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SPATIAL ANALYSIS OF FLOODING HAZARD AND IT'S IMPLICATION TO WATERSHED ECOSYSTEM RESILIENCE (A CASE STUDY FROM WANGGU WATERSHED EASTERN INDONESIA)

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ABSTRACT

The combination of climate change and deforestation in the upstream of the Wanggu Watershed has led to an increase in the intensity and scale of flood disasters. This study aims to: (1) analyze the spatial distribution of the potential flood hazards; (2) analyzing driven factors forming potential flood hazards; (3) formulating policy implications to increase watershed resilience to flood hazards. The results of this study indicate that the potential for flood hazards was dominated by medium classes of 14394 ha (47.04%), followed by low and high hazard classes respectively 10148.13 ha (33.16%) and 6057.31 ha (19, 80%). The combination of land-use change and extreme rain was thought to be the main trigger for the Wanggu River overflow event in 2017. The results of land-use changes over the past 20 years showed that the average change in forest covers an area of 329.84 ha per year (1.08%), at the same time there was an increase in bush area, dryland agriculture, settlement, and bare land, respectively 0.41%, 0.36%, 0.13%, and 0.23%. Furthermore, climatic data showed that during 2017 the average annual and monthly rainfalls were 1050.6 and 35.0 mm respectively, with an average of and 23 rain days. During the flood events on 11-13 May 2017, the average daily rainfall had reached 70 mm. The reduced protection of vegetation and high rainfall intensity had resulted in a decrease in infiltration capacity and cause a drastic increase in surface flow. This condition had triggered the river flood discharge. The policy implications that can be carried out by local governments to increase the resilience of watersheds are upstream land use regulation, increasing the size of river green open space and conservation of water catchment areas as well as encouraging the implementation of urban green infrastructure approaches.

Keywords: *Flood, Hazard, Land Use Change, Extreme Rain, Soil Types, Topography, Distance from the river, Wanggu Watershed.*

I. INTRODUCTION

The combination of climate and land-use change due to population growth pressures and socio-economic development has accelerated the occurrence of hydro-meteorological disasters, one of which is flooding (Jongman et al., 2014). Global disaster data shows that floods are the most frequent disasters and most often cause fatalities (UNISDR, 2018). Urban floodings for countries in Asia, for example in Bangladesh (Toufique and Islam, 2014), Japan (Mouri et al., 2013), Korea (Azam, Kim and Maeng, 2017) and Malaysia (Othman et al., 2014) are disasters that occur almost every year due to extreme weather and causing significant economic losses, infrastructure damage, and fatalities. Flooding in urban areas of developing countries has resulted in a significant challenge to the development and communities' lives, especially people who lived in the rapidly expanding areas of the city (Jha, Bloch and Lamond, 2012). In line with global catastrophe events, national disaster event data shows that in the period 1998-2018, 75% of disaster events in Indonesia were hydrometeorological disasters, where flooding was the most intense disaster occurring, as many as 8,971 times, which were followed by 6,315 waterspouts, 5130 landslides, 2000 drought events, 966 forest, and land fires, and 312 tidal waves consecutively (BNPB, 2018). To anticipate the increasing frequency, magnitude and potential distribution of flood events due to climate change, it is necessary to formulate an integrated risk management approach with incorporating the analysis of ecosystem resilience into the framework.

Flood disaster risk management, in general, can consist of two parts, namely flood risk analysis and flood risk mitigation. The purpose of the flood risk analysis is to analyze the influence of hazard factors, vulnerability and capacity in an ecosystem or area that triggers flood events (Mouri et al., 2013). In this context, the risk analysis aims to produce spatial distributions flood risk levels within the studied area and the factors that influence it (Meyer, Scheuer and Haase, 2009). Besides, flood risk analysis also functions to analyze the opportunities or likelihood of flooding as well as the impact of economic losses and the level of damage caused (Hansson, Danielson and Ekenberg, 2008; Liu et al., 2010; Mouri et al., 2013)Therefore, a comprehensive analysis of flood risk is an essential step in flood risk reduction (Meyer, Scheuer and Haase, 2009)(Meyer, Scheuer and Haase, 2009); (Mouri et al., 2013). Moreover, (Mouri et al., 2013) suggested that risk analysis is the foundation of risk management. Risk analysis generally consists of a combination of hazard and vulnerability analysis (Mouri et al., 2013).

Potential flood hazard analysis is the initial stage that must be carried out in flood risk assessment. Understanding flood hazards require a thorough understanding of the types and causes of floods, the probability of occurring, as well as the distribution, duration, depth, and velocity. This understanding is important for designing measures and methods that can prevent or reduce damage from certain types of flooding (Jha, Bloch and Lamond, 2012). Moreover, Twigg (2015) argues that the cause of the threat of flood hazards may be outside the boundaries of the region under the study. Deforestation in the upstream ecosystem in a watershed, for example, can cause slope instability and increase surface runoff, thus accelerating the formation of flood discharge. The data and information above are needed to formulate the level of needs, urgency and priorities in implementing an appropriate and comprehensive flood risk management approach (Jha, Bloch and Lamond, 2012).

Hazard and vulnerability analysis are two stages of analysis that can be carried out together or separately (Twigg, 2015). In practice, the use of the term "hazard" and "vulnerability" is often mixed up so that there are no clear boundaries. In this study, a hazard is defined both as a natural phenomenon and human activity that has the potential to physically damage which can cause loss of life or injury, damage to infrastructure, social disruption, and economic or environmental degradation.

Hazard analysis needs both quantitative and qualitative data. Quantitative data requires reliable and massive data and focuses on aspects that influence risk. The use of GIS technology helps in the collection of data that affect flood hazards, for example, data on land cover distributions, soil types, river zonings, topography and climate (Twigg, 2015; Meyer et al, 2008; (McCallum et al., 2016).

Disaster risk reduction is a framework that aims to reduce the hazard and vulnerability of disasters to the community while preventing the impacts of disasters by applying the principles of sustainable development (UNISDR, 2015). Disaster risk reduction efforts consist of assessing disaster risk by analyzing various relevant information, strengthening disaster risk management, and enhancing the ability to cope with disaster threats, increasing preparedness, response, recovery, rehabilitation and reconstruction and resilience education for individuals, communities, and countries against disasters (UNISDR, 2015). In the implementation of disaster management in Indonesia so far has not paid attention to aspects of resilience. Therefore, the integration of disaster risk reduction and resilience has become the focus of disaster management policies in Indonesia and has stated in the National Medium -Term Development Plan 2015-2019 of the Republic of Indonesia (Bappenas RI, 2015)

Resilience is defined as the ability of a system or community facing a disaster to survive, absorb, accommodate and recover from a disaster within a certain period of time. A resilient region is an area that has the ability of the territorial system with all elements of socio-ecological and socio-technical networks on a temporal and spatial scale to be able to manage, survive, or recover quickly when facing a disaster. Thus a strong region is defined as an area that has the ability to holding, absorbing, adapting and recovering from the effects of climate change and disasters in a timely and efficient manner (UNISDR, 2015).

This study aims to analyze the spatial distribution and index of potential flood hazards as well as the factors that influence it using the Wanggu watershed ecosystem as a unit of analysis. Wanggu watershed is one of the watersheds in Southeast Sulawesi Province, located in Eastern Indonesia which is categorized as one of the critical watersheds. This watershed was chosen as a study unit because, since 2013, floods have always occurred, but flash floods that have caused fatalities, community economic losses and damage to infrastructure have occurred twice over the past 10 years, namely in 2013 and 2017. Five factors are estimated to trigger the increased potential flood events in the Wanggu Watershed, namely (1) land-use change, (2) climate, (3) topography and altitude, (4) distance from rivers and surface runoff patterns and (5) soil types. By using GIS technology, each of these factors is analyzed its spatial distribution and influence to cause potential flood hazards within the watershed area.

The results of flood hazards analysis will be used to recommend appropriate steps taken by the local government to increase the resilience of the watershed. To this end, this research contributes to grounding the global framework of DRR into disaster risk reduction strategies and increasing resilience at the local scale (watershed ecosystem).

II. METHOD & MATERIAL

Study Area Setting

The Wanggu River Watershed is located at the “foot” of Sulawesi Island, Eastern Indonesia and is part of the Wallace Ecosystem. Therefore, the upstream watershed ecosystem holds a high level of biodiversity. This watershed has an area of 30,599.45 ha and connects 2 autonomous regions, namely Kendari City and South Konawe District (GIS Analysis, 2019). Astronomically, this watershed is located at 03058’00” - 04030’00” LS and 122023’40” - 122033’10” BT. Based on administrative boundaries, the north of the watershed is bordered by MandongaSubdistrict of Kendari City, the south is bordered by South Konawe Regency, the East is bordered by Poasia Regency, Kendari City, and North Moramo, South Konawe Regency, while the west is bordered by Konawe and South Konawe Regencies.

The Wanggu Watershed plays strategic roles for both Kendari City and Konawe Selatan District. Its upstream ecosystem, which is mainly located in South KonaweDistrict provides various forest ecosystem services, including regulating water systems, oxygen suppliers, absorbing greenhouse gases, forming microclimates and maintaining biodiversity. Besides, forest areas produce timber and non-timber forest products with high economic value, such as Tectonagrandis and Soreasp, rattan, bamboo, and honey, etc. However, the forest ecosystem has experienced significant changes due to population pressure, agricultural plantation and mining activities (Kasim et al, 2019).

The downstream ecosystem holds significant functions as a buffer zone for the river ecosystem and Kendari Bay (The Watershed Management Agency Sampara, 2018). Moreover,the area which is located in the center of Kendari City, play significant roles as the central business district and the capital town of Southeast Sulawesi Province where a lot of strategic public and private facilities are located in this area, for example, an airport, hospitals, malls, modern markets, and other trade and educational facilities. Likewise, the Kendari Bay area and its surroundings as an outlet of the Wanggu watershed have been designated as ecotourism development area by the Kendari City Government. However, the condition of the bay from time to time tends to decrease in the quality of its environmental services due to erosion and sedimentation processes both originating from the upstream watershed area and as a result of infrastructure development in the Kendari Bay circle and also domestic and private solid waste piles (Alwi, 2012).

The occurrence of flash floods due to the overflow of the Wanggu River has occurred twice over the past 10 years, namely in 2013 and 2017. The flood in 2017 occurred on May 12-14 and submerged 11 sub-districts, namely 9 regencies in Kendari City and 2 others in South Konawe District. This incident caused the economic paralysis of the city of Kendari and posed great impacts on the city's infrastructure, residential areas and the loss of various community assets (APIK USAID, 2017).

The increase in surface runoff that triggers the occurrence of flash floods in 2017 was assumed to be caused by a combination of extreme rain due to climate change and declining forest land cover. Analysis of climate data over the past 10 years showed that the average rainfall in May was 267.2 with an average of 19 rainy days (BMKG, 2019). Whilst, an analysis of weather conditions in May 2017 showed that the average daily rainfall was 35.0 mm with the number of rainy days 23 days. Monthly average temperature and humidity were 26.7 0C and 89.5% respectively

(BMKG, 2017). In this case, it appeared that the rainfall and number of rainy days in May 2017 far exceeded the average monthly rainfall over the past 10 years, where the total rainfall that occurred during the 23 days was 805 mm (BMKG, 2019).

The dynamics of land-use change was strongly influenced by an increase in population. The increase in the population size which has direct implications for the increase in food, clothing, and shelter needs affected the land use patterns, where there was a significant expansion of agricultural land (Marshall et al., 2011). Furthermore, (Fox et al., 2012), argued that in general the dynamics of land-use change could be influenced by land needs, changes in population, land allocation and changes in agricultural production.

Based on the data from BPS(the Central Statistics Agency of Southeast Sulawesi) in 2018, the number of inhabitants living in the Wanggu watershed was around 218,520 people. The results of extrapolation of population number in Wanggu Watershed for the next 20 years, using a population growth rate of 3.16% showed that the total population living in this area in 2038 amounted to 384,844 people, with a total watershed area of 305.99 km2, so that the density of the watershed population Wanggu will have amounted to 1,258 people / km2. This coupled with the poverty level of the community will cause an increase of vulnerability to flooding hazards.

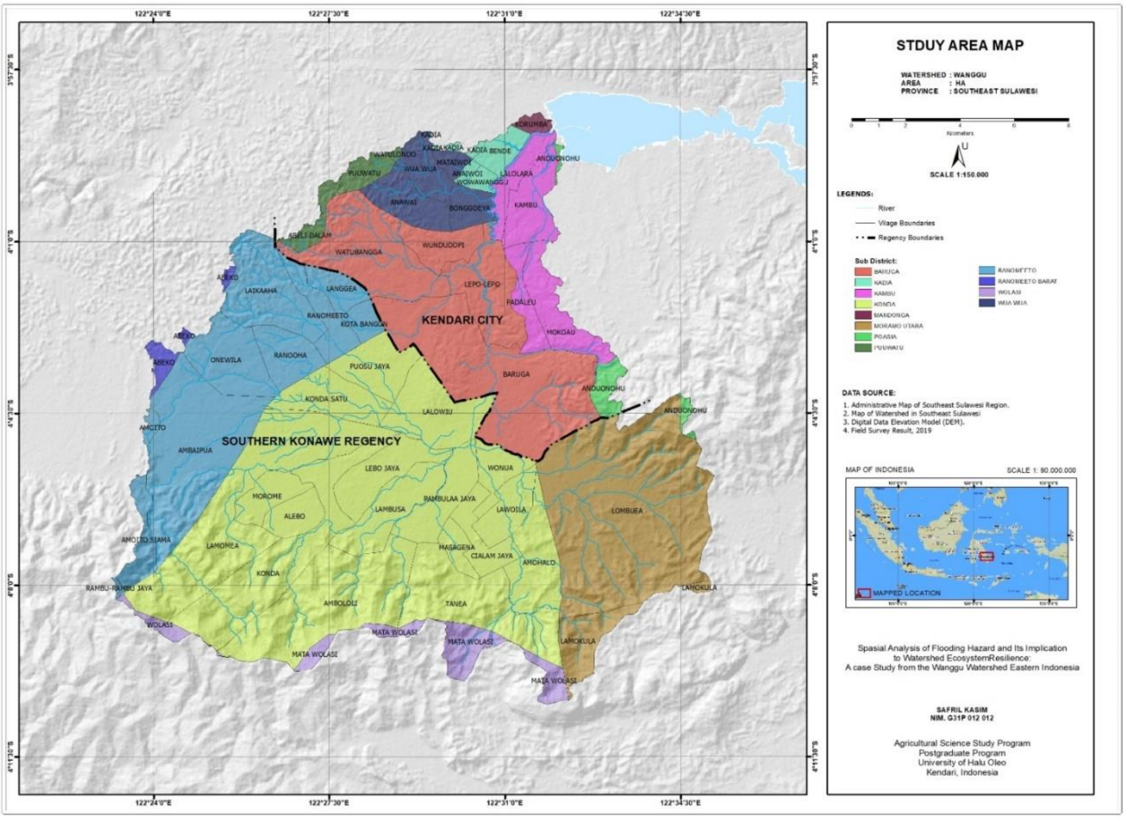

Figure 1. Location Study

Method and Data Analysis

This research was carried out effectively for eight months, from January to August 2019. The time allocation of the study included: four months for data collection and four months for tabulation and analysis of data and compilation of research results.

The collected data in this study were rainfall data for the past 10 years (2008-2018) from the observation climate station of Halu Oleo Airport and the Maritime BMKG of Kendari City, historical data on flooding events from BPBD of Kendari City and South Konawe District, map of soil types of Southeast Sulawesi Province from the Regional Planning and Development Agency of Southeast Sulawesi in 2014, Digital Elevation Model (DEM) 30 meters Resolution data, Landsat 5 Image Data (1998), Landsat 7 (2003 and 2008), Landsat 8 (2013 and 2018) path 112 row 63 obtained from The United States Geological Survey (USGS).

Spatial analysis of flood hazards was carried out using Arc Map 10.4.1 and SAGA GIS 5.0 software, where the output is thematic maps of the six variables forming flood hazards, namely : (1) thematic map of rainfall generated by employing the Polygon Thiesen Method, (2) the map of land covers in 2018 were produced using the unsupervised classification method, (3) thematic map of soil types were digitized from the map of soil, (4) thematic map of elevations and slopes were analyzed using spatial analysis of Digital Elevation Model data, (5) Thematic Map the distance from the rivers is generated by using the buffer tool (100, 300 and 500 meters) of the river borders. The thematic maps produced were then classified using the weighting and scoring methods for each flood-forming parameter using a relevant and scientifically accepted method. In detail, the weight values and scores used in each variable forming flood hazards showed in Table 1. Weights indicate the number or level of values of each parameter, while the scores indicate the value of each variable in each parameter. To determine the hazards level in each regency within the watershed area, a mathematical calculation was employed, which were the weights multiplied by scores of each variable from each parameter. The multiplication of weights and scoring resulted in hazard indexes, with values ranging from 0-1. The values of hazard index were classified into three classes, namely low (<= 0.33), moderate (> 033 - 0.66), and high (> 0.66 -1). The result of flood hazard map was then matched with the result of flood field validation survey and compared to the historical data on flood events. The output of the validation was used to update the level of accuracy of the flood hazard map.

Spatial analysis of land-use changes over the past 20 years (1998-2018) at 5-year intervals (1998, 2003, 2008, 2013 and 2018) was analyzed using the unsupervised classification method with the help of Arc Map 10.4.1 software and SAGA GIS 5.0.

Table 1.Weights Indicate The Number or Level Of Values Of Each Parameter

Parameter	Bobot (%)	Kelas/Skor		
		Low (0.33)	Medium (0.66)	High (1)
Slope (%)	20	>30	8 - 30	<8
CurahHujan (mm year-1)	20	<1500	1500-3000	>3000
Soil	20	Litosol	Mediteran, kambisol, organosol	Aluvial, Regosol
Land-Use	15	Forest	Tambak, sawah, lahanterbuka, savana, semakbelukar	Tegalan, perkebunan, kebuncampuran, pemukiman
Distance from River	15	>500 m	100 – 500 m	<100 m
Hight	10	>75 m	25 – 75 m	<25 m

Source: Author, 2019

III. RESULT AND DISCUSSION

Hazard Potential Analysis in Wanggu Watershed and the driven Factors

The results of spatial analysis showed that overall potential flood hazards in the Wanggu Watershed was dominated by medium class which cover 14394 ha or 47.04% of the total area of the watershed, and followed by the low and high classes 10148.13 ha or 33.16% and 6057.31 ha or 19.80% respectively (Table 1 and Figure2)

Table 1.Distribution of the area of potential flood hazards in the Wanggu watershed

District/City	Sub District	Low		Medium		High	
		ha	%	ha	%	ha	%
Kendari	Baruga	638.52	2.09%	2581.32	8.44%	1550.73	5.07%
	Kadia	25.88	0.08%	215.42	0.70%	115.9	0.38%
	Kambu	267.1	0.87%	642.31	2.10%	625.88	2.05%
	Mandonga	-	0%	1.66	0.01%	73.26	0.24%
	Poasia	181.52	0.59%	47.75	0.16%	17.6	0.06%
	Puuwatu	114.28	0.37%	247.73	0.81%	9.72	0.03%
	Wuawua	62.24	0.20%	889.46	2.91%	101.15	0.33%
Total (A)		1289.54	4.21%	4625.65	15.12%	2494.24	8.15%
Southern Konawe	Konda	4807.24	15.71%	4359.04	14.25%	3051.8	9.97%
	Moramoutara	2407.48	7.87%	1793.34	5.86%	74.65	0.24%
	Ranomeeto	926.94	3.03%	3482.73	11.38%	436.62	1.43%
	Ranomeetobarat	75.15	0.25%	78.86	0.26%	-	0%
	Wolasi	641.78	2.10%	54.38	0.18%	-	0%
Total (B)		8858.59	28.95%	9768.35	31.92%	3563.07	11.64%
Total (A+B)		10148.13	33.16%	14394.00	47.04%	6057.31	19.80%

Source: Author, 2019

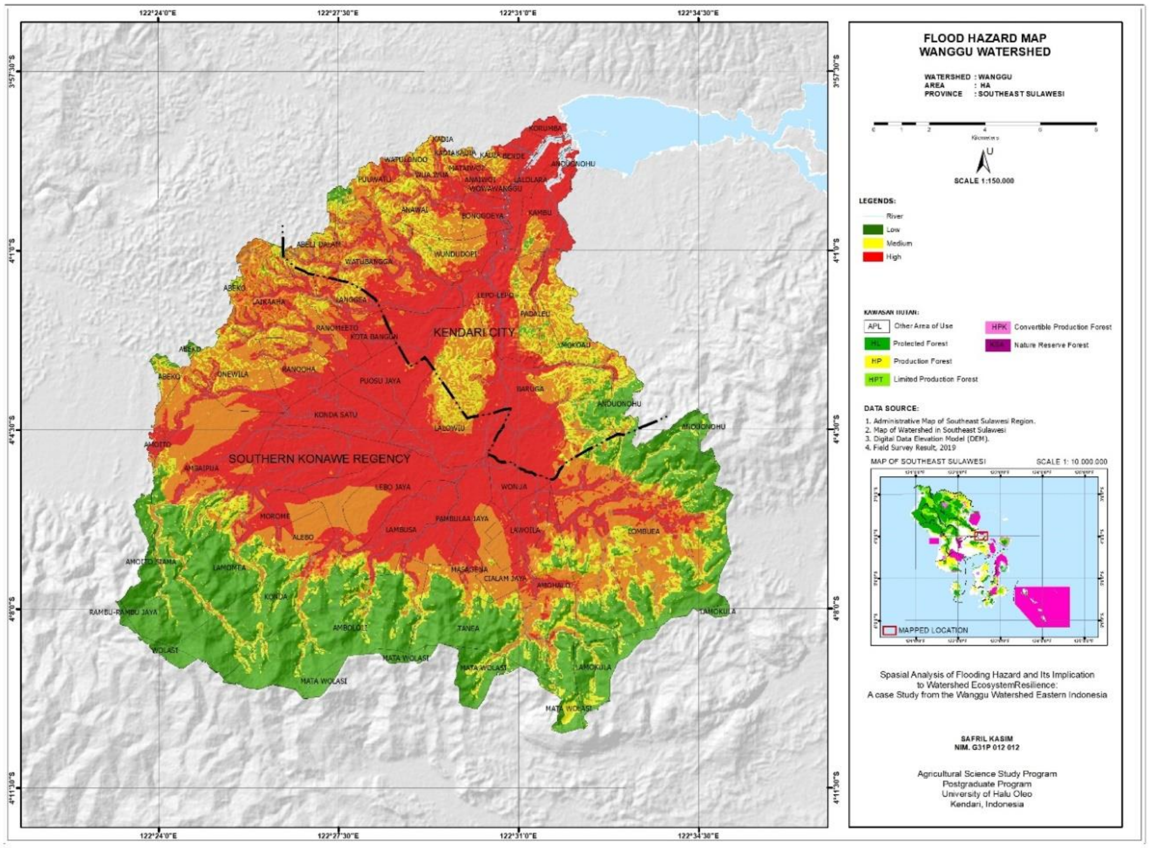

Figure 2. Flood Hazard Map of Wanggu Watershed.

Table 1 showed that based on the proportion of hazard classes in each regency in the Wanggu Watershed, Mandonga Regency was an area that had the widest potential flood of high hazard class compared to other classes, which covers 73.62 ha (0.26%) of the total watershed area, while the medium class of 1.66 ha(0.01%). The spatial distribution of the widest medium hazard class consisted of Baruga, Kadia, Kambu, Puuwatu, WuaWua, North Moramo, and Ranomeeto Barat. Meanwhile, Konda District had the widest distribution of potential low-grade flood hazards compared to other flood hazard classes. In terms of the proportion of the affected areas, Konda Regency was the most extensive area impacted by flood in each hazard class, which the low hazard class area of 5807.24 ha (15.71%), followed by medium and high hazard class covering 4359.65 ha (5.12%) and 3051.8 ha (8.15%) of the total area of the watershed.

Analysis of Dynamic Changes in Land Use

The results of the dynamic land-use change analysis in the Wanggu Watershed during the last 20 (twenty) years (1998-2018) showed that an average decline in forest land area was 329.84 ha year-1 (1.08%), which was at the same period, shrubs, dryland agriculture, settlements, and bare land increased by 124.92 ha year-1 (0.41%), 109.24 ha year-1 (0.36%), 40.85 ha year-1 (0.13%) and 70.06 ha year-1 (0.23%) of the total area of the watershed respectively (Table 2).

Table2. Results of the analysis of land-use change in the period 1998-2018 (20 years)

Landuse	Area	Year					∑ Δ	R Δ year-1
		1998	2003	2008	2013	2018		
shurb	ha	9098.27	8895.56	10836.94	8325.62	11596.66	2498.39	124.92
	%	29.74%	29.07%	35.42%	27.21%	37.90%	8.17%	0.41%
Forest	ha	18136.65	16211.85	13147.22	14252.48	11539.84	(-6596.81)	(-329.84)
	%	59.27%	52.98%	42.97%	46.58%	37.71%	-0.22)	(-1.08%)
Bare Land	ha	224.82	472.23	1362.73	1062.42	1625.97	1401.15	70.06
	%	0.73%	1.54%	4.45%	3.47%	5.31%	4.58%	0.23%
Mangrove	ha	326.34	166.23	129.54	200.21	262.68	(-63.66)	(-3.18)
	%	1.07%	0.54%	0.42%	0.65%	0.86%	(-0.21%)	(-0.01%)
Settlement	ha	1074.16	1140.39	1117.27	1346.81	1891.08	816.92	40.85
	%	3.51%	3.73%	3.65%	4.40%	6.18%	2.67%	0.13%
Dryland Farming	ha	997.62	2633.76	2954.38	4720.45	3182.41	2184.79	109.24
	%	3.26%	8.61%	9.66%	15.43%	10.40%	7.14%	0.36%
Paddy Field	ha	739.62	1077.46	1049.4	689.49	498.85	(-240.77)	(-12.04)
	%	2.42%	3.52%	3.43%	2.25%	1.63%	(-0.79%)	(-0.04%)

Source: Author, 2019

The climatic conditions in the Wanggu watershed area, especially rainfall and rainy days were analyzed based on the observation analysis of rainfall stations that exist around the Wanggu watershed, including Halu Oleo Konawe Airport Station and BMKG Maritime Station Kendari respectively for the last 10 years (2009-2018). The results of rainfall analysis showed that the two stations representing the area around the Wanggu Watershed have relatively similar rainfall and monthly rainy days Table 3

Table 3. Average rainfall and monthly rainy days over the past 10 years

Month	Average rainfall (mm) and Rainy Days in Wanggu Watershed					
	HO Airport Stasiun		MaritimStasiun		Wanggu Watershed	
	Rainfall	Rainy Days	Rainfall	Rainy Days	Rainfall	Rainy Days
January	167.5	17	210.5	19	189	18
February	252.1	19	219.3	20	235.7	20
March	296.8	22	237.6	20	267.2	21
April	227.3	21	182.2	19	204.75	20
May	358.8	21	251.2	18	305	20

June	306.2	22	253.7	16	279.95	19
July	279.7	19	237.8	16	258.75	18
August	136	14	86.8	11	111.4	13
September	82.4	11	39.9	6	61.15	9
October	105.1	11	73.8	8	89.45	10
November	187.9	14	87.1	9	137.5	12
December	211.5	17	210.7	20	211.1	19
Annual Average	217.61	17	174.21667	15	195.91	16
Oldeman Type	(6WM;1DM)		(WM4;DM4)		(WM3;DM2)	
Schmid –Ferguson Type	(ADM1.17;AWM7.9) Q = 14.8%		(ADM2.2;AWM.6) Q = 33.0%		(ADM1.2;AWM7.8) Q = 14.9%	

Source: Author, 2019

Note: WM (Wet month), DM (Dry Month), ADM (Average Dry Months), AWM (Average Wet Months).

Soil

The soil in the Wanggu Watershed consists of several types, namely, podsolic, lithosol, cambisol, alluvial, mediteran, and gleisol. Spatially the soil type in the Wanggu Watershed was dominated by podsolic types covering 9208.89 (30.09%) of the study area, followed by litosol, kambisol, aluvial, mediteran and gleisol which has an area of 7856.83 ha (25.67%), 7867.01 ha (25.70%), alluvial 4002.62 (13.08%), 1501.22 (4.90%) and 162.88 ha respectively (0.53%) (Table 4.)

Table 4. Distribution of soil types in the wanggu watershed

No	Type of Soil	Area	
		(ha)	(%)
1	Podsolik	9208.89	30.09
2	Litosol	7856.83	25.68
3	Kambisol	7867.01	25.71
4	Alluvial	4002.62	13.08
5	Mediteran	1501.22	4.90
6	Gleisol	162.88	0.53
Total		30599.45	100

Source: Author

Topography

The topography is a description of the condition of the earth's surface, topographical conditions are represented in slope conditions and altitude. The Wanggu Watershed had varying slope classes namely, flat, gentle, steep and rather steep which are depicted on the slope class map (Figure 3). The widest slope class was flat, covering 14472.35 ha (47.30%), then followed by the gentle class of 2752.29 ha (8.99%), a steep class of 4087.53 ha (13.36%), the rather steep class of 9287.28 ha (30.35%) respectively (Tab. 5).

Table 5. Slope Classes in the Wanggu watershed and Spread Area

No	Kelerengan	Luas	
		Ha	%
1	Flat (0-8%)	14472.35	47.30
2	Gentle (8-15%)	2752.29	8.99
3	Steep (15-25%)	4087.53	13.36
4	Rather Steep (25-45%)	9287.28	30.35
5	Very Steep (>45)	0	0
Total		30599.45	100

Source: Author, 2019.

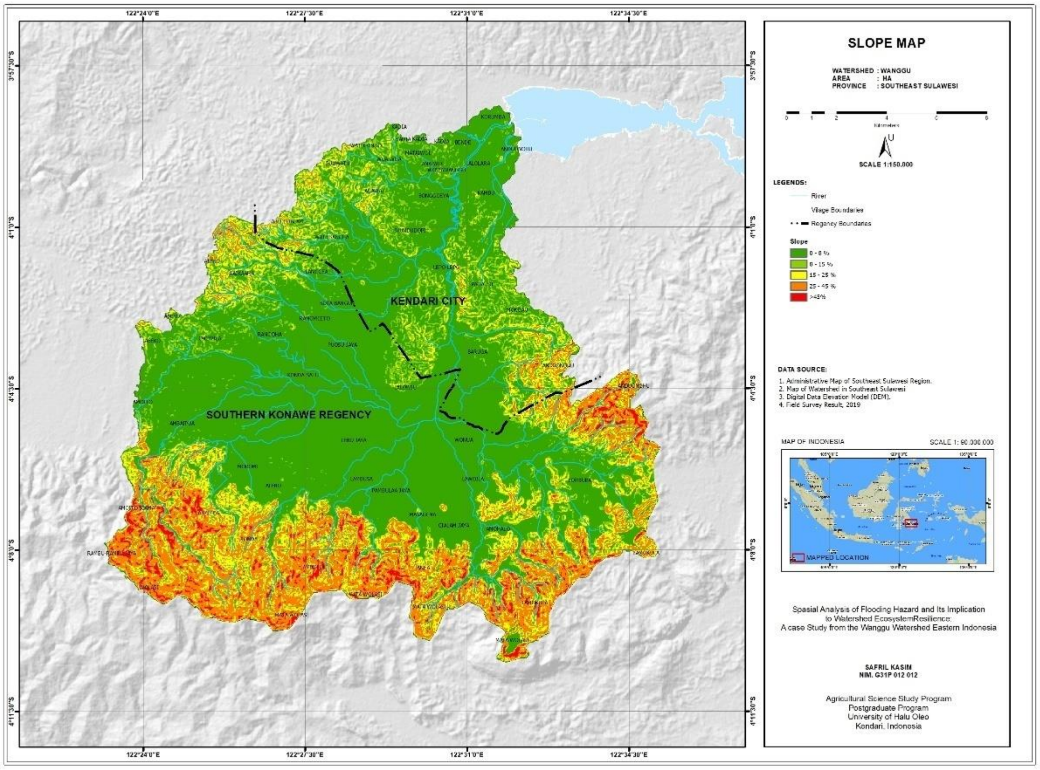

Figure 3. Slope Map

The results of the Geographic Information System analysis illustrate that the Wanggu Watershed has heights ranging from 0 - 600 meters above sea level, which are represented on the altitude map (Figure 4). Areas that have an altitude of 0 –50 meters above sea level are areas located in the downstream, while altitudes 50-600 are areas located in the upstream area of the Wanggu watershed.

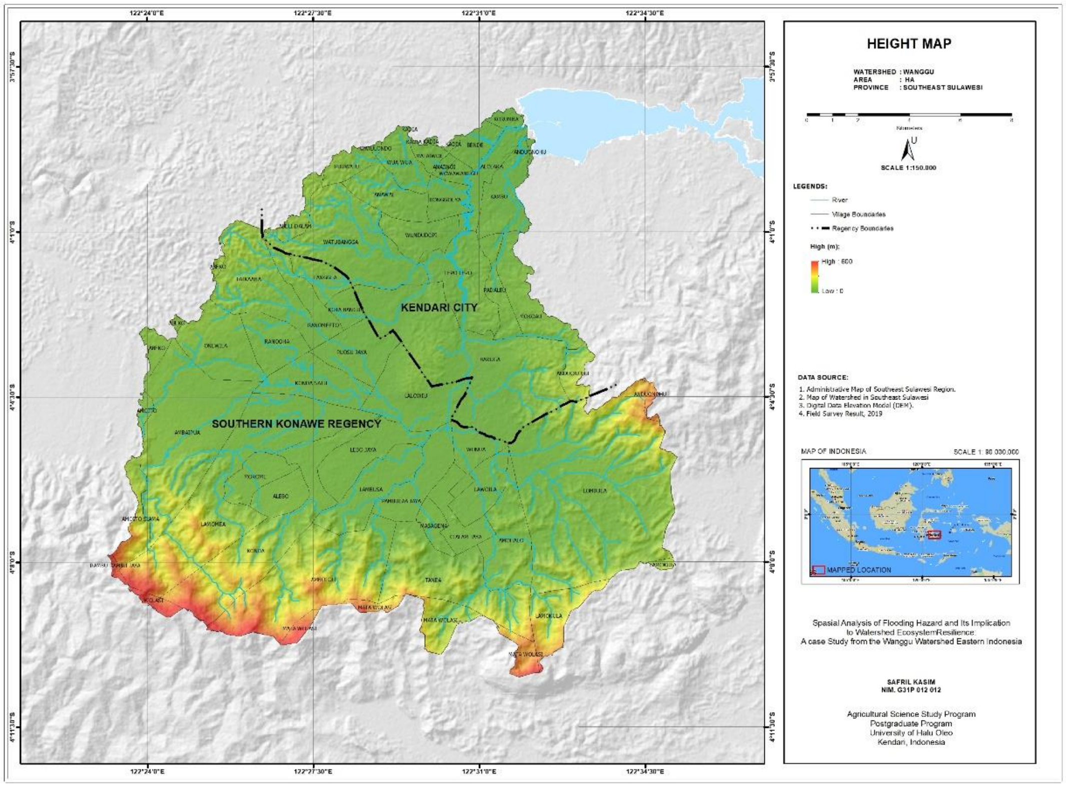

Figure 4. Height Map

Distance from The River

The results of spatial analysis of potential flood hazards indicated that the areas with potential flood high-class hazards in the Wanggu Watershed at a radius of <100 meters covering 6595,347 (21.55%). While the areas with a distance from the river > 100-500 m has a potential flood medium-class hazards of 16865.68 (5.12%), and a radius > 500 m has the low-class hazards of 7138.42 (22.33%) of the total area of the watershed (Table 5).

Table 5. The Distribution based on the distance from the river

No	Distance from River (meter)	Hazard Class	Area	
			ha	%
1	>500	High	7138.42	23.33
2	100 -500	Medium	16865.68	55.12
3	<100	Low	6595.34	21.55
Total			30599.45	100

Source: Author, 2019

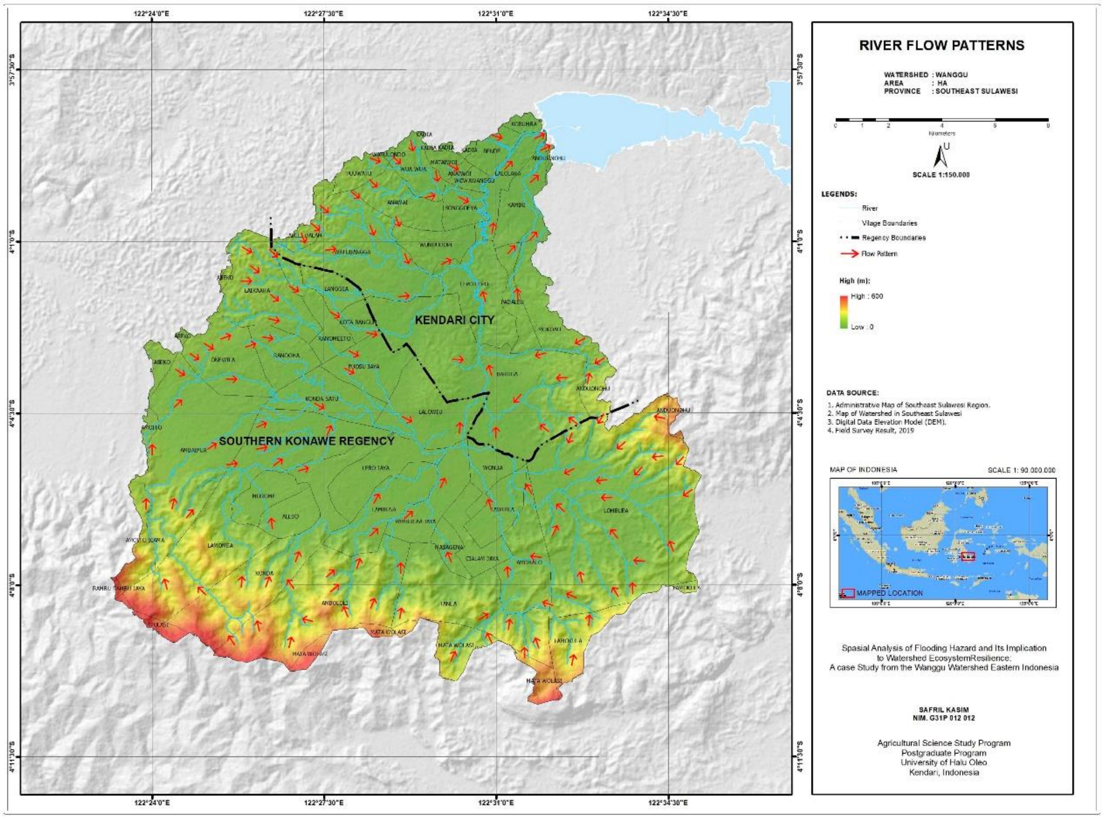

Figure 5. Flow Pattern

IV. DISCUSSION

Mandonga Regency, Kendari City was the widest area with high potential flood hazards compared to other classes. Driven factors of the hazard classes were land-uses, soil types, rainfalls, slopes, altitudes and distances from the river. Percentages of area of each characteristic forming for high potential flood hazards were land cover dominated by settlements of 73.18%, alluvial type of soil 50.65%, flat slope (0-8%) of 93.37%, distance from river 100 - 500 m with an area of 58.06%, an altitude of 0-13 meters above sea level with an average rainfall of 2388.4 mm year-1.
Meanwhile, the widest potential medium class of flood hazard was distributed to several regencies including Baruga, Kadia, Kambu, Puuwatu, Wua-wua, Ranomeeto, and West Ranomeeto, which characterized by several biophysical factors, for example, in West Ranomeeto. Potential medium class of flood hazards was formed by several biophysical characteristics, for example, in West Ranomeeto regency, land cover was dominated by shrubs of 80,28%, Cambisol and Podsolic soil types of 37,15% and 43.59% respectively, flat slope of 73.00%, distance from the river (100-500 meters) covers 60.67%, altitude of 25 - 75 meters from sea level of 80.22% with an average rainfall 2,525 mm year-1.

Areas that have the widest potential low-grade flood hazard were the Regencies of Poasia, Konda, and Wolasi, with biophysical characteristics that match with the low hazard criteria. For example, Konda Regency had 92,59% forest cover, 75,43% litosol soil, Steep and rather-steep slopes of 22,05% and 39,55% respectively, 50.56% distance from the river (100-500 meters) , 72,64% altitude (>75 meters above sea level) with an average rainfall of 2525 mm year-1.

Research findings showed that areas that had high levels of flood hazard in the Wanggu Watershed were caused not only by natural factors but also influenced by human activities in utilizing land resources. A land dominated by settlements and bare land and shrubs had high to moderate flood hazard potential. Conversely, lands that were still dominated by forest vegetation had low flood hazard potential both on a local and global scale. This is in line with the opinion of some experts that forest land cover is a very important factor in determining water availability (Ellison et al., 2017) and reducing soil erosion and flooding (Bruljnzeel et al., 2004,Ilstedt el al., 2007; Labrière et al., 2015). Nevertheless, the impact of forestation on the hydrological conditions of the watershed is highly dependent on local parameters such as climate, type of vegetation, soil and topography (Bonnesoeur et al., 2019). In addition, the decrease in forest cover will cause a decline in seasonal water flow, especially base flow in line with decreased soil infiltration capacity and increased surface runoff as well as peak flow (Lerner and Harris, 2009).

Research findings showed that there was a dynamic change of land-use. This change has resulted in a decrease in forest covers and at the same time, an increased settlement and agricultural lands. The increasing needs for residential and agricultural lands were caused by an increase in population and economic activities within the watershed. The upstream ecosystem of the Wanggu Watershed will continue to experience pressure as a result of increasing land requirements for agriculture. Meanwhile, the downstream ecosystems of the area will getting pressure from the residential sector and the construction of other urban facilities. Declining forest land use in the watershed ecosystem was a common phenomenon in Indonesia. A dynamic land-use change analysis over the past 20 years (1991-2000) in the Konaweha Watershed, Southeast Sulawesi Indonesia showed the same phenomenon, where the forest area decreased from 66.6% in 1991 to 43.6% in 2000 or decreased by 23 % (78.000 ha). At the same time, the highest increase in a land area occurred on plantation land, from 26.0% to 42.0% or an increase of 16% (54,000 ha) (Baco, 2012). Likewise, in the upper stream of Bekasi Watershed, West Java Indonesia, there was a decrease in forest area by 7,297%, and at the time residential land was a land area that experienced a very high increase, covering 13,361% (Kadri, 2011).

Deforestation in the upper stream has resulted in an increase of run-off and peak discharge of the Konaweha watershed. A decrease in forest cover area has led to an increase in the surface runoff coefficient from 31,4% to 45,6 (14.2%), and the maximum discharge increased from 246 m3s-1 to 284 m3s-1 in the 1991-2000 period (Baco, 2012). While the decrease in forest cover in the upper stream of BekasiHulu watershed of 7.297% has caused an increase in peak discharged by 578 m3 s-1 and caused a flood of 138 ha for 3 days in community settlements (Kadri, 2011).

The river flood disaster in the Wanggu watershed in July 2013 had climate characteristics with the total and average rainfall of 824.6 mm month-1 and 29.6 mm respectively, with 24 days of rain. The average temperature and humidity conditions were 25.40 oC and 89.5%, respectively (BMKG, 2013). The floodwater level reached 3 meters with flood discharge 542.54 m3 /second. Likewise, the climatic conditions of the event in May 2017 were the total monthly rainfall and average of 1050.6 mm /month and 35.0 consecutively, with 23 days of rain. The average temperature and humidity conditions were 26.70C and 89.5%, respectively (BMKG, 2017). The rainfall data showed that the incidence of rain for 24 consecutive days in July 2013 and 23 days in May 2017 resulted in soil pores, both macro, and micropores in a state of water saturation so that most of the rainwater became a surface flow. The surface runoff that occurred eventually forms a peak discharge which causes a river flood.

In general, soil types in the Wanggu watershed had low fertility characteristics, were acidic (low pH), low water holding capacity, we're susceptible to nutrient leaching and were sensitive to erosion. These soil characteristics, interacting with other factors, such as reduced vegetation cover, slope, etc. will cause a significant increase in surface runoff and trigger flood events. Alluvial soils were generally scattered in floodplains, with a low altitude, namely in river valley areas and river banks. Generally, this type of soil was porous, clays, dark-colored with a variety of organic layers. While the type of lithosol soil had a rather thick to thick soil solum, ranging from 130 cm to more than 5 m. The soil was red, brown to yellowish and has a fairly fast to moderate infiltration rate. With these soil characteristics, lithosol soil was a type of soil that had a moderate flood class.

The podsolic soil type has a very low water retention capacity so that it is easily washed away by rainwater and has a high level of soil erodibility. Podsolic soil is prone to drought in the dry season. Nevertheless, podsolic soils in the Wanggu Watershed were mainly distributed in hilly areas so that they have low to moderate flood potential.

Likewise, Mediterranean soil types were often found in forest ecosystems, had the ability to store medium-high water, so that these soil types had low flood potential in the watershed area. In addition, forested lands ha such characteristics such as porosity and high soil organic matter, so they had high infiltration and permeability capabilities. Thus, surface runoff will also be smaller than settlement, agricultural and bare land, allowing more water to be stored in the soil.

The decrease in forest cover in the upstream watershed had a negative impact on land characteristics, including reduced protection of the soil surface due to the increase interception of the forest vegetation canopy, decreased in soil infiltration capacity and increase in surface runoff which triggers flooding. (Suripin, 2002)suggests that erosion events due to loss of protection of forest vegetation cause soil pores, fill and become quickly saturated, thereby reducing infiltration capacity and increasing surface runoff.

The slope was a comparison of the presentation between vertical distance (land height) and horizontal distance (length of flat distance) (Suherlan, 2001). The slope was often expressed in units of degrees and percent. The slope could be searched from the contour line. Contour lines were imaginary lines on the field that connect points with the same height or contour lines were continuous lines on the map that showed points on the map with the same height. The slope of the land was a parameter to the size of the flood. The condition of the land with a steep slope will increase in flow velocity to the low land. It is, therefore, the degree of slope of the land was getting bigger, then the potential for flood events was lower.

The height of the place was one of the physical factors that influenced the flood hazard. Areas in the lowlands had moderate to high flood hazards, while high altitude areas had low flood potential. This was influenced by the nature of water. Water moves from the highest to the lowest (Suherlan, 2001).

The river network map (Fig. 4) showed that the drainage pattern of the Wanggu watershed resembled branches and trees that form a dendritic pattern and is circular in shape. This led to the entire river flow to follow the great river channel and accumulated in Kendari Bay. The combination of dendritic patterns with a high level of watershed drainage density caused the velocity of surface runoff to accumulate at one point and triggers flood overflow events. This condition was exacerbated by changes in land use in the up-land areas as previously explained, and degradation of a catchment area, where tree vegetation was replaced by dryland agriculture and settlements.

The data and information above showed that 66.84% of Wanggu watershed had a moderate to high flood hazards. This will exacerbate if steps are not taken to decrease the level of flood hazards. In this context, the resulting hazard map provided a visual figure that can communicate flood hazard situation/ Policy implications that can be followed up from the description of the flood hazard levels are land use regulations should be established to increase forest land cover in the upstream area and conservation of local protected areas, for example, green open spaces along rivers and water catchment areas. In addition, there is a need to endorse a green infrastructure approach to the development policies of local government both Kendari City and South Konawe District.

V. CONCLUSION

Potential flood hazards in the Wanggu Watershed were dominated by a medium level of hazards covering 9768.34 ha or 31.92%, followed by low and high ones of 8858.60 ha (28.95%) and 3563.07 ha (11.04%) consecutively. The highest hazard index was 0.793 and the lowest one was 0.33 with an average index of 0.593. Policies implications to decrease in the level of flood hazards are recommended through (a) land use regulations, (b) conservation of local protected areas, c) encouraging the development of a green infrastructure approach.

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