Assessment of erosion hazards due to land use change in Cianten subwatershed, Indonesia

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Abstract. Cianten subwatershed is a part of the Upper Cimanuk subwatershed which has high erosion values and important watersheds as it has several protection functions for the entire watershed. The research was conducted in Cianten subwatershed, Upper Cimanuk subwatershed, Garut district, West Java, Indonesia. The method used in this research was a comparative analysis survey. This method is performed by comparing the inter-time comparative effects of landuse change parameters and the prediction of erosion values with USLE formula in the period 2004-2016 in Cianten subwatershed. The results showed that there was a change of landuse type during the period 2004-2016 with the addition of land on paddy field with the width of 266.43 ha and open land with the width of 0.1 ha, while the reduction of the extent occurred in secondary dryland forest with an area of 13.75 ha, 166 ha of plantation forest, 12.9 ha of plantation, dry land farming area of 49.59 ha and shrubs of 0.98 ha. Areas that experienced the highest erosion grade class (class V) in the 2004-2016 period were in Leles District in Dano, Cangkuang, Kandangmukti and Jangkurang Villages. The highest erosion values in 2004, 2009, 2014 and 2016 were highest in open land on slope class >40%.

Keywords: Cianten subwatershed, Indonesia, land use change, erosion hazards

1. Introduction

Erosion is a moving or transporting process of topsoil from a site then deposited elsewhere by the presence of water and wind, gravity, and human disturbances [1,2,3,4]. The occurrence of erosion caused by several factors: climate, soil, topography, vegetation and human intervention [5]. Cimanuk upper watershed with 145,677 ha is one of the biggest erosion areas with erosion value reaching 2,939.889 tons/year based on [6]. An intensive cultivation, deforestation, plowing of marginal lands and the danger of extreme climate was the primarily effects of erosion in some developing countries [7,8]. One indicator of a watershed cannot function properly is the occurrence of erosion in the upper watershed area.

The erosion also occurs in Indonesia watershed, especially at Cianten subwatershed which a part of the Upper Cimanuk watershed. It is feared to cause more crisis of land and water resources in the future due to human activities if not immediately tackled [9]. Based on [6], there are several types of land use in the Cianten subwatershed such as secondary forest, plantation forest, settlement, plantation, dryland farming, rice field, shrub and open field. This research was conducted to analyze the dynamics of erosion hazard due to land use change during the 2004-2016 period in Cianten subwatershed using Universal Soil Loss Equation (USLE).
2. Material and Methods

2.1. Description Of The Study Area
This research has been carried out from December 2016 to February 2017 on Cianten subwatershed which a part of the Upper Cimanuk watershed, Garut district, West Java, Indonesia. The research location has an area of 25.888,29 ha.

2.2. Research Methods
This research uses survey and comparative method analysis. The variables used in this research are erosivity factor (R), crop management and soil conservation (CP) index and land unit (LU) value. Through overlay of each erosion unit which composed of 7 land use types, 5 soil types, 5 slope classes, resulting in 61 combinations of land units.

2.2.1. Rain Erosivity (R)
The rain erosivity (R) factor was calculated by using the formula of Bols (1978) in [10]. Bol's formula is conducted for Java and Madura climatic condition, and it is not suitable for other regions in Indonesia, especially for a dry climate. The R factor equation is as follows:

\[ R(EI30) = 6,119(RAIN)^{1.21} \times (DAYS)^{-0.47} \times (MAXP)^{0.53} \]  

Where, \( R(EI30) \)=Average monthly rainfall erosivity index, \( RAIN \)=Average monthly rainfall (cm), \( DAYS \)=Average number of rainy days in a given month (day), \( MAXP \)=Average daily rainfall maximum each month at a certain time of year (cm).

2.2.2. Soil Erodibility Index(K)
The value of soil erodibility in this study contained in Table 6 refers to the erodibility value of soil issued by [10] and the results of the study of soil erodibility by [6]. The soil erodibility index (K) of each soil type in the Cianten subwatershed is presented in Table 1.

| Num | Soil Type       | K value |
|-----|-----------------|---------|
| 1   | Andosols        | 0,28    |
| 2   | Alluvial        | 0,29    |
| 3   | Latosols        | 0,26    |
| 4   | Grumusols       | 0,16    |
| 5   | Red Yellow Podsolic | 0,20   |

2.2.3. Slope Index (LS)
Slope index was calculated refers to slope inclination factor issued [6,10], see in Table 2.

| Num. | Slope (%) | LS value |
|------|-----------|----------|
| 1    | <8        | 0,25     |
| 2    | >8-15     | 1,20     |
| 3    | >16-25    | 4,25     |
| 4    | >26-40    | 9,50     |
| 5    | >40       | 12       |
2.2.4. **Crop Management and Soil Conservation (CP)**

C and P factor values were determined using land use approach by [1,6,10]. The following determination of soil management factor (CP) is shown in Table 3.

| Num | Land Use Type     | CP value |
|-----|-------------------|----------|
| 1   | Shrubs            | 0.009    |
| 2   | Open land         | 0.380    |
| 3   | Rice fields       | 0.0015   |
| 4   | Dryland farming   | 0.180    |
| 5   | Plantation        | 0.280    |
| 6   | Settlement        | 0.020    |
| 7   | Plantations Forest| 0.040    |
| 8   | Secondary dryland forest | 0.040 |

2.2.5. **Erosion rates (A)**

The erosion value calculated by calculating the average annual soil loss and estimated due to sheet erosion and flow erosion by the Universal Soil Loss Equation (USLE) formula. The USLE formula can be expressed as follows:

\[ A = R \times K \times LS \times CP \]  

Where, \( A \)=the amount of land lost maximum (ton/ ha/year), \( R \)= average monthly rainfall erosivity, \( K \)=soil erodibility index factor (ton/ha/year), \( LS \)=Index factor length and slope, \( C \)=Factor index of crop management, and \( P \)=Factors index of soil conservation.

The erosion rates based on USLE formula calculation, classified into five classes that is very light, light, medium, heavy and very heavy based on [11] in Table 4.

| Erosion class | Erosion rate (tons/ha/year) | explanation |
|---------------|-----------------------------|-------------|
| I             | <15                         | Very light  |
| II            | 15-60                       | light       |
| III           | 60-<180                     | medium      |
| IV            | 180-<480                    | heavy       |
| V             | >480                        | very heavy  |

3. Result and Discussion

3.1. **Analysis of Land Use Change in Cianten subwatershed**

Based on Table 5 and Figure 1, there was a change of landuse from the 2004-2016 period. The Paddy fields area was increased about 266.43 ha (4.03%) and plantation forest has decreased 166 ha (8.39%). The distribution of dryland farming and paddy fields is spreading at the Cianten subwatershed on a flat slope (<8%) to a very steep slope (>40%). Furthermore, forest plantation, secondary dryland forests, plantations, shrubs bushes and open fields are only in some areas with a slope of 16% -> 40%. Dryland farming in Cianten subwatershed is generally composed of
vegetables, legume and food commodities such as green onion, chili, peanut, tomato, eggplant, corn, and cassava.

Table 5. Land use change period 2004-2016 (in hectare)

| Landuse                  | 2004    | 2009    | 2014    | 2016    | 2004-2016 | %      |
|--------------------------|---------|---------|---------|---------|-----------|--------|
| Secondary dryland forests| 2142.50 | 2142.49 | 2142.37 | 2128.75 | -13.75    | -0.64  |
| Plantation forest        | 1979.44 | 2020.65 | 1841.47 | 1813.44 | -166.00   | -8.39  |
| Plantation               | 383.47  | 383.33  | 371.57  | 370.57  | -12.90    | -3.36  |
| Dryland farming          | 11329.4 | 11287.08| 11539.87| 11279.79| -49.59    | -0.44  |
| Rice fields              | 6615.02 | 6590.71 | 6689.31 | 6881.45 | +266.43   | +4.03  |
| Shrub                    | 82.65   | 82.65   | 81.67   | 81.67   | -0.98     | -1.18  |
| Open land                | 82.61   | 82.61   | 82.71   | 82.71   | +0.10     | -0.12  |
| Others                   | 3273.22 | 3273.22 | 3139.32 | 3139.32 | -133.90   | -4.09  |

The main vegetation grown by the farmers in this area are leek, chili, and peanut. This seasonal crop is located in mountainous areas with steep slopes. Application of land tween green onion + chili + groundnut in one bending crop conservation by farmers is by cultivating intercropping be- rotation and the use of plastic mulch in each field.

Increased use of agricultural land and rice fields is also due to the increasing population needs. The rice field in the re-search area is dominated by simple irrigated rice fields. Land use on dryland farming and rice fields are scattered in various areas of the Cianten subwatershed.

Figure 1. Land use 2004, 2009, 2014 and 2016 in Cianten subwatershed

3.2. Erosion Hazard Classes in Cianten subwatershed

Grouping of each unit of land map (SPL) erosion hazard class in 2004-2016 period showed in Table 5. In Table 5, in the period of 2004, erosion hazard is categorized as very light (class I), in 2009 are two dominant classes (I and V). While for the year 2014 and 2016 are dominated by class V and categorized as very heavy (Figure 2).
Land with very light erosion hazard class includes class I on the slope <8-25%, composed by the use of wetland and plantation forest. Class of minor erosion hazard class II, III and IV have a slope spreading range of 0 to >40% with dryland farming, secondary dryland forest, forest plantations, rice fields, plantations, and shrubs. While class V erosion hazard has widespread on the slope of 26 to >40% on the use of plantation, dryland farming, and open land. Areas with the highest erosion grade class (class V) were found in Leles District in Dano, Cangkuang, Kandangmukti and Jangkurang Villages.

3.3. The Effect of Land Use Change vs Erosion Potential Value period 2004-2016 in Cianten subwatershed

Dryland farming land use was the highest total erosion of each slope in each year compared to whole land use, whereas the lowest erosion is wetland and shrub land use (Table 6). While most of the erosion on slope <8%, 8-15%, and 16-25% were dominated by dryland farming land use (Figure 3). The increase of erosion rate is due to the application of land use without soil and water conservation practice, such as cultivation of seasonal crops on the type of dry land use with a slope of 20 to >40%. This is appropriated with [12], the average erosion value on dry land farms with 3-30% slopes has a high erosion value of 60-625 tons/ha/year. In the world, 80% of current agricultural land is degraded due to global soil erosion [13].

| Erosion class | Erosion rate (tons/ha/year) | 2004   | 2009   | 2014   | 2016   |
|---------------|-----------------------------|--------|--------|--------|--------|
| I             | <15                         | 8209,4 | 6730,1 | 6600,4 | 4336,3 |
| II            | 15-60                       | 916,4  | 1875,4 | 1681,2 | 4077,4 |
| III           | 60-<180                     | 3913,5 | 3952,9 | 710,9  | 252,5  |
| IV            | 180-<480                    | 4469,9 | 2108,9 | 3768,0 | 1989,8 |
| V             | >480                        | 5103,6 | 7945,4 | 9986,4 | 11982,5|

In the slope 26-40%, the highest average erosion is found on the plantation area while the slope class >40% of the highest average erosion value is in open land (Figure 3), [14], explains that changes...
in land use settlements, gardens, cultivation and open land are positively correlated to the extent of erosion and increased by 80.30% in Keduang subwater-shed. In 2004, 2009, 2014 and 2016, open land on slope class > 40% was the highest erosion value with mean erosion rate of 926.8 ton/ha/year, 1.319.42 ton/ha/year, 3.272.62 ton/ha/year and 4.018.15 ton/ha/year respectively. The increasing of erosion on open land is caused by forest to open land conversion. [15] in the Upper Citarum watershed, shows conversion of forest into open land increases the rate of erosion so that the annual sediment reaches 100 ton/km².

Figure 3. Average erosion graph on different slope classes

4. Conclusions
Based on the results of research that has been done then can be drawn a conclusion as follows:
- A wide range of land use changes occurred in the Cianten subwatershed in the period 2004-2016. The additional land area occurred on paddy field with an area of 266.43 ha and 0.1 ha of open land, while the reduction of the area occurred in secondary dryland forest 13.75 ha, 166 ha of plantation, 12.9 ha plantation, dryland farming 49.59 ha and 0.98 ha of bushes.
The highest erosion grade class increase (class V) in the 2004-2016 period were located in Leles District in Da-no, Cangkuang, Kandangmukti and Jangkurang Villages. In 2004, 2009, 2014 and 2016 the highest average erosion rate was found on open land on slope class >40%.

Given the increasing value of erosion over each period, further research is needed to obtain more accurate erodibility (K) values at the research sites and the need for erosion precautions in the form of soil and water conservation measures, as well as improvements to land treatment in Cianten subwatershed.

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