Influence of Land Use Changes on Soil Loss/Erosion in the Cirasea Sub-watershed in Indonesia

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1. Introduction

The Cirasea sub-watershed is a part of the Citarum Hulu watershed in West Java, and the watershed is a significant source of water for the Bandung area and electric power plant in the Jatiluhur, Cirata, and Saguling dams. However, there is significant increased amount of erosion in the Citarum Hulu watershed, and the Cirasea sub-watershed area has become one of the critical areas due to the high rate of erosion there. The area can be categorized as a very high erosion level area, with potential annual erosion of 70.31-243.38 ton/ha/year based on its biophysical characteristics[1]. The erosion also causes the degradation of land productivity through the loss of sediment, and the accumulation of sediment adversely affects the water supply system.

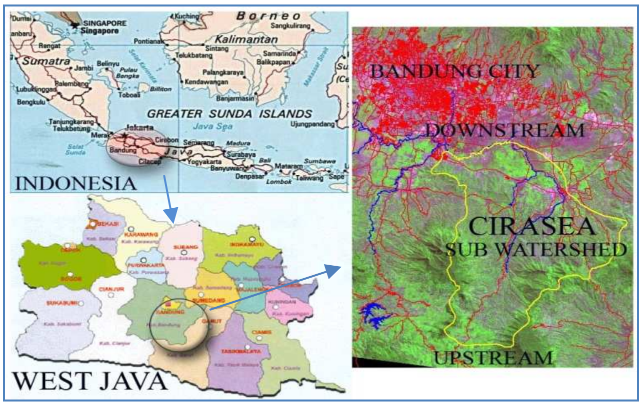

Figure 1 Study Area

Many researchers who have studied the problems of erosion and the accumulation of sediment in the water supply system in the Citarum Hulu watershed have concluded that the problems are attributable to the land-use changes that have occurred in the watershed. Poerbandono et al.[2] reported that this condition was claimed caused by the degradation of the ecosystem in the watershed, especially the increasing extent of deforestation in the upstream area. There is also a significant possibility that land-use changes occurred in the Cirasea sub-watershed were resulted from increases in the population and human activity, since the watershed includes the suburban area of Bandung City (**Figure 1).** These changes create the potential for increased erosion in the area. The goals of the research reported in this paper were to evaluate land-use changes in the Cirasea sub-watershed and to analyze the contribution each change to the increased level of erosion. Land-use changes were analyzed based on the years 2001 and 2008.

2. Evaluation Method

The evaluation in this paper is based on the prediction model proposed by Wischmeier and Smith in 1978, called the Universal Soil Loss Equation (USLE). This model was used because it is the standard method of erosion evaluation issued by the General Directorate of Land Rehabilitation and Social Forestry (RLPS) of the Indonesia Forestry Ministry, the Department that has responsibility for the watershed management in Indonesia[4] and because it has been successfully applied in many areas of Indonesia. The equation is as follows:

$$A = R * K * LS * CP,$$

where:

- *A = Average amount of annual soil erosion (ton/ha/year);*
- *R = Rainfall erosivity index,* which is a measure of the kinetic energy of the rainfall that can break the soil into small particles and remove these particles in the run-off; this index is based on the intensity and frequency of the rainfall;
- *K = Soil erodibility factor,* which is a measure of the resistance of soil particles to being separated and removed by the kinetic energy of the rainfall. This factor depends on the characteristics of the soil, such as texture, aggregate stability, infiltration capacity, and organic and chemical contents;
- *LS = Slope/elevation factor,* which is the topographic factor that can influence the ability of the run-off water to remove soil. The factor is based on the length *(L)* and steepness *(S)* of the slope.
- *CP = Land-use management/soil conservation*, which is determined by the general land use (surface cover) and the management applied to that land. *CP* is related to the surface cover, vegetation, and extent of disturbance of the soil.

Table 1 *CP* Factor

No	Land Use Class	C	P	CP factor
1.	Primary Forest	0.010	0.100	0.0010
2.	Secondary Forest	0.100	0.100	0.0100
3.	Industrial Area	0.930	0.400	0.3720*)
4.	Mining Area	1.000	0.750	0.7500**)
5.	Mixture Dry Land Agriculture	0.150	0.150	0.0225
6.	Arable Land/Field	0.400	0.500	0.2000
7.	Grassland			0.0200***)
8.	Settlement	0.600	0.400	0.2400
9.	Plantation	0.150	0.040	0.0060
10.	Rice field	0.010	0.150	0.0015
11.	Bush/ Coppice	0.170	0.150	0.0255
12.	Water Body	0.000	0.150	0.0000
13.	Open Space	1.000	0.750	0.7500

Source: Characteristics of Citarum Watersheed, BP DAS Citarum-Ciliwing, 2006. *) C: Budianto, 1997. P same with Sattlement, **) Same with Open Space, ***) Ambar in Asdak 2005

This equation can be used to calculate the annual erosion of a land unit *(ton/ha/year)*. To estimate the total amount of erosion in all areas, the number of ***A*** should be summarized for all land units and multiplied by their land-unit area. Therefore, each hectare (*ha*) of the land unit will contribute to the total amount of erosion *(ton/year)* based on its *R, K, LS,* and *CP* variables.

In this paper, we assumed that the three factors *R, K,* and *LS* were static variables to evaluate the influence of land-use changes on the increased erosion rates. Only land use (*CP*) was assumed to be a dynamic variable. Therefore, only the land-use factor was evaluated for the erosion. The total changes of all land uses were evaluated relative to their *CP* factors. The magnitude of *CP* was compiled from the characteristics of the Citarum watershed in 2006 combined with the results of previous research, as shown in **Table 1**.

The land-use change was analyzed between 2001 and 2008 by using a GIS. Land use in 2001 was derived from a land-use map of the West Java Province issued by the Planning Board (Bappeda) of West Java Province by using Landsat 7 ETM imagery 2001, while land use in 2008 was derived from SPOT2 imagery 2008.

3. Analysis and Discussion

From the analysis, it was revealed that there are some major land-use changes that could cause the increasing rate of erosion from 2001 to 2008. **Figure 2** and **Figure 3** show land use in 2001 and 2008, respectively. **Table 2** shows the matrix of land-use change that could possibly have caused the increased amount of erosion, and Table **3** shows the total changes of all land-use classes with their *CP* factors. These figures show the increasing areas of “Settlement” in the circles of **Figure 3,** and **Table 2 shows** the decreases in “Rice Field,” Secondary Forest,” and “Plantation.” These changes resulted from the facts that the Cirasea sub-watershed is a suburban area of Bandung City and that there have been increasing in population and human activities. The changes in the land-use classes have affected the amount of erosion equivalent of their area and their *CP* factors. The larger their areas and *CP* factors become, the greater the amount of erosion will be.

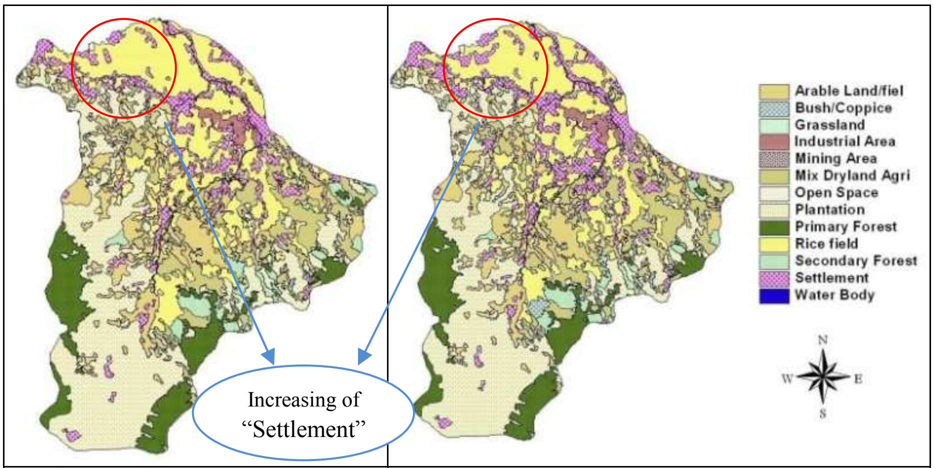

Figure 2. Land Use in 2001 **Figure** 3. Land Use in 2008

Table 2. Matrix of Land Use Change (*ha*)

Change	into									
		1. PF	2. SF	3. IA	5. Mix	6. AL	8. STL	9. PLT	10. RF	11. BC
From	1. PF	3,495	11	-	21	-	-	-	-	-
	2. SF	-	1,113	-	118	-	-	29	-	9
	3. IA	-	-	416	-	-	-	-	-	-
	5. Mix	-	-	6	4,730	33	33	-	48	-
	6. AL	-	-	-	-	4,249	8	-	41	-
	8. STL	-	-	1	-	-	3,432	-	-	-
	9. PLT	-	-	-	88	65	6	10,960	-	-
	10. RF	-	-	44	67	81	525	12	7,732	129
	11. BC	-	-	-	-	-	-	-	-	54

PF: Primary Forest, SF: Secondary Forest, IA: Industrial Area, Mix: Mixture Dry Land Agriculture, AL: Arable Land/ Field, STL: Settlement, PLT: Plantation, RF: Rice Field, BC: Bush/Coppice

Table 3. Land-Use Changes

No	Land-Use Class	2001 (*ha*)	2008 (*ha*)	Change (*ha*)	*CP* Factor
1.	Primary Forest	3,528	3,495	-33	0.0010
2.	Secondary Forest	1,268	1,123	-145	0.0100
3.	Industrial Area	416	468	52	0.3720
5.	Mixture Dry Land Agriculture	4,851	5,024	173	0.0225
6.	Arable Land/Field	4,298	4,428	130	0.2000
8.	Settlement	3,433	4,004	571	0.2400
9.	Plantation	11,128	11,001	-127	0.0060
10.	Rice Field	8,591	7,821	-770	0.0015
11.	Bush/Coppice	54	193	139	0.0255

It can be seen that the areas of the land-use classes with low *CP* factors were decreased. They are “Primary Forest” (*CP* = 0.001), “Secondary Forest” (*CP* = 0.010), “Plantation” (*CP* = 0.006), and “Rice Field” (*CP* = 0.0015). On the contrary, the areas of land-use classes with high *CP* factors increased. They are “Industrial Area” (*CP* = 0.372), “Mixture Dry Land Agriculture” (*CP* = 0.0225), “Arable Land/Field” (*CP* = 0.2), “Settlement” (*CP* = 0.24), and “Bush/Coppice” (*CP* = 0.0255). This condition will cause increased amounts of erosion. The most significant land-use changes that contributed to the increased amount of erosion was the decreased areas of “Rice Field” (-770 *ha*) and the increased areas of “Settlement” (+571 *ha*). Settlement, with its high value of *CP* factor (0.24), will produce increased erosion into equivalent of 0.24 ton/ha/year. To the contrary, “Rice Field,” with a low value of *CP* factor (0.0015), was replaced by other land use with higher *CP* factors, such as “Settlement,” “Industrial Area,” “Mixture Dry Land Agriculture,” “Arable Land/Field,” and “Bush/Coppice”. There are also some forest degradations that contribute to the increasing amount of erosion.

4. Summary

From the analysis the years 2001 and 2008, it can be summarized that:

- Land-use changes have significant influence on erosion in the Cirasea sub-watershed. Areas that had low *CP* factors were decreased, while areas with higher *CP* factors were increased. These changes resulted in increased erosion.
- There were some major land-use changes in the Cirasea sub-watershed that contributed to increased erosion. They were dominated by the increases in the areas of “Settlement” (+571 *ha*) with a *CP* factor of 0.24 and by decreases in “Rice Field” areas (-770 *ha*) with a *CP* factor of 0.0015.

References

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