Run off prediction by using small plots at teak forest, dry land and settlement areas in Pitu village, Ngawi, East Java

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Abstract. Erosion is the process of soil movement from one place to another. The different amount of erosion that occurs in every land-use is caused by the difference of land cover in every land use. The purpose of this study is to find out the amount of erosion, the value of runoff and runoff coefficients, the correlation between rainfall and runoff, also the correlation between runoff and erosion which occurred in three different land use types. This research was conducted in Pitu Village on 3 different land uses, first in the teak forest land-use, second in yard land use, and third in the agriculture field land use. Small plots of 22 m x 4 m were applied to determine the erosion and the value of runoff. SeXI-FS software is used to describe the diagram profile of vegetation condition in each land use. The data were analyzed by using liner regression to determine the correlation between rainfall thickness and runoff, also the correlation between runoff and erosion using Sigma Plot software. The result shows that the largest runoff occurred in settlement land (averaged: 95.96 mm) and the smallest runoff in dry land (11.85 mm in average). The largest runoff coefficient occurs in settlement land (averaged: 0.22) and the smallest runoff coefficient in dry land (averaged: 0.025). The runoff coefficient for each type of land use is included in the low category. Rainfall depth has a positive correlation with runoff. The greater the rainfall depth, the greater the runoff produced.

1. Introduction

Land use is one of the most vulnerable factors to the influence of changes in land cover by humans compared to other factors such as climate, soil, and topography. Rapid population growth and increasing demands for community needs on land, often resulting in conflicts of interest over land use and the occurrence of discrepancies between land use and planned allocation [1]. Humans change land and modify land cover according to living needs [2]. Excessive land use exceeds the ability and carrying capacity of land by changing natural resources such as forests, grasslands, wetlands and agricultural land into settlements can cause a decrease in the productivity of a land that is the degradation of the potential of natural resources in it [3].

Land changes use from forests to non-forests caused a reduction in recharge areas resulting in runoff. Rainwater that falls mostly cannot be restrained by vegetation and cannot seep into the soil so that most of the rainwater will become runoff [4]. Runoff occurs when the soil is no longer able to infiltrate water on the ground because the soil is already saturated [5]. The volume of runoff in large quantities and will continue to cause erosion which can transport soil particles and move these particles to water bodies such as rivers, lakes, reservoirs and so on [6]. According to Arsyad [7], runoff has a large role in decreasing land quality.
Pitu Village is one of the villages in Ngawi Regency, East Java. Pitu Village has five types of land use, i.e forest land, dry land, bushland, rice fields, and settlements areas. This research was conducted in the type of teak forest land use in Pitu Village. The teak tree has a wide leaf shape, on the surface of the leaf forming a hollow that leads to the leaf bone, and at the tip of the leaf narrows and points down. These characteristics make teak leaves have the ability to intercept rainwater that is different from other plants. Raindrops that fall and hit the surface of the leaves will accumulate and form larger raindrops. When teak leaves are unable to accommodate the falling grain of rainwater, the raindrops flow to the tip of the leaf and fall to the surface of the ground with greater kinetic energy. This can result in large runoff.

This research was also carried out on settlements area and dry land in Pitu Village. The majority of the people in Pitu Village (93%) work as farmers so that the land is used for planting annual crops in order to meet their daily needs. Land processing carried out by the Pitu Village community on annual crops in the early rainy season can cause land openness, so that the soil cannot withstand rainwater which triggers runoff.

Processing different land in each land use produces different land cover vegetation. The difference in vegetation cover of the land can result in large kinetic energy falling to the ground and different runoff and producing large erosion occurring in each of these land uses. This can affect the yield of land productivity and the retreat of crop production. Therefore, this research is important to be conducted to find out the extent of erosion in land use types in teak forests, settlements areas, and dry land, as a reference in land management so that the land can be used to the maximum indefinitely. The aim of this research are:

1) Determine the runoff and coefficients runoff in teak forest, settlement area and dry land in Pitu Village,
2) Determine the relationship between rainfall depth and runoff in teak forest land, settlement area and dry land in Pitu Village.

2. Material and methods

2.1. Materials

This research was carried out in Pitu Village, Ngawi, East Java. The materials used in this research are:

1. Rainfall depth data of the rain contained in the manual ombrometer;
2. Small plot data including volume of water in the drum and the weight of the sediment;
3. Data on vegetation include: tree height, branch-free canopy height, breast height diameter, outer canopy height, crown direction (north, east, south, west), x and y coordinates;
4. Map of Pitu village

![Figure 1. Map of land coverage in Pitu village](image-url)
2.2. Data Collection Method

2.2.1. High water level and sedimentation. Small plot method was applied in this research. Small plots is placed at six locations, i.e. on teak forest land A, teak forest land B, settlement land A, settlement land B, dry land A, and dry land B. Plots are installed in each location by one plot with a size of 22 mx 4 m with a length parallel to the slope direction. The placement of erosion plots was done purposively by finding locations that were considered to represent the amount of erosion based on land use, slope and soil type. Analysis of runoff using small plots is calculated using the formula based on Kusumandari [8] as follows:

\[ \text{Volume of Drum (ml)} = \frac{1}{4} \pi \times d^2 \times TMA \text{(cm)} \]  

(1)

where, \( d \) : diameter, \( TMA \) : water level (cm)

- Runoff (RO) \( = \frac{\text{Volume drum}}{\text{Plot Area (cm}^2)} \times 10 \text{mm} \)  

(2)

2.2.2. Rainfall Depth. Measurement of rainfall depth was carried out by installing three pieces of ombrometer in three research locations, i.e. teak forest land, settlements areas, and dry land. Rainfall data collection is carried out per rain event. Rainfall is used to find out the runoff coefficient, with the equation as follows:

\[ \frac{\text{Runoff}}{\text{Rainfall depth}} \times 100 \]  

(3)

Relationship between rainfall depths with runoff can be determined using the simple linear regression analysis with equations as follows:

\[ y = y = a \pm b_1 x_1 \]  

(4)

where, \( y \) = dependent variable, \( x = \) independent variable, \( b = \) constant

2.2.3. Vegetation Cover. A sampling of vegetation cover is carried out using a profile diagram measuring 8 meters x 60 meters. According to Kershaw [9] the method that can be used to determine canopy stratification is to make a plot measuring 8 m x 60 m served in the Figure.2 as follows:

![Figure 2. Vegetation data collection plot](image)
In these plots were recorded tree coordinates, tree species, diameter, branch-free stem height, total height, canopy projection (north, east, south, and west) and widest canopy position height. The data is processed using SExI-FS software to describe canopy cover (vertical projection) and crown state (horizontal projection).

3. Result and discussion

3.1. Runoff and runoff coefficient
Runoff is water flowing above the ground to the river channel. Runoff occurs when the amount of rainfall exceeds the rate of infiltration of water into the soil. Runoff characteristics such as number or volume, speed, and runoff fluctuations determine their ability to cause erosion. Runoff values are expressed in units of mm [10]. Runoff values for each land use are served in the graph as follows:

![Graph of Runoff Values for Each Land Use](image)

Information: TF: Teak Forest, SA: Settlement Area, DL: Dry Land.

Based on the graph, runoff occurring in each land use with the same slope in a sequence that is at a teak forest land A is 16.55 mm, teak forest land B is 14.23 mm, settlement area A is 86.72 mm, settlement area B is 105.19 mm, dry land A is 10.81 mm, and the smallest runoff in dry land B is 12.88 mm. The biggest runoff is in settlement area B, this is due to human activities such as land management practices. Suryatmojo [11] said that land management practices have a significant impact on the runoff process, runoff speed and the ability of water to go into the soil. Runoff value is also affected by understorey and trees which have an important role in reducing the runoff rate. With the presence of canopy cover, the rain water that falls can be held back by the tree canopy, so that it can reduce the rainwater that falls directly to the ground. Understorey vegetation can also increase the ability of the soil to absorb water by increasing soil porosity and increasing the amount of water infiltrated to the soil. According to Morgan [12], understorey vegetation protects the soil from the aggregate destruction process by rain and runoff, thus vegetation can reduce soil damage due to rainwater and runoff. Understorey vegetation can also reduce runoff because it can increase the absorption of water into the soil [13]. Factors that influence runoff according to Seyhan [14] are: 1) meteorological factors consist of type of intensity, duration and distribution of precipitation, temperature, humidity, solar radiation, wind speed, and air pressure, 2) watershed factors such as watershed shape, watershed slope, geology, soil type, vegetation and drainage networks, and 3) human factors in the watershed system.
Runoff can be used to calculate and find out the coefficients runoff for each type of land use. The coefficient runoff (C) is a number that shows a comparison between the amount of runoff and the amount of rainfall. The following are the results of the calculation of the runoff coefficient (C) in each land use:

| Rainfall (mm) | TF A | TF B | SA A | SA B | DL A | DL B |
|---------------|------|------|------|------|------|------|
| 395.15        | 0.04 | 0.03 | 0.20 | 0.24 | 0.02 | 0.03 |

Table 1. Calculation of the Runoff Coefficient (C) in Each Land Use

Based on the result, in teak forest land A, C = 0.04 means 4% of rainfall becomes runoff, in teak forest land B (C = 0.03), means 3% of rainfall becomes runoff, on settlement area A (C = 0.20), meaning 20% of rainfall becomes runoff, on settlement area B (C = 0.24), meaning 24% of rainfall becomes runoff, in dry land A (C = 0.02), meaning 2% of rainfall becomes runoff, in dry land B (C = 0.03), meaning 3% of rainfall becomes runoff. Runoff coefficient values for each type of use include low criteria. Factors that influence the value of C according to Suripin [15] are the rate of soil infiltration, topography, vegetation, rainfall intensity, groundwater, the degree of soil density and soil porosity.

3.2. Vegetation Cover
Vegetation is a protective layer between the atmosphere and soil [7]. According to Guo et al. [16] vegetation can influence the hydrological cycle through the process of infiltration, evapotranspiration, and interception. In this study, vegetation data collection was carried out on teak forest land A and B, settlement area A and B, dry land A and B. In the dry land B, a profile diagram is not made because there are only corn plants, understorey plants and no tree vegetation. In teak forest land A and B, the constituent plants are homogeneous so that the canopy is uniformly owned. In teak forest area A has more teak stands than in land B. The condition of the soil surface in teak A is less vegetation compared to the use of teak forest B.

At settlement area A there are more trees around the plot compared to settlement area B. The understorey vegetation in settlement area A is quite large compared to settlement area B. In the settlement area, there is community activity namely planting sugarcane at the beginning of the rainy season in the plot. The following is a profile diagram on settlement area A and B:
In dry land A and B there are only corn plants planted by the community. In dry land A there are several teak trees around the plot, while in dry land B there are no trees. The condition of the soil surface in dry land A and B is overgrown with a lot of understorey vegetation. The following is a profile diagram on dry land A:

Profile diagram is used to find out the appearance of vegetation from vertical and horizontal directions. This is done to describe the condition of vegetation around the plot. The following is a table of canopy cover values for each type of land:

| Type of Land Use       | Percent of Canopy Cover (%) | Description  |
|------------------------|-----------------------------|--------------|
| Teak Forest Land A     | 53.33                       | Medium       |
| Teak Forest Land B     | 47.29                       | Low          |
| Settlements Land A    | 16.87                       | Rarely       |
| Settlements Land B    | 26.87                       | Rarely       |
| Dry Land A             | 4.3                         | Very Rarely  |

The canopy cover values have been classified as follows [17]: very rarely (1-9%), rarely (10-29%), low (30-49%), medium (50-69%), tight (70-84%) and very tight (85-100%). Based on the results of vegetation analysis, it can be seen that the canopy cover on teak forest A is included in the medium class with a percent of canopy cover of 53.33%. The canopy cover on forest B teak is included in the low class with a percent of canopy cover of 47.29%. The canopy cover in settlement area A is included in the rare class with a percent of canopy cover of 16.87%. Canopy cover on settlement area B is included in the rare class with a percent of canopy cover of 26.87%. The canopy cover on dry land A is included in the very rare class with a percent of canopy cover of 4.3%.

From the results of the analysis it can be seen that the greater the canopy cover value, the greater the canopy interception process by the canopy. The presence of tree canopy cover can slow the rate of rain water, so that the energy kinetics become smaller. Labriere [18] adds that under certain conditions, vegetation cover with a layered canopy can increase erosion. Leaves from a layered canopy layer can
help break the kinetic energy of raindrops, but raindrops that fall from the canopy are often larger than raindrops and reach the surface with greater kinetic energy than on land that does not have canopy layer.

3.3. Relationship between Rainfall Depth (CH) and Runoff (RO)

Relationship between rainfall depth and runoff at teak forest land A, teak forest land B, settlement land A, settlement land B, dry land A and dry land B in Pitu Village can be known using regression analysis. The following are the results of relationship regression analysis between rainfall depth and runoff:

**Figure 14.** Relationship on Teak Forest A

**Figure 15.** Relationship on Teak Forest B

**Figure 16.** Relationship on Settlement Area A

**Figure 17.** Relationship on Settlement Area B

**Figure 18.** Relationship on Dry Land A

**Figure 19.** Relationship on Dry Land B
The graph of the relationship between rainfall depth and runoff produces a regression equation. The value of the regression equation can be used to predict runoff times per day in the study location by entering data rainfall depth. The graph of the relationship between rainfall depth and runoff in Figure 14 in teak forest A produces an equation \( RO = 0.0664 + (0.0363 \times CH) \), with the coefficient of determination \( R^2 = 0.819 \). This shows that the variation of runoff values can be explained by the rainfall depth factor of 81.9% and the remaining 18.1% explained by other factors. The correlation coefficient of the two variables is \( R = 0.905 \).

The graph of the relationship between rainfall depth and runoff in Figure 15 in teak forest B produces an equation \( RO = 0.00512 + (0.0364 \times CH) \), with the coefficient of determination \( R^2 = 0.864 \). This shows that the variation of runoff values can be explained by the factor of rainfall depth of 86.4% and the remaining 13.6% explained by other factors. The correlation coefficient of the two variables is \( R = 0.929 \).

The graph of the relationship between rainfall depth and runoff in Figure 16 in settlement area A produces an equation \( RO = 0.376 + (0.191 \times CH) \), with a coefficient of determination \( R^2 = 0.826 \). This shows that the variation of runoff values can be explained by the rain thick factor of 82.6% and the remaining 17.4% is explained by other factors. The correlation coefficient of the two variables is \( R = 0.909 \).

The graph of the relationship between rainfall depth and runoff in Figure 17 in settlement area B produces an equation \( RO = 0.0122 + (0.257 \times CH) \), with a coefficient of determination \( R^2 = 0.876 \). This shows that the variation of runoff values can be explained by the rain thick factor of 87.6% and the remaining 12.4% is explained by other factors. The correlation coefficient of the two variables is \( R = 0.936 \).

The graph of the relationship between rainfall depth and runoff in Figure 18 in dry land A produces an equation \( RO = -0.0176 + (0.0287 \times CH) \), with the coefficient of determination \( R^2 = 0.865 \). This shows that the variation of runoff values can be explained by the rain thick factor of 86.5% and the remaining 13.5% is explained by other factors. The correlation coefficient value of the two variables is \( R = 0.930 \).

The graph of the relationship between rainfall depth and runoff in Figure 19 in dry land B produces an equation \( RO = 0.0247 + (0.0307 \times CH) \), with the coefficient of determination \( R^2 = 0.861 \). This shows that the variation of runoff values can be explained by the rain thickness factor of 86.1% and the remaining 13.9% is explained by other factors. The correlation coefficient of the two variables is \( R = 0.928 \).

The correlation coefficient obtained is then adjusted to the correlation level table. According to Ghozali [19], the correlation level table is as follows:

| Coefficient Interval | Relationship Level |
|----------------------|--------------------|
| 0.800 – 1.00         | Very Strong        |
| 0.600 – 0.799        | Strong             |
| 0.400 – 0.599        | Strong Enough      |
| 0.200 – 0.399        | Low                |
| 0.000 – 0.199        | Very Low           |

Table 3 shows that the correlation coefficient in each type of land use includes a very strong category. From the results of the linear regression analysis shows that the greater the feeding depth of rainfall the greater the runoff produced. According to Handayani and Indrajaya [20] when the rainfall depth increases, runoff also increases especially if the rain continues continuously. Some text.
4. Conclusion
The largest runoff occurs in settlement land (averaged: 95.96 mm) and the smallest runoff in dry land (11.85 mm in average). The largest runoff coefficient occurs in settlement land (averaged: 0.22) and the smallest runoff coefficient in dry land (0.025 in average). The runoff coefficient for each type of land use is included in the low category. Rainfall depth has a positive correlation with runoff. The greater the rainfall depth, the greater the runoff produced.

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