Soil erosion in agroforestry development in South Bandung Region, Indonesia

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Abstract. Forest is an ecosystem unit in the form of a stretch of land containing biological natural resources dominated by trees in its natural environment. Ecologically, the function of forests is to absorb rainwater to prevent erosion. Land conversion of forest to other uses causes disturbed ecological functions of the forest. The agroforestry system is a land optimization system by combining the components of perennial woody crops, agricultural crops and also livestock. Agroforestry systems have become one of the alternative systems to overcome problems that arise due to the high of land conversion. Bandung District recommends 3 types of agricultural crops in the development of agroforestry in the South Bandung Region, namely coffee and tea, which are perennial crops, and vegetable crops which are annual crops. The purpose of this study is to compare the erosion level of the three types of plants used for agroforestry. The method used in this study are land suitability analysis and erosion estimation analysis. The final results of this study conclude that the erosion level of perennial crops is lower than annual crops.

1. Introduction
South Bandung Region is one potential area that has significance for the ecosystem integrity in Bandung District in supporting life, preserving environmental functions, and guaranteeing sustainable development. The position of South Bandung Region is located in the upper part of Bandung District which still has a lot of forest. Ecologically, the function of the forest is to absorb rainwater to prevent erosion.

Unbalanced development trends in the region has raised concern; first, the shrinking of the catchment area and the drop in ground water level, resulting in disruption of ground water supply; second, changes in land use and a decrease in soil productivity resulting in increased surface water runoff and flooding in the downstream. The conversion of forest land to other uses is caused by the forest land rent is lower than other uses [1]. Based on SLHD data of Bandung District (Regional Environmental Status) in 2014, in KPH (Forest Management Unit) of South Bandung Region, soil erosion has reached the value of 11 tons/ha/year.

Soil erosion is a very vital problem, especially for farmers. Soil erosion causes the fertile soil to turn out because the minerals contained in the soil have been eroded, where the nutrients needed by plants have been lost [2]. The higher the intensity of the rain the higher the energy produced and the more soil particles released from the soil [3]. The collision of raindrops with the surface of the land destroy and detach the soil structure bonds into soil particles which then splash together with raindrops [4].
Agroforestry is an alternative to overcome the problems arising due to the high conversion of forest. Agroforestry is the combination of woody plants or forestry in the form of trees, shrubs, palms, bamboo and other woody plants with agricultural crops, both in a time-series or spatial manner [5]. Agroforestry has social, ecological and economical functions. The Department of Agriculture, Plantation and Forestry of Bandung District has planned an agroforestry area with coffee, tea and vegetable crops. The selection of coffee and tea plants is because coffee and tea plants are perennial crops that have layered canopy so they can protect the soil from direct raindrops then prevent the erosion.

Agroforestry systems are aimed at approaches: 1) The introduction of annual crops into forest plantations that has aim to stabilize general land use and control erosion, especially raising livestock and increasing income; and 2) The activity of land conservation of forest into an agroforestry system as an effort to increase commercial commodities [6]. The objectives of agroforestry are: a) To ensure and improve food needs; b) Improve local energy supply, especially firewood production; c) improve qualitatively and diversify production of raw forestry and agricultural materials; d) Improve the quality of life in rural areas, especially in areas with difficult living conditions where the poor are often found; and e) Maintain and if possible improve the local production and environmental service capabilities [7].

Several studies on agroforestry in relation to farmer income have been carried out by some researchers. The results of Wulandari's research showed that agroforestry business investment in terms of financial aspects is profitable and feasible even though there is a decrease in production of 10% and 20% and a decrease or increase in interest rates by 6% which is a risk free rate and interest rate of 20% which includes nominal interest rates, certain risks and also inflation [8]. Other research results showed that agroforestry patterns in the Cimuntur watershed area (on average agroforestry land area of 0.44 ha/farmer) which could optimally reduce agroforestry land erosion rates less or equal to tolerable erosion (≤ 15.72 tons/year) and increasing net income of agroforestry farming greater or equal to KHM (minimum life needs) (≥ Rp. 8,960,000.00 / year) is an agroforestry pattern that compiled from timber plants, fruit trees, plantation crops, annual crops, and under-season crops [9].

Some conclusions obtained from the results of the research of Okojie LO, Abola MO and Sanusi RA are: 1. the proportion of respondents who are willing to pay for environmental benefit services resulting from green growth with intercropping agroforestry systems are much higher than those that do not; 2. The log offer which is offered has a negative and significant effect (P <0.05) on the possibility of receiving an offer in the assessment of Willingness to Pay (WTP); 3. Income has a positive and significant estimate of effect (P <0.10) on WTP for the environmental benefits of agroforestry; 4. The need to involve the international community in cost sharing for the promotion of green growth through agroforestry to increase mutual benefits because the variables are positive and significant (P <0.05); 5. Policy formulations involving moderate prices in payments for environmental services, in increasing income to residents and increasing counselling contact in the study field need to be done; 6. On-cost Dialogue sharing with the international community regarding the burden of promoting agroforestry practices, it is important for green growth. This will be very helpful in increasing the environmental benefits of agroforestry that can be implemented [10]. The results of Rafin, Rommy, and Firdasari's research produce the following conclusions: 1. The contribution of agroforestry to income is 88.31% or Rp. 50,142,696.00/kk/ha/year. 2. Variables that influence agroforestry farmers' income are age, area of plantation, number of workers, ethnicity, religion, slope of garden land and credit assistance [11].

Base on some of the above researches, it can be said that agroforestry has contributed to increase farmers’ income. However, how does agroforestry affect to the ecology, especially soil erosion? Agricultural crops generally have shallower roots than forest plants, and this causes their role in preventing erosion to be reduced. Three types of crops planted in the agroforestry area in the South Bandung Region are coffee, tea and vegetables. This study aims to calculate and compare the erosion levels of coffee, tea, and vegetables, in the development of agroforestry in the South Bandung Region. Previously, it was determined the level of land suitability for the three types of agricultural crops.
2. Methods
The analysis model used in this study is land suitability analysis and USLE erosion rate analysis (the universal soil loss equation). Land suitability analysis was carried out to find out the appropriate location for plants to be developed in the agroforestry area. Land suitability analysis was obtained by scoring. The data needed is a map consisting of slope maps, altitude maps, rainfall maps, and maps of soil types. The four maps are superimposed and produce several units of land. The score of each land unit is calculated, which can finally be determined the suitability.

USLE erosion rate analysis is a parametric model for predicting erosion from a plot of land. Prediction of erosion using the USLE method is obtained from the relationship between the factors that cause erosion, namely:

\[ A = R \times K \times L \times S \times C \times P \]

Where:
- \( A \) = Amount of eroded soil (tons ha\(^{-1}\) yr\(^{-1}\))
- \( R \) = Factor or rainfall and surface flow (Erosivity) (MJ mm ha\(^{-1}\) hr 1 yr\(^{-1}\))
- \( K \) = Factor of Soil erodibility (ton ha hr MJ\(^{-1}\) mm\(^{-1}\) ha\(^{-1}\))
- \( LS \) = Factor of length and slope (dimensionless)
- \( C \) = Factor of vegetation cover and crop management (dimensionless)
- \( P \) = Factor of specific measures of soil conservation (dimensionless)

After the value of \( A \) is obtained, then combined it with the soil solum data, an erosion level will be obtained. The more shallow the soil solum, the greater the level of erosion hazard in a unit of land. For more details, see table 1.

### Table 1. Table of criteria for determining erosion level.

| Soil Solum (cm)  | Erosion Hazard Classes |  
|------------------|------------------------|
|                  | I          | II         | III        | IV          | V          |
|                  | < 15       | 15-60      | 60-180     | 180-480     | > 480      |
| Deep (>90)       | VL         | L          | M          | H           | VH         |
| Medium (60-90)   | L          | M          | H          | HV          | HV         |
| Shallow (30-60)  | M          | H          | VH         | VH          | VH         |
| Very Shallow (<30)| H          | VH         | VH         | VH          | VH         |

Source: Department of Forestry (1998)

Information:
- VL = Very Low
- M = Medium
- H = Heavy
- VH = Very Heavy

3. Results and discussion
Land suitability is intended for three types of plants, namely tea, coffee and vegetables. From the results of maps superimpose, 170 land units were obtained. Of the 170 land units, the suitable land for tea plants is in 12 land units, with a land area of 40,167.14 ha. For more details, it can be seen in table 2, while the appropriate distribution of land can be seen in figure 1. The suitable land for coffee plants is in 30 land units, with land area of 71,595.43 Ha. For more details, it can be seen in table 3, while the appropriate distribution of land can be seen in figure 2. The suitable land for vegetable plants is in 55 land units, with a land area of 71,595.43 ha. For more details, it can be seen in table 4, while the appropriate distribution of land can be seen in figure 3.
Table 2. Land suitability for coffee.

| No | Land Suitability | Area (Ha) | %   |
|----|------------------|-----------|-----|
| 1  | Suitable         | 71.595,43 | 57,64 |
| 2  | Not Suitable     | 52.621,90 | 42,36 |
|    | South Bandung Region | 124.217,33 | 100,00 |

Figure 1. Land suitability for coffee.

Table 3. Land suitability for tea.

| No | Land Suitability | Area (Ha) | %   |
|----|------------------|-----------|-----|
| 1  | Suitable         | 40.167,14 | 32,34 |
| 2  | Not Suitable     | 84.050,19 | 67,66 |
|    | South Bandung Region | 124.217,33 | 100,00 |
Figure 2. Land suitability for tea.

Table 4. Land suitability for vegetable.

| No | Land Suitability | Area (Ha) | %   |
|----|------------------|-----------|-----|
| 1  | Suitable         | 63.292,19 | 50,95 |
| 2  | Not Suitable     | 60.925,14 | 49,05 |
|    | South Bandung Region | 124.217,33 | 100,00 |
Analysis of erosion estimation is carried out on land units that have the same suitability between coffee, tea and vegetables. The land units suitable for the three types of designation are land units 18, 24, 27, 30 and 40. After an A (erosion rate) is obtained, then combined with the effective soil depth data, an erosion level is obtained. Erosion rate and erosion level can be seen in tables 5, 6 and 7.

**Table 5. Erosion level of coffee.**

| LUU | R   | K   | LS  | C   | P   | A    | Erosion Rate | Erosion Level |
|-----|-----|-----|-----|-----|-----|------|--------------|---------------|
| 18  | 1152.05 | 0.28 | 0.4 | 0.6 | 0.04 | 3.10  | I             | Very Low      |
| 24  | 1152.05 | 0.28 | 3.1 | 0.6 | 0.04 | 24.00 | II            | Low           |
| 27  | 1152.05 | 0.28 | 6.8 | 0.6 | 0.04 | 52.64 | II            | Low           |
| 30  | 1152.05 | 0.28 | 1.4 | 0.6 | 0.04 | 10.84 | I             | Very Low      |
| 40  | 1152.05 | 0.28 | 1.4 | 0.6 | 0.04 | 10.84 | I             | Very Low      |

**Table 6. Erosion level of tea.**

| LUU | R   | K   | LS  | C   | P   | A    | Erosion Rate | Erosion Level |
|-----|-----|-----|-----|-----|-----|------|--------------|---------------|
| 18  | 1152.05 | 0.28 | 0.4 | 0.35 | 0.04 | 1.81  | I             | Very Low      |
| 24  | 1152.05 | 0.28 | 3.1 | 0.35 | 0.04 | 14.00 | I             | Very Low      |
| 27  | 1152.05 | 0.28 | 6.8 | 0.35 | 0.04 | 30.71 | II            | Low           |
| 30  | 1152.05 | 0.28 | 1.4 | 0.35 | 0.04 | 6.32  | I             | Very Low      |
| 40  | 1152.05 | 0.28 | 1.4 | 0.35 | 0.04 | 6.32  | I             | Very Low      |
Table 7. Erosion level of vegetable.

| LUU | R   | K | LS | C | P | A    | Erosion Rate | Erosion Level |
|-----|-----|---|----|---|---|------|--------------|--------------|
| 18  | 1152.05 | 0.28 | 0.4 | 0.4 | 0.4 | 20.64 | II           | Low          |
| 24  | 1152.05 | 0.28 | 3.1 | 0.4 | 0.4 | 160.00 | III          | Medium       |
| 27  | 1152.05 | 0.28 | 6.8 | 0.4 | 0.4 | 350.96 | IV           | High         |
| 30  | 1152.05 | 0.28 | 1.4 | 0.4 | 0.4 | 72.26  | III          | Medium       |
| 40  | 1152.05 | 0.28 | 1.4 | 0.4 | 0.4 | 72.26  | III          | Medium       |

Based on the calculation, the erosion level for coffee, tea, and vegetable crops can be obtained, that the land planted with coffee and tea has a very low and low erosion level, while the land planted with vegetables has a low, medium, and heavy erosion level. The erosion process starts when soil particles detach from the aggregate. This happens because the rain falls directly to the land surface. Coffee and tea have shady leaves, the land cover is denser than vegetables, so that rain falls indirectly to the land surface. In addition, coffee and tea have deeper roots so that soil resistance to erosion is higher than vegetable crops.

4. Conclusions
The type of crop planted affects erosion that occurs in an area. In this study Coffee and tea plants produce lower erosion level compared to vegetable crops. Coffee plants have the largest area of land suitability, covering an area of 71,595.43 hectares or 57.64%; Based on these conclusions, the suggestions put forward are: (1) Coffee and tea plants are recommended for use in the development of agroforestry in the South Bandung Region; (2) Farming analysis needs to be done to determine which is more beneficial between coffee and tea.

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