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A Study of Flood Causal Priority in Arui Watershed, Manokwari Regency, Indonesia

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Abstract

Papua is the final fortress of forests in Indonesia. However, floods recently occurred in Jayapura, Paniai, and Manokwari. If causal factors are not identified and early anticipated, the flood will become an annual disaster with more severe impacts. This study aims to identify main factors causing floods using scoring analysis. Data collected include: rainfall, river gradient, water discharge, drainage density, watershed shape, slope and land use. The research results show that the main factor of floods are average daily rainfall in wet month by 86.53 mm day^{-1} (rather high) with a score of 28, land use dominated by forest and plantation (rather low and medium) with a score of 21, watershed slope dominated by 1<8% (high) with a score of 5, drainage density of 6.4 (medium) with a score of 3, watershed shape (Rc of 0.30 < Re 0.71) with somewhat/elongated shape with a score of 2, and river gradient of 0.0062 (low) with a score of 2 respectively. High rainfall causes greater flow of water and runoff. Land use dominated by plantations (21.46%) is thought to be one of the main causes of floods in Masni District. Flood mitigation does not mean that rain should be reduced, but regulates/manages such as stopping the conversion of forest into palm oil plantations, reducing surface runoff by applying soil conservation, making bypass from meandering, dredging sediments, and constructing retaining walls.

Keywords: flood, rainfall, land use, priority, watershed

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Introduction

In Indonesia, there were 22 priority watersheds (to be restored) in 1984, increased to 39 watersheds in 1994, 62 watersheds in 1999, and 108 watersheds (including Arui Watershed in Manokwari Regency) 2009. According to the Decree of Minister of Forestry Number. 328/Menhut-II/2009, Arui Watershed is stipulated as a watershed that need immediate priority handling (watershed to be restored). Since 2012, referring to Government Regulation Number 37 of 2012 concerning watershed management, watershed is classified into 2, namely watershed to restored and watershed to be retained. Watershed damage is accelerated by the use of natural resources as a result of population growth, economic development, conflict of interests and lack of integration between sectors, between upstream and downstream areas especially in the era of regional autonomy (Adamson & Cussen 2003; Girolamo & Porto 2012; Paimin *et al.* 2012).

The watershed of which carrying capacity to be retained is watershed whose land condition, quality, quantity and continuity of water, socioeconomic aspects, investment of water buildings, and utilization of space work properly (Government Regulation Number. 37 of 2012). Meanwhile, the watershed of which carrying capacity to be restored is watershed whose quality, quantity and continuity of water, socioeconomic aspects, investment of water buildings, and utilization of space do not work properly. Several impacts of watersheds that must be restored include: floods, landslides, sedimentation and erosion that may disrupt economy and order of life of the community. According to MoLEF (2017), Arui Watershed is a watershed to be restored characterized by high erosion rates, increasing sediments, low score in the 2017 watershed monitoring and evaluation and floods in 2016.

Flood is a natural phenomenon that occurs when the intensity of falling rain is very high, while the soil is not able to absorb it well and then runoff occurs (Asdak 2010; Ngongondo *et al*. 2011; White & Howe 2010; Paroissien *et al*. 2014; Vannier *et al.* 2016). A flood occurs due to excessive water flows which can be caused by changes in rainfall and surface runoff, limited river capacity or drainage or disfunctioning in water buildings (Bera & Bhandari 2013; Hallegatte *et al*. 2013; Ran & Budic 2016; Worman *et al*.

2017). Such excessive amount of water will become puddle. Climate change and land-use change have increased the ratio of rainfall to surface flows, the amount of water directly becoming runoff flooding increasing significantly, so that the peak discharge becomes greater and decreation water quality (Mahmud *et al*. 2009; Senawi 2009;Yan *et al*. 2013; Nasir *et al*. 2017).

After the flood occurred in Arui watershed area on 29 February 2016, regional and central government visited the affected areas and they promised to normalize the watershed. However, until now such promise has not been realized. The normalization of a river needs data of siltation, rainfall, narrowing, sedimentation, erosion, conversion land functions, etc., Studies on rainfall, watershed shape, river bend, river gradient, drainage density, watershed slope, land use and water debit in the area will detect and prevent floods as early as possible. Therefore, hydrology, land and morphometrics of watershed (watershed shape, river bend, river gradient, drainage density) in the Arui River Basin should be investigated to avoid floods in the future.

Flood has become a never-ending problem in Indonesia. Several causes are known, but the actual causes are unknown for certain, whether the main causes of floods are sedimentation, land function conversion, river bend, river gradient, drainage density, moisture, topography or only high rainfall. Identifying their rates can determine what should be prioritized to be managed by c conserving soil and water and handling floods, so that the floods will not recur. On the contrary, if the main cause is not known for certain, floods will be handled carelessly so that the floods will be an annual disaster and sometimes occur more severely. No matter how small the impact of floods, it is still a disaster that must be addressed and the root causes of flooding problems should be sought. This is to prevent such disaster turning into a greater disaster or floods becoming a doom that will destroy all living creatures on the surface of the earth.

This study aims to identify the factors, including: rainfall, watershed shape, river bend, river gradient, drainage density, slope of watershed and land use and river border, that cause floods in Arui watershed especially in Masni District that occurred on 9 September 2009. It is expected that the results of this research can be developed into a model or design to handle and prevent floods, provide information to the government (PU, BPDAS, BPWS, Agricultural Agency), Private organization, NGOs, communities, and other stakeholders concerning watershed management so that it can be used as a study material in planning, implementing and deciding further policies for managing Arui watershed.

Methods

The research has been conducted at PDAS Laboratory, BWS West Papua Province, BPDAS & HL Remu Ransiki and Arui Watershed Manokwari. Materials and equipment used in this research are: administration map (scale of 1: 110.000), rainfall data 2013−2017, rollmeter, stopwatch, AWLR logger, ARR (automatic rain recorder), current meter, map of arui watershed, calculator, citra landsatd, computer, and printer. Data collected in the form of primary data, i.e. form of watershed, river curves, river gradient, river density/drainage and water discharge. While secondary data consist of: rainfall, slope and land use 2014−2017.

1 Climate

Rainfall data obtained from BWS of West Papua Province include: daily rainfall, monthly, yearly, wet month, dry month and rain intensity which were then used to classify the climate according to Schmidt & Fergusson (1954) as citated by (Soewarno 1991)

$$Q = \frac{Bk}{Bb} \subset 100\% \qquad [1]$$

note: Q = climate; Bk = Number of dry months; Bb = Number of wet months

2 Watershed shape

The shape of the watershed has significance in relation to river flow/flow velocity. To determine the shape of the basin, it is needed first to determine the value of circulatory ratio or Rc (Strahler 1964) and elongated ration or Re (Schum 1956) with the formulaas following (Equation *[2]* and Equation *[3]*):

$$Rc = 4\pi A / P2 \qquad [2]$$

$$Re = 1.129(A^{0.5}/L) \qquad [3]$$

If Re < Rc is rounded and Re>Rc elongated

note: Rc = circulatory ratio(waterbed); Re = elongation ratio; A = Area of watershed (m2), L = watershed length; P = Circumference (m); π = 3.14

Basin data circularity, elongation ratio, watershed area, total river length, and circumference were obtained through Geographic Information System. In addition to the watershed data form river bends at the location of the floods include: meandering, debit before turns and discharge after turn. Meandering (Dury 1969) is determined by first determining the sinuosity value as shown as Equation *[4]*.

$$\text{Sinuosity} = \frac{\text{Long river channel}}{\text{Distance of river axis}} \qquad [4]$$

If Sinuosity> 1.5 is called mendering

3 River gradient

The slope of the river is obtained by the Equation *[5]* (Soewarno 1991)

$$G = \frac{Vertical\ distance}{Horizontal\ distance}\ \text{distance} \qquad [5]$$

note : G = river gradient; Vertical Distance = high difference between upstream and downstream of flood location; horizontal distance = stream lenght of flood location. River gradient data was obtained through direct survey of the study sites.

4 Drainage Density

River density, long river counts including tributaries and wide watersheds are obtained through Geographic Information Systems. River density is an index that shows the number of tributaries in the watershed. The index is obtained by the following equation (Soewarno 1991) as shown as Equation *[6]*:

$$Dd = \frac{L}{A} \qquad [6]$$

note: Dd = drainage density; L= the total length of the river including the tributaries; A= wide watershed

5 Slope
The slope data are: slope class and topographic class in upper, middle, and downstream watersheds. Land use for each slope includes: forest area, not forest, percent forest, and non-forest data. Slope classes and land use are obtained through data analysis of digital elevation model (DEM) Arui Watershed in 2015.

6 Land use
Data of land use were collected from interpreted of citra landsat 20142017 obtained from MoLEF (2017) by analyzing annually land use changes.

7 Water discharge
Other data such: normal river flow in each river, water level with bridge, river border width, left and right border vegetation of the river were collected from every river in Arui River Basin. To determine the water discharge (Asdak 2010) first determine the cross-sectional area and the current velocity as shown as Equation *[7]*.

$$Q = A \times V \qquad [7]$$

note: Q = discharge (m^3 s^{-1}); V = current velocity (m s^{-1}); A = cross-sectional area of the river (m^2); t = time (seconds) as shown as Equation *[8]*

$$V = j / t \qquad [8]$$

note: V = Current velocity (m s-^{1}); j = Distance between two points of observation (m); t = time of floating objects (s) as shown as Equation *[9]*

$$A = d \times l \qquad [9]$$

note: A = crosssectional area of the river (m^2); d = river depth (m); l = width of the river(m)

Table 1 The parameters and the weight of the flood formulation

Parameter/Weight	Value	Value category	Score
Mean daily maximum rainfall in wet month (mm day^{-1}) (35%)	< 20	low	1
	21–40	rather low	2
	41–75	medium	3
	76–150	rather hight	4
	>150	hight	5
Watershed shape (5%)	oval	low	1
	rather oval	rather low	2
	medium	moderate	3
	rather round	rather hight	4
	round	hight	5
River Gradien (%) (10%)	< 0.5	Low	1
	0.5–1.0	rather low	2
	1.1–1.5	moderate	3
	1.6-2.0	rather hight	4
	> 2.0	hight	5
Drainage density (5%)	sparse	rather low	1
	less sparse	rather low	2
	moderate	moderate	3
	dense	rather hight	4
	very dense	hight	5
Average slope of Watershed (%) (5%)	< 8	low	1
	8–15	rather low	2
	16–25	moderate	3
	26–45	rather hight	4
	> 45	hight	5
Land use(40%)	Protected forest/ Conservation(nature)*	low	1
	Production forest/plantation** shrubs	rather low	2
	rice field/residental area	moderate	3
		rather hight	4
	urban area	hight	5

Sumber: Paimin *et al.* 2010

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Data processing and analysis

Flood formulation In this study data was analyzed using scoring of flood formulation according to Paimin *et al*. (2010) as shown in Table 1. The parameters and the weight of the flood formulation are as following: Average daily rainfall in wet months (mm day^{-1}) (35%) watershed form (5%), river gradient (10%), drainage density (5%), average slopes (5%), and land use (40%). The identification of the flood factor begins with determining he scores for each parameter i.e. Score 1 = Low, 2 = Somewhat Low, 3 = Medium, 4 = Somewhat High, 5 = High. The main factor causing the flood is obtained from the multiplication of weights by score. The largest total sorted score is the most influential main factor for the occurrence of floods.

Results and Discussion

Flood has become a disaster not only in Indonesia but also throughout the world. Floods that occurred in Masni District (Meiforga, Macuan, Aska, Ririnfos, Bowi Subur, and Membowi vilage) one of the districts in Arui Watershed area on 29 February 2016 have caused damage to agricultural land, settlements, roads, and bridges. Using the flood formulation paramater from Paimin, *et al*. (2010), the results of flooding analysis were presented in Table 2.

Table 2 shows that the flooding factors with highest score is rainfall (score 28), and then followed by land use change (score 16), slopes (score 5), drainage density (score 3) form of watershed (score 2), and river gradient (score 2) respectively.

The rainfall of 718 mm day^{-1} became the main factor causing the flood, preceded by the previous 5 days precipitation by 153 mm day^{-1} and the previous 6 days by 173 mm day^{-1}. The floods that occurred in Masni District were classified as surface runoff, because they only lasted 46 hours. The results of interviews with the community, showed that before the flood on February 29, 2016, in the area occurred a very heavy rain.

Changes in land use that dominated by oil palm plantations (20,2821.4%) Arui watershed were the second main factor causing flooding. Prior to the opening of transmigration and oil palm plantation area the Arui watershed area has never experienced a flood. The topography of about 60.01% Arui watershed is is flat which is high potential forly. Flat topography of rainwater from upstream areas with steep terrain to very steep uninfiltrated water into the soil will become surface runoff and accumulate in a place that could become a puddle. According to Paimin *et al.* (2010) the watershed area with slopes less than 8%(flat) has high potential for flooding.

Arui watershed drainage density is moderate, however, if high rainfall 4 rivers converge water flow will be greater to reach the peak discharge. Similarly, Arui Watershed shape is somewhat oval based on flood formulation, so it is categorized rather low for flooding (score 2). However, at the location of the flood there is meandering /curves with a sinuosity value of 2.54. The existence of river curves reduces the flow of the flowing river that impacts runoff flooded and causing flooding. If the factors causing floods occur simultaneously such as rainfall is rather high, although the form of overburden and drainage density is rare, but if the river body had many sediments and river curves the runoff will easily overflow, so that they will cause flooding. Moreover, Arui watershed area in the last 5 years has an average rainfall of 3998,2 mm. If rainfall in Arui Watershed area is high, flat topography, four rivers if together and there is a lot of silting, then easily peak discharge occurs.

Rainfall The rainfall is the input of water on the earth's surface. Distibution and intensity of rain affectedsoil absorption of rain water. At the beginning of the rain the water will be temporarily suspended in the crown stand, then flow through the stem stream and the crown canopy and absorbed by the soil. However, if the rain troughfall with a high intensity, then the stem flow will be faster, and the ground cannot absorb all water, so that it will be pooled or flowed on the ground surface. The subsequent flow of water leads to a lower area such as the (river).

The average daily rainfall during the wet month of the last 5 years in Arui watershed area is presented in Table 3.

Average daily rainfall in wet months is 86.53 (mm day^{-1}), based on flood formulation it was categorized as rather high or has a score of 4 and weight 7, so that thetotal score was 28. High rainfall number that reached 718 mm day^{-1} on 29 February 2016, 173 mm day^{-1} on 6 days before and 153 mm day^{-1} on 5 days after was the main factor that causeding flooding in Masni District (Figure 1). In the area where high intensity rainfall occurred, while then the soil quickly saturated, so that the rain water is could not absorbed in longer time by the ground, it will then flow in the surface of the soil become a surface flow. High rainfall besides beneficial also threatens water quality, landslide, sedimentation and even flood (White & Howe 2010). Likewise, according to Biswas *et al*. (2017) rainfall deadline

Tabel 2 Flood formulation analysis

Parameter	Value	Value category	Score	Weight	Total Score
Average daily rainfall in wet months (mm day^{-1})	86.53	rather high	4	7	28
Watershed shape	Re >Rc (somewhat//elongatedl)	rather low	2	1	2
River gradient	0.0062	low	1	2	2
Drainage density	6.4	medium	3	1	3
Watershed slope	1- < 8	high	5	1	5
Land use	dominated by plantations		rather low		16.21

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Tabel 3 Average daily rainfall (mm day^{-1}) of wet months of the last 5 years at Arui watershed area

Years/ month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Amount**	**Average**
2013	81.5	122.6	94.1	64	0	28	0	20	45	46	51.5	98.5	651.2	65.12
2014	96	72.5	116.5	100	96	61	41.5	39	125	0	48	63	858.5	78.04
2015	56	148	104	161	105	78	0	0	32	24	37	58.5	803.5	80.35
2016	150	71	253	215	92	39	102	35	71.5	50	32	51	1808.5	150.71
2017	115	24.5	47	106	58	18	54	0	29.5	41	91	59	643	58.45
														432.667
Average														**86.53**

Source: Source: BWS Manokwari (2017)

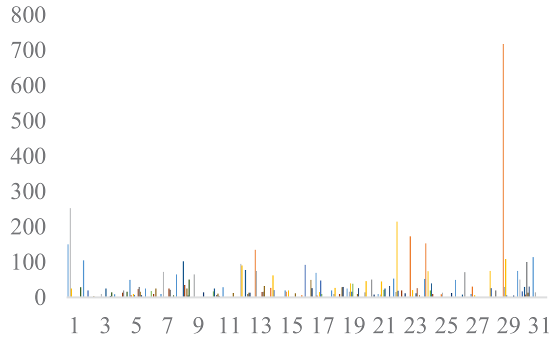

Figure 1 Daily rainfall 2016. January ( ), February ( ), March ( ), April ( ), May ( ), June ( ), July ( ), August ( ), September ( ), October ( ), November ( ), and December ( ).

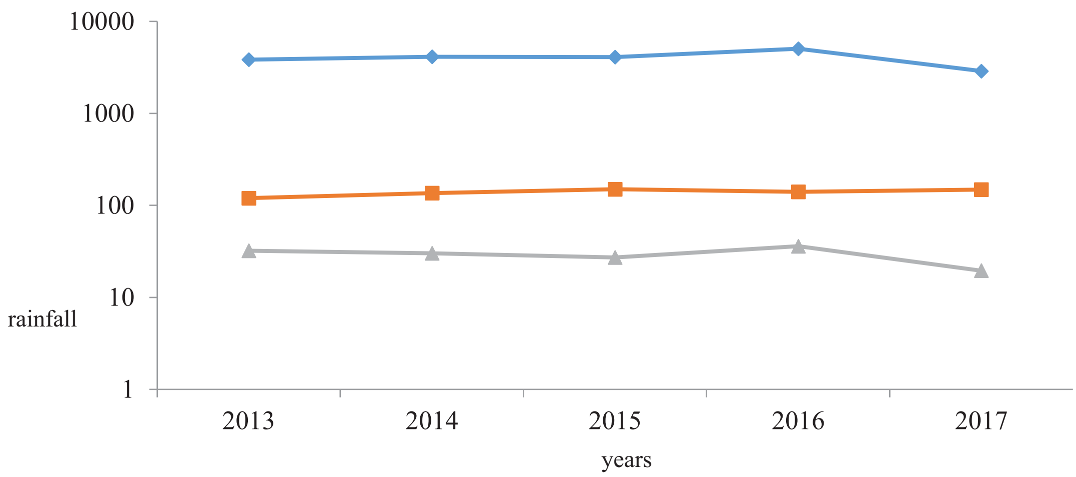

Figure 2 Daily rainfall 2016. Amount rainfall (mm) ( ), Rainfall day (mm) ( ), rainfall intensity ( ).

greatly affect for the occurrence of floods.

From Figure 2 based on the thickness of the rain, the average rainfall for 5 years is 3998.2 mm. According to Paimin *et al*. (2012) very often flooded when rainfall is very high (1800–2000 mm), infiltration is very slow, bad drainage, sometimes swamp area, 01% slope, mediteranean land, puddle> 1 m. Thus rainfall in Arui watershed > 2000 is very potential to flood threat. Rainfall during the last 5 years of 2013–2017 period of the highest rainfall in 2016 amounted to 5046.5 mm with a rain intensity of 36.05 (very high).

Forests are one of the most important factors in the water cycle, which returns rainfall to the air, both interception, and evapotranspiration. Rainfall reaches the soil, partially infiltrated (penetrates the surface of the soil), partly into the water flow above the surface (Asdak 2010; Ngongondo *et al*.

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2011; Zhang *et al*. 2017). When water accumulates in the canal, water is not easily absorbed into the soil, given the shallow groundwater depth. Consequently water flows at the soil surface or only floods if there is no lower channel. In addition to the presence of forests, the water that reaches the tree-covered land next rainwater will be immediately re-evaporated back into the atmosphere and interception (retained by the canopy which will further evaporate into the atmosphere), to the ground either through trough or droplet and flowing to the ground through the stem stream (Asdak 2010).

Annual rainfall data is further classified based on the criteria of wet, dry and dry months to obtain climatic type in Arui watershed area as shown as Equation *[10]*.

$$Q = 0.4/10.8 \times 100\% \qquad [10]$$

$Q = 3.7\%$ (tropical wet / climate type A)

From Table 3 it shows that almost 10.8 months (11 months) Arui watershed experienced rain wet months (> 100 mm).

Based on the Schmidt and Fergusson systems, Arui watershed has a tropical climate type of wet /climate type A with a value of Q = 0 - <15.3%. As the impact of tropical climate wet, Indonesia area gets sunshine all year round. The fertile soil, year-round sunshine and the not so great temperature difference between day and night impact the abundant biodiversity of Indonesia. Influenced by the movement of the circulation of the sun causing circulation of wind patterns and make the tropical climate region has two seasons, the rainy season and drought, in the absence of winter. In areas with wet tropical climates of vegetation that grow in many forests are green and dense. May affect global climate in case of significant change.

According to Fuchs *et al*. (2016), Hajani *et al*. (2017), Worman *et al.* (2017), Zhang *et al*. (2017) as impacts with high rainfall will cause enormous surface flows great rainfall impacts if the area is damaged water easily reaches the soil surface causes water flow and runoff the bigger the lower the infiltration, it is very possible that flood caused by surface runoff will often occur if the capacity of the river is full will surely overflow to the surface of the land and to the settlement. According to Vannier *et al.* (2016) if the rainfall is sufficient old with uneven distribution and excessive river capacity so the flood can't be inevitable. But according to Maryono (2004) rainfall is not merely the cause of floods. The flood is more caused if there is land conversion, sedimentation, river narrowing, and damage DAS. The flood will not occur despite high rainfall, provided that much water is absorbed in the soil, the river flows smoothly, the river is able to hold water and people do not build in the river border. By contrast, according to Neuvel & Knaap (2010) floods will occur if the rain can't be absorbed into the soil, the river can't hold water, the water flow is not smooth due to the narrowing of rivers and slum communities in the river border.

Watershed shape Arui watershed has area: 232,010,000 m^2, circumference of watershed: 98,950 m^2, length watershed: 2,407,059,410 m then RC is 0.29 and Re is 0.71 So Re>Rc mean (elongated/rather oval). As Figure 3 forms a slightly oval watershed based on flood formulation has a score of 1 and weight 2 then the total score of 2. According to Paimin *et al*. (2012), the watershed shape affects the time of water flowing into the outlet. The more rounded the watershed means the shorter the time it takes to reach the outlet, the higher the flooding fluctuations occur. Conversely increasingly oval form of watershed, water the longer the outlet. Similarly according to Wirosoedarmo *et al.* (2010), the form of a bird feather basin (elongated) produces relatively small flood peak discharge values with relatively long peak flood times. The watershed forms more round, there are many turns and if the river is more shallow then when the rainfall is high the runoff will be easily restrained and cause puddles. However, if the watershed forms are more rounded even though the rainfall is high but there are no turns and deep rivers then the water easily flows/does not stagnate to get downstream and easily water up to the sea. The shape of the watershed is rounded if there is a change of land use will decrease the water quality, the peak discharge value will be bigger and relatively fast to flood (Wirosoedarmo *et al.* 2010).

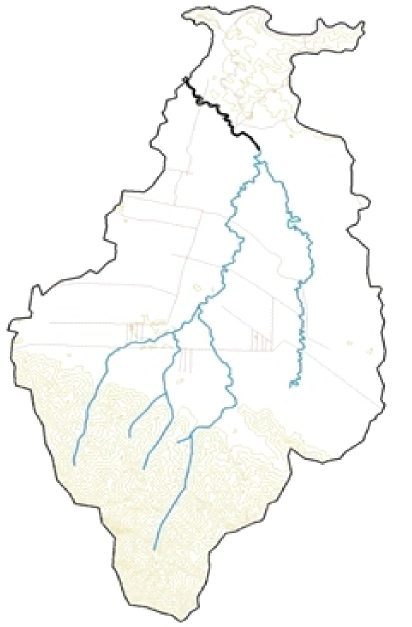

Figure 3 The shape and density drainage of Arui watershed.

Spherical and oval watersheds are not entirely the cause of floods if they are not influenced by others such as: land use change, high rainfall, slope, river slope, and drainage density. The area will be prone to flooding if rainfall is high, land use is dominated by wake area, many turns, round, and river basin shape becomes more flat. The flood is caused by rain water easily up to the surface of the soil, flowing up into the body of water, the water with a large amount concentrated in the body of water, the body of water can't overflow the excess water then the flood is inevitable.

River meandering The River meandering occur naturally because the nature of water that always flows to lower ground sometimes undermines the base, left-right rivers and precipitates sediment on the river bed as the water flow

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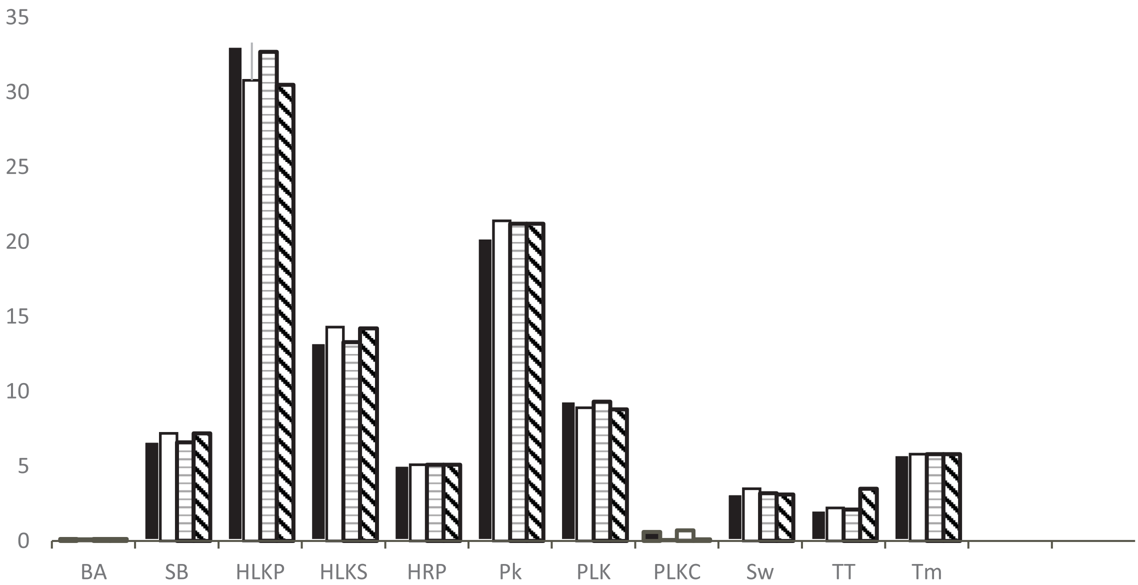
Figure 4 Meandering and location flood in Meiforga village

decreases. Flowing water tends to be straight considering the different rivers and river banks, the water will always follow the area. River bends at the flood site on 29 February 2016 are shown in Figure 4. In Figure 4 the length of the river channel of 407 m with a distance of 160 m river axis. The magnitude of sinusity at the bend of the river at the flood site is 2.54. Thus the river bend is meandering because of sinusity > 1.5, will reduce the water debit (Table 4). Measurements I before and after turns (4.35 and 3.37 m^3 s^{-1}) difference of 0 88 m^3 s^{-1}, measurement II (4.31 and 3.13 m^3 s^{-1}) difference of 1.18 and measurement III (3.53 and 2.17 m^3 s^{-1}) of the difference of 1.36 m^3 s^{-1}. At three times the normal water discharge measurement there is a difference between 0.88 to 1.36 m^3 s^{-1}. The more turns the debit will surely increase before the turn and decrease after turn. Some impacts of stagnant runoff water will erode the river border/landslides of river cliffs. If the river is more shallow then the peak discharge will often occur in the river where there are meander.

According to Nur (2009), the cause of the river meandering is litology of the river composer in the form of easy loose rock and soil type that is easily eroded. Constructing easily eroded soil such as clay and easily loose rocks like alluvial soil will facilitate the flow of the river to grind and turn. Alluvial soil types derived from sediments are easily carried by currents and at low river currents will easily settle. River curves naturally will always vary depending on river currents, types of soil that exist in the river body and the slope of the river. Any water debit in any volume can lead to a winding path, will erode the sediment from the outside of the corners and settle them on the bottom of the river. Large river currents easily carry basic river materials, river slides and sediments to flow into lower river bodies. If the flow of small rivers even no flow begins to occur sedimentation/ sedimentation that sometimes formed a river bend.

River Gradient The magnitude of river gradient /slope effect on flood, through large/small river currents. This slope is influenced by the slope of Arui watershed which has 3 slope categories: 08% (flat), 1525% (steep) and > 45% (very steep). The upstream river flow usually has a larger flow velocity than the downstream, but in the Arui watershed, which is dominated by a 60% flat river flow, is slowing down. So if large rainfall of water that does not enter into runoff. River Gradient in flood location in



Source: Interpreted image of landsat Arui watershed

Figure 5 Percentage land use change. 2014 (■), 2015 (□), 2016 (⊟), 2017 (◪). BA = Water; HLKP = Primary Dryland Forest; HRP = Primary Swamp Forest; SB = Shrub; HLKS = Secondary Dryland Land; Pk = Plantation; PLK = Dryland croping; PLKC = Mixed dryland croping; Sw = Rice field; TT = Open land; TM = Transmigration.

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Tabel 5 Water discharge (m^3 s^{-1}) before and after meandering

Date	Before							After						
	T	D	J	L	V	A	Q	T	D	J	L	V	A	Q
25/2/'18	10.6	0.41	10	10.6	0.9	4.35	4.09	9.83	0.33	10	10.3	1.02	3.4	3.47
17/3/'18	7	0.32	10	9.4	1,4	3.02	4.31	7.6	0.29	10	8.25	1.31	2.4	3.13
1/4/'18	10	0.42	10	8.4	1	3.53	3.53	13.6	0.31	10	9.6	0.73	3.0	2.17

Note : T = time (det); D = river depth (m); J= distance; L= width of the river (m); A = cross- sectional area (m^2); V = current velocity (m s^{-1}); Q = water discharge (m^3 s^{-1})

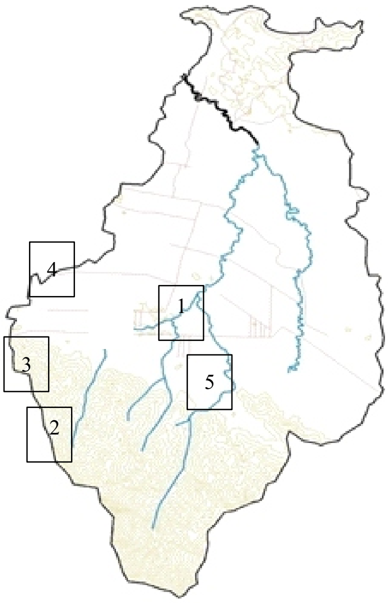

Figure 6 Map of Flood location in Arui Watershed. (1) Flood location in Meiforga village, (2) Flood location in Aska & Ririnfos village, (3) Flood location in Membowi village, (4) Flood location in Bowi Subur village, Flood location in Macuan village.

Table 5.

Different of Upstream to downstream (1.79 m + 1.79 m = 3.58 m) and the distance between upstream and downstream (290 m + 290 m = 580 m) at the flood site the magnitude of the river gradient is 3.58 m/580 m = 0.0062. The value of river gradient based on flood formulation then the value 0.006 <0.5. The value of 0.0062 with the score of 1 is low and the weight 2 then the total score is 2. Meanwhile, according to MoLEF (2017), the upper and lower upstream of Arui River is 263 m and the total river length is 11070 m, therefore the river gradient is 263 m/11070 m = 0.023. The value of river gradient based on flood formulation then the value 0.023 <0.5. The value of 0.023 with the score of 1 is low and the weight 2 then the total score is 2. The value of river gradient at flood location with all Arui watershed from upstream to downstream has the same category that is low (score 2). According to Nugroho & Cahyadi (2012), one of the application of river gradient is to predict hydrological response to rainfall in the area.

River flow in the upper and middle watershed is relatively more rapid, considering the gradient of the river is sloping and very steep. According to Barokah & Purwantoro (2014), the upstream part of the river is a source of erosion because in general the river flow through mountainous areas, hills, or mountain slopes that sometimes have a considerable height from sea level. The middle of the river is a transitional area from upstream and downstream. The slope of the river bottom is more gentle so the flow velocity is relatively small than the upstream. This section is an area of balance between the process of erosion and sedimentation that varies greatly from season to season. While the downstream of the river is usually through a plateau that has a slope of the ramps of the river bottom so that the flow speed is slow (Barokah & Purwantoro 2014). With a low river gradient in the Arui basin the actual flood potential is low. However, if the rainfall is large, there are river bends, the number of sediments at the bottom of the river and the change of land use is dominated by oil palm plantations then the river flow into surface runoff will be able to cause flooding.

Drainage Density There are five rivers flowing in Arui watershed. The rivers are rivers in the South such as, the Mariam and the Macuan, Mantedi and Nembowi rivers that converge into the Arui River and into the Sarera Kecil Bay. The drainage density is classified as a score of 1 with a weight of 3 then a total score of 3. The flow pattern (drainage pattern) of the Arui watershed river channels generally resembles the shape of tree branches (dendritic patern). Normal water flow in five rivers in Arui watershed in Table 6.

Normal water discharge between 0.487.05 m^3 s^{-1} and river water level with bridge 36 m. But on the Macuan river bridge with 3.5 m high and 10 m wide river when heavy rains can cause clogged water. As floods in 2016 in Masni District, river water overflowed due to shallow river and high river basin with bridge only 4.2 m. When shallow rivers and bridges are low the flow of water is inhibited, collected and inundated. Based on Figure 6 shows the drainage of Arui watershed drainage that is there are 4 four rivers that merge into one river (main river). Again, the only bush-shrinking river border can't function to reduce the flow of surface, sediment and mud to the river. So that water easily into the river, the capacity of the river quickly filled and eventually the water overflows. In fact the river border (riparian buffer) serves to preserve the function of the river by planting or catching eroded soil (sludge) and nutrients and chemicals

Tabel 6. River gradient in flood location

N0	From center flood to upstream		From center flood to downstream	
1	Different (m)	Distance (m)	Different (m)	Distance (m)
2	0.18	10	0.12	10
3	0.05	10	-0.08	10
4	0.06	10	0.22	10
5	0.06	10	0.13	10
6	0.12	10	0.17	10
7	0.01	10	0.04	10
8	-0.02	10	0.22	10
9	0.00	10	0.08	10
10	0.12	10	-0.05	10
11	0.075	10	-0.01	10
12	-0.08	10	0.08	10
13	-0.06	10	0.04	10
14	-0.06	10	0.01	10
15	0.1	10	-0.03	10
16	0.12	10	-0.06	10
17	0.05	10	-0.02	10
18	0.02	10	0.00	10
19	0.4	10	0.03	10
20	0.21	10	0.18	10
21	-0.07	10	0.22	10
22	0.00	10	0.03	10
23	0.07	10	0.16	10
24	0.06	10	-0.11	10
25	0.08	10	0.06	10
26	0.05	10	0.09	10
27	0.07	10	0.08	10
28	0.06	10	-0.01	10
29	0.08	10	0.08	10
30	0.04	10	0.12	10
Total	1.795	290	1.79	**290**

carried from the land on the left and right of the river so as not to enter the river (Dempsey *et al*. 2017). Riparian buffers also stabilize the river. Trees planted along rivers also further cool the rivers that create a good environment for the growth of various types of aquatic animals.

Watershed Slope Slopes/topography of land surface appearance caused by high differences in two places. Slope is one element of the occurrence of floods, erosion, and landslides. The steeper slope and the large, so the amount of surface flow for erosion or landslides the greater. In large sloped lands, the surface flow has a large velocity so that infiltration tends to decrease (Helman *et al*. 2017). Flat area and tend to concave will easily occur flooding, considering that in this area the water is easily concentrated to a lower area. The slopes in the Arui Watershed area are listed in Table 7.

Based on Table 7 shows the downstream area of Arui 60.01% watershed flat topography is potentially flooding. As according to Paimin *et al.* (2010), watershed area with slopes 1 <8 (flat) potential for high flooding. Floods that occurred in the Masni District is in a flat area and close to the river. In the Arui watershed region with a somewhat steep slope of 24.62% and very steep 15.37%. Thus the government and the public must maintain a somewhat steep and very steep terrain. Given the area with a rather steep and very steep

Table 7 Water discharge, water level and riparian river

River	Normal Water discharge (m^3s^{-1})	Height of water level with bridge (m)	Wide riparian (m)		Riparian vegetation	
			Right	Left	Right	Left
River Macuan	0.48	3.5	25	35	Palm oil	Palm oil
River mantedi	1.60	3	120	110	Palm oil	Shrubs
River Mariam	3.80	4	100	200	Palm oil	Palm oil
River Nembowi	1.25	4.80	150	210	Bush	Bush
River Arui	7.05	6	25	30	Shrubs	Shrubs

topography if the area is open when rain water flows easily in the soil surface, towards the river and when the river is full then the water will overflow either to the settlement or downstream watershed. Conversely, the topographic area is rather steep and very steep well maintained (designated as protected forest) it will serve to keep the soil fertility, protect the soil, water from landslide threats and provide more water in the dry season.

Land use as forest (13.62%) is still found even in the downstream watershed. In a downstream basin that still encounters forest will enlarge the water seep into the soil, reducing the flow of the surface so as to avoid flood disaster. In the middle watershed (22.58%) and upper watershed 15.37% are designated forests with rather steep slopes (15 <25%) and very steep (> 45%). Thus, in Arui watershed area 51.58% is still designated as forest and only 48.42% as non forest. The forest area of 51.58% in the Arui watershed can cause floods of course if the forest area is less likely to flood will be relatively larger. Whereas with the still-forested areas will be able to receive, accommodate, store and drain rainwater from the tributaries to tributaries and to the main river. So steep slopes (15 <25%) and very steep (> 45%) still found forests will be able to and control the flow of the surface. In this slope the threat of surface flow, erosion and landslides is very large, so it is necessary in this area remain as a forest area. Sloping slopes, slope length, particle-size and slope shape will affect the extent of erosion and surface flow (Arsyad 2010; Helman *et al*. 2017). According to Dessalegn *et al.* (2014), particle-size distributions were also influenced by topography such that the upland soils were dark red and coarse textured, whereas the lowland soils were dark grayish and clayey. Regarded topography as the dominant factor influencing soil property variation due to its influence on runoff, drainage, microclimate. The topographic control of the soil quality and site characteristics are attributed to varying pedogenesis processes along the toposequence as evidenced by differences in transport and deposition of soil materials.

Floods that occur in the Arui watershed are not only caused by flat topography and silting of the river. But more due to heavy rain/high intensity. Although Arui watershed 51.58% is still forested but if rain with high intensity, the soil is quickly saturated. When saturated infiltration/water seeps into the soil will stop, consequently the water inundating or flowing in the soil surface as runoff. Floods that are almost happening around the world as a result of excessive rain while the soil can't absorb water, river water overflows and creates puddles. The area with flat topography until somewhat concave when the rain water easily concentrated, flooded and if the amount of water is greater then the inundation flood is not inevitable (Marfai 2011).

Land Use increasing and development of the population there has been an increase in land use for settlement and agricultural purposes, as well as increased water demand. Arui watershed was originally predominantly forest, but the beginning of 1980 opened transmigration programs imported from Java, Nusa Tenggara and Bali. Forest areas have been converted into agricultural land, plantations, agriculture and settlements. Reduced areas of forest and forest destruction in Papua should be stopped so that floods do not recur. The area of protected forest/nature conservation in Arui watershed is still 50.6% (Table 8) flood occurs, how are if the forest < 50%.

The transmigration program is geographically very profitable for Papua Island, considering the population is still very rare, while in Java the population is very dense. However, transmigration has created new problems such as floods by 2016. The transfer of forests should be prevented as early as possible and already well managed such as for agriculture, plantations, rice fields and reclaimed/reforested. Because according to Haines & Young (2009), there are relationships between land use and biodiversity are fundamental to understanding the links between people and their environment. Considering the overuse of forest functions caused many problems, according to Hidayat (2012), if forest land area has been converted, to become forest realization is very small because it takes a long time and expensive. While changes in land use will decrease land cover that will have implications on carbon dioxide emission, climate change and biodiversity (Prasetyo 2013; Basyuni *et al*. 2015). Similarly changes in land use from ecosystem function of dung beetles, especially dung burial activity (Shahabudin 2011). Changes in the function of forest land into oil palm plantation shows changes in soil chemical properties such as pH, C-organik, cation exchange

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capacity, total N and organic matter (Oksana *et al*. 2012). According to Idris *et al.* (2017), land use and land cover change from natural forest to either or rainfed agriculture with cash crops at upper stream reduced infiltration capasity.

Similarly, the transfer of forest function to coal area conducted Purwati *et al*. (2011) resulted in an increase in the total content value of suspended materials throughout the Berau watershed. The transfer of forest into other designations such as mining (Hidayat *et al*. 2015) and rubber plantations (Oksana *et al.* 2012). Plantations have different properties than forest plants. The strength of plantation crops in retaining rainwater is not as large as the strength of forest crops that are typically tens of years old with deep roots deep into the soil. Therefore, the risk of landslides and mud floods is still a threat to this area. Land changes have affected the natural hydrological cycle, rainwater that could have been stored longer in the soil has been converted into surface streams that are directly discharged into the sea.

Based on Figure 5 out of 11 land use types the percentage of land use change tends to vary. Land use types of water bodies, primary swamp forests, plantations, and transmigrations tend to remain. Primary dryland forest, mixed dryland farming, dryland and rice fields tend to decrease between 0.01 and 2.2%. However, secondary dryland forest and open soil tend to increase between 0.6 to 1.4%. Alleged sedimentation in all rivers is the impact of land use change on Arui watershed and oil palm-dominated plantations. Since the last 4 years land use change has not changed much, but in 2016 Arui watershed area floods. Of course for subsequent years the change and transfer of forest functions must be stopped so that the floods will not recur. Likewise, the traditional agricultural system of the people of Papua with shifting cultivation systems should turn to sedentary agriculture and impose soil and water

Table 8 Slope class and topografy Arui watershed

Slope (%)	Topography	Watershed	Land use	Non forest area (ha)	Forest (ha)	Non forest area (%)	Forest(%)
0 – <8	Flat	Downstream	Water	29.64			
			Bushes	1309.12			
			Primary dryland forest		356.01		
			Secondary dryland forest		1625.90		
			Primary swamp forests		1180.69		
			Plantation	4688.68			
			Dryland croping	2004.74			
			Mixed dry land farms	150.18			
			Rice field	743.27			
			Open land	482.68			
			Transmigration	1357.96			
Sub total				10,766.27	3162.60	46.38	13.62
15-<25	rather steep	Medium	Water	3.67			
			Bushes	245.11			
			Primary dryland forest		3762.20		
			Secondary dryland forest		1463.65		
			Primary swamp forests		16.11		
			Plantation	41.13			
			Dryland farming	175.65			
			Mixed dry land farms	1.49			
			Open land	5.32			
Sub total				472,37	5,241.96	2.04	22.58
>45	very steep	Upstream	Primary dryland forest	-	3561.91		
			Secondary dryland forest	-	6,51		
Sub total				-	3568.42	-	15.38
Total				11,238.64	11,972.98	48.42	51.58

Source: Data analysis DEM and interpreted of landsat Arui watershed, 2015

Tabel 9 Land use Arui watershed

Land use (%)	Categori	Score	Weight	Score total
Protected forest/natural conservation (50.60)	Low	1	8	4.05
Production forest/plantation (21.46)	Rather low	2	8	3.43
Shrubs (7.28)	Medium	3	8	1.74
Rice field/croping (14.58)	Rather high	4	8	4.66
Settlements(5.84)	high	5	8	2.33
Grand total				16.21

conservation. According to Yan *et al*.(2013,) the impacts of land use changes on changes in streamflow and sediment yield were evaluated and quantified. Therefore quantifying the effects of land use change on spatio-temporal change patterns of sediment yield is crucial to development of soil–water resources and land use management at a catchment scale (Cai *et al.* 2012).

Several oil palm plantation sites have entered the second cycle, allegedly clearing land for planting oil palm seedlings to trigger high sediment on the river bed in Arui watershed. Sediments (ground particles) or parts of a material transported by water from a site that is eroded and enters the water. According to Mueller *et al*. (2009), found that land use change have larger impacts on sediment yield than climate change. Damage to soil erosion occurs in the form of deterioration of chemical and physical properties of soil such as nutrient loss, increased density and resistance of soil penetration, decreased infiltration capacity and soil capability in water retention (Arsyad 2010).

Conclusions

The results of the research show that the main factor of floods are the average daily rainfall in wet month by 86.53 mm day^{-1} (rather high) with a score of 28. Meanwhile land use dominated by forest and plantation (rather low and medium) with a score of 21, slope of the watershed dominated by 1<8% (high) with a score of 5, the drainage density of 6.4 (medium) with a score of 3, shape of watershed (Rc of 0.30 and Re 0.71) with somewhat oval/elongated shape with a score of 2 and river gradient of 0.0062 (low) with a score of 2 respectively. High rainfall causes greater flow of water and runoff. Land use dominated by plantations (21.46%) is thought to be one of the main causes of floods in Masni Distrik. Flat topography (60%), dense river drainage, oval-shaped/meandering watershed so that when it rains, water will easily become surface runoff that will overflow on the ground and to the settlement.

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