ECODEV ECODEVELOPMENT JOURNAL

Ecodevelopment Journal
Vol. 2 No. 1 (50-54)
https://jurnal.unpad.ac.id/ecodev

cess.unpad.ac.id

PATTERN OF LAND COVER CHANGE TOWARDS TOTAL EROSION IN CIMANUK UPSTREAM SUB WATERSHED

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ABSTRACT

Changes in land use are defined as the increasing of the use of the land from one side use to another followed by a reduced area, or changes in land function at different times. Land degradation and soil erosion are often associated with loss of forest cover, but also caused by poor land use practices (overgrazing, cleaning, land clearing and organic matter destruction clearing). The main aim of this work is to analyze the pattern of land cover changes to the total erosion in *Cimanuk* upstream sub- watershed. The results showed that there were some changes over the land from conserved area to cultivation area. Land use composition in 2009 of the studied area with a total of 146,847.4 ha: conserved and cultivation area are 13.78% and 86.32% respectively. Meanwhile, based on USLE calculation analysis, the total erosion in this sub-watershed reaches 103,475,098.62 ton from which erosion on the conserved areas and cultivated ones are 6,644,401.22 and 96,830,697.40 ton respectively. The relationship function of total erosion of the conserved areas (TEpt) to the width of this area (Aqt) is TEqt = (130.76 * Aqt) + (3 x 10‘) with R^2 = 0.8288. On the other hand, relationship function of total erosion of the cultivation regions (TEgg) to the width of this area (ABB)is TEKB' (838.59 * AKB)" (2 x 10^7) with R^2 = 0.8261. Based on the width of conserved and cultivation regions, and total erosion of respected study area projection, a monogram of land use changes and erosion was obtained from which can be used to predict land use changes pattern until 2050.

Keywords: Erosion, Land cover, Land use changes, Projection, Transfer function

INTRODUCTION

Land use is defined as any form of human intervention to the land in order to meet their basic needs both for material and spiritual Climate change, increasing population and urbanization process are some common cause which is considered as factors that contribute to changes in land use (Wu et al., 2008). In fact, land use changes does not occur due to a single factor (Verburg and Veldkamp, 2001). The complexity of the physical, biological, social, political, and economical factors which are combined at the same time are major cause of land use change process (Wu et al., 2008).

Climate change influences a variety of physical and chemical soil properties which affect infiltration and soil erosion processes. The most climate-sensitive parameters are soil moisture regime, content of organic carbon and canopy cover. The reasons for changes of the soil surface canopy cover by plants and plant residues are manifold: A shifted phenology will cause a change of planting and harvest dates (Chmielewski et al., 2004; Estrella, 2007).

Climate change forces land-use change. New crops, crop rotations and management practices will be implemented to accommodate the new climate regime. At the same time changes in plant biomass production are expected. Climate change forces land-use changes, sometimes also an alteration of land-use structure. To incorporate these processes, climate and soil erosion models have become indispensable tools for assessing the response of soil erosion to a future climate (Lal, 1998; Toy et al., 2002).

Land use changes have a large potential impact on the physical and social environment. They can affect local ecological systems including water and air pollution, local climate changes and also reduced biodiversity (Mahmood et al., 2010; Coskun, et a1., 2008; Hu, et a1., 2008; Wu et al., 2008; Kalnay and Cai, 2003; Sandin, 2009).

According to Zhou et al. (2008) in the watershed region, the percentage of forest vegetation land cover less than 30% of forest land may cause higher erosion than that by 78% vegetation cover can reduce erosion by water. Land cover can reduce erosion spark, because it can weaken the rain kinetic energy and slow down the speed of runoff, and save water due to the increased soil moisture and water holding capacity (Wei et al., 2007). Plant roots can form a dense network in topsoil physically bind soil particles, in addition, the root system of plants also affects the soil erodibility control properties, such as soil aggregate stability, infiltration capacity, soil density and texture, soil organic content and chemical composition (Gyssels et al., 2005). More complex canopy structure can prevent up to 20% or more from any incident precipitation that falls into the surface vegetation (de Jong and Jetten, 2007) as cited in Zhongming et al. (2010).

METHODOLOGY

The study was performed in Cimanuk upstream sub- watershed, in which acted as water catchment (DTA) Reservoir in Jatigede, West Java Province. Detailed map location of current work is presented in Figure 1.

This study uses a digital map of the Cimanuk-Cisanggarung watershed obtained from 1994 to 2009. Other equipment and peripheral used are mapping *software geographic information systems* (*SIG*). Mapping *Software* SIG is used to identify the changing dynamics of land by overlaying land use maps from 1994, 1997, 2001 , 2005, and 2009, to obtain the total area of each land use changes. Once this step is completed, further analysis was performed to obtain forest degradation levels for each year by analyzing land-forest changes to other land use transfer functions.

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Figure 1. Map of Cimanuk upstream sub-watershed

Land use patterns that were analyzed were divided into two major groups, namely: conserved and cultivation regions. Conserved region consists of primary forest, secondary forest, and water bodies whilst cultivation one was includes a mix of land use for garden, farm/moor, plantations, rice fields, shrubs and bare ground. The trend used to compare the extent of land use changes.

Delineation of upstream sub-watershed was performed based on the land use digital map of respected study area. Then, calculation of land use categories based on their used function was performed in order to obtain land use changes trend.

The amount of erosion that occurs in a watershed was calculated by equation method defined as Universal Soil Loss Equation or better known as the USLE equation, proposed by Wischmeier and Smith (1978) in Asdak (1995) as follows:

$$A = R\,K\,LS\,CP \qquad (1)$$

where:

- A = The amount of soil loss per land area, obtained from the multiplication of these factors in equation (1). The amount of soil loss or erosion in this case is limited to flow erosion. It doesn't include erosion from riverbanks and sediment deposited at the bottom lands with greater slope.
- R = Rainfall and surface flow (run-off) erosivity factors for a certain area, usually expressed in terms of the average erosion index (EI). Factor R is also an index number that indicates the amount of power from which rainfall can cause erosion.
- K = soil erodibility factor for a particular soil horizon, and it also means a soil loss per land area for a certain erosivity index. In this case the experimental plots used is the length of 72.6 ft (22.14 m) and a 9% slope, with a longer fallow period. Factor K is defined as the soil erodibility index: a number that indicates whether or not easily chipped particles from soil aggregate by rain precipitation or runoff.
- L = length of slope factor (dimensionless) defined as the number ratio between the amount of soil loss to slope length of 72.6 ft (experimental plots). Notation L in this case is not the actual length of the slope.
- S = gradient slope factor (dimensionless) defined as the number ratio between the amount of land loss to a certain degree of slope of the magnitude of losing ground to 9% slope. Notation S in this case is not the actual slope.
- C = land management factor (dimensionless) defined as a comparison between the amount of soil loss in farming conditions with the desired amount of ground loss when used continuously.
- P = factor of soil conservation practices (mechanical method) defined as the number ratio between the amount of soil loss in the ideal conditions of soil conservation efforts (eg, parallel contour planting techniques, planting in patio or in the bolt) with the amount of soil loss on planting conditions perpendicular to the contour lines.

Calculation of the total land use projection changes and erosion in a given certain area using a growth projection model: Verhults growth model (Burghes & Borrie 1981) as follows:

$$A_t = A_\infty \left[1 + \left(\frac{A_\infty}{A_o} - 1 \right) \cdot e^{-\lambda \cdot T} \right]^{-1} \qquad (2)$$

Where, A_t is the area of the region in t^{th} year; A_o = area of the region in the early years of projection, e = natural exponential (2.71828), λ is a Verhults parameter, T is the time (years), $A\infty$ = total area in the coming year during the leveling-off or often also called arraying capacity. Similarly to the projected development of the total erosion (TE) in a given area can use the same Verhults equation model, as follows:

$$TE_t = TE_\infty \left[1 + \left(\frac{TE_\infty}{TE_o} - 1 \right) \cdot e^{-\lambda \cdot T} \right]^{-1} \qquad (3)$$

Where, TE_t is Total Erosion in t^{th} year; TEo = Total Erosion in the early years of the projection, e = natural exponential (2.71828), λ is a Verhults parameter, t is the time (years), $TE\infty$ = Total Erosion in the coming year during the leveling-off.

RESULTS AND DISCUSSION

A. Conserved Areas

Changes in land cover as a conserved area decreased with the increasing land use conversion function from a conserved land to a cultivation one. Conserved region (A_{KL}) consists of land cover in the form of primary forest, secondary forest and water body. Significant changes occurred between 1997 and 2001, where A_{KL} area drastically decreased due to transfer function into cultivated area (A_{KB}). In 1994, the total width AKL area reach 42 945.09 ha or 29.24% of the total area of Cimanuk sub-watershed and decreased to 23 273.24 ha in 2001 or 15.85% of the total area sub-watershed. Furthermore, in 2009 AKL declined to 20 238.80 ha or 13.78% of the total portion area. The AKL trends changes and total erosion protection areas (TE_{KL}) is presented in Figure 2. Decrease in AKL area is directly proportional to TEKL, where trends tend to decrease with decrease TEKL. Based on the calculation results using USLE equation, in 1997 TE_{KL} reached 8 628 759.28 tons and it was decreased in 2001 to 5 373 511.14 tons. Yet, in The was increased once more in **2009** to 6 644 401.22 tons. The A_{KL} extensive relationship with TE_{KL} was presented in Figure 3. It modeled as TEKL = (130.76 * AKL) + (3 x 10^6) with R^2 = 0.8288. Thus, the total erosion occurred in a certain region is heavily depends on their land cover and total area.

B. Cultivation area

In accordance with the increasing population growth, land requirement for food producing was also increased. The total width area of cultivation region (A_{KB}) increased significantly from 1994 covering 102 742.7 hectares or 69.97% area of sub-watershed Cimanuk. Increased land conversion function from conserved region into cultivation one, resulted in increasing Aug in 2009 reaches 126, 608.61 ha or 86.32% of a total area of Cimanuk sub-watershed. The highest increasing Aug occured in the period of 1997 to 2001, where A_{KB} in 1997 reached 103 905.38 Ha and become 123,573.99 Ha in 2001. The land cover changes in the cultivation region during 1994 2009 are showed in Figure 4.

The increase in A_{KB} region is also directly proportional to the total erosion of cultivation region (TE_{KB}), which TE_{KB} trend tends to increase with an increase in the extent of A_{KB}. Based on calculation results using USLE equation, TE_{KB} reach 69,652,101.75 tons in 1994 and continued to increase to 96,830,697.40 tons in 2009. The A_{KB} and TE_{KB} relationship is modeled as TE_{KB} (838, 59 * A^{KB}) - (2 x 10^7) with R^2 = 0.8261 (Figure 5).

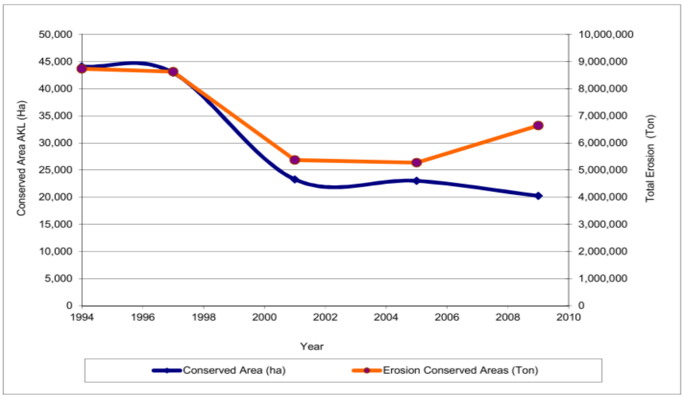

Figure 2. The pattern of land cover changes in a conserved region to the total erosion in Cimanuk upstream sub-watershed.

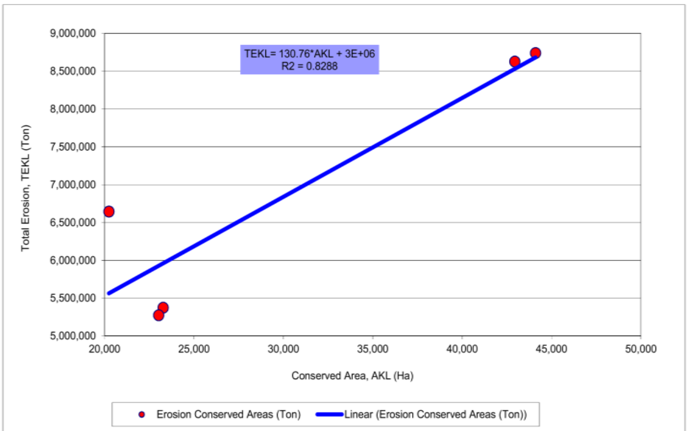

Figure 3. Linear relationship of a conserved region to the total erosion in Cimanuk upstream sub-watershed.

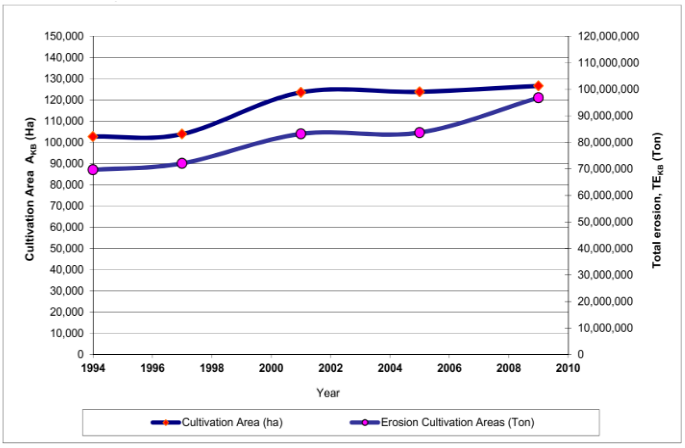

Figure 4. The pattern of land cover changes in a cultivation region to the total erosion in Cimanuk upstream sub-watershed.

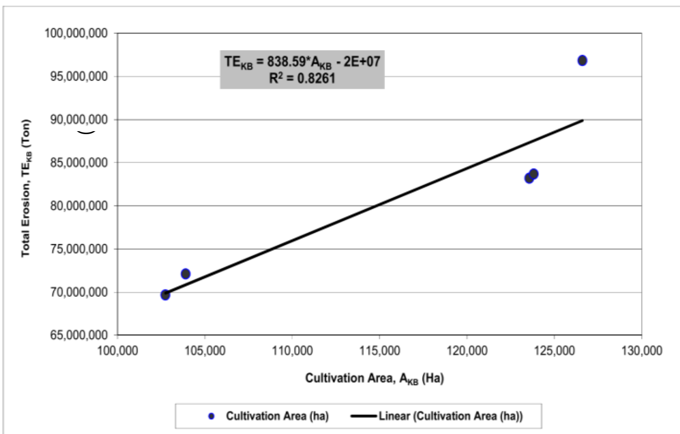

Figure 5. Linear relationship of a cultivation region to the total erosion in Cimanuk upstream sub-watershed.

C. The total erosion in Cimanuk upstream sub-watershed

Analysis result concerning land use changes from conserved region into cultivation in respected study area is shown Figure 6. In 1994, the total width area of conserved zone (A_{KL}) was 44,104.52 Ha and cultivation zone (A_{KB}) was 102,742.70 Ha, from the total width area of Cimanuk upstream sub-watershed reach 146,847.4 ha. However, in 2009, land conversion function had occurred over the land, and total width area of conserved zone has decreased to 20,238.80 Ha whilst cultivation zone area was increased to 126,608.61 hectares.

Composition changes in land use caused an increase in total erosion (TE). In 1994, where reached 78,392,211.01 tons. The increased to 103,475,098.62 tons in 2009. Increased TE occurred during 15 years period (1994-2009) amounted to 25,082,887.62 or 1,672,192.51/year. This may conclude that changes in land use functions from conserved region into cultivation one, led to increasing total erosion (TE). Land use changes and total erosion (TE) pattern for the observed location occurred from 1994 to 2009, is presented in Figure 6.

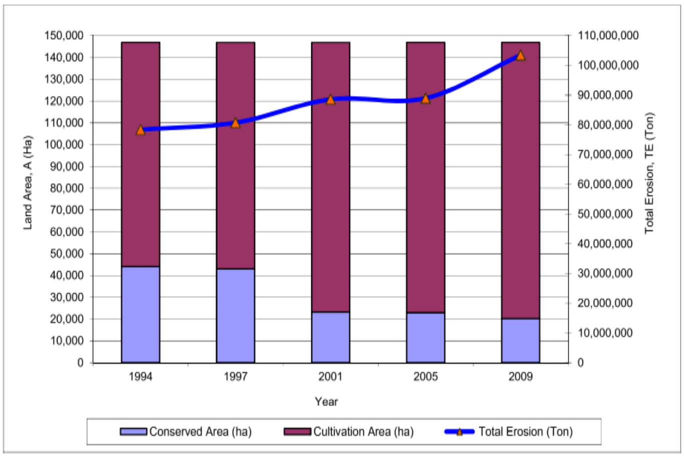

Figure 6. Land use changes and total erosion pattern from 1995 to 2009 in Cimanuk upstream sub-watershed

D. Projection of total erosion in Cimanuk upstream Sub-watershed

Based on total erosion (TE) analysis during 1994-2009, the projection of TE occurred in respected study area can be predicted. The model used for TE projection is Verhults projection model developed using a Solver in *Microsoft Excel 2003* . Optimation results by Solver provided a Verhults projection model as showed in Equation (4), with R^2 = 0.8997 and error = 6.0731. Based on this equation TE can be predicted until projected year of 2050. The actual TE obtained from 1994 to 2009 and TE projection results for 2010-2050 are presented in Figure 7. Thus, the total TE in 2050 is estimated as 149,827,902.29 tons.

$$TE_t = 200000000 * \left[1 + \left(\frac{20000000}{78392211} - 1\right) \cdot e^{-0.0274 * T}\right]^{-1} \quad (4)$$

E. Projection of total width area changes of conserved and cultivation zones

Land conversion continued to occur in Cimanuk upstream sub-watershed. The pattern of land use changes can be projected or predicted based on data over the land from 1994 to 2009. The projection result shows that the total width area of conserved zone tend to decrease until 2050. Predicted of conversed land zone derived by Verhults model is presented in Equation (5), with R^2 = 0.8619 and error = 0.0002.

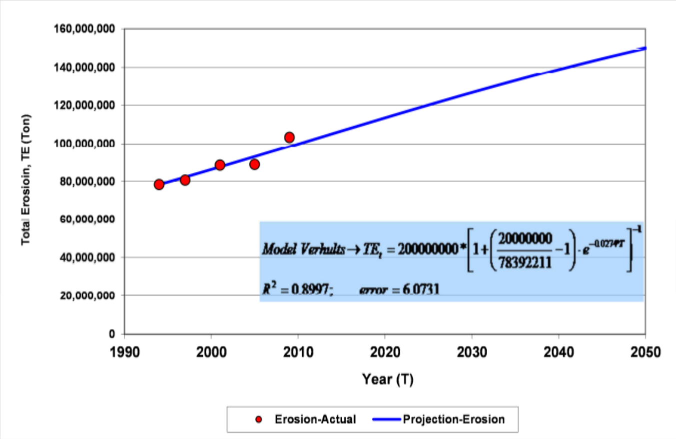

Figure 7. Verhults projection model for total erosion in Cimanuk upstream sub-watershed

$$A_{KL-t} = 146.847,4 * \left[1 + \left(\frac{44.102,52}{146.847,4} - 1 \right) \cdot e^{-(-0,0735)*T} \right]^{-1} \quad (5)$$

Whilst total width area of cultivation zone prediction was modeled as seen in equation (6), with R^2 = 0.8619 and error = 0.0054. The projected area of conserved and cultivation zone were shown in Figure 8.

$$A_{KB-t} = 146.847,4 * \left[1 + \left(\frac{102.743,7}{146.847,4} - 1 \right) \cdot e^{-0,0735*T} \right]^{-1} \quad (6)$$

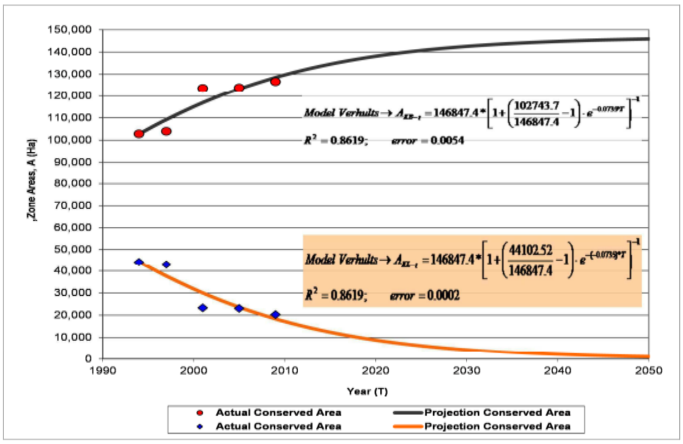

Figure 8. Verhults projection for total width area of conserved and cultivation zone in Cimanuk upstream sub-watershed

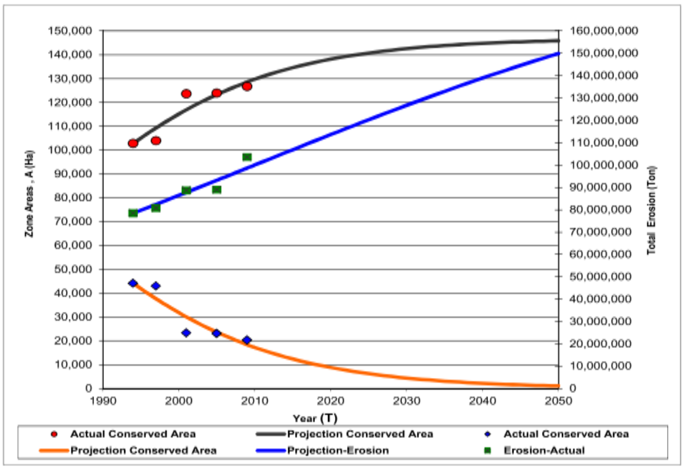

Figure 9: Projected monogram of land use changes pattern to the total erosion in Cimanuk upstream sub-watershed

Based on the land use change pattern and total erosion in the upstream sub-watershed, projection can be performed both for total width area and total erosion occurred in that location. Projection of total erosion (TE) combined with a pattern of land use changes (A_{KL} and A_{KB}) is described in Figure 9. Total A_{KL} and A_{KB} are equal to total width area of this sub watershed = 146,847.4 Ha. The presented graph shown in Figure 9, can be used as a monogram to estimate future TE.

CONCLUSIONS

Based on the results and discussion, several remarks may be concluded as follows (1) Results derived from land use change pattern analysis indicates that land transfer function had occurred over the land from conserved zone to cultivation one; (2) Land use composition in 2009: conserved area is 13.78% and cultivation area is 86.32% from the total width area of location is 146,847.4 Ha; (3) Calculation results using the USLE equation: In 2009, total erosion in this sub-watershed reached 103,475,098.62 ton, which consists of erosion on conserved and cultivation zone: 6,644,401.22 ton and 96,830,697.40 ton respectively; (4) Total erosion (TE_{KL}) to the total width area of conserved zone (A_{KL}) can be modeled as TE_{KL} = (130.76 * A_{KL}) + (3 x 10^6) with R^2 = 0.8288; (5) Whilst total erosion (TE_{KB}) to the total width area of cultivation zone (A_{KB}) can be modeled as TE_{KB} = (838.59 * A_{KB})- (2 x 10^7) with R^2 = 0.8261; (6) Based on the projection results of total width area in conserved and cultivation zone, and the total erosion in respected study area, a monogram was obtained and can be used land use to predict land use changes pattern for over the land until 2050.

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