Land conservation on banana cultivation based on erosion risks level at Jenawi District-Karanganyar, Indonesia

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Abstract. Global climate change has impacts on the increase of annual rainfall. The raising of air temperature will lead to more water evaporation into the air so the potential for heavy rainfall will also increase, as well as the potential for soil damage. The aims of this research were (1) to determine the soil risk level on the existing condition and banana cultivation; and (2) to make proper land conservation directives on banana crops. This research is an explorative descriptive with survey approach at 28 land map units supported by soil analysis. The results showed that the erosion - risk levels were from low to very high, with erosion prediction of 0.24-1600.21 ton/ha/year and 9.88-2577.80 ton/ha/year on existing condition and banana cultivation. Contour bunds and bench terraces combined with permanent grass strips and annual crops planting are the alternative tools for land conservation methods at the surrounding areas.

1. Introduction
In the last few decades, global climate change has encouraged the increase of annual rainfall. The gases of carbon dioxide have warmed the surface and lower atmosphere about one degree during the last 50 years [1]. A warmer atmosphere can hold more moisture, and globally water vapor increases by 7% for every degree centigrade of warming. Rising air temperature will cause more water to evaporate into the air. It will translate into changes in global precipitation, which is less clear-cut but the total volume of precipitation is likely to increase by 1-2% per warming degree [2]. In line with Minister of Environment Regulation No. 7 of 2006 [3], higher rainfall in an area will increase the potential of land damage in the area. Soil water regimes, soil surface roughness, tortuosity, and soil management practices will affect the surface runoff and soil erosion [4]. Jenawi Sub-district is one of the administrative areas in Karanganyar Regency of Central Java with an area of 5,608.28 ha [5]. Badan Geologi [6] stated that Jenawi Subdistrict is located on a slope area with marginally steep to steep characteristics, with the high and long intensity of rainfall where erosion could potentially occur. The average monthly rainfall that occurred during the last 10 years (2008-2017) was 3,888.2 mm year⁻¹.

Banana is a commodity that is quite interesting to be developed [7]. Banana from Karanganyar Regency comes from superior varieties which have high competitive value because of its fast growth, sweet taste, and high content of Vitamin A and C, making it very popular among the community.
The development of banana commodities in Jenawi Subdistrict needs to take various aspects into consideration including the geographical conditions of the region. Evaluation of land conservation strategies for developing banana plants needs to be conducted. Mujiyo et al. [8] stated that Jenawi Subdistrict was moderately suitable for the banana. There are 4 factors affecting soil damage, namely slope, rainfall, soil type and land use [9]. The slope factor has the most impact on soil damage. Fang et al. [10] stated that the type of land use greatly affects the amount of surface runoff which then affects the amount of soil erosion. Monde et al. [11] stated that relatively open agricultural systems may result in a very large amount of erosion because when surface runoff occurs, most of C-organic is carried away by erosion. On the other hand, forest land has a higher C-organic content, this condition is caused by the accumulation of organic material on the forest floor [12]. Mujiyo et al. [13] stated that the paddy field has a low SDP because it is commonly located on the flat area and the conservation method is conducted by the farmer by maintaining the paddy bund and terrace.

Two land conservation strategies were suggested by Arsyad [14], namely the methods of calculating erosion potential and land conservation. The erosion prediction calculation model commonly used in Indonesia is the USLE method [15], which is an erosion prediction model designed to predict long-term erosion. The purposes of this research were (1) to determine the erosion value of soil and Erosion Risks Level (ERL) on the existing condition and banana cultivation; and (2) to make proper land conservation directives on banana crops.

2. Materials and methods

The research was conducted from June to November 2017 in Jenawi District, Karanganyar Regency. The analysis of soil samples was conducted in the Laboratory of Physics and Soil Conservation, and Laboratory of Chemical and Soil Fertility in the Faculty of Agriculture, Universitas Sebelas Maret, Surakarta. This study uses a descriptive exploratory method using land mapping unit approach (LMU) as the basic unit of analysis in the field survey. LMU was determined by overlaying soil type maps, slope maps, and land use map to obtain 28 Land Map Units (LMU). The sample point was determined by using purposive sampling taking 3 points representing each of the observed variables.

The magnitude of the erosion value was calculated by using USLE method, with A = R x K x L x S x C x P. The observed variables included rain erosion (R), soil erodibility (K), slope length (L), slope elevation (S), crop management (C) and existing conservation measures (P). In this study, calculations of the land erosion value were conducted before the bananas cultivation and after by changing the value of plant management (C) for banana plants to 0.6. calculations of the land erosion value were conducted before bananas cultivation and after by changing the value of plant management (C) for banana plants to 0.6. After finding the erosion value thanconservation planning conducted on lands with heavy erosion risks.

3. Results and discussion

3.1. The general condition of the research location

Geographically, Jenawi District is located between 111° 40' 54.063"- 111° 11' 40.01" Eastern Longitude and 7° 37' 14.103"- 7° 31' 39.311" Southern Latitude which is on the western slope of Mount Lawu with an average height of 610-2056 masl, with slope variations between 0-40%. The area of Jenawi Sub-district is around 5,608.28 ha with 524.14 ha of paddy field use and 5,084.14 ha of dry land. The use of dry land for yard and building is about 765.00 ha, 1,991.00 ha of moor per farm, 1,600.67 ha of state forest, 11.00 ha of grassland and 611.00 ha of plantation. According to the geographical position and land potential, Jenawi Subdistrict has good prospects and opportunities for banana cultivation. The aspect of land conservation is our main focus by evaluating the impact of land use for banana cultivation on the soil erosion threat [16].
3.2. Land Mapping Unit (LMU)
Land Mapping Unit was obtained by overlaying several types of maps, including land type maps, land use maps, and slope maps. The types of soil contained in the study area included Andisols, Inceptisols, and Alfisols. The types of land use in the study area include irrigated paddy fields, rainfed fields, farms, and dry land with slope class divided into 5 sub-classes of 0-8%, 8-15%, 15-25%, 25-40% and >40%. The overlay of the several types of maps resulted in 28 LMU which were then used to determine the location of the survey in the field (Figure 1).

![Image of Land Mapping Unit in Jenawi Subdistrict]

**Figure 1.** Land mapping unit in Jenawi Subdistrict

3.3. Prediction of erosion value with various types of land use
Erosion is a three sequential process, namely detachment, transportation, and deposition of soil materials by erosion causing factors [17]. The magnitude of the erosion prediction value is presented in Table 1. The highest erosion was found in LMU 12 (Andisols 25-40%) of 1600.21 tons ha$^{-1}$ year$^{-1}$ having very heavy erosion risk levels. The lowest erosion prediction value was found at LMU 17 (Inceptisols 0-8%) of 0.24 tons ha$^{-1}$ year$^{-1}$ with moderate erosion risk level. The erosion distribution map can be seen in Figure 2. The high erosion value in Jenawi sub-district is due to slope and land use which is not in accordance with conservation principles and conservation techniques [18].

3.4. Prediction of erosion value with banana cultivation
The calculation of the erosion value in this research area is used as a reference in developing banana cultivation in Jenawi District. The calculation of erosion risk value with banana commodity was also conducted based on USLE method by considering the factors of $R$, $K$, $L$, $S$, $C$, and $P$. Factors $R$, $K$, $L$, $S$, and $P$ using the values obtained from previous observations, while the $C$ value was 0.6, the value for banana commodities. It should be noted that banana commodities are not generally planted in monoculture so that banana cultivation remains combined with other commodities in each LMU.
According to Table 1, the potential land for the development of banana cultivation without land conservation methods are LMU with have the value of ERL between very low-low-moderate, there are LMU 1 (Alfisols 0-8%); 6 and 7 (Alfisols 8-15%); 17 and 18 (Inceptisols 0-8%); 19 (Inceptisols 15-25%); 25 and 27 (Inceptisols 15-25%). LMU 8, 9 10 (Andisols 15-25%), and 11 (Andisols 25-40%) have moderate of ERL, but there is tea plantation so it’s not potential for banana cultivation. Lands with high and very high erosion risk levels need to take conservation measures so that the erosion risk level can be lowered to low-moderate so that it can become potential for banana cultivation.

Table 1. The value of erosion (A) and erosion risks level (ERL) on existing condition and banana cultivation in Jenawi Subdistrict

| LMU | R  | K   | L  | S    | C_{ext} | C_{ban} | P   | \( \lambda_{ex} \) Tons ha\(^{-1}\) year\(^{-1}\) | \( \lambda_{ban} \) Tons ha\(^{-1}\) year\(^{-1}\) | Effective Depth (cm) | ERL\(_{ex}\) | ERL\(_{ban}\) |
|-----|----|-----|----|------|---------|---------|-----|----------------|----------------------|------------------|-------------|-------------|
| 1   | 0.24 | 0.67 | 0.35 | 0.35 | 0.10 | 6.45 | 0.10 | 9.88 | 95 Very Low | Very Low |
| 2   | 0.23 | 0.76 | 0.35 | 0.20 | 0.15 | 62.65 | 0.15 | 155.02 | 95 Low | High |
| 3   | 0.23 | 0.65 | 0.35 | 0.45 | 0.06 | 47.24 | 0.06 | 74.86 | 80 Moderate | High |
| 4   | 0.24 | 0.68 | 0.35 | 0.40 | 0.15 | 115.25 | 0.15 | 206.47 | 90 High | High |
| 5   | 0.23 | 0.71 | 1.35 | 0.20 | 0.40 | 59.36 | 0.40 | 219.33 | 90 Moderate | High |
| 6   | 0.22 | 0.64 | 1.35 | 0.45 | 0.15 | 42.22 | 0.15 | 57.49 | 95 Low | Low |
| 7   | 0.22 | 0.79 | 1.35 | 0.45 | 0.06 | 20.94 | 0.06 | 26.89 | 95 Low | Low |
| 8   | 0.15 | 0.63 | 0.35 | 0.35 | 0.07 | 27.60 | 0.07 | 64.53 | 90 Moderate | Moderate |
| 9   | 0.14 | 0.75 | 0.35 | 0.40 | 0.07 | 35.20 | 0.07 | 78.21 | 90 Moderate | Moderate |
| 10  | 0.12 | 0.82 | 0.35 | 0.35 | 0.07 | 28.16 | 0.07 | 67.47 | 90 Moderate | Moderate |
| 11  | 0.14 | 0.65 | 0.16 | 0.50 | 0.07 | 84.16 | 0.07 | 167.52 | 112 Moderate | Moderate |
| 12  | 0.15 | 0.62 | 0.16 | 0.70 | 0.90 | 1,600.21 | 0.90 | 2,192.19 | 67 Very High | Very High |
| 13  | 0.12 | 0.75 | 0.16 | 0.70 | 0.90 | 1,514.33 | 0.90 | 2,108.69 | 67 Very High | Very High |
| 14  | 0.17 | 0.85 | 0.35 | 0.35 | 0.50 | 111.90 | 0.50 | 265.90 | 90 High | Very High |
| 15  | 0.18 | 1.06 | 12.27 | 0.05 | 0.10 | 7.96 | 0.10 | 653.96 | 112 Very Low | Very High |
| 16  | 0.18 | 0.96 | 12.27 | 0.21 | 0.40 | 591.89 | 0.40 | 2,577.80 | 112 Very High | Very High |
| 17  | 0.30 | 0.68 | 0.35 | 0.01 | 0.10 | 0.24 | 0.10 | 14.11 | 56 Very Low | Moderate |
| 18  | 0.34 | 0.67 | 0.35 | 0.35 | 0.15 | 13.74 | 0.15 | 21.51 | 95 Very Low | Low |
| 19  | 0.33 | 0.68 | 0.35 | 0.20 | 0.06 | 32.10 | 0.06 | 94.13 | 95 Low | Moderate |
| 20  | 0.32 | 0.55 | 0.35 | 0.01 | 0.15 | 3.20 | 0.15 | 184.50 | 65 Low | Very High |
| 21  | 0.31 | 0.65 | 0.35 | 0.50 | 0.40 | 478.22 | 0.40 | 521.88 | 80 Very High | Very High |
| 22  | 0.33 | 0.80 | 0.35 | 0.45 | 0.06 | 83.96 | 0.06 | 112.65 | 90 High | High |
| 23  | 0.32 | 0.66 | 0.16 | 0.20 | 0.40 | 455.44 | 0.40 | 1,385.98 | 90 Very High | Very High |
| 24  | 0.33 | 0.53 | 0.16 | 0.45 | 0.06 | 130.27 | 0.06 | 175.89 | 90 High | High |
| 25  | 0.33 | 0.63 | 0.15 | 0.20 | 0.15 | 27.86 | 0.15 | 77.64 | 95 Low | Moderate |
| 26  | 0.31 | 0.60 | 0.15 | 0.01 | 0.15 | 1.27 | 0.15 | 76.23 | 67 Low | High |
| 27  | 0.40 | 0.61 | 0.15 | 0.35 | 0.06 | 23.07 | 0.06 | 39.05 | 95 Low | Low |
| 28  | 0.40 | 0.69 | 0.15 | 0.10 | 0.40 | 49.19 | 0.40 | 287.72 | 95 Low | High |

Rain erosion (R: 3.346.61), soil erodibility (K), slope length (L), slope elevation (S), crop management on existing condition (C_{ext}), crop management on banana cultivation (C_{ban}: 0.6), existing conservation measures (P), value of erosion on existing condition (\( \lambda_{ex} \)), value of erosion on banana cultivation (\( \lambda_{ban} \)), Erosion Risks Level on existing condition (ERL\(_{ex}\)), and Erosion Risks Level on banana cultivation (ERL\(_{ban}\)).
Figure 2. Map of erosion on existing condition (a) and on banana cultivation (b) in Jenawi Sub-district

The use of banana commodity on the land coverage (C) caused a change in the erosion. Lanyala et al. [19] stated that plants have the ability to withstand different erosion rates that are influenced by their height, leaf crown continuity, produced organic matter, root systems, and planting density. The effectiveness of crop influence on erosion can be seen from the production of dry material and the plant ability to cover the soil. Banana is a type of monocot plant with roots that are not too deep (150-200 cm), so it is easy to collapse if the soil conditions are not suitable [20]. Banana leaves are round and long. The positions of banana leaves are scattered and located in a relatively long stalk so that the density of the plants is not too dense thus it can only intercept small amount of rainwater. Banana plants contribute a small amount of organic material to the soil through the remnants of the plant parts. Thus, banana plants have a low ability to withstand erosion.

3.5. Alternative methods of land conservation

The banana cultivation development in Jenawi District must take into consideration the erosion prediction value and erosion risks level. Erosion Risks Level (ERL) is the estimated maximum amount of lost soil that can happen on a land by considering the level erosion value (A) with the effective soil depth [14][15][21]. LMUs that have very low, low and moderate erosion risk levels have the potential to develop bananas without the need for land conservation methods. LMUs with high and very high erosion risk levels need to conduct land conservation so that it can be potential for the bananas cultivation development. Conservation planning conducted by selecting several alternative factors C and P, so that actual erosion can become smaller than the maximum erosion level [22]. According to Table 2, the potential land for banana cultivation after land conservation are at LMU 2, 3, 4 (Alfisols 15-25%); 26 and 28 (Inceptisols 8-15%). The lands which still have a high and very high erosion risk even after conservation is not potential for the banana cultivation.

Based on the results of the analysis of erosion parameters and erosion risks level (ERL), the method that should be performed on lands with low erosion risk level is vegetative methods. At moderate erosion risk level, the suggested management is selecting and rearranging cropping patterns, planting ground cover, using plants or crop residues as mulch, and making bench terraces combined with absorption holes. The suggested methods for lands with high erosion risks level is by planting the annual crops and industrial plants [23]. Contour bunds and bench terraces combined with permanent grass strips and annual crops planting are the alternatives for land conservation methods at the surrounding areas.
Table 2. Erosion Risk Level after land conservation methods (ERL_{cons}) on banana cultivation in Jenawi Sub-district

| LMU | R   | K   | L   | S   | C_{ban} | P_{cons} | A_{cons} \text{Tons ha}^{-1} \text{year}^{-1} | Effective soil depth (cm) | ERL_{cons} | Notes     |
|-----|-----|-----|-----|-----|---------|----------|----------------------------------------------|---------------------------|-------------|-----------|
| 2   | 0.19| 0.76| 3.57| 0.04| 41.34   | 95       | Low Potential                                |                           |             |           |
| 3   | 0.27| 0.65| 3.57| 0.04| 49.91   | 80       | Moderate Potential                           |                           |             |           |
| 4   | 0.28| 0.68| 3.57| 0.04| 55.06   | 90       | Moderate Potential                           |                           |             |           |
| 5   | 0.28| 0.71| 1.35| 0.15| 82.25   | 90       | Not Potential                                |                           |             |           |
| 12  | 0.24| 0.62| 8.16| 0.15| 365.37  | 67       | Very High Not Potential                      |                           |             |           |
| 13  | 0.19| 0.75| 8.16| 0.15| 351.45  | 67       | Very High Not Potential                      |                           |             |           |
| 16  | 0.27| 0.96| 12.27| 0.15| 966.68  | 112      | Very High Not Potential                      |                           |             |           |
| 20  | 0.31| 0.55| 3.57| 0.04| 49.20   | 65       | Very High Not Potential                      |                           |             |           |
| 21  | 0.28| 0.65| 3.57| 0.15| 195.71  | 80       | Very High Not Potential                      |                           |             |           |
| 22  | 0.33| 0.80| 3.57| 0.04| 75.10   | 90       | Very High Not Potential                      |                           |             |           |
| 23  | 0.32| 0.66| 8.16| 0.15| 519.74  | 90       | Very High Not Potential                      |                           |             |           |
| 24  | 0.34| 0.53| 8.16| 0.04| 117.26  | 90       | Very High Not Potential                      |                           |             |           |
| 26  | 0.32| 0.60| 1.35| 0.04| 20.33   | 67       | Moderate Potential                           |                           |             |           |
| 28  | 0.39| 0.69| 1.35| 0.04| 28.77   | 95       | Low Potential                                |                           |             |           |

Rain erosion (R: 3,346.61), soil erodibility (K), slope length (L), slope elevation (S), crop management on banana cultivation (C_{ban}: 0.6), conservation measures (P_{cons}), value of erosion after land conservation (A_{cons}), Erosion Risks Level after land conservation (ERL_{cons}).

Figure 3. Map of potential land for banana cultivation in Jenawi Subdistrict

4. Conclusion
The erosion risk level on the agricultural lands (existing condition) in Jenawi Subdistrict ranged from very low to very high. The erosion risk levels on agricultural lands with banana cultivation ranged from very low to very high. The land potential for the cultivation of banana commodity without land conservation methods was found in LMU 1, 6, 7, 17, 18, 19, 25 and 27. The lands that have the potential to be planted with bananas after conservation methods are LMU 2, 3, 4, 26 and 28. The lands
that are not potential for banana cultivation are LMU 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 20, 21, 22, 23 and 24. The land conservation methods that can be pursued among others are making graded terraces and bench terraces accompanied by terrace reinforcement plants such as grass strips and annual plants.

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