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Research and Full Length Article:

Biophysical Characteristics of Deli River Watershed to Know Potential Flooding in Medan City, Indonesia

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Received on: 06/12/2019
Accepted on: 07/05/2020

Abstract. This research aims to analysis the biophysical characteristics of watershed of Deli River to know potential flooding in Medan. The research is conducted at Deli River, which is located in 3 locations in North Sumatera namely Karo Regency, Deli Serdang and Medan City. Indonesia. This research used field survey method, survey activity in the form of observation and verification of characterization and biophysical identification of watershed in each location. Some properties of soil samples were analyzed in the laboratory. Field surveys were also conducted by observing the types of land use, as well as, climate and hydrological data. The results of surveyed data and soil analysis were used to assess land damage. The findings showed that understanding the biophysical flow of the river especially land use, slope, landform, and rainfall in the upstream Deli sub watershed in the Deli River in Medan is very important and sensitive. One of the causes of flooding in Medan City due to the degradation / damage of land both due to erosion, land criticality, and land use that is not in accordance with the ability of land use. The direction of conservation and land use has an impact on the decrease of maximum flood and flood volume of each Sub Watershed with 2, 5 and 10 year re-period.

Key words: Biophysical characteristics, Potential flooding, Deli River Watershed

Introduction

Every year in the rainy season, Medan (located in Indonesia) is always hit by floods. Flood incidence in Medan City is 10-12 times per year in average, and is strongly influenced by deliberate watershed of Deli River, where critical land is widespread, which may result in flooding of shipment. According to the investigation of Sub-Center for Land Rehabilitation and Soil (Central Management of Regional River Flow of Wampu Sei Ular, 1998) and Arly (1998), floods in Medan is likely due to the silting of the river of the high erosion and the rapid increase of population the need for land resources that are poorly supported by soil conservation efforts. In addition, the community is not aware of the importance of Land Rehabilitation, Soil Conservation and Flood control that has been done in Medan is focused on river flow only such as river improvement and floodway development, while off-stream management, ie maintenance work in upstream watersheds, among others, conservation, infiltration pond and so forth in an integrated way has not been done (Hasibuan, 2007). On the other hand, Deli River watershed has a strategic urgency in the upstream sector, namely the availability and sustainability of sources of safe drinking from Perusahaan Air Minum Tirtanadi (PDAM) in Sibolangit and downstream as the safety of Medan, industrial safety and Belawan port Soil (Central Management of Regional River Flow of Wampu Sei Ular, 1998).

Therefore, research is needed which is expected to produce recommendations on a flood control system with the direction of conservation in upstream, middle and downstream watersheds. The conservation directives are based on the level of damage / critical watershed / sub watershed assessed by the extent of erosion and the level of erosion hazard and other land damage. Thus, the results of this research can be used as an important input in the development of flood control technology, and can be applied to the management of other watersheds across the city of Medan, so the problem of flooding can be reduced.

Watershed

Watershed in foreign terms is known as catchment area, drainage area, drainage basin, river basin, or watershed (Notohadiprawiro *et al.*, 1999). In Indonesia, there are three terminologies in accordance with the breadth and coverage namely: Catchment, Watershed and Basin. There is no standard limit, but it is understood that the catchment is smaller than watershed, and the basin is a large basin (Priyono and Cahyono, 2001).

According to the relatively diverse definitions of the watershed based on individual goals. Watershed is an area limited by ridges and rainwater falling by a river system (Dixon and Easter, 1986). According to Seyhan (1990), the watershed is a land area bounded by a natural boundary of topography that serves to accommodate, store, and drain the water received to the nearest river system that further leads to reservoirs or lakes or seas. Another definition states that the watershed is a region located at a point on a river that by topographic boundaries drains water falling over it into the same river and through the same point in the river (Brooks, 1989; Arsyad, 2010).

Watershed is a complex ecological system in which there is a dynamic equilibrium between the incoming material energy (input) and the material out. Naturally, the change in input and output balance is slow and does not pose a threat to humans and environmental sustainability; but on a watershed system with continuous land-use dynamics from dense vegetation forms to rare vegetation forms or from vegetation forms to shapes non vegetation according to spatial land use spatial distribution, it will influence fluctuation of river flow (Asdak, 2004).

Characteristics of Watershed

A watershed has specific biophysical characteristics and is closely related to the main elements such as soil type, land use, topography, slope and slope length. These characteristics are related to the watershed response to falling rainfall at the site. The biophysical condition of the watershed affects several hydrological processes affecting the availability of water such as intercepted water, infiltration, percolation, surface flow, ground water content and river flows. Factors that play a role in determining the watershed hydrology system such as land use, slope and slope length can be engineered by humans. Thus, in planning the watershed management, land-use manipulation (change from forest to agricultural land or other land-use forms) as well as, slope and slope length arrangements become one of the activities in planning (Asdak, 2004).

The shape of the river is the ratio between the watershed and the length of the main river, the greater the shape river value indicates the fatter the watershed, so the flood will come faster. In contrast, the small shape river values indicate slim watersheds, thus flooding long enough (Isnugroho, 2002).

The watershed ecosystem is divided into upstream, middle and downstream watersheds. Biogeophysically, the upper watershed is characterized as follows: 1) a conservation area, 2) a higher drainage density, 3) an area with a high slope (> 15%), is not a flood zone 4) water use is determined by the drainage pattern, and 5) the vegetation type is generally a forest stand (Brooks, 1989; Asdak, 2004). While the downstream watershed is characterized by: 1) an area of exploitation, a smaller drainage density, 2) an area with a slope and small to very small 3) in some places is a flooded area, 4) the regulation of water consumption is determined by the irrigation building, and 5) the type of vegetation is dominated by agricultural crops except the estuary area is dominated by mangrove / peat forest. The central watershed area is the transition region of above mentioned two different watersheds

The Concept of Watershed Management

Watershed management is the process of formulation and implementation of a series of activities concerning Natural Resources (SDA) and human in a watershed by taking into account the social, political, economic and institutional factors that exist in the watershed and surrounding areas to achieve specific social goals (Dixon and Easter, 1986).

Conceptually, watershed management is a planning system of: 1) resource management activities including land use, management practices and utilization of local and external resources, 2) implementation tools to locate watershed management efforts as effectively as possible through community elements and individuals, 3) organizational and institutional arrangements in the watershed area implemented. Thus, the handling of institutional coordination mechanisms in the implementation of watershed management programs is one of the keys to success (Asdak, 2004).

Water Conservation

Water conservation is in principle the most efficient use of water that falls to the ground and the proper flow timing, so there is no destructive flooding in the rainy season and there is enough water in the dry season. Water conservation can be carried out by: a) improving the utilization of surface water and groundwater, and b) increasing the efficiency of irrigation water use (Arsyad, 2010), and also the necessary measures to conserve water resources (Prastowo, 2008).

Surface water management includes: 1) surface flow control, 2) water harvesting, 3) increasing soil infiltration capacity, 4) soil treatment, 5) use of soil clogging materials and rejection water, and 6) coating the drains.

Water conservation technology is designed to increase the entry of water into the soil through infiltration and filling of water pockets in the basin area and reducing water loss through evaporation. To achieve these goals, water conservation efforts that can be applied are water harvesting techniques, and soil management technologies. Application of harvesting technology intended to reduce the volume of surface water flow and increase the groundwater reserves and water availability for plants (Irianto and Rejekiningrum, 2008).

Floods and Influential Factors

Flood is defined as an incident of overflowing river flow on the left and right of river flow either on river banks or on flood plains. The amount of rainfall, intensity, and distribution of rain determines the strength of rain dispersion to the soil, the amount of surface flow and the strength of erosion and flow capacity. The definition of flooding is the event of overflowing river water over river troughs. Another definition mentions: a river is said to be flooded if there is an increase in the flow of a relatively larger flow, or when the flow of water melimpas out the river channel and cause disruption to humans (Isnugroho, 2002). Flood events are caused by low watershed retention capability, reduced retention along the river channel, reduced absorption area, and low socio hydraulic character (water culture). According to Cech (2005) floods occur due to precipitation and runoff that exceed the capacity of the river channel.

Flood is a natural phenomenon that occurs when the intensity of rain that falls very high, where the ability of absorption into the ground has been exceeded, resulting in runoff with the number and rate of large flow which can then become flooded. Floods cannot be deemed to be an annual routine disaster. Floods can damage various public facilities and infrastructure that must be repaired after floods, plus if there is a loss of life. At least seven public sectors are always affected by floods, such as agriculture and forestry, water resources and irrigation, transportation, housing and settlements, environment and spatial planning, health and social welfare. Thus, directly or indirectly, floods can have a serious effect on the efficient use of local and national budgets. Various forms of activities to cope with flooding have been done by many parties, but have not shown any real results (Center for Land Resources Studies of Gadjah Mada University, 2007). Therefore, floods need to be addressed so that losses and damage and casualties can be reduced to the lowest level.

Land use change is the main cause of flooding compared to others. For example, if a forest in a watershed is converted into a settlement, the peak river flow will increase between 6 to 20 times. The numbers 6 and 20 depend on the type of forest and the type of settlement. Similarly for other changes there will be a significant increase of peak discharge (Kodoatie and Sugiyanto, 2002).

As shown in Fig. 1 the structural method is divided into the improvement and regulation of rivers and flood control buildings. To support the success of flood control, management activities, river improvement and river capacity are needed. This work involves: 1) adding dimension to river flow, 2) minimizing roughness value of river flow, and 3) straightening or shortening of river flow in rivers or bermeander (Kodoatie and Sugiyanto, 2002).

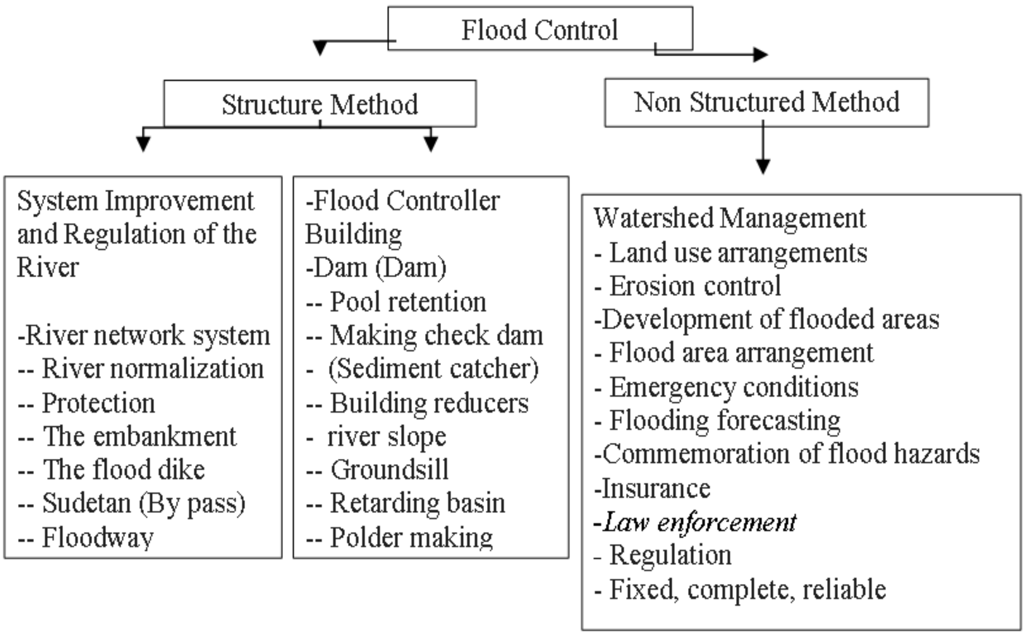

Fig. 1. Integrated flood control and watershed management (Hasibuan, 2007)

Land Damage

Today the damage to agricultural land is increasing. This may result from erosion, water logging, accumulation of salts in saline areas, the accumulation of elements or compounds that are toxic to plants due to the use of chemical fertilizers and chemical drugs continuously every year or every season cropping, and the absence of recycling of agricultural wastes resulting in the loss of nutrients and organic matter in root areas (Asdak, 2004). In addition, there is also a constriction of land ownership due to limited land area, while the population continues to grow.

The aim of this study was to analysis the biophysical characteristics of watershed of Deli River to know potential flooding in Medan.

Material and Methods

The research was conducted at Deli Watershed, which is located in 3 locations in North Sumatera namely Karo Regency, Deli Serdang and Medan City. Based on its geographic position the Deli watershed is located between 3°12'58" LU-3°47'15" N and between 98°28'50" BT-98°41'50" E with altitude of place 0-40 m above sea level. Geographically the total area of Medan City is 26510 ha, the largest land use pattern is for settlement (80%). Field research began in February 2010 to January 2011.

The data on watershed Map Sub Deli Basin, using ArcView GIS software version 3.3, obtained the Deli River area 47772 ha.

This research used field survey method in the form of observation and verification of characterization and biophysical identification of each Deli River watershed which are the parameters needed for the study of land damage, soil observation by drilling and making minipit soil (land section or soil profile, but smaller size and more shallow) in this study the size of minipit soil was: 50×50×60 cm and soil sampling minipit.

Field surveys were conducted by observing the types of land use, as well as, climate and hydrological data. The results of surveyed data and soil analysis were used to assess land damage. The land damage assessment was based on prediction of erosion and erosion hazard, land classification, land use classification, flood analysis, watershed, followed by analysis of impact of conservation guidance on the decrease of flood discharge and flood volume.

Materials used in the study include earth map, geology/lithology map, topographic map, soil map, Landsat digital image of 2003, land use map, vegetation density map.

For image processing and database equipment using a single computer device, ArcView GIS Software version 3.3 and PC Software ArcGIS version 9.3, were used for analysis and presentation of data, Software Analysis Frequency and Rational Method (Faculty of Civil Engineering Universitas Gadjah Mada), and flood assessment Software (PSSL UGM, 2007) for flood assessment, cameras as a means of survey documentation.

The tools used in the study include: 1) Stationeries, 2) Work Map Scale 1: 100,000, 3) Field measuring tools (eg GPS Garmin, geological compass, meter roll, soil drill, drill and permeability ring), and 4) Work tools in the field (scopes, hoes, fork and crowbar, plastic bags, loops, field knives).

Results

Biophysics Characteristics of Deli Watershed

The biophysical status of Deli watershed is one of the determinants, either directly or indirectly, as one of the causes of flooding in Medan City. The biophysical status of the Deli watershed is generally reflected by morphometry, soil conditions, land use, slope, and hydrology. The biophysical status of the watershed greatly determines the characteristics of the watershed, and the parameters of the Deli watershed. The influential morphometric conditions include the shape and size of the watershed, the length and gradient of the main river, the flow density and travel time, and the slope of the slope. Soil components include soil type and soil depth, while land use is a type of use and vegetation density.

a. Watershed Morphometry / Deli Watershed

Watershed area is an important factor in the formation of flow hydrograph. The wider the watershed, there is a tendency of the greater the amount of rainfall received. However, the time lag between the peak rainfall and the peak hydrograph flow becomes longer. Similarly, the time required to reach the hydrograph crest and the length of time for the overall hydrograph flow also becomes longer, this will determine the occurrence of flooding in the watershed (Asdak, 2004).

High differences within the watershed determine the gradient of slopes, streams and runoffs. The highest and lowest points on the watershed / sub watershed of Deli can be seen in Table 1

Table 1 shows that the Petani' Watershed has the highest difference and the lowest point is 1530 m, while other Sub watershed the difference between the lowest is relatively smaller, such as Simai-mai 325 m, Babura Sub-Basin 341 m, Bekala Sub-Basin 145 m, Sub-Basin Sei Kambing 15 m, Deli Sub-district 150 m, and Sub watershed Paluh Besar difference of highest and lowest point is 10.4 m. This situation indicates that most of the Deli Sub Basin has basic relief ramps are steep relief only a small part. Thus, the water surface flow in almost all Deli Districts is slow, except in the Farmers' Sub-Watershed (Table 1).

Table 1. Highest and lowest point differences in deli sub basins

Watershed Sub district	Lowest point (m)	Highest point (m)
Petani	150	1680
Simai-mai	50	375
Babura	20	361
Bekala	30	175
Deli	0.0	150
Sei Kambing	15	30
Paluh Besar	2.1	12.5

Data Source: BPDAS wampu sei ular (2003)

b. The Slope of the Deli River Basin

The slope of the Deli River slopes affects the hydrograph behavior in terms of timing. The larger the slope of a watershed, the faster the running water rate. Based on the results of analysis of data updating on Slope classification as shown in. Using Arcview GIS version 3.3 software obtained spatial distribution of each slope class of each sub watershed Deli like

Soil Condition of Deli River Watershed

Based on the result of soil watershed land delineation analysis obtained from Soil Sub Map of Land Rehabilitation and Soil / Snake Soil Conservation (1999), using Arcview GIS version 3.3 software, the spatial distribution of units of soil contained in each sub watershed Deli as listed in Table 2 (Hutapea, 2019).

Table 2. Soil sub unit of deli river basin

sub watershed	Land Unit		
	Group	Area (ha)	(%)
1	2	3	4
Petani	Dystrandept Eutrandept Dystrandept	3865	30
	Dystropept Dystrandept Tropudult	4491	35
	Dystropept Troporthent Tropudult	2590	20
	Dystropept Tropudult Troporthent	563	4
	Hydrandept Eutropept Troporthent	1313	10
Total		12824	100
Simai-mai	Dystrandept Eutrandept Dystrandept	785	24
	Dystropept Dystrandept Haplorthox	652	20
	Dystropept Dystrandept Tropudult	1795	55
Total		3233	100
Babura	Andaquept Tropaquept	725	14,6
	Dystrandept Eutrandept Dystrandept	1045	21
	Dystropept Dystrandept Tropudult	3188	64
Total		4959	100
Bekala	Dystrandept Eutrandept Dystrandept	198	4
	Dystropept Dystrandept Tropudult	4346	95
Total		4544	100
Deli	Andaquept Tropaquept	2259	35
	Dystrandept Eutrandept Hydrandept	341	5
	Dystropept Dystrandept Tropudult	2303	35
	Hydraquent Sulfaquent	751	11
	Tropaquept Fluvaquent Tropohemist	509	7
	Tropopsamment Tropaquent	282	4
Total		6447	100
Sei Kambing	Andaquept Tropaquept	2607	61
	Dystrandept Eutrandept Hydrandept	718	16
	Dystropept Dystrandept Tropudult	938	22
Total		4264	100
Paluh Besar	Andaquept Tropaquept	7071	61
	Hydraquent Sulfaquent	1382	12
	Tropaquept Fluvaquent Tropohemist	2297	20
	Tropopsamment Tropaquent	747	6
Total		11498	100

Land Damage Based on Erosion of Deli River

Rain Erosivity (R)

Rain Erosivity or total rain kinetic power with rain intensity greater than 1 inch per hour (Hudson, 1981). Rain erosivitas is the result of total kinetic power of rain with maximum rain intensity over a period of 30 minutes. The formula used to calculate the rain erosivity factor is using the Lenvain formula (1975) in Arsyad (2010).

The rainfall data of Deli watershed was obtained from 6 rainfall station, over a period of 21 years (1989-2009). Data obtained from Meteorology Climatology and Geophysics Council of North

Sumatera Medan. Based on the calculation of the average of monthly rainfall, the average rainfall erosivity value in each rainwater catchment station of Deli watershed.

One of the causes of flooding in Medan City due to the degradation / damage of land both due to erosion, land criticality, and land use that is not in accordance with the ability of land use. The direction of conservation and land use has an impact on the decrease of maximum flood and flood volume of each Sub Watershed with 2, 5 and 10 year re-period. The smallest maximum discharge decrease is 2.3% found in Deli sub-watershed, the largest of 26.3% is in the Simai-mai Basin. While the smallest flood volume decrease is 2.3% is found in the Deli watershed, and the largest is 36.2% in the Bekala sub-basin, this decrease is expected to be part of the flood mitigation effort in Medan City.

The largest erosion contribution was from Farmers' Sub Watershed at 780.736 tons with an average erosion of 60.9 ton/ha/yr; Babura sub-watershed 180.313 tons with an average erosion of 36 ton/ha/yr; Bekala Sub-watershed 176.0 tons with an average erosion of 38 ton/ha/yr; Simai-mai basin was 132.971 tons with an average erosion of 41 ton /ha/yr; Sub DAS Paluh Besar 20.154 tons with an average erosion of 1 ton/ha/yr; Sei Koding Sub-basin 2.067 tons with average erosion of 1 ton/ha/yr; and Deli Subdivision 1.517 tons with an average erosion of 1 tons / ha / year.

Table 3 shows that the highest rainfall erosivitas is located at the Tuntung rainfall station, which is 167.8 ton/ha, following the Pancurbatu rainfall station 149.8 ton/ha, Belawan rainfall station 127.8 ton/ha, Polonia's rainfall station of 117.5 ton/ha, and the lowest erosivity value was found at a 97.2 ton/ha rainfall station.

Table 3 Value of deli river erosivity

Erosivity	Rainfall Station					
(Ton/ha)	Togkoh	Pancur Batu	Tuntungan	Polonia	Seumayang	Belawan
January	111	84	111	72	37	85
February	103	59	59	41	35	34
March	141	95	103	60	44	49
April	182	104	90	85	52	53
May	79	176	186	135	94	108
June	55	119	133	90	69	83
July	52	111	100	88	68	100
August	54	166	161	129	91	156
September	102	284	320	228	234	185
October	165	247	308	209	209	211
November	216	216	212	155	124	219
December	167	132	226	114	104	240
Annual Rate	116	149.8	167.8	117.5	97.2	127.8

Value of Soil Erodibility Factor (K)

Table 4 shows that the highest mean erodibility factor (K) value for the Deli watershed is 0.32 with an area of 12664 ha or about 26.5% of the Deli River area, whereas the lowest average of erodibility (K) value is 0.15 with an area of 652 ha or about 1.4% of the Deli River Basin Area.

Table 4. Erodibility value (K) deli watershed

No	Land Unit / Group	Erodibilitas (K)			
		Average	Class	Wide (ha)	%
1	Andaquept Tropaquept	0.32	Medium	12664	26
2	Dystrandept Eutrandept Dystrandept	0.21	Medium	5894	12
3	Dystrandept Eutrandepts Hydrandept	0.21	Medium	1059	2
4	Dystropept Dystrandept Haplortox	0.15	Low	652	1
5	Dystropept Dystrandept Tropudult	0.17	Low	17064	35
6	Dystropept Troporthent Tropudult	0.16	Low	2590	5
7	Dystropept Tropudult, Troporthent	0.16	Low	563	1
8	Hydrandept Eutropept Troporthent	0.21	Medium	1313	2
9	Hydraquent Sulfaquent	0.19	Low	2133	4
10	Tropaquept Fluvaquent Tropohemist	0.25	Medium	2806	5
11	Tropopsament Tropaquent	0.16	Low	1029	2
	Deli watershed			47772	100

Long Index Factor and Slope Tilt (LS)

The long and slope factor (LS) index value values are converted from the slopes of the Deli River slopes. The slope slope map is derived from the digital elevation model (MED) obtained from the digitization and interpolation of contour lines with GIS. In areas that have the same slope class are given a line boundary, so it is known that the difference and the spread of the slope classes on each Deli River. The value of the Deli DAS LS index is converted by using the slope slope conversion Table to LS value, according to the Director General of Reforestation and Land Rehabilitation 1986 from the conversion result, the value of LS index and spatial distribution is based on the length and slope of the Deli watershed as listed in Table 5. The index values are included in mapping the length and slope of the Deli basin with ArcView GIS software version 3.3, the spatial distribution for each of the Deli Watershed is listed in Table 5.

Table 5. Extent of slope length index and slope (LS) of deli river basin

Slope	Slope Class	Wide and Tilt of Slope (LS)		
		Value LS	Wide (ha)	%
0 - 8 %	I	0.5	19718	41
> 8- 15 %	II	1.4	10796	22
> 15 - 25 %	III	3.1	-	-
> 25 - 40 %	IV	6.1	12728	26
> 40 %	V	11.9	4529	9
Deli watershed			47772	100

Identification of Causes of Floods in Medan City

Land Change Factor

The condition indicates that the Deli watershed is damaged, in accordance with the opinion of Maryono (2005) which states a watershed if more than 30% of the land use has been used as residential land or settlement, the watershed is indicated as damaged watershed. Therefore, efforts to reduce the rate of increase of occupancy land in the Deli watershed, given the increasing percentage of land area of settlements.

Rain Factor

Based on the results of the measured rainfall recordings on geophysical stations Rainfall gains that occurred on January 5, 2011 has 96 mm/day. While on April 1, extreme rain intensity occurred at Tuntung rainfall station with intensity reaching 175 mm/day. Although that meet the criteria of extreme rain intensity only in Tuntungan but because it occurs simultaneously in all areas of Medan then there was accumulation of rainwater that was on the surface and resulted in the flood. Floods that occur on the basis of the above data are not delinquent floods from the upstream of the Deli River but the floods caused by the accumulation of rainfall in the central part of Medan and its surroundings (Meteorology Climatology and Geophysics Council of Wampu Sei Ular, 2011).

Discussion

The condition indicates that the Deli watershed is damaged, in accordance with the opinion of Maryono (2005) which states a watershed if more than 30% of the land use has been used as residential land or settlement, the watershed is indicated as damaged watershed. Therefore, efforts to reduce the rate of increase of occupancy land in the Deli watershed, given the increasing percentage of land area of settlements.

Consequently there is an increase of a forest area when converted into a settlement then what happens is that forests that can withstand surface runoffs are substantially replaced into settlements with small surface runoff resistance. As a result, there is an increase in the flow of soil surface to the river and this result in a large increase in river flow.

Damage of land based on predicted erosion rate of Deli watershed shows that the highest erosion value found in Sub Watershed of Farmers reaches 266.1 ton/ha/year, following Simai-mai Basin 182.5 ton/ha/yr, Babura and Bekala sub watershed 162.4 ton/ha/yr, Deli subdivision of 90.6 ton/ha/yr, Sei Kambing Subdistrict 22.0 ton/ha/yr and Sub DAS Paluh Besar with erosion value of 11.6 ton/ha/yr.

Conclusion

Understanding the biophysical flow of the river especially land use, slope, landform, and rainfall in the upstream Deli sub watershed in the Deli river in Medan is very important and sensitive. One of the causes of flooding in Medan City due to the degradation / damage of land both due to erosion, land criticality, and land use that is not in accordance with the ability of land use. The direction of conservation and land use has an impact on the decrease of maximum flood and flood volume of each Sub Watershed with 2, 5 and 10 year re-period.

Deli land destruction is dominated by biophysical factors, especially land use, slope, landform, and rainfall in upstream Deli sub watershed. This is what causes flooding in Medan.

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