Vietnam J. Agri. Sci. 2017, Vol. 15, No. 10: 1365-1374 Tạp chí Khoa học Nông nghiệp Việt Nam 2017, 15(10): 1365-1374
www.vnua.edu.vn

ĐÁNH GIÁ XÓI MÒN VÀ LƯỢNG DINH DƯỠNG ĐẤT BỊ MẤT TRÊN CÁC KIỂU SỬ DỤNG ĐẤT TRỒNG XEN CÂY *Macadamia* TẠI HUYỆN TUY ĐỨC, TỈNH ĐĂK NÔNG

Le Trong Yen[1], Nguyen Van Dung[2*], Vu Thi Binh[3]

[1]PhD fellow of Vietnam National University of Agriculture
[2]Vietnam National University of Agriculture
[3]Vietnam Soil Science Society

Email[*]: nvdung1@vnua.edu.vn

Received date: 12.10.2017 Accepted date: 20.11.2017

TÓM TẮT

Sử dụng đất là một trong những yếu tố quan trọng nhất ảnh hưởng đến xói mòn đất vì các loại/kiểu sử dụng đất sẽ tác động đến thay đổi bề mặt đất và độ che phủ đất, hàm lượng dinh dưỡng đất. Nghiên cứu một số kiểu sử dụng đất nông nghiệp (đất trồng cà phê, hồ tiêu và rừng) có xen cây *Macadamia* trên đất đỏ Bazan tại huyện Tuy Đức, tỉnh Đăk Nông cho thấy các kiểu sử dụng đất này có ảnh hướng rõ rệt đến xói mòn rửa trôi và lượng dinh dưỡng đất mất đi. Kết quả của 6 thí nghiệm (Tr), trong đó 4 thí nghiệm gồm *Macadamia* 3 tuổi trồng thuần và 3 thí nghiệm *Macadamia* 3 tuổi trồng xen với cà phê, hồ tiêu và rừng bố trí trên đất có độ dốc 6 - 7^o, trên đất có độ dốc 12 - 13^o bố trí 2 thí nghiệm *Macadamia* 6 tuổi trồng thuần và trồng xen rừng cho thấy: Ở độ dốc 6 - 7^o công thức *Macadamia* xen cà phê (Tr.2) có độ che phủ đạt cao nhất (72,09%), *Macadamia* trồng thuần (Tr.1) có độ che phủ là 6,96%, dòng chảy mặt dao động từ 153 - 195 mm, lượng đất xói mòn từ 10,8 - 26,4 tấn/ha/năm. Ở đất dốc 12 - 13^o tương ứng dòng chảy mặt là 188 - 285 mm và xói mòn đất 15,6 - 33,7 tấn/ha. Quá trình trên còn phụ thuộc vào loại hình sử dụng đất, trên đất trồng thuần ở độ dốc 12 - 13^o lượng đất mất là 33,7 tấn/ha, trên đất trồng xen với cây rừng lượng đất mất chỉ 25,3 tấn/ha. N; P_2O_5; K_2O tổng số mất nhiều hơn ở dạng dễ tiêu, như công thức *Macadamia* trồng thuần (CT1) năm 2014 đạm tổng số mất 100,23 kg, trong đó ở dạng dễ tiêu chỉ mất 25,08 kg/ha.

Từ khóa: Kiểu sử dụng đất, *Macadamia*, dòng chảy mặt, xói mòn, dinh dưỡng mất.

Evaluating Soil Erosion and Nutrition Depletion on Land Use Types Intercropped with Macadamia in Tuy Duc District, Dak Nong Province

ABSTRACT

Land use is one of the most important factors that affects soil erosion because land use types impact changes in soil surface, land cover, and soil nutrition. This study of agricultural land use types (coffee, pepper, and forest) intercropped with *Macadamia* on basalt soil in Tuy Duc district, Dak Nong province showed that these land use types clearly affected soil erosion, leaching, and soil nutrition depletion. Four treatments (Tr) were planted on a 6 - 7^o slope including 1 treatment of 3 - year old *Macadamia* trees planted as a monoculture and 3 treatments of 3 - year old *Macadamia* trees intercropped with coffee, pepper, or forest trees, and 2 treatments were planted on a 12 - 13^o slope including 6 - year old *Macadamia* trees planted as a monoculture and *Macadamia* intercropped with forest tress. The results of the 6 treatments showed that at the slope of 6 - 7^o, treatment 2 (Tr.2; *Macadamia* and coffee) had the highest coverage (72.09%) and the *Macadamia* monoculture (Tr.1) had the lowest coverage (6.96%). Surface runoff varied from 153 to 195 mm, and the amount of soil erosion was from 10.8 to 26.4 tons/ha/year. At the slope of 12 - 13^o, surface runoff was from 188 to 285 mm and soil erosion amount was from 15.6 to 33.7 tons/ha. The above results also depended on land use types. On the land use type of *Macadamia* monoculture planted on a slope of 12 - 13^o, soil loss was 33.7 tons/ha. On land use type of *Macadamia* intercropped with forest trees, soil loss was only 25.3 tons/ha. Total N, P_2O_5 and K_2O were lost more than those in available form. For example, in treatment 1 (only *Macadamia*), total N loss was 100.23 kg, of which, available N loss was only 25.08 kg/ha.

Keywords: Land use types, *Macadamia*, surface runoff, erosion, nutrition depletion.

1. INTRODUCTION

Land use is one of the most important factors that affect soil erosion because it affects land surface changes, soil cover, soil fertility, soil water permeability, and soil nutrient depletion (Kosmas *et al.*, 1997; Flanagan, 2002; Fiener *et al.*, 2011).

Currently, basalt soil of Dak Nong province has been exploited and used for planting industrial crops and forest trees such as coffee, pepper, and planted forests, mainly in the form of monoculture. In recent years, some areas have grown coffee intercropped with forest trees, fruit trees, or legumes to increase the rate of land cover and protect the soil. These models have had great effect on the level of cover and have minimized the level of soil reduction of the environment (Tich Giang, 2016).

Macadamia is a kind of nut tree belonging to a perennial tree with wooden trunk. It has been planted in Vietnam, mainly in the Central highlands, for 20 years (Nguyen Cong Tan, 2012). The Ministry of Agriculture and Rural Development has evaluated *Macadamia* as a multi - purpose tree, as a forest tree that can cover land and as an agricultural tree with high economic value. This study investigates the effect of intercropping with *Macadamia* to evaluate the land use type of this industrial tree in Tuy Duc District to reduce soil erosion and nutrition depletion on slopping lands and to ensure that the land is used effectively and sustainably.

2. MATERIALS AND METHODS

2.1. Study site

The study sites were Quang Truc and Dakbukso, Tuy Duc district, DakNong province.

2.2. Study duration

Experiments were implemented for 3 years, from 2014 to 2016. Meteorological data was collected for 15 years, from 2002 to 2016.

2.3. Objectives

The main objective was to evaluate land cover by measuring land use type, surface runoff, soil erosion, and nutrition depletion in eroded soil and in runoff water of land use types intercropping *Macadamia* with coffee, pepper, or forest on two sloping degrees.

2.4. Methods

2.4.1. Field experiment with land use types intercropping macadamia on two slope levels (compared with land use types macadamia monoculture)

The field experiment consisted of six treatments. In treatment 1, 3 - year old *Macadamia* trees were planted as a monoculture at a density of 278 trees/ha on land with a slope of 6 - 7°. In treatment 2, 3 - year old *Macadamia* trees were planted at a density of 124 trees/ha and intercropped with coffee (1,100 trees/ha) on land with a slope of 6 - 7°. In treatment 3, 3 - year old *Macadamia* trees were planted and at a density of 185 trees/ha intercropped with pepper (1,100 trees/ha) on land with a slope of 6 - 7°. In treatment 4, 3 - year old *Macadamia* trees were planted at a density of 124 trees/ha and intercropped with forest trees (1,600 trees/ha) on land with a slope of 6 - 7°. In treatment 5, 6 - year old *Macadamia* trees were planted as a monoculture at a density of 278 trees/ha on land with a slope of 12 - 13°. In treatment 6, 6 - year old *Macadamia* trees were planted at a density of 124 trees/ha and intercropped with forest trees (1,600 trees/ha) on land with a slope of 12 - 13°.

The experiments were replicated 3 times. The erosion plot area was $100m^2$ (5m×20m), with a 20cm high border. A tank was located below the plots to collect eroded soil and surface water runoff with the dimensions of 5m x 1m x 1m (Fig. 1).

2.4.2. Determining the land cover rate (% coverage/ha)

The average area of tree canopy on the soil surface in circle form (Vu Tien Hinh *et al.*, 1992) was determined by the equation:

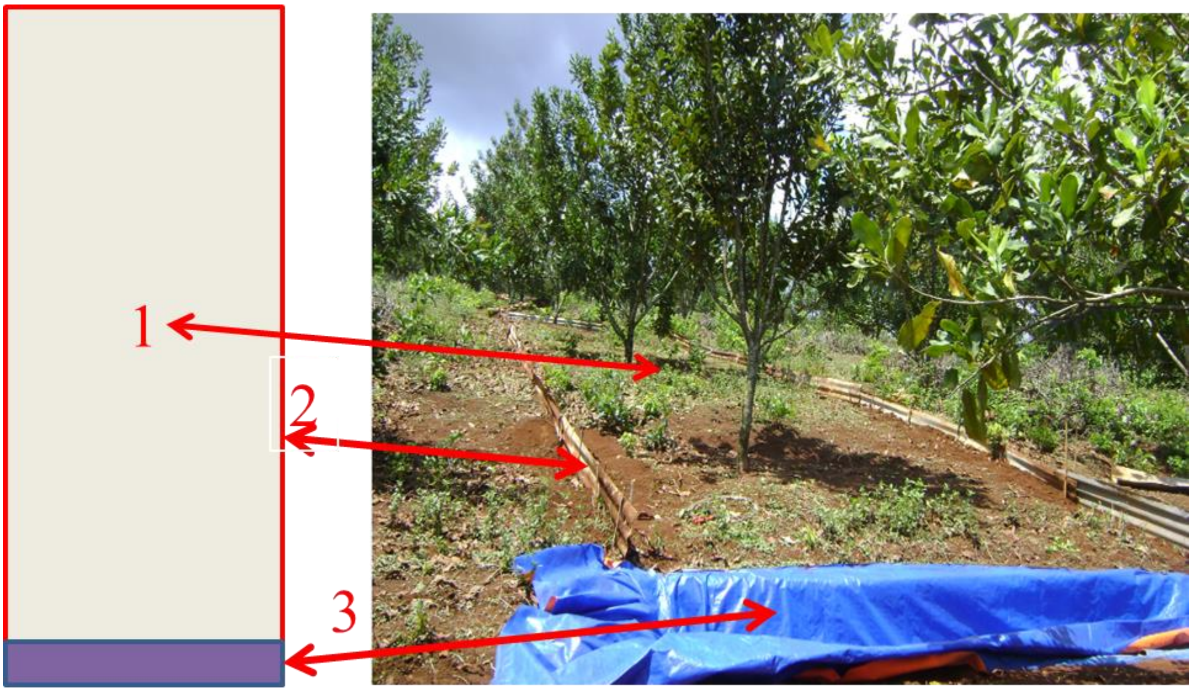

Figure 1. Soil erosion plot

Note: (1): Soil erosion plot: 5 m x 20 m; (2): Border of 20cm in height; (3): Tank used to collect eroded soil, sediment, and surface water runoff: 5m x 1m x 1m

$$St(m^2) = \frac{\pi}{4} \times Dt^2 = 0,785 \times Dt^2$$

Where: *St* is the average area of the tree canopy on the soil surface in circle form (m^2), and *Dt* is the average diameter of the tree canopy at the widest position (m).

2.4.3. Determining surface runoff (mm)

Surface runoff included 3 parts: the total evaporated water from the collection tank from 1st sampling time to 2nd sampling time + volume of water in tank + water amount in mud layer in the collection tank:

$$W = ETo + (W_1/10) + (W_2/10)$$

Where *W* is the water volume lost due to surface runoff (mm); *ETo* is the freely evaporated water volume (mm) which equals the total evaporated water volume from the 1st to 2nd sampling time (free evaporated water volume collected from Dak Nong meteorological station); W_1 is the water collected in collection tank (m^3) as calculated by the depth of the water layer (from the water surface to the mud surface) multiplied with tank area; and W_2 is the water volume in mud layer of the collection tank (m^3) as determined by the volume method.

Total surface runoff (mm/year) was equal to the total surface runoff of the 5 sampling times (1st time + 2nd time + 3rd time + 4th time + 5th time)

2.4.4. Determining the eroded soil amount

Eroded soil consisted of 2 parts: the total suspended matter in surface runoff and the soil eroded in the collection tank. The total suspended matter in the surface runoff was determined by the evaporation method in which we determined the water volume in the collection tank, and then sampled 1 litter of water from the collection tank to determine the suspended matter. The eroded soil amount (tons/ha) was determined by weighing all the mud and soil in the collection tank, and then drying 1kg of the soil to determine soil moisture by calculating the dry soil weight using the following equation:

$$M = \{m_1 + \left(\frac{p_2}{P_1} \times m_2\right)\} \times 0.1$$

where M is the eroded soil amount (tons/ha); m_1 is the soil amount in solution (kg/100m^2); m_2 is the soil amount in the collection tank (kg/100m^2); P_1 is the weight of the soil sampled from the collection tank (kg); and P_2 is the weight of the dried soil sample (kg).

The total eroded soil amount (tons/ha/year) was equal to the total eroded soil of the 5 sampling times (1st time + 2nd time + 3rd time + 4th time + 5th time)

We determined the soil moisture by the weighing method.

2.4.5. Sampling time

Soil and water samples were collected 5 times, once every month, from the 1st of May to the 10th of October, annually.

Soil and water samples were analyzed at the Center of Soil, Fertilizer, and Environment Research of Highland.

2.4.6. Indicators and methods of soil, water analysis: determine nutrition depletion in eroded soil

The indicators and methods for the soil analyses were as follows: pH_{KCl} was measured with a pH meter; OC% was measured following Walkley and Black; total P_2O_5 was measured using the colorimetry method; available P_2O_5 was measured following the methods from Oniani; total K_2O digestion by $HClO_4$, HF, and HCL acids, measured by flame photometer; available K_2O was measured following the method of Matslova via a flame photometer; total N was measured following the methods of Kjeldhal; hydrolysis of N was measured following the methods of Tiurin and Kononova; texture was measured via a pipette following the methods of Robinson; and bulk density was measured using the core method.

The indicators and methods for the water analyses were as follows: pH was measured using a pH meter; suspended matter content was measured after evaporating, drying, and weighing samples; OC was measured following the methods of Walkley and Black; total N and soluble N were measured by distilling and using a colorimeter directly; total P was measured by digestion using H_2SO_4 and $HClO_4$, and then determining P using a colorimeter; soluble P was measured through the creation of the molypden blue color using $SnCl_2$; and total K and soluble K was measured using a flame photometer.

3. RESULTS AND DISCUSSION

3.1. Soil physical and chemical characteristics before the experiment

The experiment was carried out on basalt soil (Rhodic Ferrasols). The soil texture was heavy loam with a bulk density from 0.92 - 0.94 g/cm^3, a particle density of 2.52 - 2.55 g/cm^3, porosity of 63.5 - 63.8%, and clay content of 57.2 - 58.2%. Soil was acidic (pH_{KCl} from 3.93 to 4.43) and contained organic carbon from 3.54 to 4.03% and total N contents were at a medium level from 0.151 - 0.202%. Available P and K were from a medium level to quite high (from 6.9 - 7.2 mg/100g soil), and total P was rich (0.18 - 0.21%) while total K was poor (0.07 - 0.10%).

3.2. Rainfall characteristics

The average rainfall/year over a 15 - year period, 2002 - 2016, at the Dak Nong meteorological station was 2353 mm, in which, the highest rainfall was in 2006, 3351 mm, and the lowest rainfall was in 2010, 1495 mm. In the experiment area, rainfall during the 3 years of this study (2014, 2015, and 2016) were 2041, 1959, and 1956 mm, respectively. These rainfall levels were lower than the average 15 - year value by 312 to 397 mm (Fig. 2).

The calculated average rainfall for a 15 - year period during the rainy season, from May to October, was 2039 mm (accounting for 87% of the total yearly rainfall). Heavy rainfall can result in erosion and surface runoff during the 3 years of study, which was lower than the average value by 317 to 422 mm. Besides, in 2016, although total rainfall was 1959 mm, maximum rainfall during the rainy season reached 1808.8 mm, higher than the average 3 - year value of 1659 ± 133 mm.

To assess the potential for soil erosion, the intensity of rain during a rainstorm is the main factor causing erosion and surface runoff. During the study period, 24 - 32% of rainstorms had rainfall greater than 10 mm/day, and 13 - 17% of rainstorms had rainfall of more than 30 mm/day. In 2014 there were 16 days of heavy rain, in 2015 there were 19 days, and in 2016 there were 17 days. The highest daily rainfall measured for each year in the study period was 78.2 mm on May 21, 2014, 121.4 mm on May 21, 2015, and 82.3 mm on June 20, 2016.

3.3. The effect of land use types of intercropped *Macadamia* on land coverage

Because the *Macadamia* trees were only 3 years old, soil conservation was not well promoted, but the intercropping models were positively effective in increasing land coverage (Table 1).

For treatments of *Macadamia* monocultures, land coverage ranged from 6.96% to 21.13%. The treatment of *Macadamia* intercropped with pepper (Tr.3) had the lowest coverage (24.72%, of which, the coverage of *Macadamia* was 2.6% and pepper was 22.12%), compared to treatments Tr.2, Tr.4, and Tr.6. As for Tr.2, *Macadamia* intercropped with coffee had a coverage of 72.09% (*Macadamia* had a coverage of 3.89% and coffee had a coverage of 68.20%). The main reason for this difference is that the treatments using coffee and forest trees had entered a business period. This coverage rate had a positive impact on soil protection and soil water conservation because it reduced surface runoff and soil erosion, promoted nutrient cycling, increased plant nutrition efficiency, and may have increased soil fertility.

3.4. The effect of land use types of intercropped *Macadamia* on surface runoff and soil erosion

3.4.1. Surface runoff

Although basalt soil has high porosity and good permeability, during the rainy season in the Central highlands in general and in Dak Nong in particular, rainfall is great, so all the rain water cannot penetrate the soil and often flows on the soil surface. The results of monitoring surface runoff during the experiment

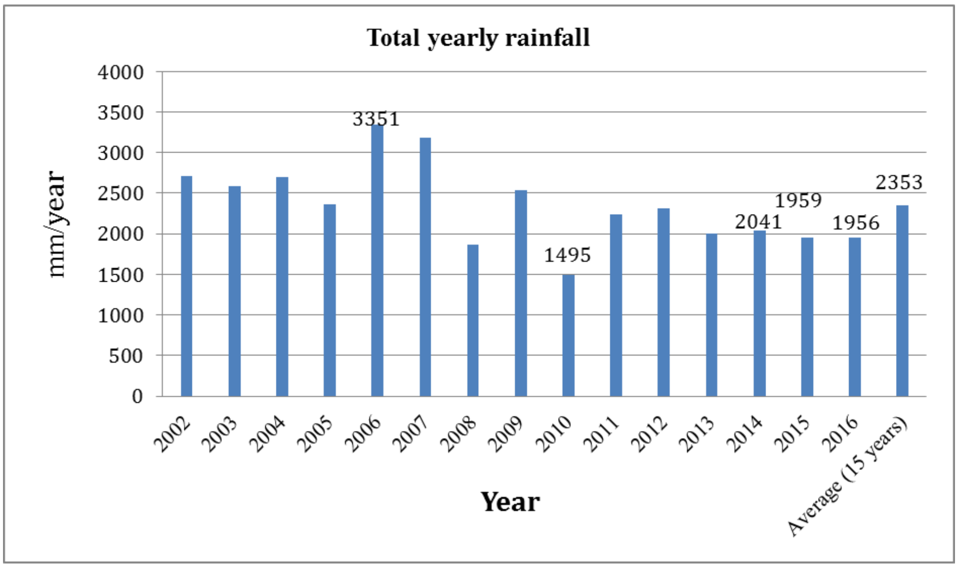

Figure 2. Total yearly rainfall

Table 1. Land coverage of trees

No.	Treatment	Tree	Canopy diameter (m)	Canopy view area (m^2)	Number of tree /ha	Coverage area (m^2)	Coverage rate (%)
1	CT1	*Macadamia*	1.78	2.50	278	695.00	6.96
2	CT2	*Macadamia*	1.64	2.10	185	388.85	3.89
		Coffee	2.81	6.20	1,100	6820.00	68.20
3	CT3	*Macadamia*	1.64	2.10	124	260.40	2.60
		Pepper	1.60	2.00	1,100	2211.70	22.12
4	CT4	*Macadamia*	1.56	1.90	124	235.60	2.36
		Forest	2.34	4.30	1,600	6880.00	68.80
5	CT5	*Macadamia*	3.11	7.60	278	2112.80	21.13
6	CT6	*Macadamia*	3.00	7.10	124	876.50	8.77
		Forest	2.42	4.60	1,600	7369.00	73.60

of growing *Macadamia* trees over 3 years (2014 - 2016, Fig. 3) showed that the water loss amount due to surface runoff was greater when the land had a slope of 12 - 13° (from 259 - 285 mm/year) than when the land had a slope of 6 - 7° (189 - 195 mm/year) every year. Comparison of the treatments having the same slope, the treatment of *Macadamia* intercropped with coffee, pepper, or forest trees had less water loss due to surface flow.

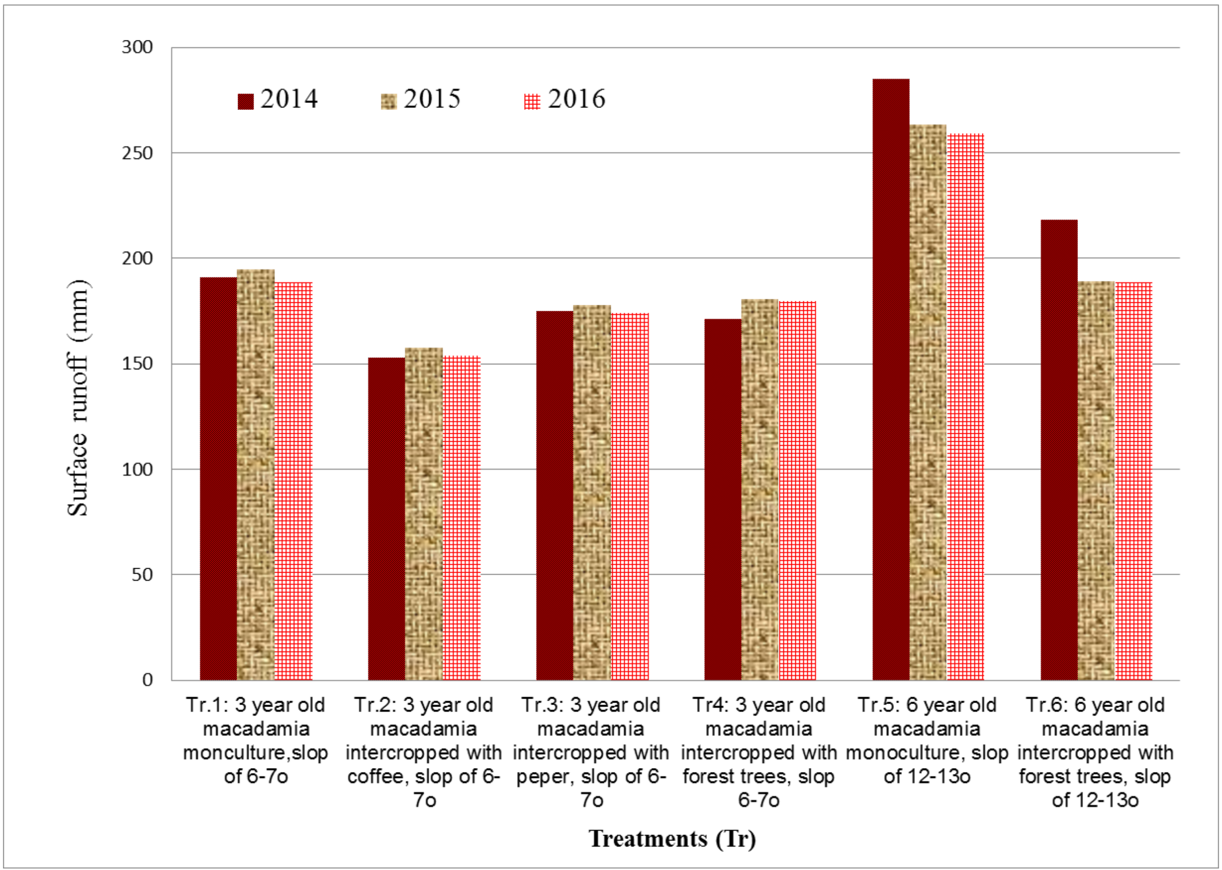

Figure 3. The effect of land use types of intercropped *Macadamia* on surface runoff

Total precipitation during the experiment years of 2014, 2015, and 2016 was 1616.1 mm, 1808.6 mm, and 1552.8 mm, respectively. Water surface runoff loss due to surface flow in the *Macadamia* experiment on land with a slope of 6 - 7^{o} was from 153 to 195 mm/year, and on land with a slope of 12 - 13^{o}, it was from 188 to 285 mm/year. Rainfall of a rainstorm as well as total annual rainfall were the main causes leading to the loss of water due to different surface runoffs. In 2015, the total rainfall was greatest, 1808.6 mm, leading to surface runoff from 157 to 195 mm/year in experiment of *Macadamia* planted on land having a slope of 6 - 7^{o}. However, on the land sloped 12 - 13^{o}, the total loss of water due to surface runoff depended mainly on slope. In 2015, the total rainfall in the rainy season was 1615.1 mm with treatment Tr.5 having the greatest amount of water lost due to surface runoff, 285 mm/year (Fig. 3).

Surface runoff values also differed between intercropping treatments. For example, the average 3 - year value of surface runoff for treatment Tr.1 (*Macadamia* monoculture) was 191 mm, much higher than in treatment Tr.2 (*Macadamia* intercropped with coffee) which was 155 mm. The average water loss amount due to surface runoff measured in the treatments was 174 ± 15.0 mm.

3.4.2. Soil erosion

The energy of the raindrops can break down the soil structure, making the conjunction between soil particles weaker, while the amount of rainwater that penetrates the saturated soil causes the flow on the surface carrying clay particles and other materials (the amount of clay particles and sediment flowing with water on the surface is called soil erosion). The results of soil erosion monitoring over the 3 - year period of 2014 - 2016 showed that soil erosion was proportional to the water measured in the surface runoff. If the treatments of *Macadamia* had high levels of surface runoff, then soil erosion was great, and if the treatments had low levels of surface runoff, then soil erosion was low (Fig. 4).

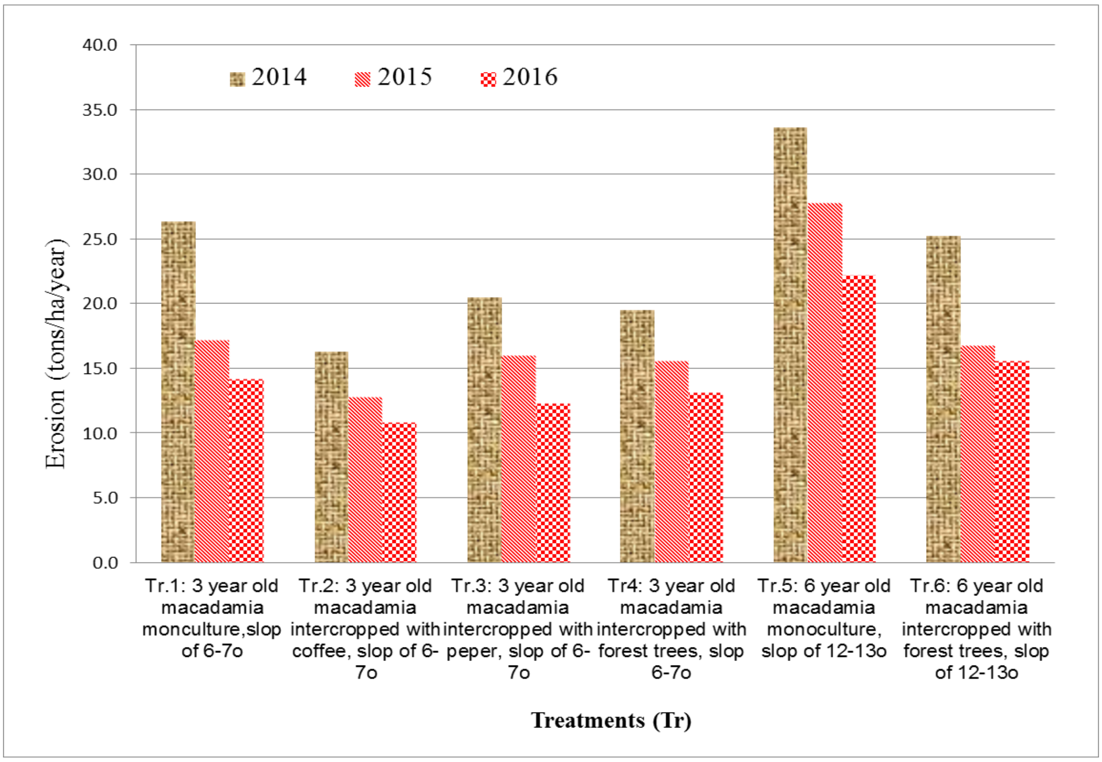

Figure 4. The effect of land use types of intercropped *Macadamia* on soil erosion amount

Slope is also a terrain factor, which can play an important role affecting soil erosion. Soil erosion in the *Macadamia* treatments was from 10.8 to 26.4 tons/ha/year on the land sloped 6 - 7°, and from 15.6 to 33.7 tons/ha/year on the land sloped 12 - 13°. Soil erosion also depends on land use types. At the same slope, different land use types had different amounts of soil erosion. In 2014, the *Macadamia* monoculture treatment (Tr.5) which was planted on a slope of 12 - 13°, the amount soil erosion was 33.7 tons/ha/year, while in the *Macadamia* intercropped with forest trees (Tr.6), the soil erosion amount decreased to 25.3 tons/ha/year (Fig. 4). The above results were also consistent with the findings of Zingg (1940) and Smith *et al.* (1958).

3.4.3. The effect of land use types of intercropped macadamia on soil nutrition depletion due to soil erosion and surface runoff

Organic carbon plays an important role for soil fertility. Organic carbon contributes to improving soil physical properties (helps improve soil porosity and soil colloid stability), soil chemical properties (available nutrients such as N, P, K, etc.), and soil biological properties (populations of beneficial microorganisms in the soil are increased), thus, providing important nutrients for plants. Therefore, the assessment of organic carbon in lost soil due to erosion is very necessary. The amount of organic carbon lost due to soil erosion in the treatment soil of the *Macadamia* plots over the study three years (2014 - 2016, Table 2) was quite great. On the soil with a high slope, organic carbon in the eroded soil was more than that on low sloped land. On the slope of 12 - 13°, lost organic carbon in Tr.5 was from 1,226 to 1,947 kg/ha, while on the slope of 6 - 7°, lost organic carbon of Tr.1 was from 898 to 1,495 kg/ha. On the same slope, different land use also had different amounts of lost organic

Table 2. Soil nutrition depletion from erosion and surface runoff (kg/ha/year)

No	Treatment	Year	Organic carbon	Nutrition depletion					
				Total			Available		
				N	P_2O_5	K_2O	N	P_2O_5	K_2O
1	Tr.1	2014	1495	100.23	57.72	27.19	25.08	4.78	4.73
		2015	983	76.63	40.34	17.08	24.18	4.16	3.68
		2016	898	71.33	34.25	17.23	17.94	3.41	3.81
2	Tr.2	2014	964	70.74	36.06	18.29	22.98	3.22	3.21
		2015	718	59.78	29.03	12.96	20.09	3.49	2.79
		2016	669	55.06	25.36	13.43	18.48	2.67	2.77
3	Tr.3	2014	1179	73.72	46.21	22.93	21.76	3.38	3.92
		2015	786	67.46	32.86	14.02	20.03	3.98	3.25
		2016	740	62.75	28.28	13.79	14.78	2.90	3.17
4	Tr.4	2014	1054	75.02	44.71	19.10	22.11	3.50	2.98
		2015	806	69.36	34.31	14.84	18.09	3.79	3.14
		2016	733	57.82	27.80	14.74	13.33	2.93	2.87
5	Tr.5	2014	1947	131.36	77.93	35.88	43.96	6.77	5.65
		2015	1398	109.58	57.23	29.13	41.06	5.66	5.41
		2016	1226	100.78	50.79	25.68	37.68	5.70	5.27
6	Tr.6	2014	1480	103.15	58.40	28.28	26.10	4.57	3.67
		2015	890	71.77	37.24	18.04	25.15	3.78	3.51
		2016	886	70.51	35.29	18.17	23.47	3.63	3.42

matter. For the treatment of the *Macadamia* monoculture on the slope of 12 - 13°, in 2014, organic carbon loss was 1947 kg/ha, however, treatment Tr.6 only lost 1480 kg/ha because its coverage reached 82.37%.

Erosion and surface runoff swept away a great amount of nutrition from the surface soil horizon. Table 2 shows that organic carbon content in eroded soil and leached soil of the treatments of intercropped *Macadamia* was smaller than that in the treatment of only *Macadamia*. The results of calculated nutrition (N) lost in runoff water and soil erosion in 2014, 2015, and 2016 are presented in Table 2. Treatment Tr.1 had a total N loss of 100.23 kg, while treatment Tr.5 lost 131.36 kg of total N/ha.

3.4.4. Discussion

For the land use type of *Macadamia* intercropped with coffee on a slope of 6 - 7° or *Macadamia* intercropped with forest trees on a slope of 12 - 13°, the eroded soil and surface runoff equaled only 61.9 to 76.24% in comparison with the *Macadamia* monoculture land use type. In 2014, soil erosion in land planted with a *Macadamia* monoculture was 33.7 tons/ha, or 8.4 tons/ha higher than in land intercropped with *Macadamia*. The results were similar to Gafur *et al.* (2003), who found that soil erosion in Bangladesh was nearly 30 tons/ha, and Mai (2007). For example, Tr.4 (the 3 - year - old *Macadamia* trees intercropped with forest trees) in 2014, the eroded soil amount was 19.5 tons/ha, but by 2016, due to the increased coverage, the amount of soil erosion was only 13.1 tons/ha. The above result was also consistent with the soil erosion control experiment result in Hoa Binh province, which showed that soil erosion on forest land was only 2.9 tons/ha, while on upland rice, it was 13.3 tons/ha (Nguyen Van Dung *et al.*, 2008). In addition, the experiment also showed that starting from the second year, due to the trees having more roots, trunks, and canopies, the impact of raindrops to the soil was reduced. Soil erosion and surface runoff in 2016 was smaller than in 2015. For example, in treatment Tr.1 (3 - year old *Macadamia* on 6 - 7° slope), the surface runoff in 2016 was 189 mm, while in 2015, it was 195 mm. The above results were consistent with the results of Trinh Cong Tu (2016), who showed that coffee production in commercial periods had lower soil erosion than young crops or in coffee during the period of basic construction.

4.1. CONCLUSION

The experimental treatments of planting coffee, pepper, or forest trees intercropped with *Macadamia* trees on basalt soil of 2 different slopes showed that soil erosion and surface runoff were clearly reduced in comparison to the *Macadamia* monoculture. On the slope of 6 - 7°, soil erosion of treatments of intercropped *Macadamia* ranged from 10.8 to 26.4 tons/ha/year, and surface runoff was from 153 to 195 mm. On the slope of 12 - 13°, soil erosion was from 15.6 to 33.7 tons/ha, and surface runoff was from 188 to 285 mm.

Land use types of intercropped *Macadamia* also resulted in the reduction of nutrition depletion due to soil erosion and surface runoff, compared to the land use type of a *Macadamia* monoculture. Soil nutrition depletion in the treatment of only *Macadamia* in 2015 was 983 kg/ha, but in the land use types of intercropped *Macadamia*, it was from 700 to 800 kg/ha.

REFERENCES

Flanagan, D. (2002). Erosion Encyclopedia of Soil Science, 1st ed.; Marcel Dekker: New York, NY, USA. pp. 395-398.

Fiener, P., Auerswald, K., and van Oost, K. (2011). Spatio - temporal patterns in land use and management affecting stremflow response of agricultural catchments - a review. Earth Sci. Rev., 106: 92-104.

Gafur, A., Jensen, J.R., Borggaard, O.K., and Petersen, L. (2003). Runoff and losses of soil and nutrient from small watersheds under shifting cultivation in the Chittagong Hill Tracts of Bangladesh. Journal of Hydrology, 274: 30-46.

Kosmas, C., Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., and Farand, R. (1997).

The effect of land use on runoff and soil erosion rates under Mediterranean conditions. Catena., 29: 45-59.

Mai, V.T. (2007). Soil erosion and nitrogen leaching in Northern Vietnam: Experimentation and modelling. Ph.D. Thesis. Department Plant System, Wageningen University, Wageningen. pp. 182.

Nguyen Van Dung, Tran Duc Vien, Nguyen Thanh Lam, Tran Manh Tuong, and Georg Cadish, (2008). Analysis of the sustainability within the composite swidden agroecosystem in Northern Vietnam" - Partial nutrient balances and recovery times of upland fields Agriculture. Ecosystems and Environment, 128: 37-53.

Nguyễn Công Tạn (2012). Nghề trồng cây Mác ca. Nhà xuất bản Nông nghiệp Hà Nội.

Smith, D.D., and Wischmeier, W.H. (1958). Factors affecting sheet and rill erosion. Am. Geophys. Union Trans., 38: 889-896.

Trình Công Tư (2016). Thực trạng xói mòn đất ở Đăk Lawk ngày càng nghiêm trọng, www.tintaynguyen.com/tinh-trang-xoi-mon-dat-o-dak-lak-ngay-cang-nghiem-trong/96083.

Tích Giang - TCCT: Trồng xen canh cây công nghiệp vào vườn cà phê: Nhất cử ba, bốn cái lợi. Truy cập ngày 15/7/2017 tại http://www.tapchicongthuong.vn/trong-xen-canh-cay-cong-nghiep-vao-vuon-ca-phe-nhat-cu-ba-bon-cai-loi-20130516051112278p12c15.htm.

Vũ Tiến Hinh, Vũ Văn Nhân, Phạm Ngọc Giao, Lê Sỹ Việt, Ngô Sỹ Bích và Chu Thị Bình (1992). Giáo trình Điều tra - Quy hoạch điều chế rừng, Phần II - Điều tra rừng. Trường Đại học Lâm nghiệp.

Zingg A.W. (1940). Degree and length of land slope as it affects soil loss in runoff. Agric. Eng., 21: 59-64.