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Study on Effect of Cultivating Measures to Soil Erosion and Coffee Growth on Sloping Land in Dak Lak Province of Vietnam

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Abstract **– Laying Central Highlands, Dak Lak province is called the "capital" of Vietnam coffee. However, coffee trees in the local were planted mainly on sloping land, where soil erosion caused by rainfall is unavoidable. To find out the measures of soil protecting from erosion, an experiment with 6 treatments of (i) farmer practices (control), (ii) draining, (iii) banking, (iv) making pond, (v) intercropping with peanut and (vi) intercropping with peanut and crotalaria pallida was implemented in coffee plantation on sloping land of 12 degrees during 2019-2020. The experimental treatments were replaced 3 times and ranged in randomized complete block design (RCBD), with basic plot size of 189 m^2 (9 m x 21 m). The results showed that cultivating measures impacted evidently to soil erosion and coffee growth. Intercropping coffee with peanut and crotalaria pallida and making pond around coffee tree gave the best effectiveness for protecting soil and growth of coffee tree, reduced soil loss by 3.39 $t.ha^{-1}.y^{-1}$, corresponding 27.9%, increased perimeter of stem by 15.6%, diameter of canopy by 13.5%, pairs of branch by 14.9%, length of branch by 16.9% and nodes per branch by 14.1% in comparison with control.**

Keywords **– Coffee, Erosion, Growth, Sloping Land, Soil Loss.**

I. INTRODUCTION

Coffee trees have been officially planted by humans since the 14th century (Nghiep, 1985). First introduced by the French in 1857, the Vietnamese coffee industry developed through the plantation system, becoming a major economic force in the country (Henry, 1931; Sung, 1987). After an interruption during and immediately following the Vietnam War, production rose once again after reforms, making coffee second only to rice in value of agricultural products exported from Vietnam. Today, coffee production has been a major source of income for Vietnam.

The Central Highlands of Vietnam are located at elevations between 150 m - 1,500 m als., covering an area of 57,370 km^2 or about 18% of the total area of Vietnam. This region is the main producer of agricultural export products such as natural rubber, timber and coffee beans.

Laying Central Highlands, Dak Lak province is called the "capital" of Vietnam coffee because there are very big coffee fields on soil basaltic (Rhodic Ferralsols). However almost coffee of Dak Lak province were planted on sloping land, where has a very precarious ecological environment. While the annual average rainfall here is rather high (the rainy season is from May to October with a peak in July, August and September, occupying 80% of the annual rainfall). Therefore soil erosion caused by rainfall is unavoidable. Erosion and leaching caused by rain being have transformed fertile soil into degraded soil with low fertility (Phien and Siem, 1996). The traditional method of farming does not seem to be suitable on the sloping land (Phien and Siem, 1998). The world has lost 20 per cent of its top soil during the past 40 years in areas that practiced inappropriate farming methods and in places where farmers had little understanding of the farming techniques and lack of investment capital or equipments. An average of 6 - 7 million hectares of land have been eroded every year and decreased the agricultural productivity (Siem and Phien, 1999). Agriculture in mountainous areas of Southeast Asia is often blamed for being unsustainable by enhancing deforestation and soil erosion (Sam, 1994 and Souvanthong, 1994).

From above mentions, to develop sustainable coffee production on sloping land in Dak Lak province, the first thing pays attention is to study and apply techniques of protecting soil from erosion.

II. Materials and Methods

2.1. *Study Site*

The study was implemented at Cư Mgar district, belongs to Dak Lak province. The topography is hilly and slope, divided strongly. Annual average rainfall is 1,800 mm distributed in 6 months of rainy season, with a peak in July, August and September.

2.2. *Materials*

The TR4 *robusta coffee* variety in period of 24 months. According to FAO classification, the soil belongs to Rhodic Ferralsols, lays on sloping land of 12 degrees, with low bulk density, quite high porosity, reaction of acid and medium content of nutrient elements.

2.3. *Methods*

2.3.1. *The Field Experiment*

The experiment was conducted on sloping land of 12 degrees with 6 treatments such as:

T1: Farmer practics (Monoculture coffee, without soil protecting - control);

T2: Monoculture coffee, with drains (25cm x 25cm) between 6 coffee rows;

T3: Monoculture coffee, with banks (25cm x 25cm) between 6 coffee rows;

T4: Monoculture coffee, with pond around coffee tree;

T5: Intercropping peanut betwwen 2 coffee rows, with pond around coffee tree;

T6: Intercropping peanut betwwen 2 coffee rows and *crotalaria pallida* betwwen 6 coffee rows, with pond around coffee tree.

The experimental treatments were replaced 3 times and ranged in randomized complete block design (Fig.1), with basic plot size of 189 m^2 (9 m x 21 m).

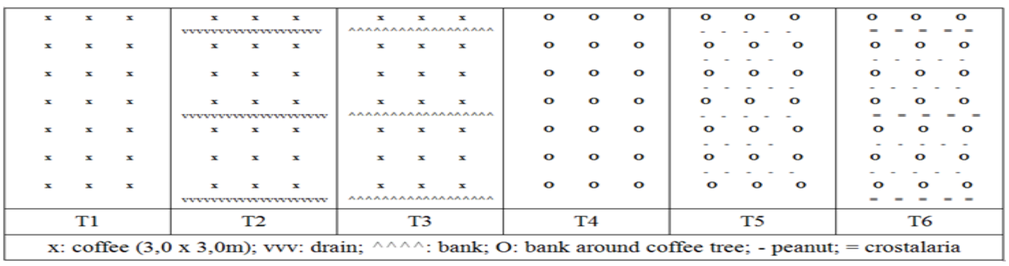


Fig. 1. Diagram of the experiment.

2.3.2. *Calculating Oil Erosion through Analyzing Data of Activity Be-7*

- Principles:

Beryllium-7 (Be-7; Half-life time: T1/2 = 53.3 days) is a cosmogenic radionuclide, produced by natural processes in the upper atmosphere. Upon formation, Be-7 becomes associated with aerosols and its delivery to the Earth's surface is largely via wet deposition whereupon Be-7 is rapidly absorbed to soil particles. The cohesive behaviour of Be-7 in soils, coupled with its short half-life, has underpinned its application as a tracer of soil redistribution across rainfall events or wet seasons (Taylor et al., 2019).

- Sampling at the Reference Site:

Samples were taken on a defined surface area. Maximum depth of isotope diffusion can be determined by sampling for layer of 1 cm gradually until no longer detectable isotopes in the soil. Some of the following criteria should correspond to the research location: (i) as close as possible research location; (ii) the same height with a research location; (iii) smooth relief and not flooding; (iv) land is not erosion or sedimentation.

- Sampling at the Study Sites:

For detailed studies of erosion for a particular area, including assessment of land redistribution in the region, the sampling sites are designed in a network pattern. The level of detail of the meshes depends on the specific shape of the terrain. The study, in general the samples are taken by the parallel lines. The sampling sites on each line are distanced by about 5-15 m depending on the complexity of the terrain. The terrain changes as quickly as the sample points to thick to facilitate for subsequent data processing. Fig. 2 shows the schematic illustration of sampling for the study of erosion in relatively simple terrain.

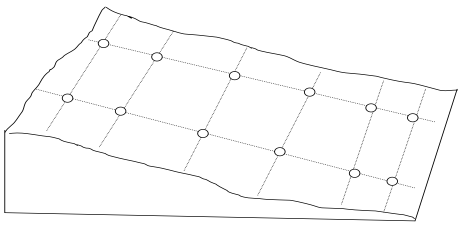


Fig. 2. Diagram of sampling.

- Analyzing Be-7

Radio nuclides Be-7 were determined by gamma spectrometry, using high purity germanium detectors with a 30% relative efficiency. Gamma counting usually lasts for 24 hours. For this analysis, all samples were prepared as a fine homogeneous powder and were cast using polyester resin in the desired geometry. Radionuclide Be-7 was measured at 478 keV.

- Calculating Soil Loss

The rate of soil erosion was calculated by using the model of Taylor *et al.* (2019).

$$h = 10.ho.\ln(A/A_{ref}) \quad (1)$$

where:

h = rate of soil erosion ($t.ha^{-1}.y^{-1}$);

h_0 is the relaxation mass depth, describing the shape of the initial ^{7}Be depth distribution (kg m^{-2}).

$h_0 = 1.b^{-1}$, with b is constant from equation of $Y = a.e^{-b.X}$ (Y: Be-7 activity; X: cumulative mass);

A is Be-7 inventory at the study site ($Bq.m^{-2}$).

A_{ref} is Be-7 inventory at the reference ($Bq.m^{-2}$);

2.3.3. *Monitoring Growth of Coffee Tree*

- Tree height (cm): measuring from soil surface to top of tree.
- Stem perimeter (mm): measuring at 10cm far from transplantation place.
- Canopy diameter (cm): measuring at biggest place.
- Number of branch paires per tree: counting for every tree.
- Branch length (cm): measuring from stem to top of branch.
- Number of leaf paires per branch: counting for every branch.

2.3.4. *Statistical Methods*

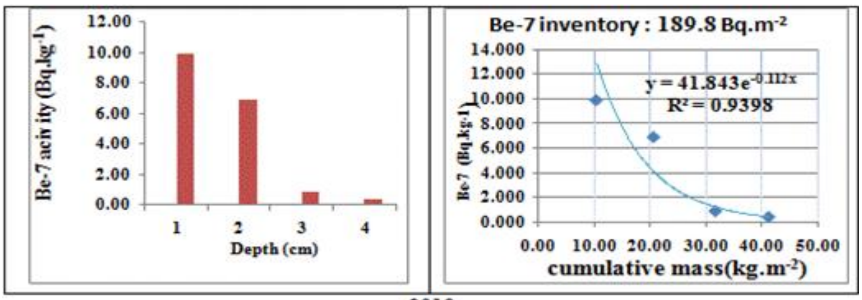
$CV\% = (SD.\,\overline{X}^{-1}).10^2$ where CV: coefficient of variation; SD: standard deviation; and $\overline{X}$: mean of X. The calculations were implemented in the SPSS program.

III. Results and Discussion

3.1. *Effect of Cultivating Measures to Soil Erosion*

3.1.1. *Distributions of Be-7 at the Reference Site*

The reference site locates to Ea Chucap Hill, Dak Lak province, with coordinates of 12°35'21" N, 108°7'13" E and elevations of 700 m asl. The depth distributions of Be-7 at the reference site was shown in Fig.3. The maximum penetration depth of Be-7 at the reference site was in the range of 3 - 4 cm and the majority of ^{7}Be was concentrated in the top 2 cm of the soil profiles. Acorrding to Hai et al (2011), 80% Be-7 was in the top soil (0-2 cm). These results agree with those reported by Walling *et al. (1999)*). This evidence suggests that the Profile-Distribution Model (1) is appropriate for the assessment of soil erosion rates at the study sites. The correlation equation between cumulative mass and Be-7 activity were $y = 41.843^{-0.112x}$ ($R^2 = 0.9398$) in 2019 and $y = 39.645^{-0.110x}$ ($R^2 = 0.9445$) in 2020. The relaxation mass depth *h*0 at the study area estimated from the distribution were $1 \times 0.112^{-1} = 8.93$ $kg.m^{-2}$ in 2019 and $1 \times 0.110^{-1} = 9.09$ $kg.m^{-2}$ in 2020. Hai *et al.* (2007) estimated $h0 = 8.5$ $kg.m^{-2}$ for Lam Dong area, where is 100 km far from this study.



2019

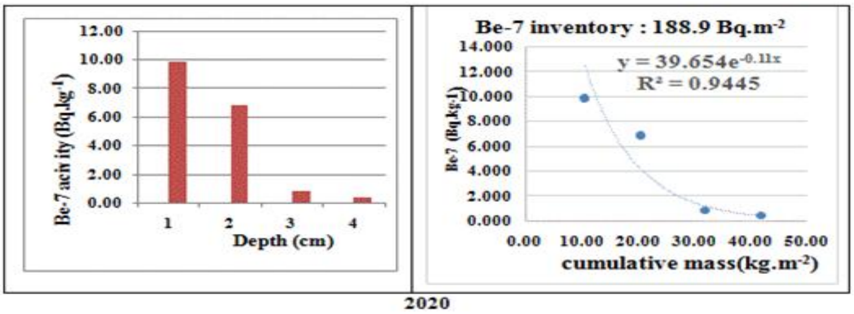


Fig. 3. The depth distribution of ^{7}Be in undisturbed soil at the reference site.

3.1.2. *Distributions of Be-7 at the Study Sites*

The data in Table 1 showed that Be-7 activity at study sites ranged 3.718 – 3.872 Bq.kg^{-1}, corresponding 166.0-172.5 Bq.m^{-2} in 2019 and 3.711-3.854 Bq.kg^{-1}, corresponding 165.0-171.2 Bq.m^{-2} in 2020. They were 9.1-12.6% in 2019 and 9.4-12.6% in 2020 less than reference site. The Be-7 inventory at treatment of T1 (control) were 3.718 Bq.kg^{-1}, corresponding 166.0 Bq.m^{-2} in 2019 and 3.711 Bq.kg^{-1} corresponding 165.0 Bq.m^{-2} in 2020, equaling 12,6% lower than the reference site. They showed redistribution of soil (Hai *et al.*, 2008; Tu and Hai, 2014; Wallbrink and Murray, 1996).

Table 1. Effect of cultivating measures to Be-7 inventory in soil.

Treatment	**2019**				**2020**			
	D (kg.m^{-3})	**A**		**A. A $_{Ref}$$^{-1}$ (%)**	**D (kg.m^{-3})**	**A**		**A.A$_{Ref}$$^{-1}$ (%)**
		Bq.kg^{-1}	**Bq.m^{-2}**			**Bq.kg^{-1}**	**Bq.m^{-2}**	
A_{Ref} (Bq/m^2)	1044.0	4.546	189.8	100.0	1045.0	4.518	188.9	100.0
T1(control)	1116.0	3.718 a	166.0 a	87.4	1111.7	3.711 a	165.0 a	87.4
T2	1112.7	3.756 b	167.2 ab	88.1	1109.0	3.748 b	166.3 a	88.0
T3	1114.0	3.759 b	167.5 b	88.2	1108.7	3.750 b	166.3 a	88.1
T4	1115.3	3.838 c	171.2 c	90.2	1112.0	3.823 c	170.1 b	90.1
T5	1115.0	3.860 d	172.1 cd	90.7	1110.0	3.838 cd	170.4 b	90.2
T6	1114.0	3.872 d	172.5 d	90.9	1110.3	3.854 d	171.2 b	90.6
CV (%)		2.8	2.7			2.8	2.7	

Values in a column with the same letter are not significantly different; $p < 0.05$.

3.1.3. *Effect of Cultivating Measures to Soil Erosion*

Radionuclide Be-7 was applied for estimating soil loss of the coffee field for the duration of seven months in rainy season. Short-term erosion rates estimated by Conversion Models for the plot of monoculture (without protecting measure) were 11.97 t.ha^{-1} in 2019 and 12.29 t.ha^{-1} in 2020, average of 12.13 t.ha^{-1}.y^{-1}. Tu (2006) reported similar results at the local. The rates of soil loss reduced by 5.5-6.3% for building of drains (T2) or banks (T3); 22.7% for making pond around coffee tree (T4); and 25.4-27.9% for intercropping legumes with making pond around coffee tree (T5 and T6). The treatment of intercropping coffee, peanut and *crotalaria pallida* and making pond around coffee (T6) had lowest soil loss, with 8.74 t.ha^{-1}.y^{-1}, reduced by 3.39 t.ha^{-1}.y^{-1} in comparison with control and 0.31-2.72 $t.ha^{-1}.y^{-1}$ comparing to others. Generally, applying measures of soil protecting such as building of drains or banks, making pond around coffee tree, intercropping legumes restricted remarkably soil erosion (Table 2).

Table 2. Effect of cultivating measures to soil erosion.

Treatment	2019 (ho = 8.93)		2020 (ho = 9.09)		Average	
	$t.ha^{-1}$	%	$t.ha^{-1}$	%	$t.ha^{-1}$	%
T1 (control)	11.97 d	100.0	12.29 b	100.0	12.13 d	100.0
T2	11.33 c	94.6	11.60 b	94.4	11.46 c	94.5
T3	11.16 c	93.2	11.58 b	94.2	11.37 c	93.7
T4	9.21 b	76.9	9.55 a	77.7	9.38 b	77.3
T5	8.72 ab	72.8	9.37 a	76.3	9.05 ab	74.6
T6	8.52 a	71.1	8.97 a	73.0	8.74 a	72.1
CV (%)	14.2		13.1		13.5	

Values in a column with the same letter are not significantly different; $p < 0.05$.

3.2. *Effect of Cultivating Measures to Growth of Coffee Tree*

Monitoring results showed that during 24 months height of coffee tree increased by 70.0-72.6 cm. The treatment without applying soil protecting measure had lowest tree high growth, with 70.0 cm per 24 months. Making drains, banks, ponds or intercropping with legumes increased tree height by 70.9-72.6 cm per 24 months, corresponding 1.3-3.7% higher than treatment of control. However, the difference were not significant.

Coffee perimeter of stem did not change trivially under draing or banking, but in the case of making pond around coffee tree, the parameter increased by 10.4% in comparison with control. The treatment of intercropping coffee with legums and making ponds had highest growth of stem perimeter, reaching 70.4-71.1 cm, 14.5-15.6% higher than control treatment.

Coffee canopy diameter increased by 51.8-58.8 cm during 24 months. Whereby, lowest growth was the treatment without applying soil protecting measures. The treatment of intercropping peanut and *crotalaria pallida* and making ponds increased canopy diameter by 13.5% compared to control. This treatment had highest growth of canopy diameter (Table 3).

Table 3. Changing coffee tree height, stem perimeter and canopy diameter after 24 months.

Treatment	Height of Tree		Perimeter of Stem		Diameter of Canopy	
	cm	%	mm	%	cm	%
T1 (control)	70.0 a	100.0	61.5 a	100.0	51.8 a	100.0
T2	70.9 a	101.3	62.9 a	102.3	53.1 ab	102.5
T3	71.5 a	102.1	63.6 a	103.4	53.6 ab	103.5
T4	72.1 a	103.0	67.9 b	110.4	56.1 bc	108.3
T5	72.4 a	103.4	70.4 c	114.5	58.3 c	112.5

Treatment	Height of Tree		Perimeter of Stem		Diameter of Canopy	
	cm	%	mm	%	cm	%
T6	72.6 a	103.7	71.1 c	115.6	58.8 c	113.5
CV%	2.3		6.1		5.9	

Values in a column with the same letter are not significantly different; $p < 0.05$.

There were difference of branch number among experimental treatments. Whereby, treatment of control had lowest growth of branch numbers, with 10.1 pairs of branches a tree per 24 months making drains or banks increased branch number by 3.0%. The growth of branch numbers improved by 6.9% in the case of making pond around every coffee tree. The treatments of intercropping with legums and making ponds had highest growth of branch numbers, reaching 11.6 pairs of branches a tree per 24 months, meaning 14.9% higher than control.

Robusta coffee is a variety which can not bloom again on old place, so it is very necessary for new branches to become longer (Sung, 1999). Observating results showed that measures of drains or banks impacted weakly on growth of coffee branches, but building ponds increased strongly new branch length. Treatments of intercropping and making ponds improved length of branch by 9.6-16.9%. Whereby, intercropping coffee with peanut and *crotalaria pallida* and making ponds gave best growth.

Coffee flowers bloom at nodes on branches. Thus, the more nodes is on branch, the higher coffee yield is producted (Sung, 1999). Experimental results presented that cultivating measures effected to number of nodes. The treatment of coffee monoculture without soil protecting not only caused loss of soil and nutrient, but also impacted badly to growth of coffee node. Applying measures of soil protecting increased evidently number of nodes per branch. Intercropping coffee with legumes and building pond around coffee tree gave highest growth of nodes, reaching 10.3-10.5 nodes per branch, corresponding 12.0-14.1% higher than control (Table 4).

In summary, making drains, banks or ponds prevented run off and kept nutrient (Loan et al., 1996). Besite, intercropping increases cover, restricts impacting power of rain on soil surface and prevents nutrient loss thought evaporating so the crops is better growth (Tu, 2003).

Table 4. Changing coffee number of branch and node after 24 months.

Treatment	Pairs of branch per tree		Length of branch		Nodes per branch	
	Number	%	cm	%	Number	%
T1 (control)	10.1 a	100.0	41.5 a	100.0	9.2 a	100.0
T2	10.4 a	103.0	42.1 ab	101.4	9.4 a	102.2
T3	10.4 a	103.0	43.3 ab	104.3	9.6 ab	104.3
T4	10.8 ab	106.9	45.2 b	108.9	10.0 abc	108.7
T5	11.6 b	114.9	45.5 b	109.6	10.3 bc	112.0
T6	11.6 b	114.9	48.5 c	116.9	10.5 c	114.1
CV%	7.0		6.2		6.3	

Values in a column with the same letter are not significantly different; $p < 0.05$.

IV. Conclusion

The cultivating measures impacted evidently to soil erosion and coffee growth on sloping land in Dak Lak province of Vietnam. Intercropping coffee with peanut and *crotalaria pallida* and making pond around coffee tree gave the best effectiveness for protecting soil and growth of coffee tree, reduced soil loss by 3.39 $t.ha^{-1}.y^{-1}$, corresponding 27.9%, increased perimeter of stem by 15.6%, diameter of canopy by 13.5%, pairs of branch by 14.9%, length of branch by 16.9% and nodes per branch by 14.1% in comparison with control.

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