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Analysis of land use changes effect on erosion and sedimentation potential in Progo watershed

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Abstract. Progo Watershed is an ecosystem consists with Progo Rriver as the main river. One of the problems in the Progo River is the formation of sediment deposits in the downstream. The purpose of this study is to analyze the effect of land use on the erosion and sedimentation potential. Erosion prediction are based on Wischmeier and Smith's research which presents the Universal Soil Loss Equation (USLE). In this research, the erosion and sedimentation potential has different land uses; from 1990, 2000, and then 2011. Generally, there has been an increase in the average erosion rate at Progo watershed, from 165 tons/ha/year in 1999 to 184 tons/ha/in 2011,;or if classified based on the erosion hazard level, it continues to become heavier. Sub-watersheds that have experienced a significant increase in erosion rates are Blongkeng Sub-watershed, Gemurung Sub-watershed, and Progo Hulu Sub-watershed, where the status differed from medium to heavy category. Some locations that were silting due to sediment became prone to floods.

1. Introduction

One of the important indicators to determine the damage of a watershed is its hydrological conditions which is characterized by erosion, landslides, sedimentation, and unbalanced flow distribution (occurrence of floods and droughts). Another indicator can be seen from the shrinking area of forests and damage of land, especially protected areas around the watershed. This occurrence was caused by the increasing number of population which increased the intensity of land and water utilization [1].

Land management activities in a watershed that do not pay attention to conservation principles has the potential to increase land use change and the occurrence of land erosion; eroded soils will be carried to the river and cause river silting due to sediment deposition [2]. Damage of land resources, especially in the upstream of the watershed, will reduce land productivity, affect production function, ecological function, and hydrological function of the watershed [3]. The upstream part of the watershed is usually intended for water catchment areas. So, the success of downstream watershed management depents on the success of watershed management in the upstream [4]. Successful management of land resources in the upstream area can save downstream areas, because it can decrease sedimentation, water pollution, flood risk, and drought [5].

Previous studies on the effects of land cover changes on air sediment and soil erosion, mostly carried out by spatial, numerical, and hydrological modeling [6]–[9]. Most studies focus on changing forest land cover and settlement on water yields and sedimentation of soil erosion. In addition, scientific papers on the effects of land cover on water and sediment yields on a watershed in Indonesia are still difficult to find. The study area has a characteristic where rainfall is high from November to March and dry in the following month. The purpose of this study was to analyze trends in land use

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change from 1990 to 2010 and then predict increased erosion and flooding. This research is useful to find out flood-prone and erosion-prone areas so that management efforts can be focused on specific watershed conditions.

2. Methodology

2.1. Study Area

This study is located in the Progo Watershed, covering an area of 2458.54 km^2, passes through the two administrative regions of the province, Central Java Province and Special Region of Yogyakarta with the Progo river as the main river along 142 km. The Progo River is currently used as a source of irrigation, drinking water, and sand mining activities. Water quality and development of water resources are very important to support regional economic activities [10], [11].

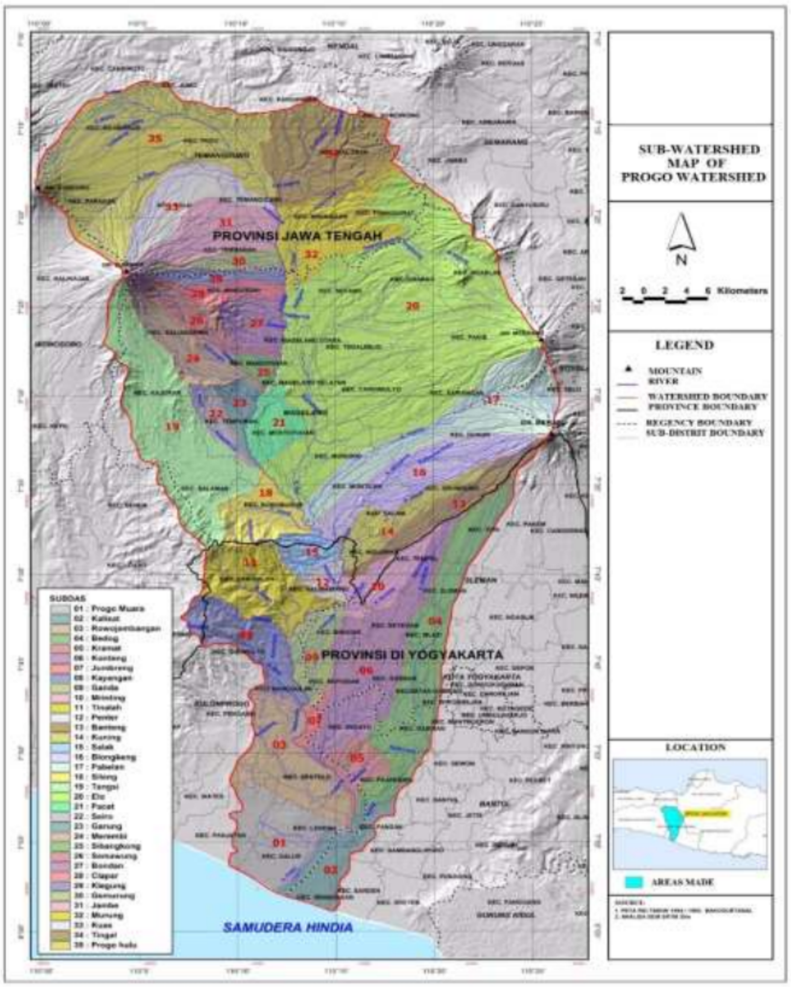

Figure 1. Map of Sub-Watershed

2.2. Hydrometry Survey
In general, hydrometric survey activities will consist of secondary data collection and river morphology surveys. The data collected includes: rain data taken from the nearest station with observation records up to the latest rainfall data, discharge data or water level of the nearest AWLR or staff gauge or published by PSDA Board, investigation of sediment transport, soil types, and land use of Progo watershed. Hydrometric survey aims to obtain data about the characteristics of rivers, river branches.

2.3. Data Analysis of Erosion and Sedimentation
Common equations that are often used in erosion prediction are based on Wischmeier and Smith's research which presents the Universal Soil Loss Equation (USLE). From the calculation, the land erosion rate will be obtained from the amount of sediment transported in the river by multiplying the rate of erosion with the sediment delivery ratio (SDR), because not all eroded sediments will be transported all to the river.

Table 1. Precipitation Coefficient Value Based on Land use

No	Penggunaan Lahan	PC Value
1	Secondary Dryland Forest	0.050
2	Shrubs	0.010
3	Settlement	0.500
4	Rice field	0.020
5	Open space	1.000
6	Plantation	0.020
7	Water	0.000
8	Dryland Agriculture	0.430
9	Mixed Dryland Agriculture	0.140
10	Plantation Forest	0.200

Based on the determinants of land erosion as described before, the erosion potential in the Progo sub-watershed could be calculated.

Table 2. Classification of erosion hazard levels

Solum of Soil (cm)	**Level of Erosion**				
	I	**II**	**III**	**IV**	**V**
	Erosion (ton/ha/year)				
	<15	**15-60**	**60-180**	**180-480**	**>480**
Deep **>90**	SR 0	R I	S II	B III	SB IV
middle **60-90**	S II	B III	SB IV	SB IV	SB IV
shallow **30-60**	S II	B III	SB IV	SB IV	SB IV
Very shallow **<30**	B III	SB IV	SB IV	SB IV	SB IV

Information:
0-SR = very light
I-R = light
II-S = middle

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III-B = heavy IV-B = very haevy

3. Results and Discussion

Progo watershed consists of tributaries which empties into the Progo river as the main river. Progo River has a length of around 142 km which are located in Serayu Opak River watershed board. Progo watershed is divided into 35 sub-watersheds where the distribution and naming are based on digital topographic maps. Figure 1. presents a map of sub-watershed distribution in Progo watershed.

3.1 Erosion Analysis

With rainfall data from the Rain Measuring Station in the Progo watershed, the erosion index can be calculated. High erosion trends occur from December to March due to high rainfall. In December, the rainy season is saturated so that the erosion index increases. Whereas in the dry season in May to November the value of the erosion index declined sharply where the peak of the dry season occurred at the beginning. The biggest change of land use function occurred in the shrub area which decreased by 2,973 Ha and the plantation area decreased by 1,307 Ha. On the other hand, there are additions to open land of 637 ha and plantations of 7,142 ha. This change resulted in an increase in erosion where the plantation area in the highlands had been converted into open land. Whereas the shrub area changes more and more into a plantation forest.

Table 3. Calculation of Erosion Index Value (R)

	Jan	Feb	March	Apr	May	June	July	Augs	Sep	Oct	Nov	Dec
Pm	38.33	35.86	32.70	23.00	14.46	13.34	5.14	9.19	3.62	14.87	16.84	34.13
N	22.00	24.00	21.00	15.00	11.00	10.00	5.00	5.00	5.00	15.00	16.00	19.00
Pmax	3.40	7.24	7.92	7.00	14.30	0.50	0.70	1.10	1.30	6.56	6.78	12.50
R	225.72	298.40	298.01	213.59	205.79	33.01	17.23	44.24	15.66	121.71	139.69	418.98
Total R												2,032.04

Table 4. Land use of Progo Watershed

NO	LAND USE	YEAR (HA)		
		2011	2000	1990
1	Secondary Dryland Forest	465	461	4.087
2	Plantation Forest	79.164	79.003	72.022
3	Open field	2.352	1.714	1.715
4	Settlement	46.574	46.855	46.438
5	Plantation	249	391	1.556
6	Dryland Agriculture	25.074	25.041	25.060
7	Mixed Dryland Agriculture	21.428	21.341	21.341
8	Rice field	68.252	68.367	68.367
9	Shrubs	1.336	1.723	4.309
10	Water	960	960	960
	TOTAL	**245.855**	**245.855**	**245.855**

Land use data is used as a base in determining the C and P factors in the Usle equation.

In general, erosion that occurs in the Progo watershed area is in the moderate category. The spatial map of erosion hazard levels in the study area is shown in the figure below. One of the problems that occur in the Progo River is the formation of sediment deposits in the downstream of the river which caused changes in river morphology in a relatively short period of time. [12]. The disruption of the watershed's hydrological conditions is caused by an increase in the number of people and an increase in land requirements, which makes land that should be a buffer zone change its function into residential land or other land uses. The effect of uncontrolled land use changes in the Progo watershed is the occurrence of flooding and drought on water sources which signified a critical watershed condition.

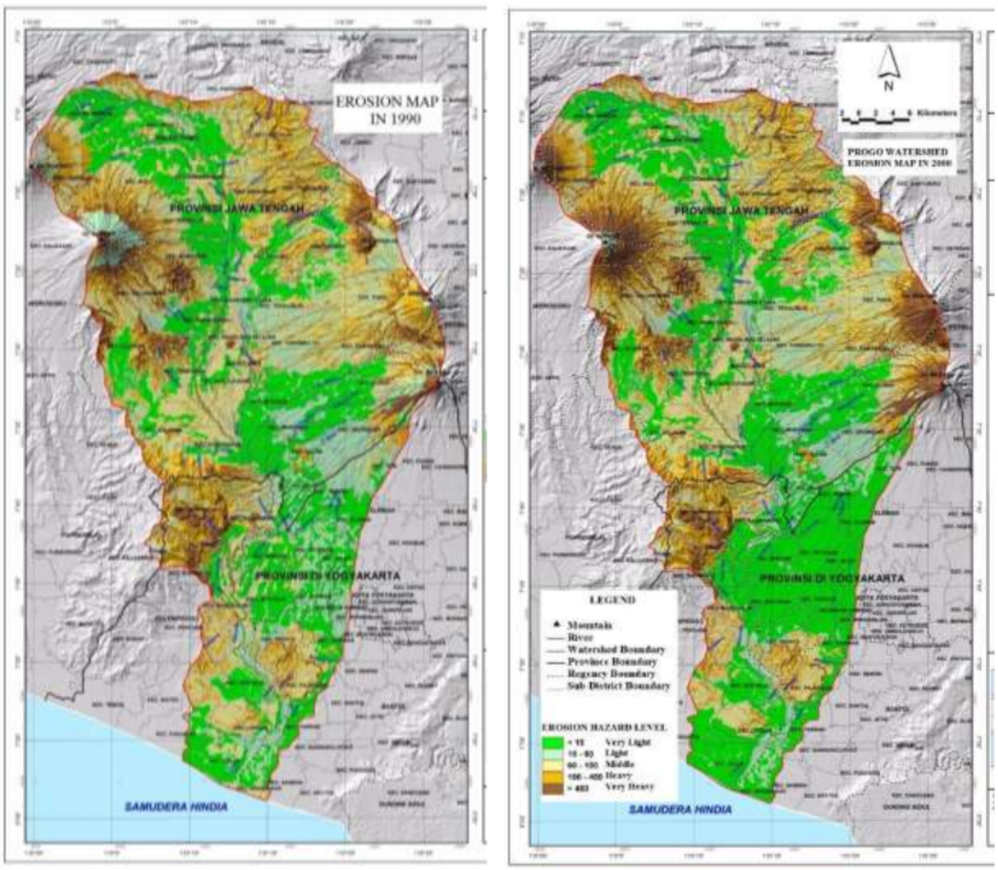

Figure 2. Erosion Map of Progo Watershed Based On Land Use in 1990 and 2000

Erosion and sedimentation potential which refered to different land uses has increased the average erosion rate from 165 tons/ha/year in 1999 to 184 tons/ha/year in 2011; or if classified based on erosion level hazard, it is heading to heavy. Sub-watersheds which have experienced a significant increase in erosion rate are Blongkeng Sub-watershed, Gemurung Sub-watershed, and Progo Hulu Sub-watershed, where the status of erosion level strats from the medium to heavy category.

Based on the identification of erosion potential, it could be seen that dry agricultural land and settlements areas are the biggest contributors to erosion potential [13]. Other identification show that construction land and agricultural land have the highest sediment concentration, while forests and grasslands have the lowest [8]. Dynamics in the land use affected hydrology condition in watershed, it suggests that the results of erosion predictions, surface runoff, surface runoff coefficient, and river regim coefficient are simultaneously increasing from year to year [14]. Sand mining activities in the upstream area of the river also accelerate erosion. Sand material is available when the volcano erupts

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and causes river morphology to change. Suspended sediment is not only affected by the percentage of forest cover, but it is also influenced by the traditional mining activities [15].

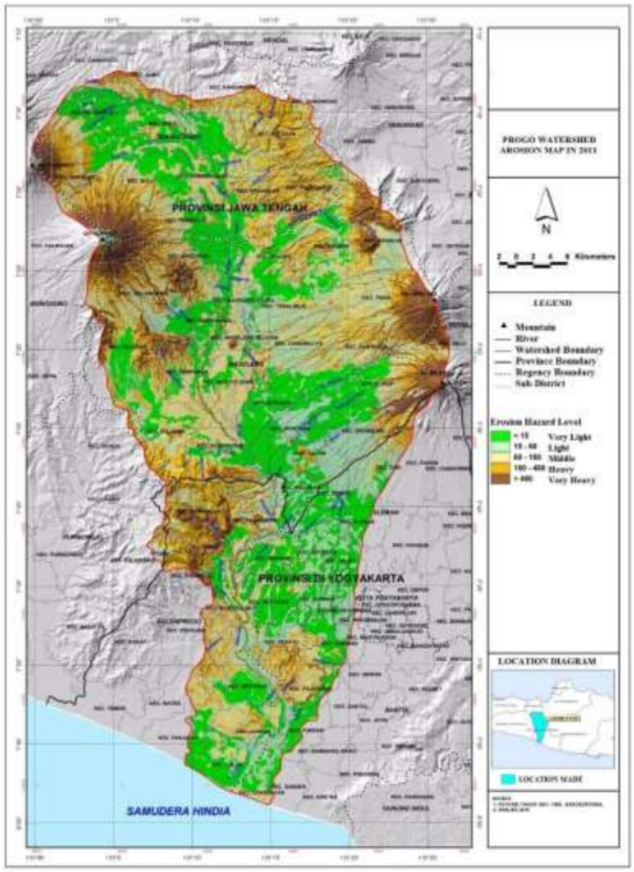

Figure 3. Erosion Map of Progo Watershed Based On Land Use in 2011

Table 5. Prediction of Progo River Sediment Yield.

	Q2 th	**Q5 th**	**Q10 th**	**Q50 th**
Sediment Total (ton)	28,382	123,456	221,631	37.66
Density (t/m3)	1.65	1.65	1.65	1.65
Volume (m3)	17,201	74,822	134,322	298,015

The sediment movement process occurs along the flow, there is a balance process between erosion and precipitation in the river so that if a cross section occurs on the basis of erosion, eventually the cliff will have the potential for an avalanche. The erosion in a cross section has the potential for sedimentation in the downstream cross section. Some locations that were silting due to sediment became prone to floods. In the 50th return flood discharge (Q50), most of the cross section in the downstream Progo river has the potential to run off, also in the Central Progo area, around the Mungkit area, due to very high sedimentation.

One of the most important focuses in the Progo watershed with dry and semi-arid characteristics is water erosion and sediment transport which can cause the soil fertility to gradually decrease. In addition, clogged sedimentation in waterways also allows the transfer of pollutants to agricultural land and dams. Where the function of the dam is for irrigation and drinking water needs.[16] The investigation was based on consideration of statistical parameters, flow interval features, base flow separation and trend analysis in 1990, 2000 and 2011. The results illustrate that the detected daily, monthly, and annual rainfall flows had very dry impacts on the Progo watershed area. This drought conditions occurred in 2000 to 2011 .(Fig. 2 & Fig. 4) Changes in land use are also a result of displacement of sedimentation as an initial impact of erosion occurring in 5 (five) areas in the Progo watershed. Changes occurred in 1999 towards the year 2000, there were significant changes in the sub-district of Minggur, Seyegan, Mlati, Godean, and Moyudan indicated that the area was quite wet and humid.

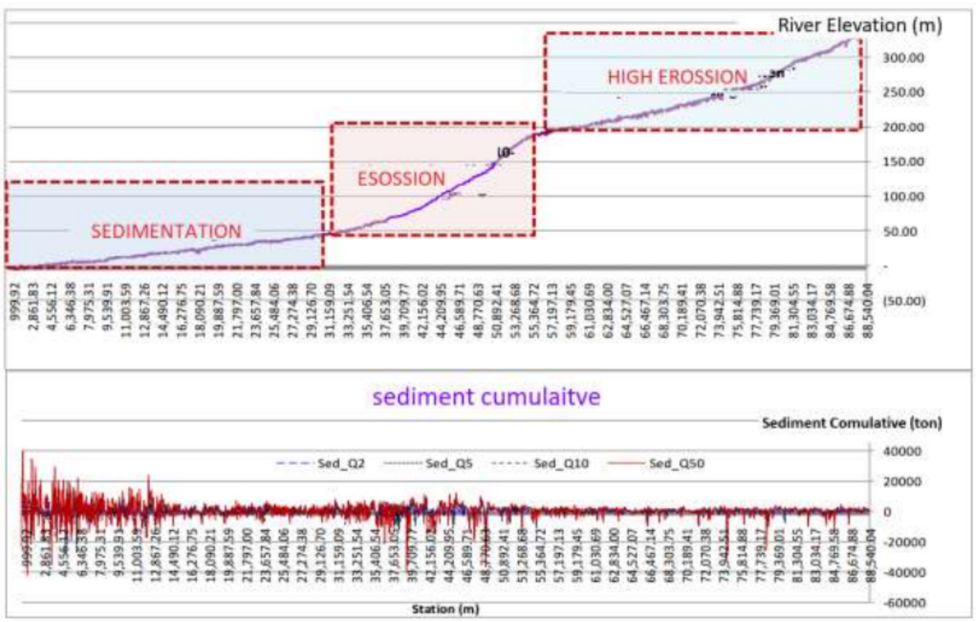

Figure 4. Accumulation of Sedimentation along Progo River

This study has found the greatest impact on sedimentation and erosion in the Progo watershed, namely the effects of development. Significant increase of 3000 tons per year of the Progo sub-watershed due to sedimentation and a rise in water levels of 50 m per year due to erosion. In the previous study, the biggest impact of the contribution of erosion effects and sedimentation on water runoff was to increase the built area, replace grazing areas for farming or agriculture, and also lack of effectiveness in maintaining water production in the Progo watershed watershed regional basin. [17]–[19] Based on this, if seen in the sedimentation and erosion problems in the Progo watershed area, there are similarities in the effects of sediment and erosion.

4. Conclusions

The biggest change of land use function occurred in the shrub area which is decreased by 2,973 Ha and the plantation area decreased by 1,307 Ha. On the other hand, there are additions to open land of 637 ha and plantations of 7,142 ha. This change resulted in the increase of erosion where the plantation area in the highlands had been converted into open land. Whereas the shrub area changes more and more into a plantation forest. Erosion and sedimentation potential in different land usesin Progo watershed has been increased throughout 1990, 2000, and 2011, where the average erosion rate starts from 165 tons/ha/year in 1999 to 184 tons/ha/year in 2011; or if classified based on the erosion hazard erosion level, it is heading to heavy. Sub-watersheds that have experienced a significant increase in erosion rates are Blongkeng Sub-watershed, Gemurung Sub-watershed and Progo Hulu Sub-watershed, where the status differ from medium to heavy category. Dry agricultural land and settlements areas which was converted from forest are the biggest contributors to erosion potential. Some locations that were silting due to sediment became prone to floods. High erosion trends occur from December to March due to high rainfall. In December, the rainy season is saturated so that the erosion index increases. Whereas in the dry season in May to November the value of the erosion index declined sharply where the peak of the dry season occurred at the beginning.

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