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Measures to Reduce Soil Erosion on Cassava Farms in Central Highlands of Vietnam

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Abstract: ***Cassava has become an important crop in developing countries. However, growing cassava on sloping land can result in serious erosion due to the wide spacing and thin canopy. This study discusses measures to reduce soil erosion on cassava farms in Central Highlands, Vietnam. A field experiment on sowing direction (horizontal strip and contour) and intercropping (0, 1, 2 and 3 peanut rows between 2 cassava rows) was conducted on sloping land with a 15% grade during 2021-2022. The treatments were arranged in a split-plot design with 3 replications. The results showed that the contour growing and intercropping peanut among cassava rowsreduced the rate of soil loss in comparison with strip planting and monoculture. Intercropping reduced cassava productivity but produced peanuts, keeping the total income balanced. In addition, growing peanut fixed nitrogen and produced biomass that contained OM and minerals for better soil fertility. The treatment that had the highest economic and environmental effectiveness was contour sowing and intercropping 3 peanut rows between 2 cassava rows.***

Keywords: cassava, contour, erosion, intercropping, productivity

1. Introduction

In Vietnam, three-quarters of the land area is dominated by mountainous topography. The forest canopy coverage of 48.0percent in the 1980s has decreased to 23.6 percent today. Even in some places, this figure has dropped to only 10 percent. To survive, and due to the introduction of the market economy, despite the disastrous damage to the forest, humans have cut down trees, and the unsound use and management of land has turned fertile land into fallow ground (PhienandSiem, 1996)[5]. To develop sustainable agricultural production on this type of poor soil, the effective use of the soils and applying intensive farming to protect and improve soil fertility are of primary importance.

Central Highlands has an area of 54,474 square kilometers, accounting for 16.8% of the total area of Vietnam. The topography is hilly and sloping and is divided strongly. The forest has been cleared and replaced by plants and secondary forests such as thin cover. However, the annual average rainfall is quite high and is distributed across the 6 months of the rainy season. Therefore, soil erosion is clear, especially on sloping land with crops with thin canopies, such as cassava. If no anti-erosion approaches or good methods are used, soil erosion will continue to threaten agricultural production in the region, reducing vegetation structure and fertility, destroying streams, and polluting water resources (Tu, 2015)[9].

Central Highlands of Vietnamhas cassava area of 157,000 ha, produces 3 million tons of fresh roots a year, accounting for 33.0% of the country. However, growing cassava can result in serious erosion due to the wide spacing and low cover (PhienandSiem, 1998 [6],SiemandPhien 1999 [8]). The objective of this study is to determine measures to reduceerosion and stabilize soil fertility on cassava farms in Central Highlands, Vietnam.

2. Materials and Methods

2.1 Study site

The research was conducted during 2021-2022in Dak Lak province, where belongs to the Central Highlands of Vietnam (Figure 1) and has a cassava area of 32,000 ha. The local area is affected by the tropical monsoon. The rainy season is from May to October, with a peak in July, August and September (Figure 2), causing erosion on sloping land.

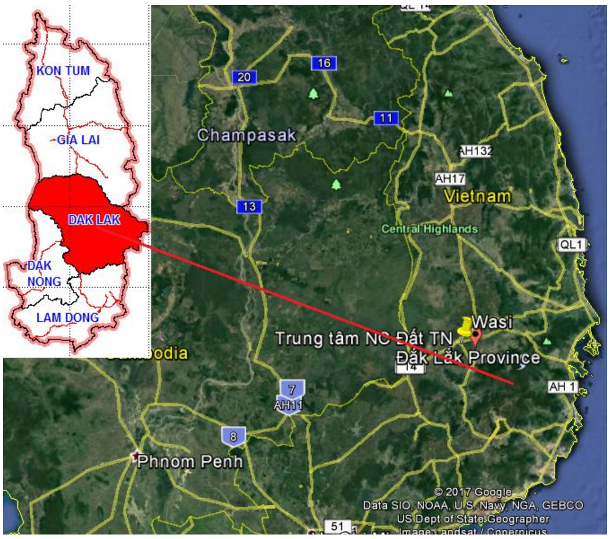

Figure 1: .Study site

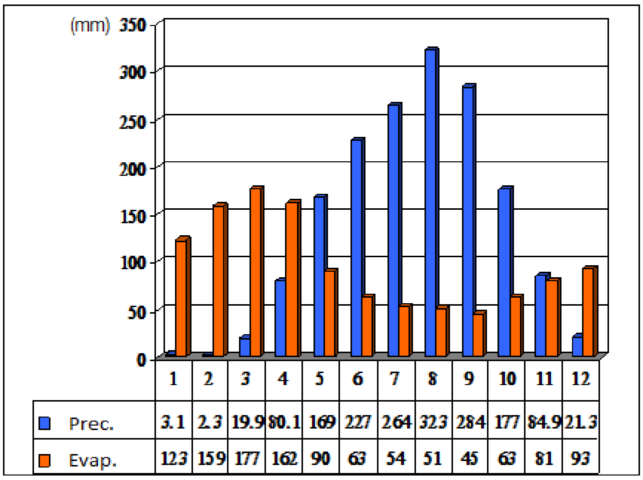

Figure 2: Precipitation and evaporation in months at study site

2.2 Materials

The KM149 cassava and GV10 peanut varieties were used for study, with a cassava spacing of 1.0 m x 0.8 m and a peanut spacing of 0.5 m x 0.3 m. Both cassava and peanut were sown on the first of May every year. The experiment was conducted on sloping land with a 15% grade and belongs to a group of gray soil (Haplic Acrisols), which has a high bulk density, quite low porosity, an acidic pH and a medium content of nutrient elements.

2.3 Methods

2.3.1 The experimental design

A field experiment on sowing direction (horizontal strip and contour) and intercropping (0, 1, 2 and 3 peanut rows between 2 cassava rows) was implemented, including 8 treatments as follows:
A1B1: horizontal strip, cassava monoculture;
A1B2: horizontal strip, 1 peanut row between 2 cassava rows;
A1B3: horizontal strip, 2 peanut rows between 2 cassava rows;
A1B4: horizontal strip, 3 peanut rows between 2 cassava rows;
A2B1: contour, cassava monoculture;
A2B2: contour, 1 peanut row between 2 cassava rows;
A2B3: contour, 2 peanut rows between 2 cassava rows;
A2B4: contour, 3 peanut rows between 2 cassava rows;

The treatments were arranged by split-plot design with 3 replications. The following is the experimental diagram (Figure 3).

Rep. I				Rep. II				Rep. III			
A1B1	A1B2	A1B4	A1B3	A2B4	A2B2	A2B3	A2B1	A1B3	A1B2	A1B1	A1B4
A2B4	A2B1	A2B3	A2B2	A1B2	A1B4	A1B1	A1B3	A2B1	A2B4	A2B3	A2B2

Figure 3: The experimental diagram

2.3.2 Monitoring soil erosion

A system with main and sub tanks for monitoring soil erosion was set up at the end of a slope (Figures 4). Eroded soil comes to the main tank, and the sludge continues to flow into the sub tank if the main tank is full. After every rain, eroded soil was collected from tanks, weighed, analyzed for moisture and converted to tons per hectare.

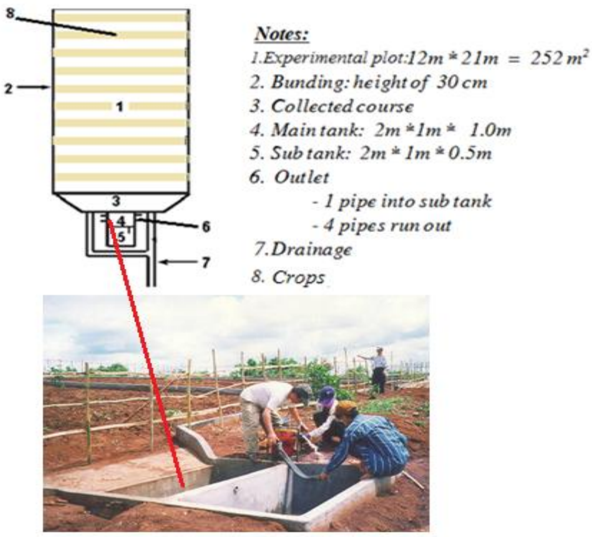

Figure 4: System of monitoring soil erosion for an experiment plot

2.3.3 Soil collection and analysis

Soil samples were taken at depths of 0-30 cm, at 4 corners and the center of the plot and then mixed well. The soil samples were analyzed as follows: acidity (pH_{KCl}) was measured with a pH meter with a ratio of 1.0 soil:2.5 KCl 1N; organic matter (OM) by Walkley-Black; nitrogen (N total) byKjendahl; phosphorus (available P_2O_5) by Bray II; potassium (Available K_2O) byflame photometer; and exchangeable Ca and Mg by AAS.

2.3.4. Statistical methods

CV% = (SD / $\overline{X}$) x 100 where CV: coefficient of variation; SD: standard deviation; and $\overline{X}$: mean.
The calculations were implemented instatistical analysis systems (SAS).

3. Results and Discussion

The Central Highland of Vietnam belongs to the tropical monsoon zone, where the rainy season usually begins in May and ends in October every year (Figure 2). On the first of May, the ground is dry, and the soil particles are less aggregated, so they are disintegrated easily by rain and then washed away by water. In addition, May is the sowing month, but the cover of the crop is still thin, so soil erosion is heavy in this period. Although the precipitation in June is higher than that in May, the rate of soil loss is lower because the development of crops increased the cover rate. From July to September, soil erosion increases strongly again because of high precipitation. The soil void spaces are filled with water, so erosion occurs easily. The data from Table 1 show that the total soil loss on the experimental farm ranged from 39.0-52.3 t/ha.

Table 1: Effect of cultivation measures to soil erosion on cassava farm (t / ha)

Sowing direction (A)	Intercropping (B)				Average of A
	B1 (monoculture cassava)	B2 (1 peanut row between 2 cassava rows)	B3(2 peanut row between 2 cassava rows)	B4 (3 peanut row between 2 cassava rows)	
A1 (horizontal strip)	52.3a	50.1ab	48.6bc	45.9cd	49.2A
A2 (contour)	45.2cd	43.5de	40.8ef	39.0f	42.1B
Average of B	48.8*A*	46.8*AB*	44.7*BC*	42.5*C*	

CV% = 4.27; Means with the same letter are not significantly different from each other, p<0.05

The difference in soil erosion among treatments in the sowing month (May) was trivial due to the same cover levels. From June onward, canopies of the cassava and peanut crops had formed and developed with different rates, resulting in differences in soil erosion among experimental treatments (Figure 5).

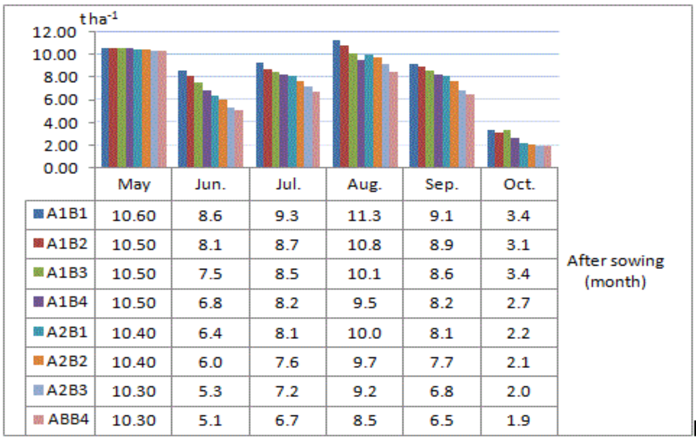

Figure 5: Chart of soil erosion through months

The rate of soil loss from the contour and intercropping treatments was lower than that in the horizontal strip and monoculture treatments because the contour lines prevented flowing and intercropping cassava with peanut increased the level of ground cover and reduced the effect of rainfall action; therefore, the soil surface was protected from erosion. The experimental result showed that, the contour growing method reduced soil loss by 6.1 t/ha, corresponding to 12.4% in comparison with the horizontal strip. In addition, the rate of soil loss from intercropping treatments was lower than in cassava monoculture because combining cassava with peanut increased the rate of cover and reduced the effect of rainfall action; therefore, the soil surface was protected from erosion. The treatment that had the lowest rate of soil erosion was contour sowing and intercropping 3 peanut rows between 2 cassava rows, which produced 39.0 t/ha (Table 2). The results are similar to those of Hung & Tu(2005) [3]. Integrated methods of cultivation techniques such as intercropping, balanced fertilization and proper crop management in cassava fields are considered to encourage the sustainable development of agriculture in mountainous areas. An experiment by Dung *et al*. (2014) [1] on a slope of 10% at the same location (Central Highland region) found that the amount of soil loss in treatments of intercropping cassava with legumes (*Crotalaria, Cajanuscajan, Tephrosia candida*) was 30 t/ha. It was 2.0-2.5 t/ha, or 7-8%, lower than the control of cassava monoculture. Generally, the rate of soil loss from Dung's research is lower than this study's results because Dung's research was conducted on sloping land with a 10% grade, 5% lower than the slope of the current experimental site.

Table 2: The content of organic matter (OM) and mineral nutrient in erosive soil (%)

Treatment	OM	N	P_2O_5	K_2O
A1B1: strip, cassava monoculture	8.4a	0.43a	0.219a	0.126a
A1B2: strip, 1 peanut row between 2 cassava rows	8.5a	0.45a	0.221a	0.128a
A1B3: strip, 2 peanut rows between 2 cassava rows	8.3a	0.43a	0.224a	0.127a
A1B4: strip, 3 peanut rows between 2 cassava rows	8.6a	0.46a	0.22a	0.127a
A2B1: contour, cassava monoculture	8.4a	0.45a	0.219a	0.125a
A2B2: contour, 1 peanut row between 2 cassava rows	8.3a	0.43a	0.223a	0.126a
A2B3: contour, 2 peanut rows between 2 cassava rows	8.5a	0.44a	0.222a	0.128a
A2B4: contour, 3 peanut rows between 2 cassava rows	8.4a	0.45a	0.221a	0.125a
CV%	1.38	3.93	0.85	1.58

Means in column with the same letter are not significantly different from each other, p<0.05

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The layer of the top soil is rich in OM and mineral nutrients, which play important roles in the growth and development of plants. The difference in nutrient content in erosive soil among treatments was not significant, but their rate of nutrient loss was very clear because the amount of soil loss was very different. In intercropping systems, crops compete for nutrients, sunlight, moisture and other living conditions, resulting in a decrease in cassava productivity. However, peanut is a type of legume that can fix free nitrogen from the atmosphere, supplying nitrogen to the soil, so crops in intercropping systems with peanut uptake more nitrogen (Eaglesham *et al*., 1981 [2], Sanginga*et al*., 1997 [7], Ogoke *et al*., 2003 [4], Yusuf *et al.*, 2008 [10]). In addition, growing peanut created biomass that supplied OM and minerals and improved soil fertility.

The analysis results from Table 2 indicated losses of 8.3-8.6% in OM, 0.43-0.45% in N, 0.219-0.224% in P_2O_5 and 0.125-0.128% in K_2O in the sediment. Based on soil loss and nutrient content in erosive soil, rates of nutrient loss from the experimental plots were calculated. In general, every year, there were losses of 3,276.0-4,393.2 kg OM, 175.5-224.9 kg N, 86.2-114.5 kg P_2O_5, and 488-65.9 kg K_2O per hectare (Table 3).

Table 3: Effect of cultivation measures to loss of OM and mineral nutrient on cassava farm (kg / ha)

Treatment	OM	N	P_2O_5	K_2O
A1B1: strip, cassava monoculture	4,393.2a	224.9a	114.5a	65.9a
A1B2: strip, 1 peanut row between 2 cassava rows	4,258.5a	225.5a	110.7ab	64.1ab
A1B3: strip, 2 peanut rows between 2 cassava rows	4,033.8b	209.0b	108.9b	61.7b
A1B4: strip, 3 peanut rows between 2 cassava rows	3,947.4b	211.1b	101.0c	58.3c
A2B1: contour, cassava monoculture	3,880.8b	207.9b	101.2c	57.8c
A2B2: contour, 1 peanut row between 2 cassava rows	3,693.5c	191.4c	99.2c	56.1cd
A2B3: contour, 2 peanut rows between 2 cassava rows	3,553.0c	183.9cd	92.8d	53.5d
A2B4: contour, 3 peanut rows between 2 cassava rows	3,360.0d	180.0d	88.4d	50.0e
CV %	2.47	3.14	2.87	3.06

Means in column with the same letter are not significantly different from each other, p<0.05

The horizontal strip sowing and cassava monoculture treatment had the highest nutrient loss, with losses of 4,393.2 kg OM, 224.9 kg N, 114.5 kg P_2O_5, and 65.9 kg K_2O per hectare. In contrast, contour sowing and intercropping 3 peanut rows between 2 cassava rows remarkably restricted the loss of nutrients, with loss amounts of OM, N, P_2O_5 and K_2O of 3,276.0, 175.5, 86.2 and 488 kg per hectare, respectively.

According to the classification system of FAO-UNESCO, the experimental soil belongs to FeralicAcrisols (ACf.). The analysis results in Table 4 showed that before the experiment, the total organic matter, total nitrogen, available phosphorus and available potassium content in the soil were quite uniform, ranging from 3.16-3.22 % OM, 0.152-0.156 % N, 48.1-48.6 mg P_2O_5/kg and 13.1-13.7 mg K_2O/kg. After 2 years of the experiment, the horizontal strip and monoculture treatment quickly reduced the OM, nitrogen, phosphorus and potassium contents in the soil down to 2.96 % OM, 0.131 % N, 36.9 mg P_2O_5/kg and 10.6 mg K_2O/kg, respectively. Soil fertility was reduced slowly in the contour sowing and intercropping cassava with peanut treatments with reductions of 3.13-3.20 % OM, 0.147-0.151 % N, 45.1-47.1 mg P_2O_5/kg and 12.7-13.4 mg K_2O/kg.

Table 4: Changing soil nutrient under cultivation measures

Treatment	**OM (%)**		**N (%)**		**P_2O_5(mg / kg)**		**K_2O (mg / kg)**	
	Be.	**Af.**	**Be.**	**Af.**	**Be.**	**Af.**	**Be.**	**Af.**
A1B1: strip, cassava monoculture	3.19a	2.96d	0.156a	0.131e	48.2a	36.9f	13.6a	10.6d
A1B2: strip, 1 peanut row between 2 cassava rows	3.20a	3.01cd	0.155a	0.135de	48.5a	38.1f	13.4a	11.3cd
A1B3: strip, 2 peanut rows between 2 cassava rows	3.16a	3.07bc	0.153a	0.138cd	48.3a	40.6e	13.7a	11.9bc
A1B4: strip, 3 peanut rows between 2 cassava rows	3.17a	3.11ab	0.154a	0.140cd	48.4a	42.7d	13.1a	12.5abc
A2B1: contour, cassava monoculture	3.20a	3.14ab	0.155a	0.143bc	48.6a	43.5cd	13.3a	12.8ab
A2B2: contour, 1 peanut row between 2 cassava rows	3.18a	3.13ab	0.152a	0.147ab	48.1a	45.1bc	13.1a	12.7ab
A2B3: contour, 2 peanut rows between 2 cassava rows	3.21a	3.17a	0.154a	0.151a	48.5a	46.2ab	13.7a	13.4a
A2B4: contour, 3 peanut rows between 2 cassava rows	3.22a	3.20a	0.153a	0.151a	48.3a	47.1a	13.4a	13.2a
CV%	0.36	1.83	0.93	2.59	0.46	2.15	0.90	5.6

Be. Before experiment; Af. After 2 years of experiment
Means in column with the same letter are not significantly different from each other, p<0.05

Contour planting not only reduced soil erosion but also improved cassava productivity. The experimental results showed that the cassava yield in the contour sowing treatments was 2.6 t/ha higher than that in the horizontal strip treatment. The cassava productivity in monoculture treatments was higher than in intercropping plots. However, the intercropping treatments created peanut products (Table 5). These results are consistent with the soil erosion and fertility data in Table 1 and Table 4.

Table 5: Effect of cultivation measures to cassava productivity (t / ha)

Sowing direction(A)	Intercropping (B)				Average of A
	B1 (monoculture cassava)	B2 (1 peanut row between 2 cassava rows)	B3(2 peanut row between 2 cassava rows)	B4(3 peanut row between 2 cassava rows)	
A1 (horizontal strip)	27.1bc	25.3cde	23.6ef	21.8f	24.5A
A2 (contour)	29.6a	27.9ab	26.1cd	24.8d	27.1B
Average of B	28.4*A*	26.6*B*	24.9*C*	23.3*D*	

CV% = 4.30; Means with the same letter are not significantly different from each other, p<0.05

Growing peanut produced 0.26-0.78 t/ha for horizontal strips and 0.32-0.86 t/ha for contour growth. This treatment produced an additional product, which improved total income for intercropping treatments. Hence, the difference in total between intercropping and monoculture treatments was not significant. The treatment that had the highest economic and environmental effectiveness was intercropping 3 peanut rows between 2 cassava rows and contour sowing, which produced 4,585 USD/ha (Table 6).

Table 6: The economical effectiveness of cassava cultivation measures

Treatment	Cassava		Peanut		Income
	t / ha	USD / ha	t / ha	USD / ha	USD / ha
A1B1: strip, cassava monoculture	27.1	4,065	0	0	4,065
A1B2: strip, 1 peanut row between 2 cassava rows	25.3	3,795	0.26	260	4,055
A1B3: strip, 2 peanut rows between 2 cassava rows	23.6	3,540	0.51	510	4,050
A1B4: strip, 3 peanut rows between 2 cassava rows	21.8	3,270	0.78	780	4,050
A2B1: contour, cassava monoculture	29.6	4,440	0	0	4,440
A2B2: contour, 1 peanut row between 2 cassava rows	27.9	4,185	0.32	320	4,505
A2B3: contour, 2 peanut rows between 2 cassava rows	26.1	3,915	0.60	600	4,515
A2B4: contour, 3 peanut rows between 2 cassava rows	24.8	3,720	0.86	860	4,585

Price: tube cassava: 150 USD / t; bean peanut: 1,000 USD / t

4. Conclusion

In monsoon tropical conditions, soil erosion under rainfall occurred strongly on sloping land, where the ecological environment is precarious and special, on farms with crops with low levels of cover, such as cassava crops. The contour sowing and intercropping cassava with peanut prevented soil erosion, restricted the loss of organic matter and mineral nutrients and preserved soil fertility. Although intercropping reduced cassava productivity, peanut was produced, maintaining a balance of total income. In addition, growing peanut fixed nitrogen and produced biomass that contained OM and mineral for better soil fertility. The treatment that had the highest economic and environmental effectiveness was contour sowing and intercropping 3 peanut rows between 2 cassava rows.

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