Analysis of Erosion Hazard at Gagakan Sub-Watershed, Blora District, Central Java Province, Indonesia

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Abstract. *Auliyani D, Basuki T M. 2017. Analysis of Erosion Hazard at Gagakan Sub-Watershed, Blora District, Central Java Province, Indonesia. Proc Internat Conf Sci Engin 1: 85-89.* Availability of soil erosion data is crucial for recovering carrying capacity of a degraded watershed. This study aims to analyze the level of soil erosion hazard in Gagakan Sub-Watershed, located at the downstream of Solo Watershed. Slope steepness of this area vary from very steep at the upper part and flat at the downstream. The dominant land cover is teak forest which consists of young and old stands. The level of soil erosion hazard was calculated by USLE (Universal Soil Loss Equation) and then analyzed spatially using GIS (Geographic Information System). The degree of erosion hazard was classified into five classes, i.e very slight, slight, moderate, severe, and very severe. The results showed that erosion hazard level of Gagakan sub-watershed ranged from very slight to very severe. The dominant is very slight (69%), while the others classified as slight (11%), moderate (15%), severe (1%), and very severe (4%). The countermeasures of soil erosion should be focused on the area with severe and very severe level of erosion hazard.

Keywords: Soil erosion, Teak forest, USLE

INTRODUCTION

As part of a watershed ecosystem, soil provides many valuable environmental goods and services, such as food, carbon sequestration, water regulations, and habitat provision (De Vente et al., 2013). Along with the population growth, the need for land resources is also increasing as well. Human intervention in the utilization of land resources beyond its carrying capacity may cause soil erosion (Eisazadeh, Sokouti, Homaee, & Pazira, 2012; Gholami, 2013) which leads to decrease in land productivity and environmental degradation.

Soil erosion is becoming the main issue of watershed management (Baja, Ramli, & Lias, 2009), which generate negatively effect not only in the erosion spot (on-site impact) but also in the downstream area (off-site impact) (Boardman, 2006). Its socio-economic negative impact and environmental degradation caused were seized the researcher and policy.

Availability of soil erosion data is crucial for recovering carrying capacity of a degraded watershed. Gagakan Sub-Watershed is the downstream area of Solo Watershed, one of the priority watersheds that the carrying capacity should be restored by forest and land rehabilitation (RHL) activities (Dirjen PDASHL, 2015). According to the background, this study aims to analyze the level of soil erosion hazard in Gagakan Sub-Watershed.

MATERIALS AND METHODS

Study area

This study was conducted in Gagakan Sub-Watershed of Blora District, Central Java Province. This area is the upper parts of Solo Watershed, extending from 111°30'34'' to 111°35'52" East Longitude and 7°2'22" to 7°7'57" South Latitude. The administrative map of Gagakan Sub-Watershed is provided in Figure 1.



Figure 1. The administrative map of The Gagakan Sub-Watershed.

Procedures

The data used for analysis consists of (1) land cover maps derived from Google Imaginary, (2) soil map obtained from Regional Physical Planning Programme for Transmigration (RePPProT), (3) slope steepness generated from Digital Elevation Model (DEM) of Shuttle Radar Topographic Mission (SRTM) (30 m resolution) acquired from Earth Explorer Database of United States Geological Survey (USGS), and (4) ground truth data obtained from field surveys. Rainfall data were collected from climatology stations of Watershed Management Technology Center.

Data analysis

The erosion hazard level was analyzed spatially using Geographic Information Systems (GIS). Soil loss estimation calculated based on Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978):

$$A = R x K x LS x CP$$
(1)

Where:

- A = Average annual soil loss per unit area (ton.ha⁻¹.vear⁻¹)
- R = Rainfall erosivity factor
- K = Soil erodibility factor
- LS = Slope length and gradient factor
- CP = Vegetation cover and management factor

1. Rainfall Erosivity Factor

The estimation method using maximum rainfall intensity for 30 minutes is the most accurate procedure (Widiatmaka & Soeka, 2012). Therefore, the Bols equation (Bols, 1978) was applied to estimate rainfall erosivity.

$$EI = 6,119 \text{ x } \mathbb{R}^{1,21} \text{ x } \mathbb{D}^{-0,47} \text{ x } \mathbb{M}^{0,53}$$
(2)

Where:

EI = Rainfall erosivity (KJ/ha)

R = Monthly rainfall (cm)

- D = Average number of rainy days (day)
- M = Maximum rainfall during 24 hours within the corresponding month (cm)

Table 2. The value of vegetation cover and land management (CP).

2. Soil Erodibility Factor (K)

Soil erodibility is defined as the degree of soil sensitivity to the kinetic energy of rainfall. The smoother texture of the soil, it will more easily erode (Herawati, 2010). The K value in this study was obtained from secondary data on soil type.

3. Slope Length and Gradient Factor (LS)

Digital elevation model were able to generate the accurate value of slope steepness (Hrabalíková & Janeček, 2016). In this study, to calculate the LS value, DEM were classified into five classes, i.e. <5 %, >5-15 %, >15-35 %, >35-50 %, and >50 %. The LS value is presented in Table 1.

Table 1. Length and slope (LS) values.

0,25
1,20
4,25
9,50
12,00

4. Vegetation Cover and Management Factor (CP) The value of vegetation and management factor in this study were obtained from Java erosion model (Ministry of Public Work, 2012) as presented in Table 2.

No	Land cover	Slope Classes / CP Value				
NO		0-2 %	2-15 %	15-40 %	>40 %	
1.	Settlement	0,0500	0,0500	0,0500	0,0500	
2.	Paddy field	0,0100	0,0100	0,0100	0,0250	
3.	Dry land agriculture	0,0445	0,0625	0,0955	0,1365	
4.	Estate	0,0045	0,0104	0,0199	0,0338	
5.	Mixed garden	0,0223	0,0313	0,0478	0,0683	
6.	Natural forest	0,0002	0,0005	0,0010	0,0010	
7.	Production forest	0,0010	0,0010	0,0020	0,0020	
8.	Shrubs	0,0010	0,0015	0,0020	0,0020	
9.	Grass land	0,0050	0,0100	0,0200	0,0200	
10.	Bare land	1,0000	1,0000	1,0000	1,0000	

Source : (Ministry of Public Work, 2012)

The results of the soil loss calculation then classified into five classes according to decree No P.7/DAS-V/2011 presents in Table 3.

Table 3. Erosion hazard classification.

		Erosion Hazard Classes					
No	Soil Solum (cm)	I <15 ton/ha/year	II 15-60 ton/ha/vear	III 60-180 ton/ha/vear	IV 180-480 ton/ha/year	V >480 ton/ha/year	
1	> 90	Very slight	Slight	Moderate	Severe	Very severe	
2	60 - 90	Slight	Moderate	Severe	Very severe	Very severe	
3	30 - 60	Moderate	Severe	Very severe	Very severe	Very severe	
4	< 30	Severe	Very severe	Very severe	Very severe	Very severe	

Source : (BPDASPS, 2011)

RESULTS AND DISCUSSION

The average monthly rainfall in Gagakan Sub-Watershed during 2016 was 167 mm, with the average number of rainy days was 17 days, and maximum rainfall during 24 hours was 53 cm. The highest rainfall was occurred in November while the lowest rainfall occurred in August (Figure 2).



Figure 2. Monthly rainfall of Gagakan Sub-Watershed in 2016.

The soil types of Gagakan Sub-Watershed consists of tropudalf (73,2%) and eutropepts (26,8%). According to the secondary data of soil types, K value of tropudalf is 0,23 (Undang & Suwardjo, 1984), while eutropepts is 0,29 (Hamer, 1980).

Topography of Gagakan Sub-Watershed vary from very steep at the upper part and flat at the downstream. Analysis of DEM (USGS, 2015) showed that the dominant slope steepness in this area sequentially were sloping (33%), moderately slope (27%), flat (24%), steep (13%), and very steep (3%) (Figure 3).



Figure 3. The map of slope classes.

Satellite image from Google Earth 2014 and ground checks in 2016 were used to classify the existing land cover of the study area. The dominant land cover is teak forest which consists of old (53%) and young (23%) stands, and dryland agriculture (20%). Spatial distribution of existing land cover of Gagakan Sub-Watershed is provided in Figure 4.



Figure 4. The map of land cover.

Erosion prone are the potential areas for soil erosion. Most of the study area categorized as very slight level of erosion vulnerability (69%). Spatially distribution of erosion hazard in the Gagakan Sub-Watershed is presented in Figure 5, while the administrative distribution is provided in Table 4.



Figure 5. The spatial distribution of erosion hazard level at Gagakan Sub-Watershed.

Spatially, both of severe and very severe of erosion hazard classes occurred in bare land, settlement, and dry land agriculture area. In the study area, dry land agriculture area was generally planted with corn with fewer ground plants. Therefore, the soil will be more susceptible to the kinetic energy of rainfall and lead to potentially higher soil loss. The countermeasures of soil erosion should be focused on the area with severe and very severe level of erosion hazard.

Table 4. The administrative distribution of erosion hazard level.

Sub Districts/ Villages	Area (Ha)				
Sub-Districts/ villages -	Very Slight	Slight	Moderate	Severe	Very Severe
Сери	248,95	156,67	342,55	3,49	66,60
Balun	172,52	122,77	283,15	3,46	52,32
Karangboyo	31,72	22,33	47,03	0,03	13,65
Tambakromo	44,71	11,57	12,37	-	0,63
Jiken	793,19	4,52	-	-	-
Cabak	755,97	3,83	-	-	-
Janjang	6,50	0,19	-	-	-
Nglobo	30,72	0,50	-	-	-
Kedung Tuban	3,96	0,00	-	-	-
Kalen	0,04	-	-	-	-
Nglandeyan	0,08	-	-	-	-
Ngraho	3,84	0,00	-	-	-
Sambong	3435,75	528,97	623,66	42,13	206,11
Brabuan	84,83	38,23	16,96	9,54	3,98
Gadu	102,94	73,43	113,09	1,29	22,09
Gaggakan	145,34	30,30	4,49	-	2,00
Ledok	222,02	97,91	-	-	-
Pojokwatu	417,01	60,29	73,17	13,09	30,66
Sambong	566,94	79,88	198,93	5,82	88,38
Sambongrejo	1788,00	147,97	214,45	11,46	58,22
Temengeng	108,67	0,97	2,58	0,95	0,76
Total	4481,85	690,16	966,21	45,63	272,70
Percentage (%)	69	11	15	1	4

CONCLUSIONS

The results of this study showed that erosion hazard level at Gagakan sub-watershed ranged from very slight to very severe. The dominant is very slight (69%), while the others classified as slight (11%), moderate (15%), severe (1%), and very severe (4%). The countermeasures of soil erosion should be focused on the area with severe and very severe level of erosion hazard.

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