The land use patterns for soil organic carbon conservation at Endanga watershed Southeast Sulawesi Indonesia

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Abstract. The Endanga basin is one part of the Konaweeha watershed located in South Konawe, Southeast Sulawesi Province, covering an area of 1,353.67 hectares. The land use patterns in Endanga Watershed contained forests, shrubs, oil palm plantations, pepper fields, and cultivated fields of field rice, corn monoculture and intercropping of peanuts and corn. This watershed needs serious attention because most of its territory is on slope of 15-40\%, with erosion hazard levels (EHL) varying from mild erosion to severe erosion. The loss of organic carbon (C-organic) soil is measured from the soil carried along with the surface stream and into the reservoir on various land uses. The result measurement of C-organic soil loss on forest land use is 14.02 kg ha\textsuperscript{-1}, shrubs land 22.71 kg ha\textsuperscript{-1}, oil palm 151.32 kg ha\textsuperscript{-1}, pepper garden 93.69 kg ha\textsuperscript{-1}, field rice 313.80 kg ha\textsuperscript{-1}, monoculture of maize 142.44 kg ha\textsuperscript{-1}, intercropped maize and corn 51.10 kg ha\textsuperscript{-1} and open land 1,909.16 kg ha\textsuperscript{-1}. The forest land and shrubs is best in conserving soil C-organic, but economically unfavorable for the community, so land use pattern for intercropping and pepper plantation can be used for soil C-organic conservation.

1. Introduction
Development progress has increased the conversion of forest to agricultural or non-agricultural land. This conversion is unavoidable as development progress increases the demand of better quality of life. The conversion seems rational from economical point of view with direct short-term benefit that can be obtained, yet this does not consider long-term environmental impact from the loss of forest or protected area [1-2]. Conversion of forest or grassland into farms causes the loss of soil organic carbon. Grassland and forest suffer 20–50\% loss of their soil organic carbon after developed for 40–50 years [3].

Organic materials are essential in soil ability to support plants, thus the decrease of soil organic will result in the degradation of soil productivity. Soil degradation caused by decrease of organic materials is a frequent problem in developing countries, since the amount and intensity of degraded soil increase as the development is progressing. Soil degradation in on-site area of a watershed will reduce soil productivity as it will decrease soil fertility and its water retention ability, which subsequently affect production, ecological, and hydrology functions of the watershed [1, 4-6].

Endanga watershed is a part of Konawehe watershed located in South Konawe Region, Southeast Sulawesi Province, which covers \( \pm 1,353.67 \) ha area. The land use in Endanga watershed includes forest, shrubs, intercropping farming, upland rice, and sago palm plantation [7]. Endanga watershed is a safety and preservation buffer of Konawehe watershed that serves as buffer zones for protecting...
water quality and flood control of Konaweha River. The Endanga watershed requires serious attention as most of its area is located in 15-40% slope with erosion hazard varied from low to high level [8].

Erosion causes loss of top soil that contains organic materials and nutrients. It also has better physical and biological properties than lower soil. Indonesia has high soil erosion rate of agricultural land with slope 3-15%, with the number reaches 97.5–423.6 t ha \(^{-1}\) [9]. In reality, there are many agricultures in Indonesia located in area with slope more than 15%, thus their soil erosion rate is likely to be significantly higher. Hence, land use need to consider soil and water conservation to prevent or reduce erosion that will degrade soil productivity.

This study was aimed to measure the number of soil organic carbon (C-organic) transported/lost by erosion, calculate economic value of loss of soil organic material, review efficiency of land use based on soil organic components that are preserved by Endanga watershed.

2. Materials and Methods

This study was conducted in Endanga watershed is a part of Konaweha watershed located in South Konawe Region, Southeast Sulawesi Province, which covers ± 1,353.67 ha area. Geographically, it is located in 04°5’20”–04°9’46” South and 122°14’49”–122°16’42” East. Soil analysis was conducted in Soil Laboratory, Faculty of Agriculture, Halu Oleo University and Laboratory of Testing, Soil Research Center, Agricultural Land Resources Research Center, Bogor.

Approximately 84% (1,131.24 ha) of Endanga watershed was located in 15–40 % slope. Dominant types of soil are Ustult (84.42%) and Tropext (15.58%), formed from various parent materials such as conglomerate, sandstone, phyllite, and quartz. Average annual rainfall for 10 years (2005–2014) was 2,388.96 mm, the lowest average monthly rainfall was 62.93 mm on September and the highest average was 305.58 mm on March [10].

Soil samples for C-organic measurement were taken from erosion sedimentation, which was directly conducted in erosion plot (sized 22.1 x 2 m, 9% slope). A “soil collector” or a sedimentary reservoir was placed in the lower end of the plot. Erosion plots were used to simulate land use of forest, shrubs, oil palms, pepper, upland rice, corn monoculture, intercropping of corn and peanuts, and a clearing with no vegetation. Observation was conducted every day after rain, which causing run-off, occurred.

Soil C-organic concentration was stated in percentage based on Walkley and Black method on every type of cover crop. Soil C-organic data was multiplied by the amount of eroded soil and converted into organic materials (C-organic x 1.724). Soil C-organic data was then tested statistically by ANOVA followed by BNT test with \( \alpha = 0.05 \). Economic value of loss of soil C-organic was calculated by the number of C-organic transported by eroded soil converted into organic material, then it was used to calculate the cost of loss of soil C-organic, by multiplying the number of C-organic loss with the price of organic fertilizer used by farmers (Rp 3,000 kg \(^{-1}\)).

3. Results and discussion

3.1. Erosion and soil C-organic concentration

Erosion causes the transportation of soil particles, nutrients, and organic materials. The number of soil C-organic lost depended on the amount of erosion the concentration of C-organic in the sediment. The result of erosion and soil C-organic concentration calculation in Endanga watershed is shown in Table 1. Table 1 shows the amount of sedimentation in various types of land use varied from 0.86 ton ha \(^{-1}\)y \(^{-1}\) to 328.46 ton ha \(^{-1}\)y \(^{-1}\). Forest and shrubs had the lowest amount of erosion, because they are considered as dense vegetation with litter in soil surface, which covers soil surface from raindrop impact, thus, soil is protected from destruction of soil aggregates.

This in turns prevent or reduce the number of run-off and erosion. Forest conversion to oil palms plantation or monoculture of upland rice and corns increased the amount of eroded soil. Lower and denser vegetation is more effective in protecting the soil from erosion. Vegetation effectiveness in reducing the number of run-off and erosion is influenced by canopy height, canopy area, vegetation density, and root density [1,11]. Vegetation is essential factor influencing the amount of erosion, and
this factor can be easily changed by humans. Vegetation is able to cover soil surface from raindrop impact, to prevent soil dispersion or destruction of soil aggregates.

Table 1. The amount of erosion and percentage of soil C-organic lost in various types of land uses in Endanga watershed

| No. | Land Use                | Erosion (ton ha\(^{-1}\) y\(^{-1}\)) | Soil C-organic (%) | Soil organic material (%) |
|-----|-------------------------|---------------------------------------|--------------------|--------------------------|
| 1   | Forest                  | 0.86\(^c\)                            | 1.63               | 2.81                     |
| 2   | Bush                    | 3.39\(^e\)                            | 0.67               | 1.15                     |
| 3   | Oil palms               | 18.64\(^e\)                           | 0.81               | 1.40                     |
| 4   | Pepper                  | 6.25\(^{de}\)                         | 1.50               | 2.58                     |
| 5   | Paddy fields            | 48.27\(^b\)                           | 0.65               | 1.12                     |
| 6   | Corn monoculture        | 14.58\(^{cd}\)                        | 0.98               | 1.68                     |
| 7   | Intercropping of corn and peanuts | 8.88\(^{de}\)           | 0.58               | 0.99                     |
| 8   | No vegetation           | 323.46\(^a\)                         | 0.59               | 1.02                     |

Source: Calculation and laboratory analysis results in 2015
Note: Numbers followed by similar letter did not have real difference in BNT test with \(\alpha = 0.05\)

The highest number of soil C-organic and organic materials concentration in erosion sedimentation was found in plots with forest and pepper, with the numbers for other types of land use were low. The high number of C-organic lost in forest caused by organic materials from litter on soil surface. Most of organic materials in soil surface are decomposed and mineralized, thus the number of organic materials in soil surface is high. In land with pepper plantation, the high number of organic carbon is caused by the addition of organic fertilizer in flowering phase.

3.2. Economic value of loss of soil c-organic
Economic value of loss of soil C-organic is translated as an indirect value of one type of land use. The estimation of economic value was aimed to measure how much the loss of C-organic cost in Indonesian Rupiah. To obtain economic value of loss of soil C-organic, the number of C-organic lost was converted to organic material or organic fertilizer with specific price in order to calculate economic value of each type of land use. The price of organic fertilizer in area of Endanga watershed is Rp 3,000 kg\(^{-1}\). The number of soil C-organic lost was directly proportional to the amount of erosion (Table 2).

The economic value of loss of soil C-organic due to erosion per hectare is shown in Table 2. As can be seen in Table 2, the highest loss of soil C-organic occurred in land with no vegetation, while in contrast, the lowest number was in forest. Meanwhile, in farmland, the highest loss occurred in upland rice while the lowest occurred in intercropping of corn and peanuts.

Forest conversion to oil palms plantation or monoculture of paddy fields and corns yielded the high number of soil C-organic lost. On the contrary, land covered with intercropping plants reduced the number of soil C-organic lost. A land with no vegetation had 3,291.39 kg ha\(^{-1}\) loss of soil C-organic, or economically, the loss cost Rp. 9,874,160.- per hectare. Meanwhile, the loss of organic materials in forest was 24.17 kg ha\(^{-1}\), with Rp. 72,510.- economic value.

In farmland, land with upland rice had the highest economic loss of soil C-organic (Rp. 1,622,970) compared to oil palms, pepper, corn monoculture, and intercropping of corn and peanuts. In contrast, land with intercropping plants had low economic loss of soil C-organic (Rp. 264,290.-), this number was nearly as low as the economic cost of land with bushes. The low economic cost was influenced by the cover of soil surface from dense vegetation, which protects the soil from raindrop impact, and subsequently reduces erosion.
Table 2. Economic value of loss of soil C-organic due to erosion per hectare in various types of land use in Endanga watershed

| No. | Land Use     | Soil C-organic (kg ha\(^{-1}\)) | Soil organic material (kg ha\(^{-1}\)) | Economic value (Rp ha\(^{-1}\)) |
|-----|--------------|----------------------------------|----------------------------------------|--------------------------------|
| 1   | Forest       | 14.02\(^{d}\)                   | 24.17\(^{d}\)                          | 72,510                         |
| 2   | Shrubs       | 22.71\(^{d}\)                   | 39.15\(^{d}\)                          | 117,460                        |
| 3   | Oil palms    | 151.32\(^{c}\)                  | 260.88\(^{c}\)                        | 782,630                        |
| 4   | Pepper       | 93.69\(^{cd}\)                  | 161.52\(^{cd}\)                       | 484,560                        |
| 5   | Upland rice  | 313.80\(^{b}\)                  | 540.99\(^{b}\)                        | 1,622,970                      |
| 6   | Pepper       | 142.44\(^{c}\)                  | 245.57\(^{c}\)                        | 736,700                        |
| 7   | Intercropping of corn and peanuts | 51.10\(^{cd}\) | 88.10\(^{cd}\) | 264,290                        |
| 8   | No vegetation| 1,909.16\(^{a}\)                | 3,291.39\(^{a}\)                      | 9,874,180                      |

Note: Numbers followed by similar letter did not have real difference in BNT test with α = 0.05

3.3. Efficiency of land use in soil C-organic retention

The loss of soil C-organic (organic materials) due to erosion can be minimized by proper cropping pattern, since it will protect soil surface from raindrop impact, which in turns reduces run-off and erosion, and subsequently minimizes the loss of soil organic material. This means that organic material retention ability of the soil and its productivity is maintained. The low number of soil organic material lost means that farmers could reduce organic fertilizer costs, which will bring economic benefits for them. The economic value of organic material retained by soil with various types of land use in Endanga watershed is displayed in Table 3.

Table 3. Economic value of retained organic materials in Endanga watershed

| No | Land use                  | Number of retained organic materials (kg ha\(^{-1}\)) | Economic value of retained organic materials (Rp ha\(^{-1}\)) |
|----|---------------------------|--------------------------------------------------------|-------------------------------------------------------------|
| 1  | Forest                    | 3,267.22                                               | 9,801,660                                                   |
| 2  | Shrubs                    | 3,252.23                                               | 9,756,690                                                   |
| 3  | Oil palms                 | 3,030.51                                               | 9,091,530                                                   |
| 4  | Pepper                    | 3,129.87                                               | 9,389,610                                                   |
| 5  | Upland rice               | 2,750.41                                               | 8,251,230                                                   |
| 6  | Corn monoculture          | 3,045.82                                               | 9,137,460                                                   |
| 7  | Intercropping corn and peanuts | 3,203.30     | 9,609,900                                                   |
| 8  | No vegetation             | 0.00                                                   | 0.00                                                        |

Note: Unit cost of organic material = Rp. 3,000/kg

Table 3 shows forest is type of vegetation with the highest efficiency in retaining organic materials, with the number reached 3,267.22 kg ha\(^{-1}\) or its economic value was Rp. 9,801,660.-. Land with paddy field was ineffective in retaining organic materials, thus from economic point of view, paddy field is had low benefit as farmers need to spend more money for fertilizer. The number of retained organic materials in paddy field was 2,750.41 kg ha\(^{-1}\) with economic value of Rp. 8,251,230.-.

Based on the economic value, forest and shrubs had high economic value from soil and water conservation point of view. However, as population grows, it is impossible for a watershed area to be maintained as forest and bush. Therefore, land with intercropping plants can be a choice for agricultural crop as it showed the highest ability in retaining soil C-organic materials or low cost of
soil C-organic lost. The use of land for upland rice, oil palms, pepper, and corn plantation should be intercropped with other cover crops to reduce erosion and subsequently minimizing cost of loss of soil organic materials.

4. Conclusions
It is concluded that (1) The number of soil C-organic lost in various types of land use in Endanga watershed in ascending order was 14.02 kg ha\(^{-1}\) (forest), 22.71 kg ha\(^{-1}\) (shrubs), 51.10 kg ha\(^{-1}\) (intercropping of corn and peanuts), 93.68 kg ha\(^{-1}\) (pepper), 142.44 kg ha\(^{-1}\) (corn), 151.32 kg ha\(^{-1}\) (oil palms), 313.80 kg ha\(^{-1}\) (upland rice), and 1,909.16 kg ha\(^{-1}\) (no vegetation); (2) The number of economic value of C-organic lost (per hectare) due to erosion in Endanga watershed in ascending order was Rp 72,510.- (forest), Rp. 117,480.- (shrubs), Rp. 264,270.- (intercropping of corn and peanuts), Rp. 484,560.- (pepper), Rp. 736,710.- (corn), Rp. 782,640.- (oil palms), Rp. 1,622,940.- (upland rice), and Rp. 9,874,170.- (no vegetation); (3) Types of land use with efficient ability of retaining soil C-organic were forest, bush, intercropping plants, and pepper plantation.

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