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INFILTRATION CHARACTERISTICS OF SOIL UNDER CINNAMON AND ACACIA PLANTATION FOREST IN HEADWATER OF VIET NAM

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TÓM TẮT

For determining infiltration characteristics of soil under Cinnamon and Acacia plantation forest, double rings infiltrometer was used in 15 different locations (5 times for one part) of up - hill, mid - hill and downhill part in each kind of forest. Research was conducted from June to September 2017. Dye tracer - a new method was used to determine spatial distribution of infiltration in three plots. The first plot had a Cinnamon tree, the second plot had an Acacia tree and the reference plot did not have any tree. Influencing factors such as dry bulk density, vegetation cover, porosity and soil moisture were also analyzed. After carrying out the research, some main findings were: (1) Infiltration rate in both kinds of forests tended to be decreased over time, the rate was the highest at the downhill and the lowest at the middle hill. Both initial and stable infiltration rate of Acacia forest (13.5 and 2.2 mm/min respectively) are higher than those of Cinnamon forest (9.0 and 1.3 mm/min respectively). The infiltration rate in both types of forests were not high and they have chance to occur overland flow; (2) Spatial infiltration distribution of dye in three plots was different, dye tended to be infiltrate with the deepest depth and the biggest area into soil at reference plot (1177 cm^2 and 70 cm in 4^{th} layer), dye tended to infiltrate bigger in Acacia plot (90 to 427 cm^2) and deeper in Cinnamon plot (40 to 60 cm); (3) Infiltration rate had positive relationship with vegetation cover, soil moisture and porosity. The findings implied that infiltration rate under Acacia plantation forest has been higher than Cinnamon forest.

Từ khóa: Acacia forest, Cinnamon forest, dye tracer, infiltration rate, spatial infiltration, vegetation cover

Đặc điểm thấm nước của đất dưới rừng trồng Quế và Keo tại vùng đầu nguồn của Việt Nam

Để xác định đặc điểm thấm nước của đất dưới rừng trồng Quế và Keo, chúng tôi đã sử dụng vòng đo đôi tốc độ thấm ở 15 vị trí khác nhau cho mỗi loại hình rừng trồng. Cụ thể, tại khu vực sườn trên, sườn giữa và sườn dưới ở mỗi loại rừng đều tiến hành đo 5 lần khác nhau. Thời gian đo được thực hiện từ tháng 6 đến tháng 9 năm 2017. Ngoài ra, thuốc nhuộm đồng thời được sử dụng ở các 3 điều kiện: đất trồng Keo, Quế và đất có cỏ che phủ để xác định đặc điểm thấm nước của đất theo không gian sâu và ngang. Các yếu tố ảnh hưởng đến đặc điểm thấm nước như dung trọng, độ xốp, độ che phủ và độ ẩm của đất cũng được phân tích. Sau khi thực hiện nghiên cứu, một số phát hiện chính là: (1) Tốc độ thấm nước của đất ở cả hai loại rừng có xu hướng giảm dần theo thời gian. Cả tốc độ thấm nước ban đầu và ổn định của rừng keo (tương ứng 13,5 và 2,2 mm/phút) đều cao hơn so với rừng Quế (lần lượt là 9.0 và 1,3 mm/phút). Lượng nước thấm tính theo giờ ở cả 2 loại hình rừng đều không cao và có nguy cơ lớn xuất hiện dòng chảy bề mặt tại khu vực nghiên cứu; (2) Đặc điểm thấm nước theo không gian ở các loại hình rừng và đất có cỏ che phủ là khác nhau. Nước có xu hướng thấm sâu và diện tích thấm lớn nhất ở đất có cỏ che phủ (1177 cm^2 bề rộng và 70 cm độ sâu ở lớp 4, cách chỗ đổ thuốc nhuộm 10 cm) và giảm dần ở các loại hình rừng. Diện tích thấm nước của đất dưới rừng keo (90 đến 427 cm^2) lớn hơn rừng Quế, trong khi độ sâu thấm nước của đất dưới rừng Quế (40 đến 60 cm) lại lớn hơn so với đất rừng Keo; (3) Tốc độ thấm có quan hệ chặt với thực vật che phủ, độ ẩm và độ xốp của đất.

Keywords: Rừng trồng keo, rừng trồng quế, thấm nước theo không gian, tốc độ thấm nước của đất, thực vật che phủ

I. INTRODUCTION

Infiltration is the movement downward of water into soil or other materials (Horton, 1933). It is a dynamic and complex process that varies with several soil parameters and is one of the most critical processes in the soil phase of the hydrologic cycle, since infiltration determines the amount of runoff, sediment accumulation and forming of overland flows. Thus, in the area that has high infiltration rate, soil has high infiltration capacity, there will be little or no overland flow (Horton, 1933, Sharma *et al.,* 1980). Hence, surface erosion does not occur or occurs with very low frequency. In this situation, regulated water help protecting the soil and enhancing water quality. In contrast, soil having low infiltration rate and low infiltration capacity leads to more overland flow. During heavy storms, there may occur erosion and overland flows. In the world, there have been many researches were conducted on infiltration since 1930s of 20th century by many researchers (Horton, 1933). Most of researchers have been concerned about factors that affect infiltration rate of soil such as soil, precipitation, vegetation to find out the rules of infiltration (Dien *et al.,* 2006).

Soil factors that control infiltration rate are vegetation cover, root development, and organic content (Dune *et al.,* 1991). In general, soil with great vegetation cover has high infiltration rate. Furthermore, some factors such as soil moisture, bulk density, porosity, permeability, soil texture and structure also have significant effects on infiltration rate. Apparently, different types of soil have different infiltration rates. Soil with low moisture content, high proportion of sand has higher infiltration rate than that of the one with high moisture content and high proportion of clay. Another important factor is precipitation. The characteristics affecting infiltration are depth of storm, storm intensity, and duration (Haws *et al.,* 2004). Infiltration rate is low if storm intensity is high. However, in reality, precipitation is the most difficult factor to control.

In terms of vegetation cover factor, plantation forest is very popular nowadays. Acacia and Cinnamon are two kinds of trees that have high economic value and short harvest duration. Acacia belongs to Fabaceae family, which is believed to have nitrate fixation ability and to make soil become better (May *et al.,* 2014). Thus, it helps to conserve soil, promote vegetation development (Brockwell *et al.,* 2005). In contrast, Cinnamon tree which belongs to Lauraceae family is famous for Cinnamon oil in leaves, barks, and branches. Some hypotheses have supposed that the oil fallen leaves of Cinnamon has bad effects on the development of understory vegetation. The loss of understory vegetation can reduce infiltration capacity of soil and lead to some serious problems such as Horton overland flow and soil erosion. Moreover, in this research, experiment on spatial infiltration was carried out to observe the water movement inside the soil particles under Cinnamon and Acacia trees compared to the reference plot that did not have trees, and to compare temporal and spatial infiltration characteristics of two types of forest to conclude whether this hypothesis is right or not. The measurement of infiltration experiment was conducted by using double - ring infiltrometer and to identify the soil temporal infiltration characteristics of Acacia and Cinnamon plantation forest.

Although many researches on infiltration were conducted in the world but in Viet Nam it still limited. Especially, spatial infiltration is a new experiment being concerned about in recent years with the aim of figuring out the movement of water inside the soil (Chyba *et al.,* 2013). By now, in Vietnam there has been only one survey about this field. As a result, a scientific research had choosen to be carried out with the title: "*infiltration characteristics of soil under Cinnamon and Acacia plantation forest in headwater of Vietnam*". The aims of this research are to find out spatial and temporal infiltration characteristics in two forest types. Basing on the result of this research, the researchers would find out the correlation between Acacia and Cinnamon tree with infiltration rate of soil and the effects of two kinds of trees in process of forming overland flow and erosion.

II. STUDY SITE AND METHODS

2.1. Study site

This study was conducted in Acacia (*Acacia mangium*) and Cinnamon (*Cinnamomum cassia*) plantation forest that located in Mau A town (21° 52′ 41″ N, 104° 41′ 44″ E), Van Yen district, Yen Bai province (Fig. 1). Acacia and Cinnamon forest had area is 15 ha and 12 ha respectively. Both forest hill are quite steeps with slope ranged from 12 to 35° and elevation about 800 m above the sea level. (Fig. 1) This area has average temperature is about 1800 to 2000 mm per year and average relative humidity vary from 81 to 86% and mean annual temperature of study site is approximately 29°C. Both forests have been silvicultured for many years. Although the age of trees was not high (about 2 or 3 years) but they are new generation. Before their growth, many previous generations of Acacia and Cinnamon were planted and harvested so the effects of trees to the soil and environment is undeniable.

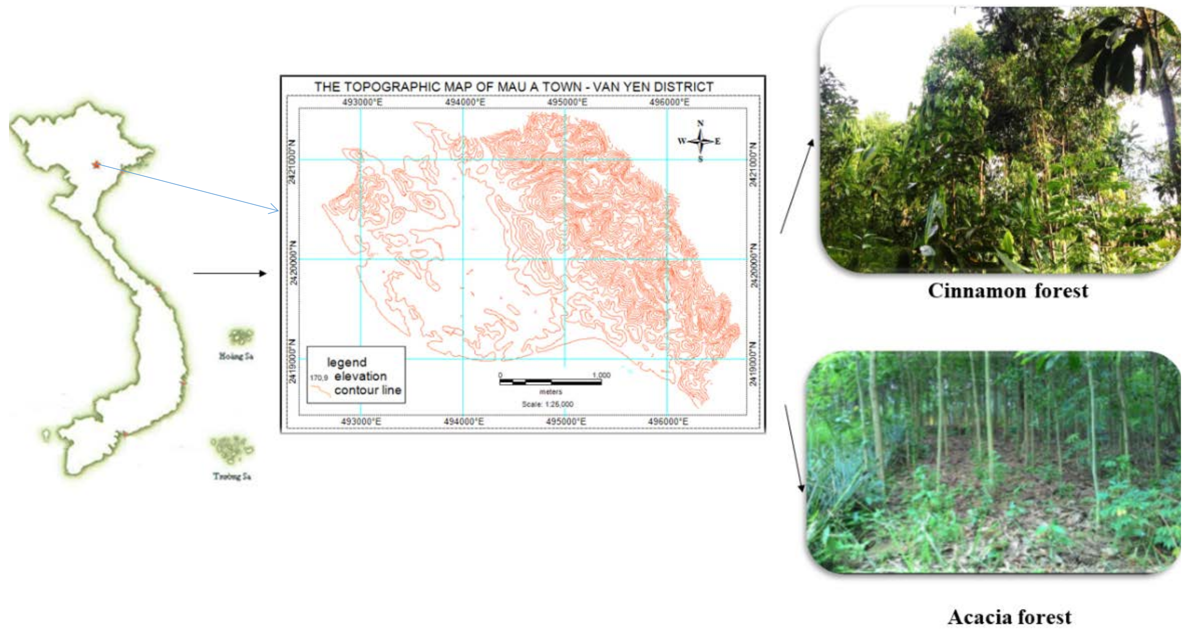

Figure 1. The location of study site

2.2. Methods

Infiltration rate was measured by using double - ring infiltrometer with 20 cm diameter inner ring and 25 cm diameter outer ring. Infiltration measurements were conducted with 5 locations in the uphill part, 5 locations in the middle hill part and 5 times in the downhill part in each kind of forest (Fig. 2). Time to carried the research range from June to September - 2017. On the other hand, understory vegetation cover was also measured by taking pictures. Soil samples were taken at each location where measured infiltration rate by using dry bulk density tube. In addition, other characteristics of soil such as dry bulk density, porosity, soil moisture was analyzed in laboratory. MapInfo software and R - studio were used to process data in order to find the correlation between Infiltration rate and other factors and calculated the area of dye.

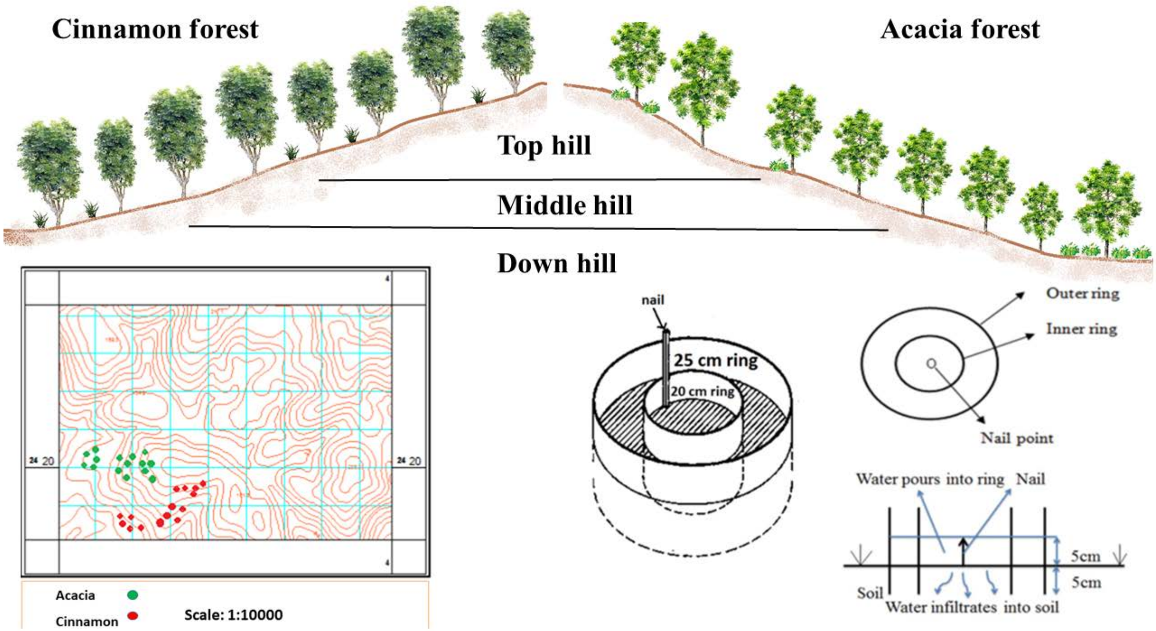

Figure 2. Location and the method used to measure soil infiltration at the study site

The dye tracer experiment was conducted at three plots that have the same specifications like slope, elevation, soil type. The experiment was conducted in 3 plots. The adjacent plot did not has any tree, one plots has an Acacia tree and the other one has a Cinnamon tree (Table 1).

Table 1. Characteristics of trees in two plots

N_0.	Species	Circumference (m)	DBH (cm)		Height (m)	
			EW	SN	Total height	Average height
1	*Cinnamomum cassia*	1	7	6.5	2	1.8
2	*Acacia mangium*	1.2	8	8	2.2	2

The first plot had a Cinnamon tree, the second one had an Acacia tree and the adjacent plot had no tree. Experiments were carried out in 2 days (Fig. 3). On the first day, we poured the dye into three plots, and recorded all the characteristics of the two areas, as the slope, forest floor, canopy cover. On the second day, dye - poured soil will be dug to observe the movement of dye. Four layers of soil is dug with 10 cm space between layers and 1 m deep for every layers. The similar steps were also implemented for the other plot (Fig. 3).

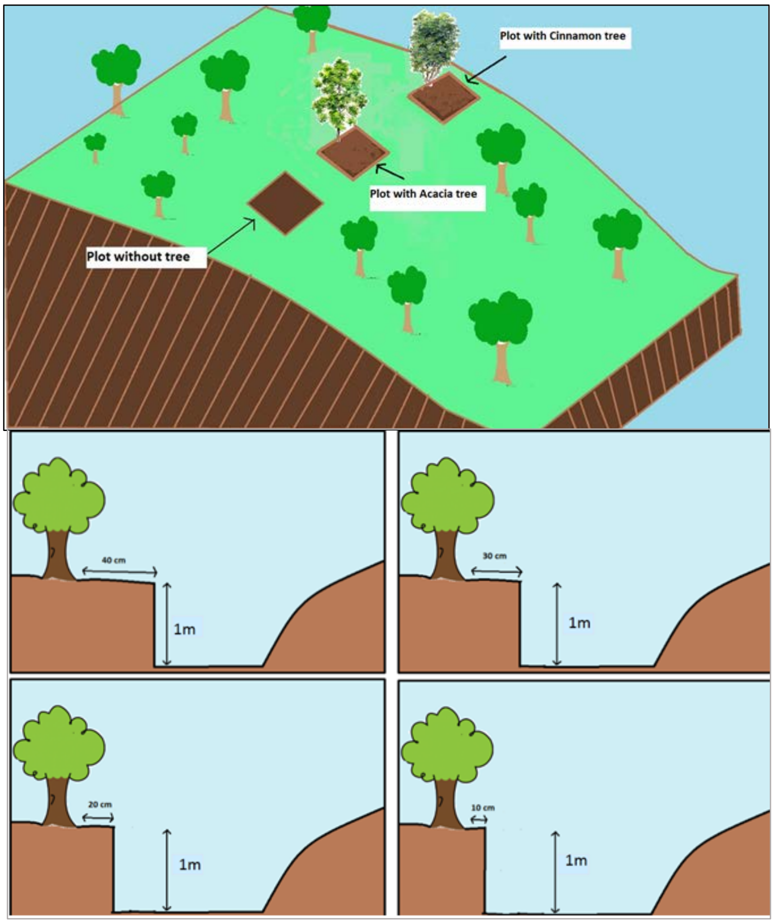

Figure 3. Spatial infiltration measurement using dye tracer at the study site

III. RESULTS AND DISCUSSION

3.1. Temporal infiltration characteristics

3.1.1. Infiltration rate in Acacia and Cinnamon plantation forest

The bottom part of Acacia hill has gentler slope and vegetation cover because the sediment run off the flows usually accumulates in this part and makes soil become better. That is why this part get the highest average infiltration rate compared to middle hill and top hill (Fig. 4). Average initial infiltration rate was 23.8 mm/min, stable infiltration rate was 3.2 mm/min (Fig. 5). Middle hill, and top hill have steep slope and less vegetation cover. Initial infiltration rate of middle hill and top hill was 8.1 and 8.6 mm/min in turn. The stable infiltration rate of middle hill and top hill was 1.3 and 1.6 mm/min in turn (Fig. 5). Thus, the middle and top parts of Acacia forest have more change to occur overland flow and erosion than bottom hill (Fig. 5).

Average initial rate of bottom hill under Cinnamon was 10.6 mm/min and average stable infiltration rate was 2.1 mm/min (Fig. 5). Middle hill had average initial infiltration rate was 8.3 mm/min and stable rate was 0.9 mm/min. 8.1 mm/min was the average initial infiltration rate of top hill and 1.0 was the value of stable rate (Fig. 5). Like Acacia forest, the infiltration rate in bottom of Cinnamon forest tended to be higher than that of middle and top hill (Fig. 5). The reasons are quite the same as each other's, because of gentle slope, better soil and vegetation cover.

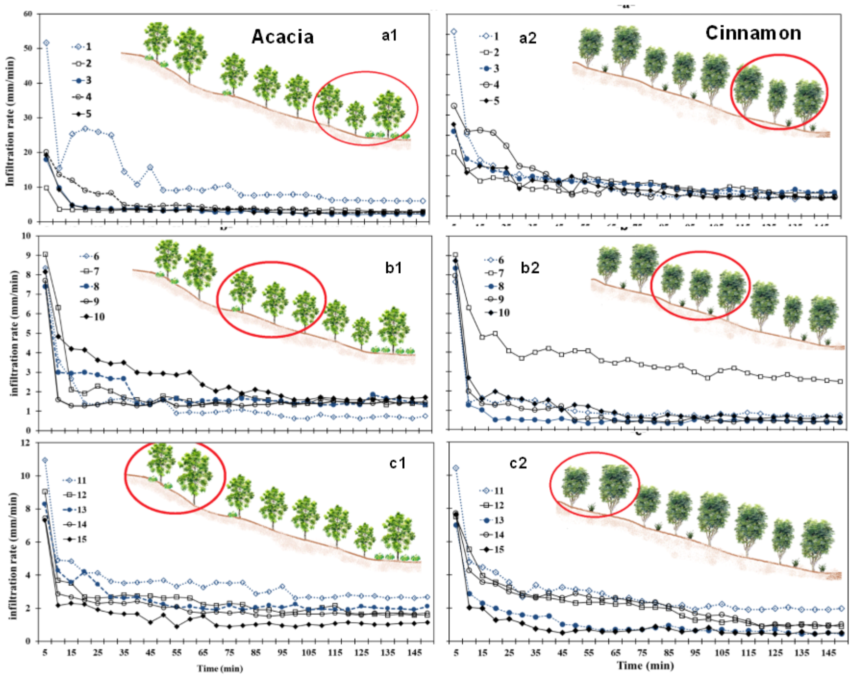

Figure 4. Temporal infiltration characteristics of soil under Acacia plantation (a1 - c1) and Cinnamon plantation (a2 - c2) at different location measurement

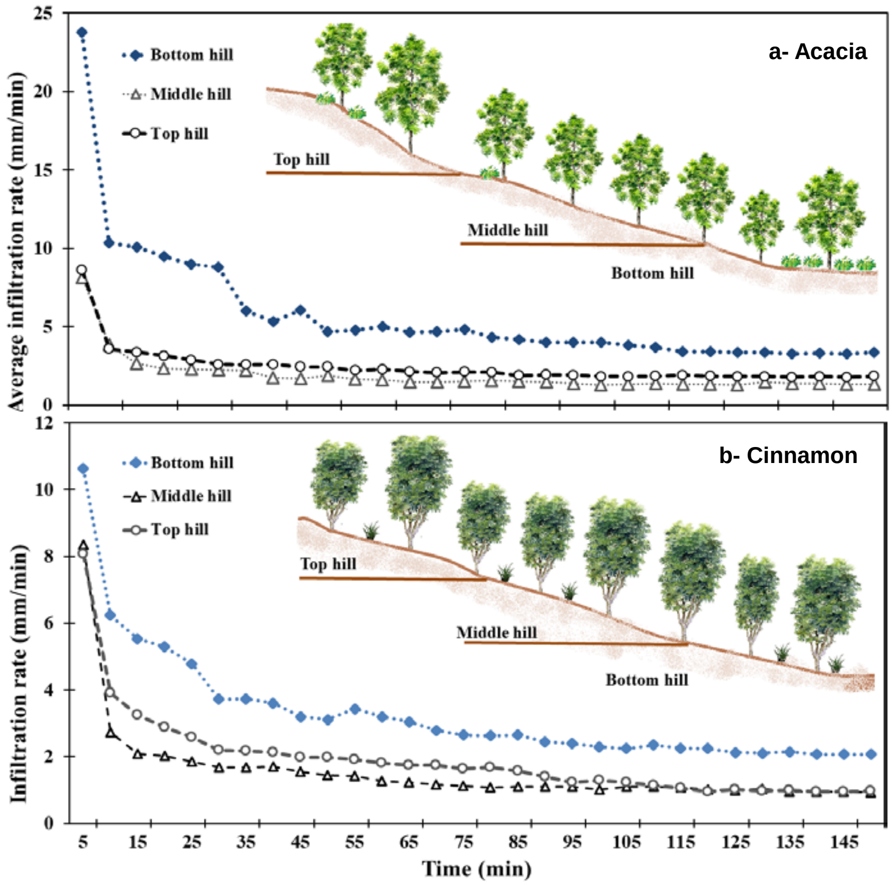

Figure 5. Temporal infiltration characteristics of soil under a_Acacia plantation and b_Cinnamon plantation

The stable infiltration rate of Acacia forest and Cinnamon forest is 2.2 mm/min and 1.3 mm/min respectively. Howerver, the infiltration study of Dung 2016 demonstrated that the stable infiltration rate in various vegetation types was higher (Acacia auriculiformis was 9.7 mm/min, Pinus was 3.6 mm/min and *Acacia mangium* was 2.7 mm/min). The infiltration rate in both kind of forests in our research had low values as the results in Dung 2016 conducted in bare land (1.1 mm/min) and grasses land (1.9 mm/min). The reasons that should be considered for this results including steep slope of study site especially in the top and middle parts (15 to 20^0), and low vegetation cover (average 22% and 44% for Cinnamon and Acacia forest, respecticely). Zaslavsky and Sinai (1981) found that infiltration rate tended to be decreased as the gradient increased.

The infiltration rate of Acacia forest was higher than that of Cinnamon forest, may the oil in leaves and branches of Cinnamon have somehow negative impacts to the soil in decomposition processes. Moreover under canopy of Cinnamon trees, there are less vegetation cover was founded and their development was low. A same hypothesis was also supposed when conducted a research in Huu Lung commune, Lang Son province that oil in leaves of Eucalyptus tree make upper soil layer become drier and prevent the development of understory vegetation. The Eucalyptus trees were planted in swamp in Australia to turn swamp into drier soil for cultivation. Moreover, leaf and bark litter of Eucalyptus contain phytotoxin (which known as a plant herbicide) and caused bad effects to understory vegetation (grasses, shrubs and herbs). A research on oil trees also depicted that leaves of Cinnamon tree contrain tannin which also known as a natural herbicides. Thus, the following researches should consider with some kinds of trees that contain oil in leaves and branches such as *Illicium verum* or *Melaleuca alternifolia.* Like Eucalyptus or Cinnamon, these kind of trees can produce fragant hot oil and contain compounds play as natural herbicides and pesticides which believed has bad effects on soil and vegetation. On other hand, one previous research on Acacia forest at Thinh Duc commune, Thai Nguyen province also showed that infiltration rate in 6 years old Acacia forest had bigger infiltration capacity than 3 years old Acacia forest. Soils under a variety of tree species are often higher in nitrogen, phosphorus and other nutrients and Acacia litter contributes greatly to soil fertility due to the tree's ability to fix atmospheric nitrogen (Dowling *et al.*, 1986). Another research of Mugunga about effects of Acacia species in Songa pasture, Rotkittikhun et al. (2007) also found out that soil under Acacia tree canopy were significantly richer in N as compared to grasses. Hence, the notion that Acacia trees can make soil better is somehow appropriate.

3.1.2. Total water infiltrated in 1 hour

Total water infiltrate in 1 hour of Acacia forest was quite high. The highest was in bottom hill with 238.9 mm/hr and the lowest was 22.8 mm/hr. The bottom part has small change to occur overland flow, middle and top parts have higher change to occur overland flow than bottom parts (Fig. 6a). Total water infiltrate in 1 hour of Cinnamon forest varied from 14.9 to 66.9 mm. The total amount of water was moderate and lower than total amount of water in Acacia forest. Thus, Cinnamon forest are more likely to occur overland flow and erosion than Acacia forest (Fig. 6b). Thus, both kind of forests had the same tendency - higher value of total water infiltrated in 1 hour at the bottom and lower at top and middle parts. Some studies (Weiler *et al.,* 2002) supposed the relationship between slope and infiltration rate. It is obviously the steep slope in middle and top parts of hill have lower infiltration rate due to gravity force. By contrast, in gentle and flat areas, the change to occur overland flows and erosion is not significant.

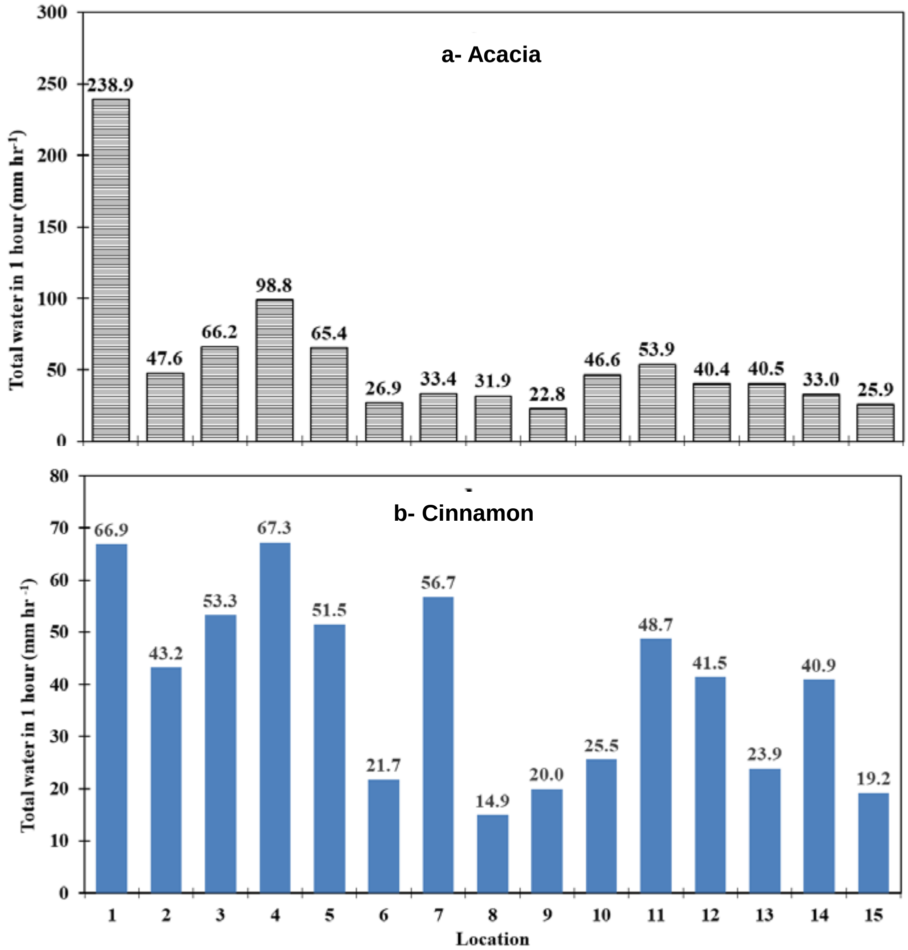

Figure 6. Total water infiltrated in 1 hour of soil under a_Acacia plantation and b_Cinnamon plantation

Comparison with total water infiltrated in 1 hour in other researches, the amount of water in Cinnamon and Acacia forest were very low (3 to 15 times lower). Therefore, it exposed more chances to occur overland flow in both types of forest. The reasons may be caused by high density of tree leading to undeveloped understory vegetation cover and steep slope (Fig. 7). The total water infiltrate in 1 hour implied about chance to occur overland flow during storms. Precipitation is one of the most critical influence factors of infiltration process as well as erosion. In areas that have low precipitation such as temperate zone, the main reason of erosion is by wind but Viet Nam is located in tropical monsoon area so the main driver of erosion is by rain. The characteristics of precipitation that has direct relationship with infiltration rate is rain intensity and duration. Normally, during a storm, initial infiltration rate quite high but then the soil become saturated and water cannot soak into soil. Hence Horton over land flow occur and the lead to following consequences such as erosion, soil loss nutrients and fertility or even flood. Ben - hur and Wakindiki (2004) showed that rainfall intensity had significant effects on the rainfall infiltration, water redistribution in soil, and the microcosmic movement of soil water. High amount of water infiltrate din 1 hour indicated that the chance to occur overland flows is lower and vice versa.

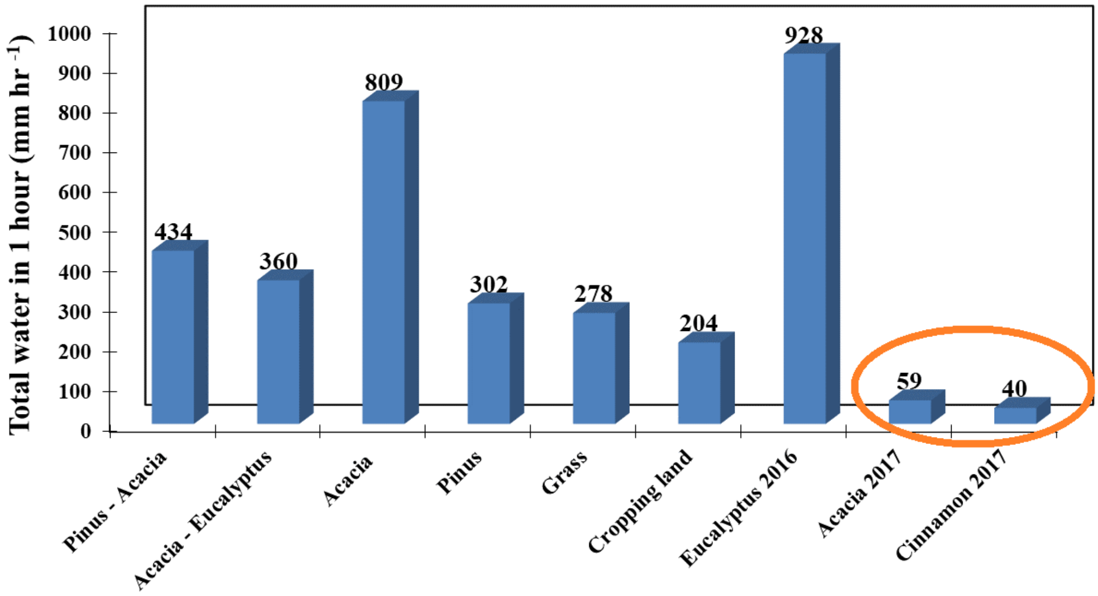

Figure 7. Total water infiltrated in 1 hour of soil at different land cover in the previous studies

3.2. Spatial infiltration characteristics

The first layer was 40 cm far from dye tracer. Plot without tree had the largest dye infiltrated (129 cm^2) with the depth 50 cm, and then soil with Acacia tree (90 cm^2) with the depth 60 cm. Soil with Cinnamon tree had the smallest dye area (56 cm^2) and the lowest depth (20 cm). The dye area in all three plots were quite small. The second layer was 30 cm far from dye tracer area. It was noticed that more dye infiltrated into soil in all three plots. The plot with Cinnamon tree had lower dye area than other plots (182 cm^2) and the deepest point of dye was 30 cm. The dye area of plot with Acacia tree was 199 cm^2 with the depth was 40 cm. The plot with no tree gained the largest dye area (394 cm^2) with the depth of dye was 60 cm. The third layer was 20 cm far from dye tracer. There was more dye being observed in plot without tree, the dye area was 640 cm^2 while the depth was about 70 cm. The plot with Cinnamon tree had dye area of 289 cm^2 and depth of 60 cm, the plot with Acacia tree had the smallest dye area (221 cm^2) and the lowest depth (40 cm). The fourth layer was just 10 cm far from the dye tracer. In this layer, all dye area in three plots were considerable. The plot without tree still got the largest dye infiltrated area of about 1177 cm^2 and the depth of 70 cm. The dye concentrated in areas that have large pores caused by earthworms or grass roots. The plot with Cinnamon tree had the dye area of 400 cm^2 and the depth of 60 cm (Figure 8).

In general, dye tended to infiltrate with the deepest depth and the highest area in reference plot (plot without tree). In plots with trees, dye had tendency to move deeper in plot with a Cinnamon tree and larger in plot with an Acacia tree (Fig. 8). Pervious research which used dye tracer experiment under Eucalyptus plantation forest also showed that dye tend to move deeper in plot without a tree compare to plot with a tree (Dung *et al.*, 2016). Dye tracer experiments provide qualitative pictures to illustrate the flow pathways in soil, they provide better understanding of hydrodynamic aspect of flow processes in soil (Alaoui, 2008). The results in our research illustrated that dye tend to be more concentrated in area with more macrospores.

Root channels, cracks, animal burrows, and aggregate soil structure forming macrosporesin forest soils. Weiler M (2006) also argued about the positive relationship of infiltration rate and pores in the soil by using brilliant blue dye tracer experiment. The depth and area of dye implied that the soil is good or bad. A research of Pagliai (2005) about relationship of porosity and soil quality proposed that decrease of porosity is generally associated with an increase of penetration resistance. The pore shape and size distribution are also strictly related to chemical, biochemical and biological properties, like enzyme activity, and root growth.

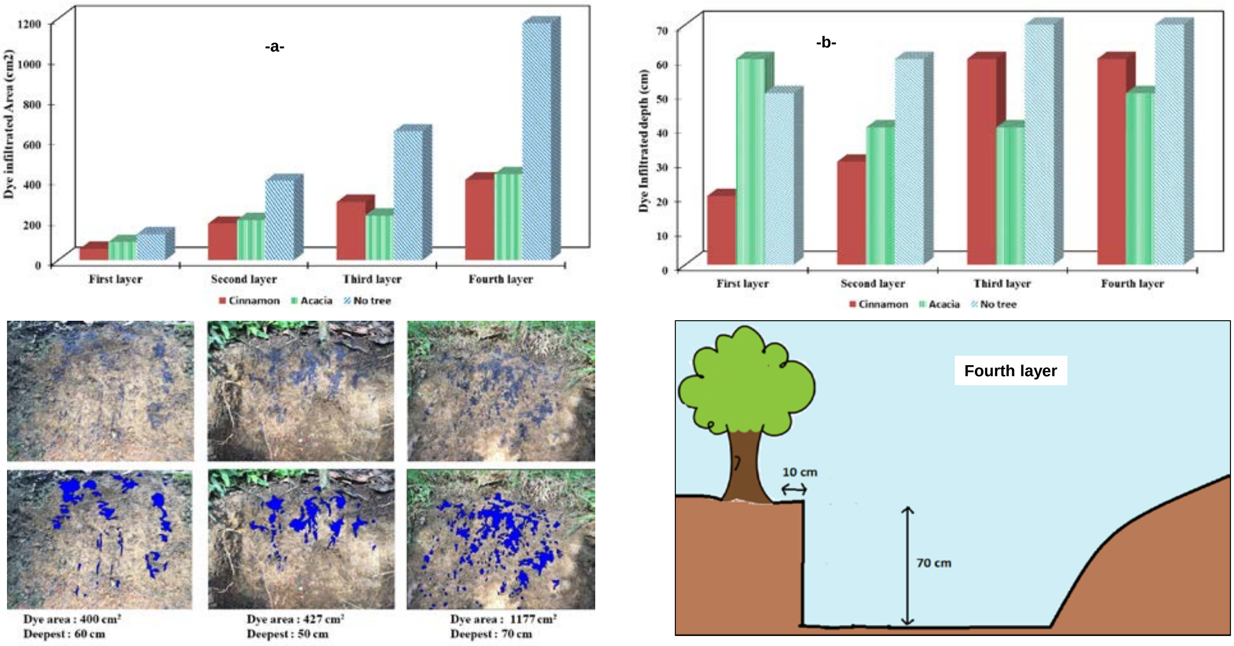

Figure 8. Spatial infiltration of soil under Acacia and Cinnamon plantation at the study site

3.3. Relationship of infiltration rate with other factors

3.3.1. Acacia plantation forest

Porosity of soil in Acacia forest quite high, it varied from 54.1 to 65.6%, average porosity of Acacia forest soil was 59.4% (± 3.41 Standard deviation SD). The soil moisture of Acacia forest varied from 15.4 to 30.5 %, average soil moisture of Acacia forest was 21.1% ± 3.62 (Table. 3.1). Many researchers have indicated that vegetation has a critical impact on reducing rain plash and protecting the soil (Khoa, 1997). Mature, structurally and floristically complex, plant communities, significantly reduce surface erosion and contribute greatly to maintaining slope stability (Menashe *et al.*, 1998). Vegetation in Acacia forest ranged from 30 to 90%, the average vegetation coverage of Acacia forest was 44% (± 14.2 SD). Dry bulk density of Acacia forest ranged from 0.91 to 1.21 g/cm^3, average bulk density of Acacia forest was 1.08 g/cm^3 (± 0.09 SD). Normally, soil with small dry bulk density had high humus content, large porosity, high humidity, and vice versa (USDA Natural Resources Conservation Service). Thus, the proper dry bulk density is less than 1 g/cm^3 and the results of Acacia forest in our research is acceptable for cultivation (Table 2).

Table 2. Influence factors of Acacia forest

Value	Dry bulk density (g/cm^3)	Porosity (%)	Moisture (%)	Vegetation cover (%)	Initial infiltration rate (mm/min)	Stable infiltration rate (mm/min)
Average	1.11	58.0	21.0	44	13.5	2.2
Max	1.21	65.6	30.5	90	51.7	6.1
Min	0.91	54.1	15.4	30	7.3	0.8
SD	0,09	3,41	3,62	14,20	11,47	1,26

SD mean Standard deviation

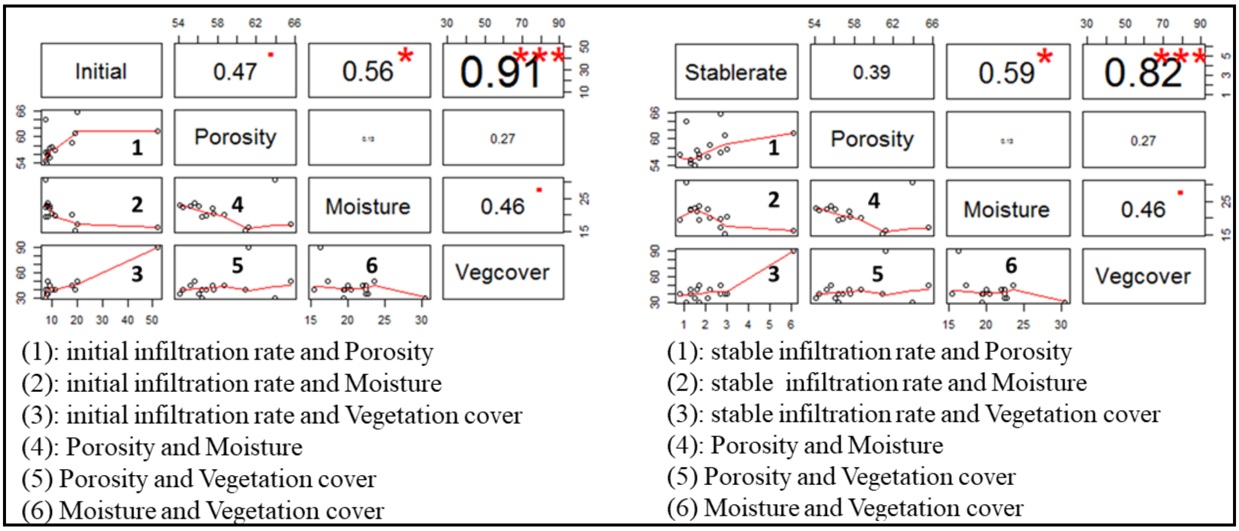

Figure 9. The relationship among Initial and stable infiltration of soil under Acacia plantation with other factors at the study site

The graph illustrates correlation between infiltration rate in Acacia with other factors: Porosity, Soil moisture and Vegetation cover. The initial infiltration rate seems to have strong relationship with Vegetation cover with correlation of 0.91, and then moisture and porosity with correlation 0.56 and 0.47 in turn. The stable infiltration rate also has intensive relationship with Vegetation cover with correlation being equal to 0.82. 0.59 is correlation between soil moisture and stable rate and porosity has correlation 0.39 with stable rate (Fig. 9).

3.3.2. Cinnamon plantation forest

The porosity of Cinnamon forest varied from 53.8 to 66.1%, average porosity of soil in Cinnamon forest was 58.1% (± 3.35 SD), lower than Acacia forest which value was 59.4%. Soil moisture in Cinnamon forest varied from 10.2 to 32.5%, average soil moisture of Cinnamon forest was 23.9% (SD ± 6.01), higher than soil moisture of Acacia forest whose value was 21.1%. Vegetation coverage in Cinnamon forest varied from 0 to 66%, average vegetation coverage was 22%, (SD ± 15.12) - lower than average value of Acacia forest. With such low coverage, the soil may be detached by rain plash and it can lead to erosion or overland flow. The dry bulk density of Cinnamon forest varied from 0.9 to 1.23 g/cm^3 (SD ± 0.09). Average dry bulk density of Cinnamon forest was 1.13 g/cm^3, higher than Acacia forest (Table 3).

Table 3. Influence factors of Cinnamon forest

Value	Dry bulk density (g/cm^3)	Porosity (%)	Moisture (%)	Vegetation cover (%)	Initial infiltration rate (mm/min)	Stable infiltration rate (mm/min)
Average	1.08	59.4	23.9	20	9.0	1.2
Max	1.23	66.1	32.5	60	18.3	2.5
Min	0.90	53.7	10.2	0	6.4	0.4
SD	0,09	3,35	6,10	15,12	2,83	0,79

The correlation between initial and stable infiltration rate with affecting factors in Cinnamon forest is illustrated by this graph. The initial infiltration rate has strong relationship with vegetation cover and porosity with correlation is 0.90 and 0.69 in responsibility. Correlation with soil moisture is 0.49. The stable infiltration rate has strong relationship with moisture with correlation is 0.66. Besides, the correlation between stable rate with vegetation cover and moisture are 0.34 and 0.35 respectively. It means that the relationship is not very significant (Fig. 10).

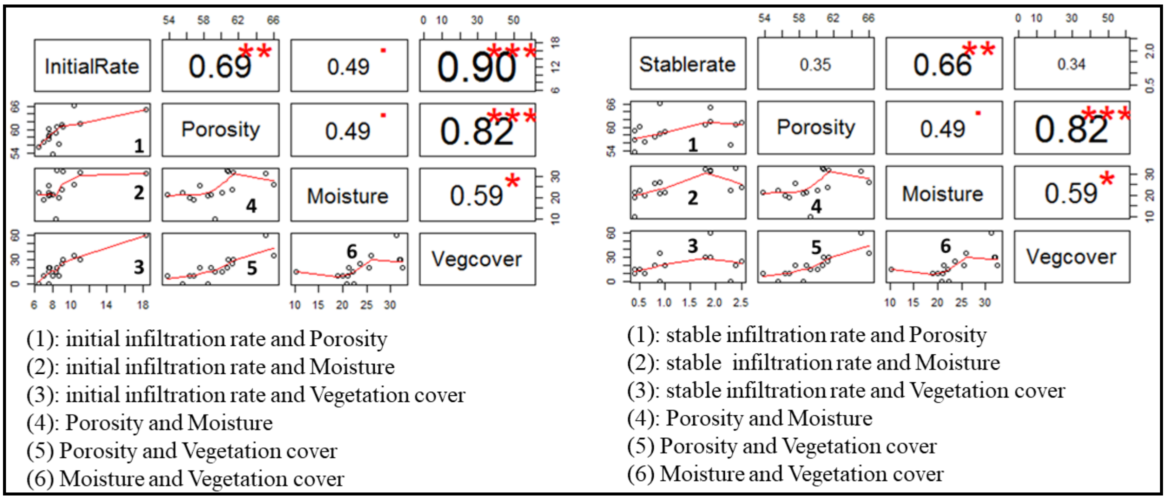

Figure 10. The relationship among Initial and stable infiltration of soil under Cinnamon plantation with other factors at the study site

The average rainfall of study site in one year is very high (1800 to 2000 mm/yr) especially in summer and fall. The calculated data showed that total water infiltrate in 1 hour of Acacia forest varied from 22.8 to 238.9 mm/hour and average value was 58.2 mm/hour. Cinnamon forest had total water infiltrate in 1 hour varied from 14.9 to 66.9 mm/hour, average value was 39.7 mm/hour. Thus, both forests show the change to occur overland flow, especially in rainy season months (from May to September) in which the amount of rainfall is quite high with strong frequency. Hence, some methods to grow understory vegetation, add nutrients via tillage should be emphasized. The result of many studies (Onda and Yukawa, 1995) and this study implied that the factor has the most influence to infiltration rate is vegetation cover. When plants cover the soil surface, it will minimize the impact of raindrops and reduce detachment effects. On the other hand, soil with abundant understory vegetation cover, during storms rain will follow the leaves and branches flowing through the trunks and infiltrate into soil. The deep root system of the tree facilitates the growth permeability. Hence, to improve infiltration capacity of soil, understory vegetation should be concentrated because its effects and easy to control. Some kind of grass such as Vetiver (which has 3 m vertical depth roots system and suitable to multiple soil types) can help to enhance soil quality should be well study and applied (Rotkittikhun *et al.,* 2007).

IV. CONCLUSION

For determining the characteristics of infiltration, double - ring infiltrometer was used to measure temporal infiltration characteristics and dye tracer experiments was applied for spatial infiltration characteristics. In addition, some software such as MapInfo, Microsoft Excel, and R - studio successfully help in analyzing data. Some general conclusions were proposed including: (1) Both soil in Acacia and Cinnamon forest has infiltration rate tend to decrease over time. Initial and Stable infiltration rate of Acacia forest is higher than that of Cinnamon forest. In additional, total water infiltrate in 1 hour of Acacia forest is also higher than ones of Cinnamon forest (59 and 40 mm hr^{-1}); (2) Dye tend to go deeper and dye area bigger in plot has no tree (only grass). In plot has tree, dye soak deeper in plot with Cinnamon tree, and total dye area infiltrated in soil of plot has Acacia tree is larger than that of Cinnamon tree. The morphology of Cinnamon tree depicted that the root system of Cinnamon tree is very long and thrive deeply into soil, small roots spread across each other and they absorb water stronger than Acacia tree; (3) Initial and Stable infiltration rate in Acacia forest has strong positive relationship with vegetation cover and moderate relationship with soil moisture. Initial infiltration rate in Cinnamon forest has strong positive relationship with vegetation cover and moderate relationship with soil moisture. Stable infiltration rate in Cinnamon forest has moderate positive relationship with soil moisture.

Some studies are recommended to fill the gaps observed in this study. These include, using rain stimulation for infiltration measurement to better estimate the infiltration rate in reality by considering rain drop impacts, analyzing other feature of soils such as soil textures, cogitating other vegetation cover especially trees kinds which contain oil in leaves and branches.

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REFERENCES

1. Alaoui A, Goetz B, 2008, Dye tracer and infiltration experiments to investigate macrospore flow, Soil Science Section, Geoderma (Amsterdam) Journal, vol. 144,, pp. 279 - 286
2. Ben - Hur M, Wakindiki I.C, 2004, Soil mineralogy and slope effects on infiltration, interrill erosion, and slope factor, Water Resour. Res., vol 40, issue 3, pp. 34 - 42
3. Brockwell J, Suzette DS, Alison CJ and Waayers M, 2005, Nitrogen Fixation in Acacias: an Untapped Resource for Sustainable Plantations, Farm Forestry and Land Reclamation, pp.132 - 145
4. Chyba J, Kroulik M, Lev J and Kumhala F, 2013, Influence of soil cultivation and farm machinery passes on water preferential flow using brilliant blue dye tracer, Agronomy Research 2013 Vol.11, pp. 25 - 30

5. Dien PV. 2006. Research on water holding capacity in some types of vegetation cover in Hoa Binh Hydropower Plant. Doctorate in Agriculture, VietNam National University of Forestry.

6. Dowling A.J,Webb A.A, and Scanlan J.C,1986, Surface soil chemical and physical patterns in a brigalow - Dawson gum forest, central Queensland, Australian Journal of Ecology, vol. 11, pp. 45 - 47

7. Dune T, Zhang W, Aubry BF. 1991. Effects of rainfall, vegetation and microtopographyon infiltration and runoff. Water Resources Res, vol 46, issue 7, pp. 67 - 74

8. Dung BX, Linh PT, Thuy TT, Linh NTM, Kha LN, Trang PTT, 2016, Infiltration characteristics of soil under Eucalyptus plantation forest in headwater of Viet Nam, Forestry Science and Technology magazine vol 2 (2017), pp. 63 - 74

9. Haws NW, Liu B, Boast CW, Rao PSC, Franzmeier DP, 2004, Spatial variability and measurement scale of infiltration rate on an agricultural landscape. Soil Science Society of America Journal vol 68, pp. 1818 - 1826

10. Horton RE, 1933. The role of infiltration in the hydrological cycle. Transactions, American Geophysical Union 14, pp. 446 - 460

11. Onda Y, Yukawa N. 1995. The influence of understories on the infiltration capacities of Chamaecyparis obtusa plantation, Journal of Japanese Forestry Society vol 77, pp. 399 - 407

12. Pagliai M, Vignozzi N,2004, The Soil Pore System as an Indicator of Soil Quality, Soil and Tillage Research vol 79, pp. 131 - 143

13. Rotkittikhun P, Chaiyarat R, Kruatrechue M, Pokethitiyook M, Baker A, 2007, Effects of soil amendment on growh and lead accumulation in grasses *Vetiveria zizanioides* and *Thysanolaena maxima* grow in lead - contaminated soil, School of Botany Journal vol 66, pp. 45 - 53

14. Sharma ML, Gander GA, Hunt CG, 1980, Spatial variability of infiltration in a watershed. Journal of Hydrology vol 45, pp. 101 - 122

15. Weiler MH, McGuire KJ, and McDonnell JJ, 2002, Infiltration Dye Experiment, Journal of Hydrology vol 14,pp. 6 - 8

16. Zaslavsky D, and Sinai G, 1981, Surface hydrology: I-Flow in sloping, layered soil, Water Resource Research vol 42, pp. 142 - 149.

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