for the extent of Bantimurung Bulusaraung National Parkis dominated by the Core Zone and the Jungle Zone. Bantimurung Bulusaraung National Parkis part of the Karst Maros-Pangkep region that makes this area a part of karst water system in Maros and Pangkajene Kepulauan regencies that become the water source of the surrounding community. There are about 47 village administrative areas that become buffer villages of Bantimurung Bulusaraung National Park which depend heavily on the existence of this area. Bantimurung Bulusaraung National Parkis a catchment area for several major rivers in South Sulawesi, including the Waianae River (a river affecting the hydrological system of Lake Tempe in South Sulawesi), Pangkep river, Pute river, and

Bantimurung-Maros river. The rivers affect and are influenced by the existence of Bantimurung Bulusaraung National Park. Based on river network data across the Bantimurung Bulusaraung National Park identified about 33 river networks affecting the hydrological system of buffer villages. From the results of field surveys and information from the community, there are several rivers that cause the occurrence of flood disasters. Where, these rivers have a river upstream inside the Bantimurung Bulusaraung National Park and its downstream points to Pangkajene Kepulauan and Maros regencies, as can be seen in figure 2.

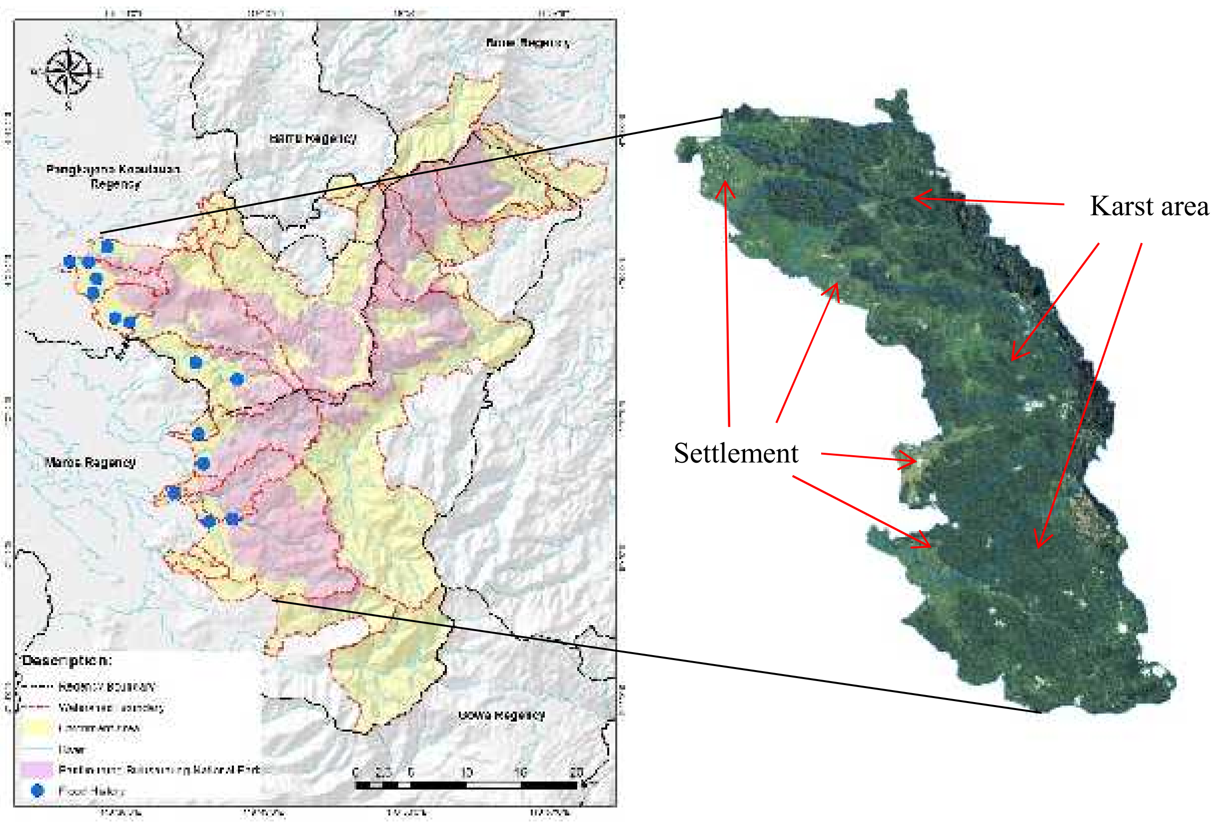

Figure 2. Watershed Area of Bantimurung Bulusaraung National Park and Flood History

From figure 2 above, it can be seen that there are buffer villages that have historically happened flood disaster. The area is influenced by eight streams from 33 streams that affect and influence the area of Bantimurung Bulusaraung National Park. The eight rivers are Pangkajene (Pangkajene 1 and Pangkajene 2), Timbarenreng River, Jennae River, Mangemba River, Leang-Leang River, Bantimurung River and Sambueja River (table 2). The eight streams have upstream which is dominated by karst landform so that the flow characteristics are different from non-karst river flow. Where, the flood disaster that occurred not only caused by the overflow of the surface stream (river) but also caused by overflow underground flow due to karst characteristics that hollow and very quickly pass the water. Thus, a deep study is needed to measure the extent of affected areas and to know the characteristics of flood disasters occurring due to climate variability.

Table 2. Watershed causes flooding around Bantimurung Bulusaraung National Park.

No.	Watershed	Area (Ha)	Percent of Karst Area (%)
1.	Pangkajene 2	1,936.48	28.83%
2.	Timbarenreng	1,801.08	31.46%
3.	Pangkajene 1	1,721.23	39.41%
4.	Sambueja	10,313.99	47.16%
5.	Mangemba	4,945.18	53.47%
6.	Leang-Leang	5,224.63	62.86%
7.	Bantimurung	2,891.13	73.35%
8.	Jennae	7,425.39	75.40%
	Total	36,259.12	56.03%

3. Methods

3.1. Data Collection and Compilation.

Data are the most basic requirement in describing the region to gain a brief overview of physical and socio-economic (non-physical) in the area. They are also as an input to perform vulnerabilities, and risks analysis related to climate change impact spatially. The collected data consist of secondary and primary data, either in the form of spatial data or non-spatial. Spatial data are used to characterize the physical environment of study area such as actual daily climate data, land use data, morphological catchment area, slope/topography data, infrastructure path data, landforms data geological data and type of soil. Non-spatial data were collected from various institutions such as the Government of South Sulawesi, the Government of Maros and Pangkajene Kepulauan Regency.

3.2. Climate Related Hazard.

Analysis of hazardous level in the Bantimurung Bulusaraung National Park and its surrounding is done by identifying the types of hazards related to climate change in the region. Types of hazards that were analyzed in this study related to hydro-meteorological disasters are floods. The most decisive parameter in this study is climate components. The level of hazard is determined using simulation under actual climatic conditions and climate change scenarios. Actual climate data were taken from Global Weather Data from 2004 to 2013 while climate change simulated using RCP 4.5 and RPC 6.0 scenarios.

Each selected model scenario will describe specific characteristics of the region in projecting climate. Climate model GFDL-ESM2M was selected for RCP 4.5 situation indicating a pessimistic model where the rainfall predicted to decrease in the future. While the GISS climate model-E2-R ** was selected for RCP 6.0 scenario indicating an optimistic model where future rainfall predicted to increase. Climate change was analyzed to perform the prediction of the extent of rainfall as a climate component. Limitations of baseline data in the validation of the accuracy of climate projection such as temperature, relative humidity, solar radiation, and wind speed cause only rainfall data were predicted. Improvement, the analysis of climate change, will be needed to obtain more information related to the level of hazard for certain disaster that would occur in the future.

Projection analysis of climate change was done with the help of software Statistical Bias Correction for Climate Scenarios (SiBiaS) version 1.1. SiBiaS is software used to ease the use of GCM CMIP5 output data and the process of its bias correction. The statistic bias correction technique in this program consists of two choices that are by using the delta method and distribution correction method. Delta method was used in this study. Delta method is the simplest downscaling method and usually are used in the preparation of climate change scenario for local scale study. Delta method is a bias correction process through addition or multiplication approach of Δµta value and observation value at baseline period as in the following equation model:

$$X_{cor,i} = X_{o,i} + \mu_p - \mu_b \quad (1)$$

$$X_{cor,i} = X_{o,i} x \frac{\mu_p}{\mu_b} \quad (2)$$

Xcor, i value is corrected model value and X0, i is observation value at baseline period. µ is the average value in which b and peach indicate simulation data of baseline period and projection of the model. Equation (1) is generally used for data on temperature, whereas equation (2) is used for rainfall data correction [6].

3.3. Flood Hazard Model.

To know the areas affected by the flood hazard, the analysis is to develop a mapping-based model. Hazard component mapping is done by scoring method supported by the Soil and Water Assessment (SWAT) model analysis (the SWAT model working mechanism is shown in figure 3). For scoring, method is analyzed by giving value for each parameter. Determination of component classification level is divided into several class intervals using the Sturgess equation. The description of the components of the flood hazard analyzed include landform, drainage on left-right river slope, maximum monthly rainfall at actual condition (Period 2004-2013) and climate change projection scenario RCP 4.5 and RCP 6.0 (Period the 2030s / refers to duration of regency spatial planning in the study area), land use, meandering river and water control building [1]. From the results of this scoring analysis will be known how big the coverage area affected by flooding.

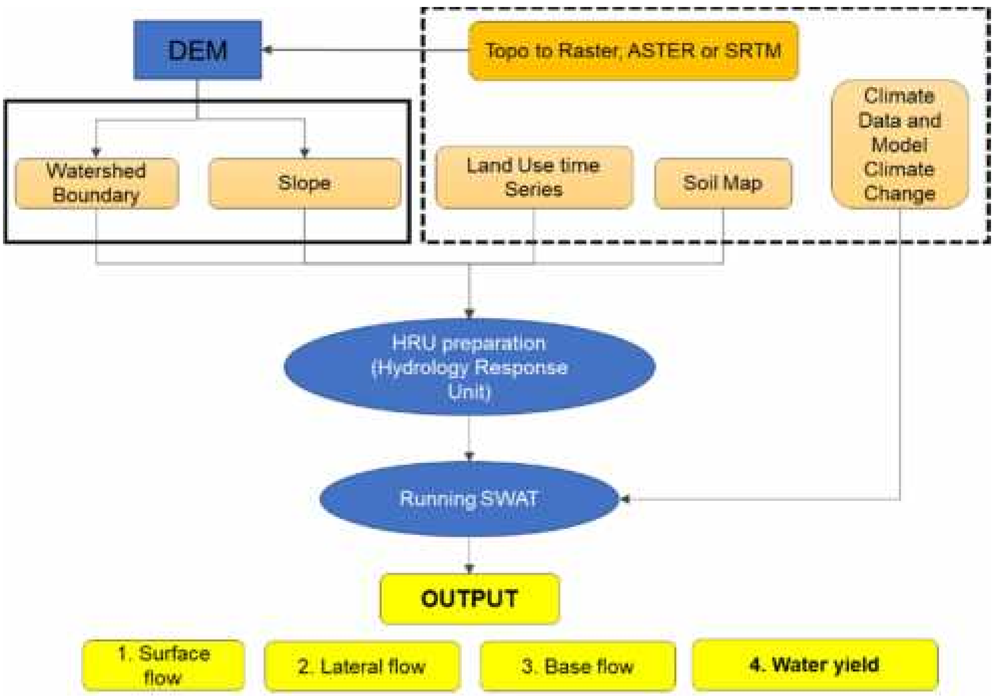

Figure 3. SWAT Model Working Mechanism

Once the affected areas are identified, they will then be analyzed for the flow characteristics of each affected area by influencing watersheds, using the SWAT model of actual condition climate data (Period 2004-2013) and climate change projection scenario RCP 4.5 and RCP 6.0. The SWAT model [7, 8] was chosen for various reasons. This model combines climate change data and containment functions into simulated river basin impacts [9] and can combine climate data inputs from several climate change scenarios to study river basin hydrology [10,11]. This simulation model can describe the phenomena and characteristics of watershed hydrology by considering climate, soil, topography, river characteristic, and land cover aspects. The stages in the simulation model consist of three work stages: (1) input parameters, (2) current process models, and (3) the definition of output simulation models related to flood hazard.

4. Result and Discussion

4.1. Climate Change in Bantimurung Bulusaraung National Park.

The climate scenario used in this study is similar to that contained in the Fifth Assessment Report (AR5) issued in 2013 [12]. This scenario is the latest generation of climate change scenarios known as Representative Concentration Pathways (RCP). The RCP scenario types used are RCP 4.5 and 6.0. Scenarios RCP 4.5 and scenario 6.0, by current policies and conditions, particularly in Indonesia, for common emission scenarios.

In the RCP 4.5 scenario, the climate model of GFDL-ESM2M is a pessimistic climate model where in the future it is predicted that rainfall will decrease. While the scenario RCP 6.0 used climate model GISS-E2-R ** is an optimistic climate model wherein the future predicted rainfall would increase. Changes in actual rainfall patterns and climate change scenarios in the Bantimurung Bulusaraung National Park is presented in table 3, and a visualization of the distribution of rainfall is presented in figure 4, where the color gradation illustrates that the lighter blue the region will be dry, the darker the region will get wetter.

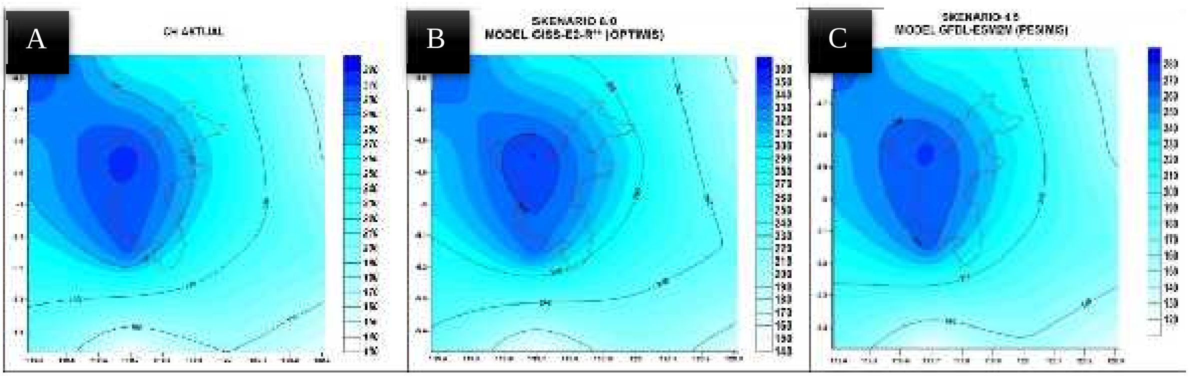

Figure 4. Actual Rainfall (A) dan Simulation of Rainfall Change-based on RCP 4.5 Scenario using GFDL-ESM2M Model (B) and RCP 6.0 Scenario using GISS-E2-R** Model (C) (average in mm/year)

Table 4. Monthly Average of Rainfall Pattern Changes (mm) for Actual Condition, RCP 4.5 using Model GFDL-ESM2M and RCP 6 using Model GISS-E2-R **

Month	Rainfall Actual	RCP 4.5		RCP 6.0	
		GFDL-ESM2M	Rainfall Change	GISS-E2-R**	Rainfall Change
Jan	400.66	359.99	-40.67	389.24	-11.42
Feb	328.91	260.87	-68.04	303.27	-25.64
Mar	315.36	288.08	-27.28	342.39	27.03
Apr	295.76	274.25	-21.51	304.06	8.3

Month	Rainfall Actual	RCP 4.5		RCP 6.0	
		GFDL-ESM2M	Rainfall Change	GISS-E2-R**	Rainfall Change
May	207.07	234.26	27.19	241.89	34.82
Jun	176.34	144.83	-31.51	195.1	18.76
Jul	122.81	80.65	-42.16	184.21	61.4
Aug	61.81	36.42	-25.39	71.83	10.02
Sep	49.8	33.51	-16.29	60.63	10.83
Oct	132.03	67.81	-64.22	167.97	35.94
Nov	265.26	238.14	-27.12	362.86	97.6
Dec	403.29	366.93	-36.36	464.85	61.56

4.2. Flood Hazard.

Floods in buffer zone areas are floods caused by disruption of watershed hydrological systems affecting buffer villages. Based on the results of field surveys obtained information from the community that the incidence of flooding in this region occurred due to the overflow of water from the river in the rainy season with high rainfall intensity and occurred in the river border with flat and sloping slopes. Falling rain cannot be entirely accommodated by the river body so that it overflows into puddles, as a result of the utilization of border rivers in the region into residential areas.

Based on the Global Weather data analyzed, information was obtained that the maximum daily rain intensity that occurred during the period 2004-2013 in the Bantimurung Bulusaraung National Parkis very high (> 150 mm) in the rainy season, as well as climate change scenario results in the 2030s, use the GFDL-ESM2M climate model for RCP 4.5 scenarios and climate models GISS-E2-R ** for RCP 6.0 scenarios. This condition illustrates the high volume of water that will fall in the area of Bantimurung Bulusaraung National Park. If the ability of Bantimurung Bulusaraung National Park especially the water bodies on the surface cannot accommodate the volume of water, then there is a flood of water in some places. Thus, future anticipation for disaster preparedness related to floods can be done in the months with high rain intensity. Natural factors are so extreme that supported by local custom around Bantimurung Bulusaraung National Park who built settlements close to surface water sources (such as rivers), causing community living in the region is very sensitive to the incidence of flooding.

Several locations become flood concentration in Bantimurung Bulusaraung National Park. Based on the results of scores on some flood parameters such as landform, drainage on the left-right slope of the river, maximum monthly rainfall, land use, meandering rivers, and water control buildings, obtained flood hazard levels with the most vulnerable classes in the study areas presented in table 5.

Table 5. Flood Affected Villages

Regency	District	Village	Affected Area (Ha)		
			Actual	Model GFDL-ESM2M (RCP 4.5)	Model GISS-E2-R (RCP 6.0)
Maros	Bantimurung	Kalabbirang	450,26	450,26	457,29
		Leang-Leang	703,84	703,64	703,64
	Camba	Pattiro Deceng	44,79	44,79	44,79
		Timpuseng	4,49	4,49	4,49
		Cempaniga	47,64	37,79	37,79
		Mario Pulana	76,21	20,36	20,36
	Cenrana	Baji Pamai	64,72	64,72	64,72

Regency	District	Village	Affected Area (Ha) Actual	Model GFDL-ESM2M (RCP 4.5)	Model GISS-E2-R (RCP 6.0)
		Laiya	243,40	134,28	3.354,23
		Lebbotengae	112,64	112,64	1.396,04
		Limam Poccoe	229,88	229,88	630,89
		Rompe Gading	10,78	10,78	10,78
	Mallawa	Bentenge	98,97	11,92	11,92
		Gattareng Mattinggi	12,91	1,66	1,66
		Paddaelo	92,78	12,10	12,10
		Samaenre	99,30	12,64	12,64
		Uludaya	37,23	3,25	3,25
		Wanua Waru	19,33	2,01	2,01
	Simbang	Jenetaesa	601,69	601,69	602,73
		Samangki	416,74	416,74	1.161,22
		Sambueja	575,37	575,37	823,85
	Tompu Bulu	Bonto Manai	348,94	348,94	2.575,81
		Bonto Manurung	649,65	25,02	5.545,55
		Toddolimae	375,77	375,77	1.848,71
Pangkep	Balocci	Tompo Bulu	0,25	0,25	0,25
		Balleangin	191,36	191,36	191,36
		Balocci Baru	208,95	208,95	208,95
		Kassi	706,42	706,42	706,42
		Tonasa	338,38	338,38	338,38
	Minasatene	Kabba	374,47	374,47	374,47
		Panaikang	464,15	464,15	464,15
		Biraeng	543,10	543,10	543,10
		Bontokio	383,69	383,69	383,69
		Kalabbirang	384,06	384,06	384,06
		Minasatene	237,90	237,90	237,90
	Pangkajene	Pabundukang	247,09	247,09	247,09
	Tondong Tallasa	Bantimurung	18,20	18,20	18,20
		Bulu Tellue	360,31	356,63	356,63
		Malaka	151,53	151,53	151,53
Bone	Lappariaja	Mattampa Walie	416,16	237,19	237,19
	Tellu Limpoe	Bonto Masunggu	6,10	6,10	6,10
		Polewali	9,70	0,74	1,26
		Samaenre	21,17	11,03	11,03
Total			10.380,31	9.061,99	24.188,26

Based on table 5 it can be seen that there are 42 buffer villages prone to flood. The details consist of 23 villages located in 6 districts on Maros Regency,15 villages in 4 districts on Pangkajene Kepulauan Regency and 4 villages in two districts on Bone Regency. Visually the impact of flood disaster around Bantimurung Bulusaraung National Park is presented in figure 5 below.

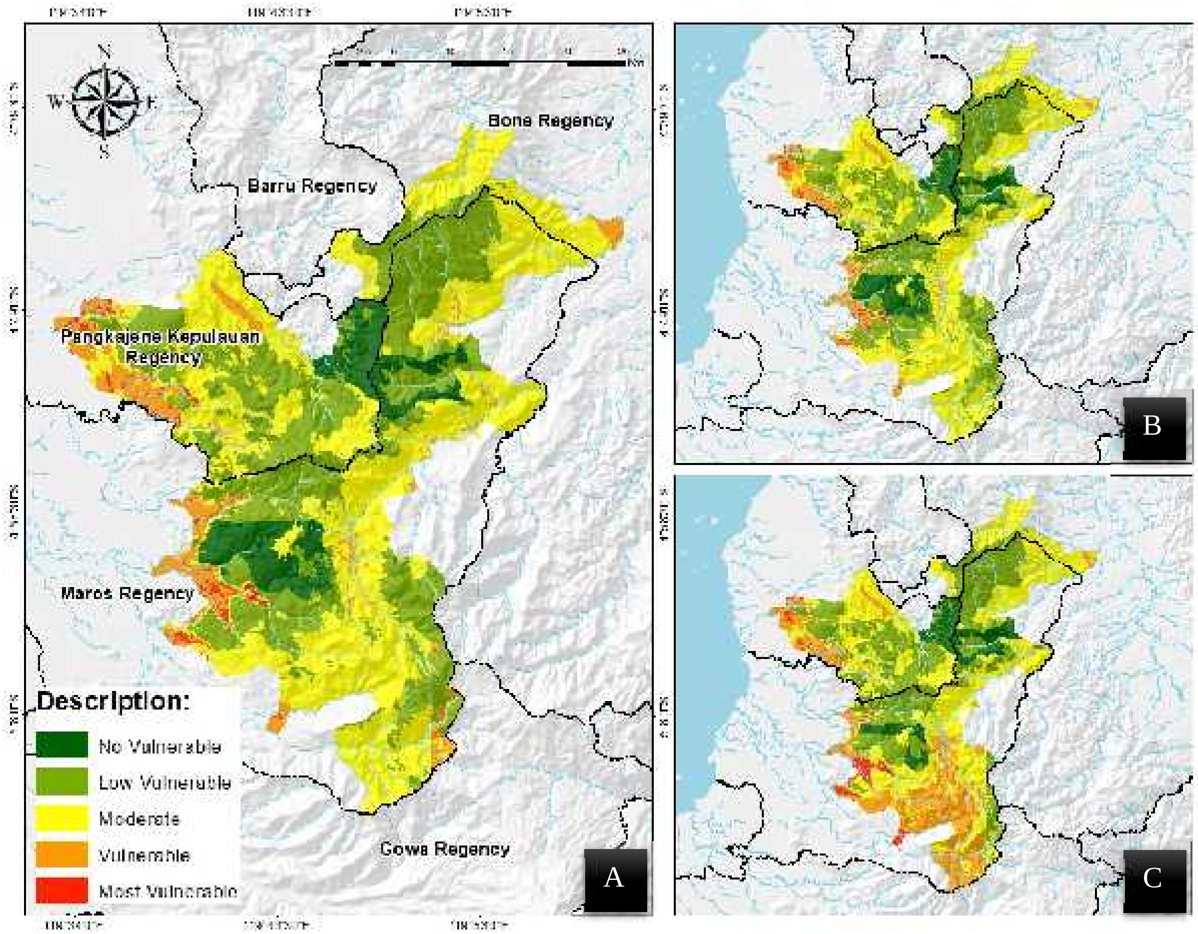

Figure 5. Flood Hazard on Actual Condition (A), RCP 4.5 Scenario using GFDL-ESM2M Model(B) and RCP 6.0 Scenario using GISS-E2-R** Model (C)

Based on figure 5, it can be seen that the potential distribution of potential hazard floods in the future will be wider if the assumptions used are the RCP 6.0 scenario using the GISS-E-R ** model (the optimistic model where rainfall is increased in scenario). Comparison of flood hazard levels in actual conditions and scenario RCP 6.0 gives an illustration that in the future the level of flood hazard will be wider and increasing. From the visual depiction can also be seen that the flood-affected areas in buffer villages are a village on the west side of Bantimurung Bulusaraung National Park.

The high level of flood hazard on the west side of buffer villages is influenced by the characteristics of the landscape from the river flow pattern in the region. It is known that the western side of the area is influenced by eight streams from 33 streams that affect and influence the area of Bantimurung Bulusaraung National Park. The eight streams have upstream which is dominated by karst so that the flow characteristics are different from non-karst river flow. The result of analysis of hydrological response from eight streams using the SWAT model obtained by river regression coefficient value on all river flow above 50. The value is the ratio between the maximum discharge occurring during the wet season and the minimum discharge occurring during the dry season, where the value above 50 gives an illustration of the imbalance of the water system of a river drainage that can be caused by the high transfer of land function in the region or the morphological character of the river itself. The average monthly discharge data for the eight streams are presented in figure 6.

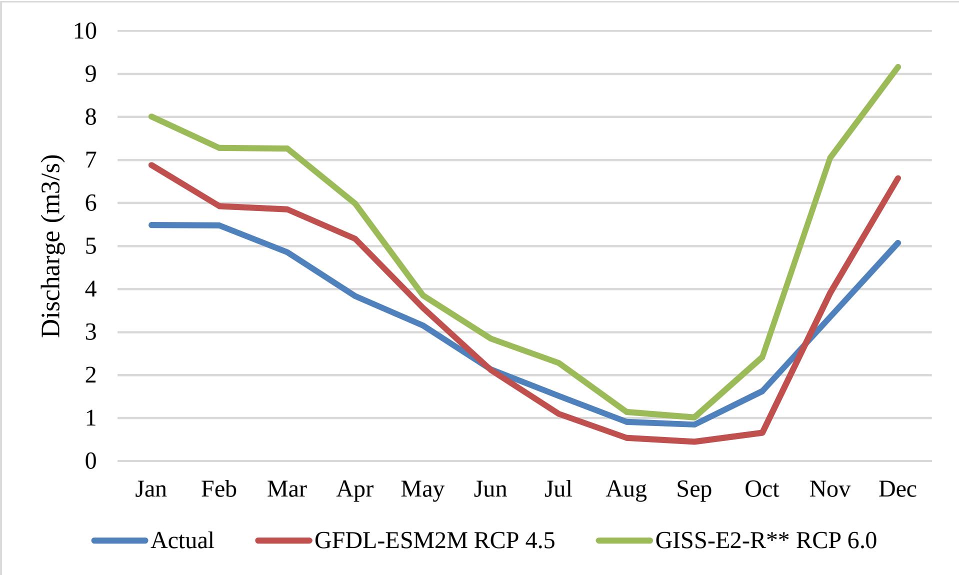

Figure 6. Flow characteristics on Eight Rivers in Bantimurung Bulusaraung National Park

The results of interviews with communities residing in buffer villages, it is known that flood events often occur in recent years in the region with flood heights between 50 cm to 100 cm. Flood events in this region is caused by the high intensity of rainfall in the rainy season and also because it is influenced by landscape character in the region, where the size of the width of the upstream river is quite large and towards the middle part which is a wide settlement narrow residential area, because the landform influences it is karst as well as the morphology of the watershed with the shape of the average watershed somewhat elongated (slightly oval with the value of Circulation Ratio 0.125-0.25). Where according to [13] that this type of watershed shape has a very rapid peak discharge characteristics, but also rapidly decreases. So, the overflow that occurs temporary nature but quickly. Therefore, the flood characteristic of this region is in need of special handling.

5. Conclusions

Floods in buffer zone areas are floods caused by the disruption of watershed hydrological systems. Based on the simulation of the impact of climate change, it is known that the potential distribution of potential hazard floods in the future will be wider if the assumption used is the RCP 6.0 scenario using the GISS-E-R ** model. From the analysis, it is found that there are 42 buffer villages prone to flood. The high level of flood hazard in buffer villages, especially on the west side, is influenced by the characteristics of the landscape of the river flow pattern in the region. It is known that the vulnerable area is influenced by eight river basins having upstream which is dominated by karst landform, so the flow characteristics are different from non-karst river flow. Where the flood disaster that occurred not only caused by the overflow of the surface stream (river) but also caused by overflow underground flow due to karst characteristics that very quickly pass the water.

Acknowledgment

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