Landscape planning of tobacco plantation based on erosion potential in Eastern Region of Mount Sindoro Temanggung

IOP Conf. Series: Earth and Environmental Science **393** (2019) 012072 doi:10.1088/1755-1315/393/1/012072

Landscape planning of tobacco plantation based on erosion potential in Eastern Region of Mount Sindoro Temanggung

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Abstract. Mount Sindoro slope is a tobacco plantation area. Based on variations in slope, there is erosion potential on most of the slopes. This study aimed to determine the way of structuring tobacco plantations in the eastern region of Mount Sindoro due to intensive land use. This research was conducted in Gunungsari Village, Bansari District, Temanggung Regency, from April to July 2018. This research was conducted using a survey method and continued with the determination of the level of soil erosion potential on area A (more than 20% slope), area B (15-20 % slope) and area C (less than 15% slope) using USLE method. Landscape planning was carried out based on the application of land conservation methods with the main purpose of reducing the level of erosion potential using agronomic and mechanical methods. The results show that the actual erosion potential of area A, B and C is 42.67 tons/ha/year, 44.81 tons/ha/year and 31.80 tons/ha/year, respectively, and is categorized as moderate to severe erosion level. The application of agronomic methods in the form of intercropping systems of tobacco and peanuts could reduce the erosion potential from 42.67 to 32.43 tons/ha/year (area A); from 44.81 to 33.61 tons/ha/year (area B) and from 31.80 to 23.85 tons/ha/year (area C). Meanwhile, the application of the ridge terraces and bench terraces, consecutively, reduced erosion potential from 42.67 to 6.40 and 1.71 tons/ha/year (area A); from 44.81 to 6.72 and 1.79 tons/ha/year (area B); and from 31.80 to 4.77 and 1.27 tons/ha/year (area C). Thus, it can be concluded that bench terraces is more effective in reducing erosion potential than ridge terraces.

1. Introduction

The surface area of Temanggung Regency includes the highlands and regional topographic patterns in the form of basins or depression that are open in the Southeast, South and West, which are bordered by two mountains, namely Mount Sumbing M (3,260 m asl) and Mount Sindoro (3,151 m asl). Geomorphologically, Temanggung is a complex of geological formation, such as plains, hills, mountains, valleys and mountains with slope angles between 0% - 70%. Temanggung Regency has a tropical climate with two seasons, namely the dry season from April to September and the rainy season from October to March, with generally high annual rainfall [1].

Eastern region of Mount Sindoro, one of the Tobacco-production centers, has a very steep slope which has the potential for erosion due to intensive land use for tobacco plants. Crop cultivation will always influence the earth surface. Intensive soil tillage causes some changes on soil micro surface, breakdowns soil structure, and reduces organic matter content, thus finally increases soil erodibility. According to Benavidez *et al.* [2], soil erosion is a major problem around the world because of its influence on soil productivity, nutrient leaching, river siltation and water quality degradation. Tobacco cultivation is associated with the destruction of groundwater resources, river sedimentation, biodiversity destruction, and soil fertility degradation. Intensive tobacco cultivation in Temanggung Regency on steep land causes land degradation and environmental damage due to erosion. About 20 - 53 tons/ha/year of top soil layers on Tobacco land in Temanggung Regency were lost due to erosion [3, 4].

The universal soil loss equation (USLE) is the simplest way to predict the average soil loss caused by all forms of erosion by water on agricultural land [5]. The USLE application has been developed not only for predicting soil loss, but also for planning the landscape of conservation agriculture by integrating the formula with GIS procedure. According to Pieri *et al.* [6], monoculture can increase soil quality degradation. In addition, the results of his research indicated that in 4 years, the rotation between corn-wheat-alfalfa-alfalfa could substantially reduce soil erosion and showed the potential to become a sustainable cropping system.

Landscape structure has a direct impact on soil erosion and sedimentation on agricultural land [7]. Devianti [8] has examined the rate of runoff and soil erosion in agroforestry landscape in the Cianten-Cipancar watershed, West Java Province, Indonesia, proving that agroforestry systems with intercropping system can reduce runoff and soil erosion rates. Based on this fact, this paper presents the results of a study on the landscape planning of tobacco plantations based on the erosion potential of a land area that has long been used as a tobacco plantation area with an intensive soil tillage.

For areas with steep slopes, the vegetative method (agronomy) is not effective in reducing the rate of erosion. Mechanical methods by making terraces can significantly reduce the rate of erosion. Slope reduction and slope cutting are more effective in reducing runoff flow rates. Terracing can increase rate of water infiltration into soil. Ridge terracing is a mechanical method that can increase water retention because water can be absorbed by the soil [9]. Research results of Khelifa *et al.* [10] showed that bench terraces that applied in an area of 50% of the watershed area, could reduce run off by about 19% and sedimentary material by about 22%.

2. Materials and Methods

A study on the landscape planning for tobacco plantation based on erosion potential in the Eastern Region of Mount Sindoro was carried out in Gunungsari village, Bansari District, Temanggung Regency (Fig. 1), Central Java, from April to July 2018. The research location is a tobacco plantation that is used throughout the year so that it has the potential for serious soil erosion. The research location is part of the foot of Mount Sindoro with condition of wavy to hilly topography. An intensive land use on sloping land for agricultural cultivation has implications at low nutrient status. Besides, nutrient washing due to the erosion phenomenon is caused by low input that cannot be balanced by the process of nutrient absorption by plants [11].

Figure 1. Gunungsari village, Bansari District, Temanggung Regency

This research was conducted using survey methods through observation of primary and secondary data. Primary data include information on existing conditions (topography, slope, soil characteristics and tobacco plantations) obtained from local government agencies and the results of soil samples analysis, while secondary data are complementary data needed in drafting the concept of landscape planning for tobacco plantation. Determination of soil sample points was carried out on the basis of the topographic pattern of the area. The area was classified based on the differences in slope, consisting of area A (slope >20%), area B (slope between 15-20%) and area C (slope <15%).

Erosion predictions and erosion hazard level were determined using the Universal Soil Loss Equation (USLE) formulation which is influenced by rainfall, length and slope, soil and land cover along with conservation measures. The equation used in this assessment, as followed:

$$A = R \times K \times SL \times C \times P$$

The result of erosion predictions was used as a main basic concept in planning the landscape completed with conservation method in reducing erosion potential.

3. Results and Discussion

3.1. The Factors that Influence Soil Erosion

3.1.1. Rainfall Erosivity

Erosivity is the rain potential to cause erosion in an area. The level of erosivity depends on the amount of rainfall on the area as presented in Table 1.

Table 1. Average rainfall and erosion index of the location.

Month	Average Rainfall (mm)	P (cm)	R
January	332	33.20	258.90
February	342	34.20	269.57
March	288	28.80	213.39
April	335.4	33.54	262.52
May	161.4	16.14	97.08
June	119.8	11.98	64.73
July	73	7.30	33.00
August	38.4	3.84	13.77
September	81.2	8.12	38.14
October	92.6	9.26	45.60
November	243	24.30	169.36
December	352.3	35.23	280.67
Average	**204.9**	**20.49**	**145.56**

Table 1 shows that the research location has an average annual rainfall of 204.9 mm and is included in the middle level rainfall criteria. Due to the condition of the soil texture which is dominated by silt fraction, and is influenced by the slope length and slope of the land, this rainfall may cause a considerable threat of soil erosion. Raindrops and the duration of rain are important components as the initial cause of erosion through the destruction of soil aggregates. In this case, Kinnell and Wood [12] stated that erosion modeling showed that raindrops play an important role in the erosion process.

3.1.2. Soil Erodibility

Soil erodibility is the sensitivity of the soil to be eroded and depends on the physical and chemical properties of each type of soil as presented in Table 2.

The results of laboratory analysis found soil erodibility (K) of area A, B and C were 0.41, 0.47 and 0.46 tons/ Kj, respectively. Based on the K value (erodibility), land with K value between 0.41- 0.55 tons/Kj has a high erodibility. The high soil erodibility values indicate that the soil in Gunungsari Village is easily eroded. The erodibility value of a land can be influenced by several factors such as soil texture, organic matter, soil structure and soil permeability.

Table 2. Soil erodibility of the location.

Area (slope)	Texture			Soil texture class	Organic matter (%)	Soil structure	Permeability (cm/hour)	K (tons/Kj)
	Silt	Clay	Sand					
	(%)							
A (> 0%)	60.97	12.84	26.20	Silty clay	3.9	Blocky, Platy, Massive	0.75	0.41
B (15-20%)	76.74	6.14	17.12	Silty clay	2.3	Blocky, Platy, Massive	0.73	0.47
C (< 15%)	75.98	3.39	20.71	Silty clay	2.4	Blocky, Platy, Massive	0.73	0.46

From the results of the soil texture analysis and based on the USDA triangle, the three soil samples form Gunungsari Village were classified into the silty clay class with low water infiltration capacity, thus allowing greater runoff flow compared to water infiltration to the soil, and this soil texture will create the potential for soil erosion.

The results of laboratory analysis showed that levels of organic matter in area A, B and C were 3.9%, 2.3% and 2.4%, consecutively. The results of this determination indicate a low organic matter content so that the aggregate of the soil is unstable and easily eroded.

The results of the analysis showed that soil samples at three sample points had a massive blocky and platy type of soil structure. With a low content of organic material, this soil structure has no stability, making it easily destroyed by kinetic energy of rain. Soil particles released from their aggregates can close the soil pores, thereby reducing soil infiltration capacity.

The results of soil permeability determination showed that the three soil samples had slow permeability (area A= 0.75 cm/hour, area B=0.73 cm/hour, and area C=0.73 cm/hour). Based on the class of soil permeability, permeability values between 0.5- 2.0 cm/hour is categorized in slow permeability. This shows that soil samples from the three sampling sites have a low ability to percolate water, resulting in a greater run-off than water infiltration into soil.

3.1.3. Slope length and slope
Topographic factors that influence the level of erosion potential in an area are the slope length (L) and slope (S). Field observations on slope length and slope at the research location are presented in Table 3. Topographic factors that affect the level of erosion potential are slope length and slope. The difference of LS value of the location will affect the level of soil erodibility, and proportionally directly influence the rate of erosion that occurs.

Table 3. Topographic factor of the location.

Area	Slope (%)	Length of slope (m)	LS
A (> 0%)	20	129.7	1.43
B (15-20%)	16	111.6	1.31
C (< 15%)	13	60.1	0.95

3.1.4. Erosion Potential
Erosion potential is the amount of erosion that occurs in a region, which is estimated using the formulation of USLE (Universal Soil Loss Equation) based on data of rainfall erosivity, soil erodibility,

slope length, slope, ground cover factors and conservation efforts. The potential for erosion in Gunungsari Village, Bansari Temanggung Regency is presented in Table 4.

Table 4. Erosion potential of the location.

Area (slope)	R	K	LS	CP	A (tons/ha/year)	Class of erosion	Soil depth	Level of erosion hazard
A (> 0%)	145.56	0.41	1.43	0,5	42.67	II	60-90	Moderate
B (15-20%)	145.56	0.47	1.31	0,5	44.81	II	30-60	Serious
C (< 15%)	145.56	0.46	0.95	0,5	31.80	II	30-60	Serious

Based on the USLE equation, the actual erosion rates in each location are 42.67 tons/ha/year (area A), 44.81 tons/ha/year (area B), and 31.80 tons/ha/year (area C). Table 4 shows that Gunungsari Village has moderate to severe erosion hazard due to the high erosion value with very high intensity of rainfall so that it has the potential to cause large erosion. In addition, high soil erodibility factors are influenced by a high silt fraction, causing low infiltration and increasing the surface flow rate (run off).

One of the factors that influence the high erosion rate, especially on the slopes of the Mountain, is the topographic factor in the form of slope length and slope. Besides, the slope and slope length affect surface runoff and accelerate run off. In addition to environmental factors, there are other factors that can affect the rate of erosion, namely the land use system. The use of land for tobacco plantations in the slopes of Mount Sindoro has resulted in high erosion rates.

3.2. Landscape Planning for Tobacco Plantation Based on Potential Erosion

Soil tillage in agricultural activities can basically change the condition of soil surface. Intensive tillage can increase soil erodibility, especially that is caused by soil structure degradation. Tobacco cultivation on the eastern slope of Mount Sindoro, one of the forms of annual crop cultivation with intensive tillage, has the potential to increase soil erodibility and erosion potential. Based on the erosion potential that can occur in the tobacco plantation area as shown in Table 4, landscape planning is needed in restructuring land use by utilizing a agriculture model that can reduce potential erosion.

Conservation agriculture is one model that can be used in tobacco plantations on the eastern slope of Mount Sindoro. One of the agronomic methods that can be done is the application of inter cropping patterns between tobacco and peanuts, because the density of inter cropping morphology can reduce the kinetic energy of rain. Rahim (2006) stated that peanut plants can function as cover crops and can fertilize the soil. Mixed cropping patterns to reduce erosion rates are presented in Table 5.

Table 5. Intercropping between tobacco and peanut in reducing soil erosion.

Area (slope)	R	K	LS	CP	A (tons/ha/year)
A (> 0%)	145.56	0.41	1.43	0.38	32.43
B (15-20%)	145.56	0.47	1.31	0.38	33.61
C (< 15%)	145.56	0.46	0.95	0.38	23.85

Table 5 shows that the application of inter cropping causes erosion rates in each location to decrease from 42.67 to 32.43 tons/ha/year (area A), from 44.81 to 33.61 tons/ha/year (area B) and from 31.80 to 23.85 tons/ha/year (area C). Area C with a slope below 15% is flat land and it has erosion potential of 31.80 tons/ha/year (Table 4). Thus, area C does not require terracing treatment, and is more suitable to be treated using agronomic method by applying intercropping between tobacco and peanuts, as shown in Figure 2.

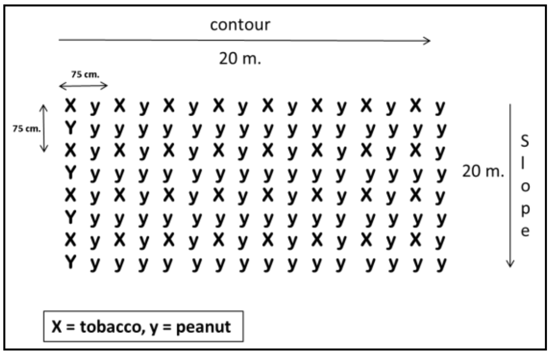

Figure 2. Intercropping between tobacco and peanuts

One of the determinants of erosion severity is land slope conditions that have a significant effect on the rate of water flow on the ground. One of the recommended mechanical methods is terracing, which serves to reduce the slope of the land and cut the length of the slope. Ridge terrace is applied to areas with a slope between 15-20%, while the bench terrace is suitable for areas with slopes above 20%.

Tobacco is a plant that is not suitable for the condition of water excess because it can cause root rot problems. Therefore, the application of a ridge terrace and bench terrace was equipped with water channels. The application of ridge terraces in areas that have a slope between 15-20% (area B) can significantly reduce erosion rates as shown in Table 6.

Table 6. Application of ridge terraces in Gunungsari Village.

Area (slope)	**R**	**K**	**LS**	**CP**	**A (tons/ha/year)**
A (> 0%)	145.56	0.41	1.43	0.08	6.40
B (15-20%)	145.56	0.47	1.31	0.08	6.72
C (< 15%)	145.56	0.46	0.95	0.08	4.77

According to Table 6, it can be seen that the application of the ridge terraces and bench terraces can reduce the rate of erosion in each area of observation. The erosion rate in area A, B, and C decreased to 6.40, 6.72, and 4.77 tons/ha/year, respectively.

The bench terrace is made by cutting the length of the slope and leveling the ground at the bottom, so that there are rows of physical buildings which like benches. Like the ridge terraces, the bench terraces can also reduce the rate of erosion in each area as shown in Table 7.

Table 7. Application of bench terraces in Gunungsari Village.

Area (slope)	**R**	**K**	**LS**	**CP**	**A (tons/ha/year)**
A (> 0%)	145.56	0.41	1.43	0.02	1.71
B (15-20%)	145.56	0.47	1.31	0.02	1.79
C (< 15%)	145.56	0.46	0.95	0.02	1.27

Compared to the application of ridge terraces, bench terraces in the observation area turned out to be more effective in reducing erosion rates. The erosion rate in area A, B, and C decreased to 1.71, 1.79, and 1.27 tons/ha/year, consecutively. Based on the results of the application of the terrace, when compared with the rate of erosion before the application of the terrace, the use of ridge terraces and bench terraces can reduce the erosion rate of tobacco plantation area in Gunungsari Village by 85% and 96%, respectively.

The difference in land slope between area A and area B results in different erosion potential. Based on Table 6 and 7, for these two areas, the application of bench terraces is more effective than the ridge terrace in reducing erosion potential. The specific difference between area A and B is the thickness of the soil (soil solum).In addition, area A has greater slopes than area B, as well as greater soil thickness (60-90 cm soil depth) than area B (30-60 cm soil depth). On the basis of this, the application of ridge terraces is more suitable for area B. On the other hand, bench terraces can be applied in area A which has a greater slope and a thicker soil solum. Technical construction of ridge terraces for area B and bench terrace for area A are presented in Figure 3.

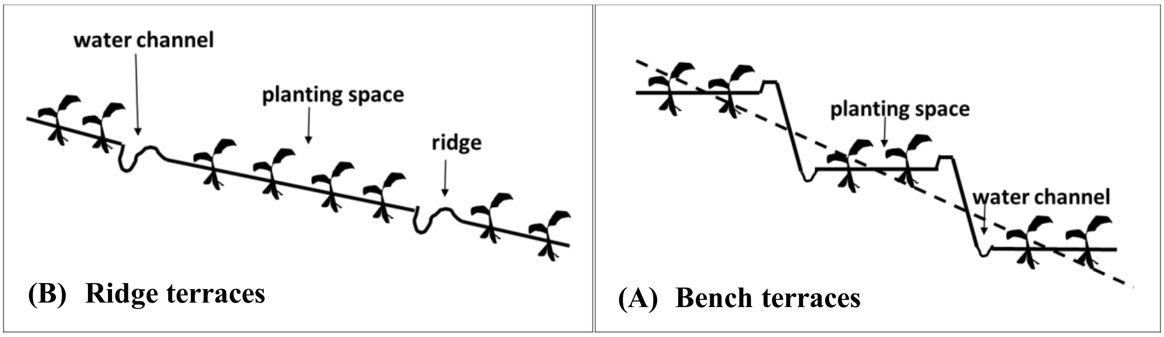

Figure 3. Construction of ridge terraces (A) for area B and bench terraces (B) for area A

Conservation agriculture models applied in each location were used as the basis of landscape planning of tobacco plantations, with the purpose that land in various slope conditions can still be utilized and the soil erosion potential can be reduced. The landscape planning of tobacco plantations is presented in Figure 4.

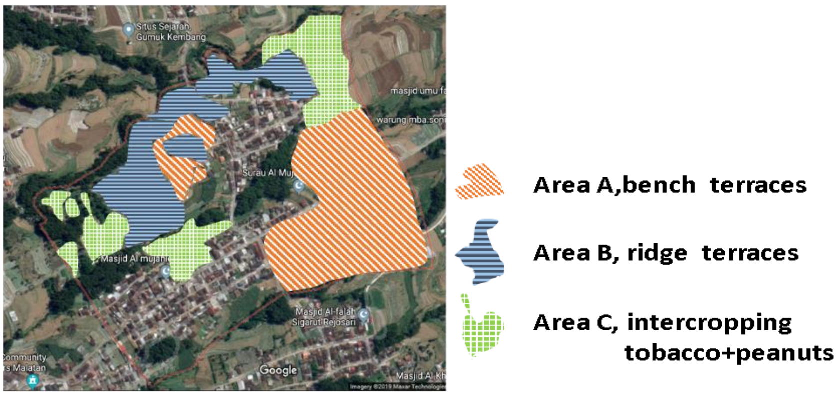

Figure 4. Landscape planning of tobacco plantation.

Figure 4 shows that tobacco plantations and resident settlements are in a region with various conditions of land slope that cause serious soil erosion threats. Based on these conditions, landscape planning efforts in land use patterns are absolutely necessary because erosion that occurs on tobacco plantations will influence the stability of residential land.

4. Conclusion

The application of conservation agriculture on tobacco plantations in Gunungsari Village, Bansari, Temanggung Regency can reduce the potential of soil erosion. Agronomic conservation could reduce the erosion potential from 42.67 to 32.43 tons/ha/year (area A); from 44.81 to 33.61 tons/ha/year (area B) and from 31.80 to 23.85 tons/ha/year (area C). Meanwhile, the application of the ridge terraces and bench terraces, consecutively, reduced the erosion potential from 42.67 to 6.40 and 1.71 tons/ha/year (area A); from 44.81 to 6.72 and 1.79 tons/ha/year (area B); and from 31.80 to 4.77 and 1.27 tons/ha/year (area C). Intercropping between tobacco and peanuts can be applied on land with the slopes below 15% (Area C). A ridge terrace can be applied on land with the slope between 15-20% (Area B), and a bench terrace can be applied on land with a slope above 20% (Area A).

Acknowledgement
The authors would like to acknowledge local government for permitting the use of location and the Head of Soil and Plant Nutrition Laboratory, Universitas Muhammadiyah Yogyakarta for providing material and equipment for analysis works.

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