TEMPORAL INFILTRATION CHARACTERISTICS OF SOIL UNDER DIFFERENT AGES OF ACACIA PLANTATION IN LUONG SON HEADWATER, HOA BINH, VIETNAM

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SUMMARY

To determine the temporal infiltration characteristics of soil under different ages of Acacia plantation forest in a headwater of Hoa Binh Province, Vietnam, the field experiment for infiltration measurement by double ring method was established at different vegetation cover conditions (including bare land after burning, 1-year-old Acacia plantation, 2-year-old Acacia plantation, 3-year-old Acacia plantation, 4-year-old Acacia plantation and 5-year-old Acacia plantation) from July to September 2019. Potential factors affecting on soil infiltration were determined, including soil physical and vegetation characteristics of Acacia plantation. The main findings included: (1) Temporal infiltration rate in different ages of Acacia plantation tend to be decreased with increasing of ages. Both initial and stable rate are increased from bare land (initial rate: 7.9mm/min; stable rate: 1.2mm/min) to 5-year-old of Acacia plantation (initial rate: 14.2mm/min; stable rate: 2.5mm/min); (2) Temporal infiltration rate has a strong relationship with soil physical characteristics and understory vegetation cover. Initial infiltration rate of soil has a strong relationship with understory vegetation (R=0.84), porosity (R=0.87) and soil moisture (R=-0.87), but do not have significant relationship with dry bulk density (R=-0.22). While stable rate has a strong relationship with understory vegetation (R=0.70), it has a moderate relationship with porosity (R=0.53), dry bulk density (R=-0.51) and soil moisture (R=-0.44); (3) The findings implied that infiltration rate under Acacia plantation forest has been higher than bare land after burning. It can be explained that the root and understory vegetation have important impacts on infiltration characteristics of soil.

Keywords: Acacia plantation, bare land after burning, infiltration, headwater, vegetation cover conditions.

1. INTRODUCTION

Infiltration is the process by which water on the ground surface enter the soil or other materials and it is commonly used in both the field of hydrology and soil science in term of watershed management (Horton, 1933). The characteristics of infiltration can determine the establishment of surface and subsurface flow, which can control peak flow rates, runoff volumes, soil erosion and plant-available water capacity. In terms of the location which has higher infiltration rate, there is no chance or little of generating overland flow (Horton, 1933). Therefore, the frequency of phenomenon of soil erosion is low or even not occurring if the infiltration of soil is high and soil will absorb water rapidly. On the other hand, there will be frequently degrading issues, including landslide and soil erosion caused by overland flow and low infiltration capacity (Hai, 1993).

There are number of factors affecting infiltration rate of soil, such as precipitation characteristics, soil characteristics, terrain and vegetation and combine the amount of rain, intensity and frequency of rainfall (Dien and Tuan, 2006), especially the role of vegetation in improving the infiltration rate of soil (Hiraoka, 2010). With the respect to heavy rainfall and intensity of rainfall, the infiltration of the soil witnessed the trend to be small. Regarding precipitation and intensity of rainy season, the infiltration capacity will be higher (Haws et al., 2014). Soil factors that control infiltration rate are vegetation cover, root development, organic content (Dune et al., 1991). Additionally, some factors such as soil moisture, bulk density, porosity, soil texture and structure also have significant effects on infiltration rate. Among three factors that influence the infiltration of soil, we can manage two factors including soil characteristics and vegetation. Therefore, management approaches are also concentrated on these two factors. Previous studies on surface runoff and soil erosion by Lung and Hai (1997) show that the thicker the forest is, the more water is absorbed into the soil and turned into the underground flow. The authors affirmed that in Vietnam, forest trees are capable of consuming a large amount of water. At the same time, affirmation of forest land is also a factor that influences the infiltration velocity. Differences in soil properties, mainly the

physical properties of soils, will directly affect the soil's infiltration

In terms of vegetation cover factor, plantation forest is very popular these days. In Vietnam, about 24% of the forest area is planted forest, in which Acacia Mangium is a popular crop. Acacia Mangium Wild., also known as Mangium, is a species of indigenous plants to Northern Queensland (Australia), found in Indonesia's Irian Jaya, Maluku (Doran and Skelton, 1982). This is a fast-growing species, which is widely used for various purposes such as timber, firewood, agroforestry, land improvement (Turnbull et al., 1983). Acacia belong to Fabaceae family, which is believed to have nitrate fixation ability and make soil become better. Thus it helps to conserve soil, promote vegetation development (Brockwell et al., 2005). Some hypotheses have supposed that the oil fallen leaves of Acacia Mangium has negative effects on understory vegetation. The loss of understory vegetation can reduce infiltration capacity of soil and lead to the increase of overland flow and soil erosion. Therefore, in this research, experiment on infiltration can observe the infiltration capacity of soil under bare land and five different ages of Acacia plantation to conclude whether this hypothesis is right or not. These days, the research on infiltration in Vietnam is limited. Therefore, the study on *Temporal infiltration characteristics of soil at different ages of Acacia plantation forest in a headwater of Hoa Binh, Vietnam* is necessary. Based on the results of the research, the interaction between the ages of Acacia Mangium and infiltration rate of soil will be determined, then some suggestions will be provided to get effective watershed management in the headwater of Hoa Binh, Vietnam, especially in soil and water resources management.

2. RESEARCH METHODOLOGY

2.1. Study site

This research was conducted in the headwater of Luong Son district, Hoa Binh Province (Fig. 1). Luong Son climate is tropical monsoon with two distinct seasons: the winter is cold and little rain, and the summer is hot and much precipitation. Annual precipitation is from 1,520.7 to 2,255.6 mm/year. Mean annual temperature is from 22.9 to 23.3 ^{o}C. In Hoa Binh province, Acacia Mangium is one of the most plants which occur about 92% amount of forest areas.

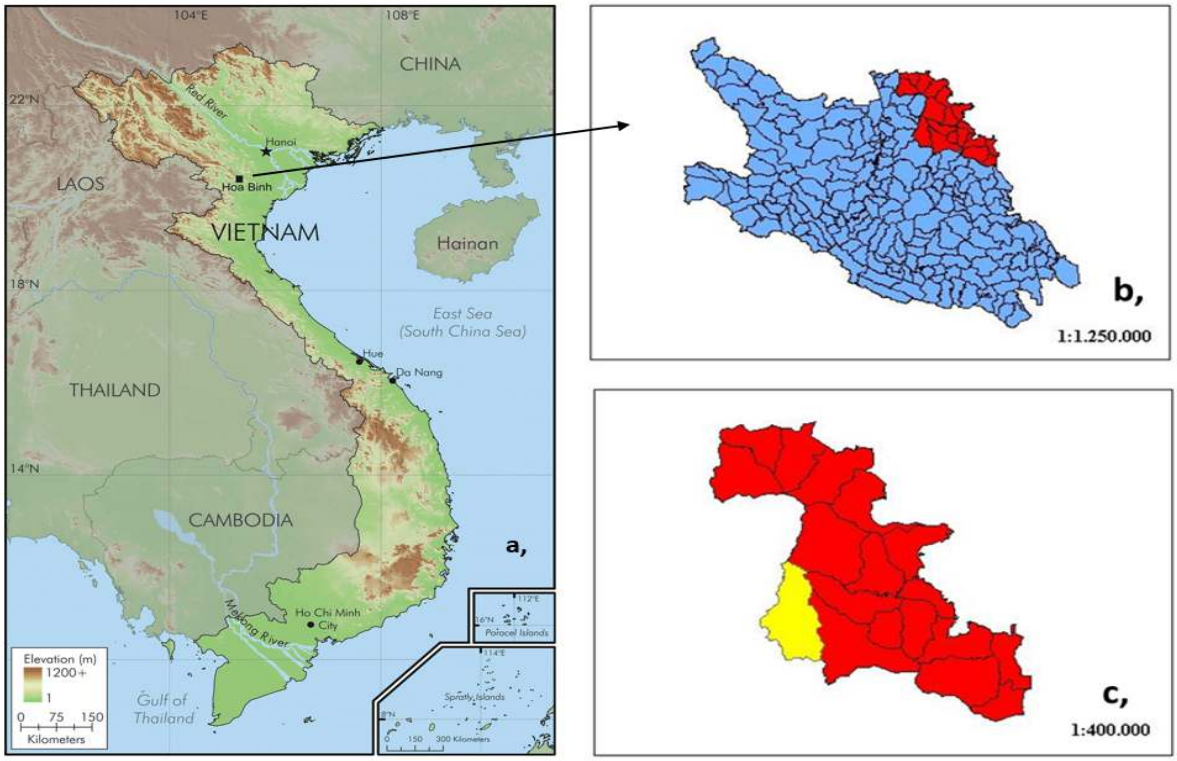

Figure 1. The location of study site: a_Hoa Binh Province on Vietnam map; b_Luong Son District; c_Truong Son Commune of study site

2.2. Method

Temporal infiltration rate was measured by using double-ring infiltrometer with the diameter of inner and outer ring are 20 cm and 25 cm, respectively (Fig. 2b). Infiltration measurements were conducted with 6 conditions, namely, bare land after burning; 1-year-old Acacia plantation (DBH 1.1 cm; height 0.8 m); 2-year-old Acacia plantation (DBH 3.6 cm; height 1.7 m); 3-year-old Acacia plantation (DBH 4.2 cm; height 6.5 m); 4-year-old Acacia plantation (DBH 8.6 cm; height 8.6 m); and 5-year-old Acacia plantation (DBH 10.2 cm; height 9.6 m), from July to September 2019. The slope of six plots range from 23 - 26^o (Table 1).

Firstly, drive the ring into the ground up to the three-inch mark. The best way to do this is to pound a small block of wood laying across the ring with a mallet. Firm the soil around the inside of the ring. Secondly, put a nail in to the ground of the center of the ring, the nail has the length of 5 cm after plugged into the soil. In general, the water level was kept at or above 5 cm depth. Thirdly, using a cylinder to pour the water slowly into the ring of 5 cm initial water above the topsoil, with 10 cm nail. Record in each minute how many water infiltrates. Measuring 5 times in each condition, each time was measured about 95 - 100 minutes to reach the stable rate.

Regarding impacting factors, understory vegetation cover was inventoried by using the Canopy Cover Free application. To soil properties measurement, soil samples were collected by using a bulk density tube. Then, the IBM SPSS Statistics 23 and R-studio software was used to check the median and outlier range of data and to determine the correlation between the infiltration rate and impacting factors.

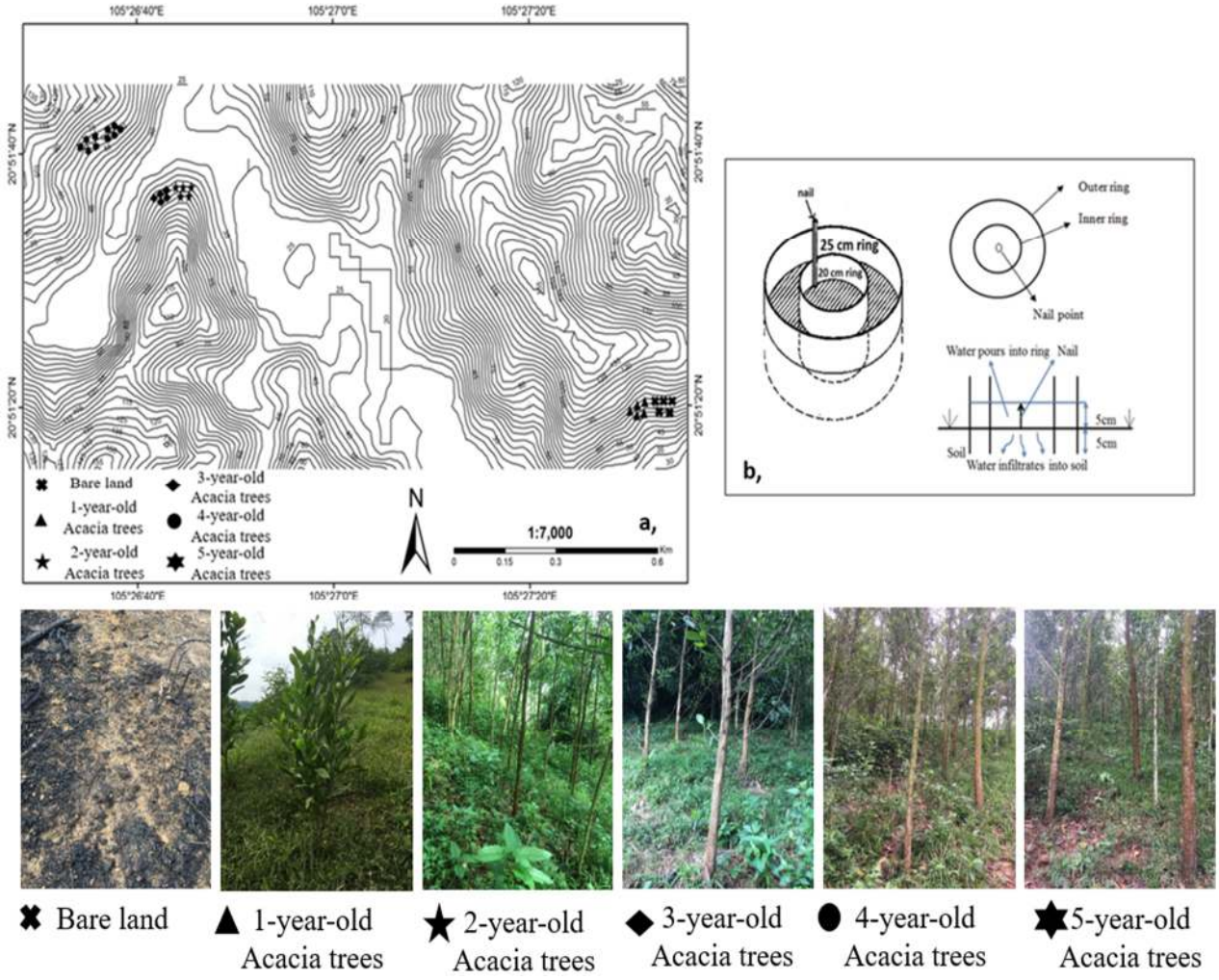

Figure 2. a) Location at the study site; b) The method used to measure soil infiltration

Table 1. Soil properties and characteristics of experiment plots

Parameters		Bare land	1-year-old Acacia	2-year-old Acacia	3-year-old Acacia	4-year-old Acacia	5-year-old Acacia
Dry Bulk Density (g/m^3)	Max	1.56	1.43	1.38	1.54	1.29	1.35
	Min	1.30	1.19	1.00	1.03	0.85	0.74
	Mean	1.46	1.31	1.22	1.36	1.13	1.19
	SD	0.05	0.04	0.07	0.09	0.07	0.11
Porosity (%)	Max	37	46	49	51	55	56
	Min	28	35	38	37	35	36
	Mean	33	42	44	46	44	46
	SD	2	2	2	2	3	3
Soil Moisture (%)	Max	34.9	29.9	27.9	27.0	28.3	31.1
	Min	31.0	12.3	14.7	12.1	12.7	11.7
	Mean	32.0	20.7	20.0	17.2	19.5	17.7
	SD	0.7	3.8	2.8	2.8	3.4	3.5
Understory vegetation (%)	Max	0	56.2	55.6	57.4	57.2	59.9
	Min	0	45.8	35.6	45.9	48.4	51.9
	Mean	0	50.5	46.0	52.6	53.4	56.8
	SD	0	1.7	3.5	2.0	1.9	1.4
DBH of Acacia (cm)	Mean	0	1.1	3.6	4.2	8.6	10.2
Height of Acacia (m)	Mean	0	0.8	1.7	6.5	8.6	9.6
Slope (º)	Mean	23	23	24	25	24	26

3. RESULTS AND DISCUSSION

3.1. Temporal soil infiltration characteristics at different ages of Acacia plantation

3.1.1. Soil infiltration rates under different ages of Acacia plantation

Infiltration rate was the highest under 5-year-old Acacia plantation (14.2 - 19.1 mm/min of initial infiltration rate and 2.5 - 3.3 mm/min of stable infiltration). The infiltration rates decrease when the age of trees decrease. Respectively, under 4-year-old Acacia plantation (13.8 - 18.6 mm/min of initial infiltration rate and 2.1 - 2.9 mm/min of stable infiltration); under 3-year-old Acacia plantation (14.0 - 18.1 mm/min of initial infiltration rate and 1.8 - 2.6 mm/min of stable infiltration); under 2-year-old Acacia plantation (14.2 - 17.9 mm/min of initial infiltration rate and 1.8 - 2.4 mm/min of stable infiltration), 1-year-old Acacia plantation (12.3 - 17.4 mm/min of initial infiltration rate and 1.4 - 2.3 mm/min of stable infiltration). The lowest infiltration rate was under bare land (7.1 - 8.7 mm/min of initial infiltration rate and 1.2 - 1.6 mm/min of stable infiltration) (Fig. 3). The potential reason might be the difference in understory vegetation cover and crown canopy with different ages of Acacia plantation. Since the stable infiltration rate tends to have a positive relationship with porosity of soil (Dung, 2016).

With t-test, the mean of initial rate and stable rate at bare land is significant different with that at other Acacia plantation covers with the p-value ≤ 0.01. It also was the significant difference between the mean value of initial rate at bare land & other Acacia plantation forests ($p=0.00$); and between 4-year and 5-year Acacia plantation forest ($p=0.01$). However, the mean number of initial rate at the other pairs including 1-year & 2-year ($p=0.04$); 1-year & 3-year ($p=0.21$); 1-year & 4-year ($p=0.26$), 1-year & 5-year ($p=0.15$); 2-year &3-year ($p=0.32$); 2-year & 4-year ($p=0.42$); 2-year & 5-year ($p=0.25$); 3-year & 4-year ($p=0.25$); 3-year & 5-year ($p=0.39$) is not significantly different. While most of paired means of stable rate at different ages of Acacia tree is considerably divergent with the p-value ≤ 0.03, there is not a significant difference between 1-year & 2-year ($p=0.19$); and between 3-year & 4-year ($p=0.09$) (Fig. 4

and Table 2). The infiltration characteristics between two to four different ages of Acacia trees are more significantly different than those of one-year pairs of Acacia trees. It might be because of different in canopy cover and little fall from leaves and branches of Acacia trees that had somehow impacts to the soil infiltration.

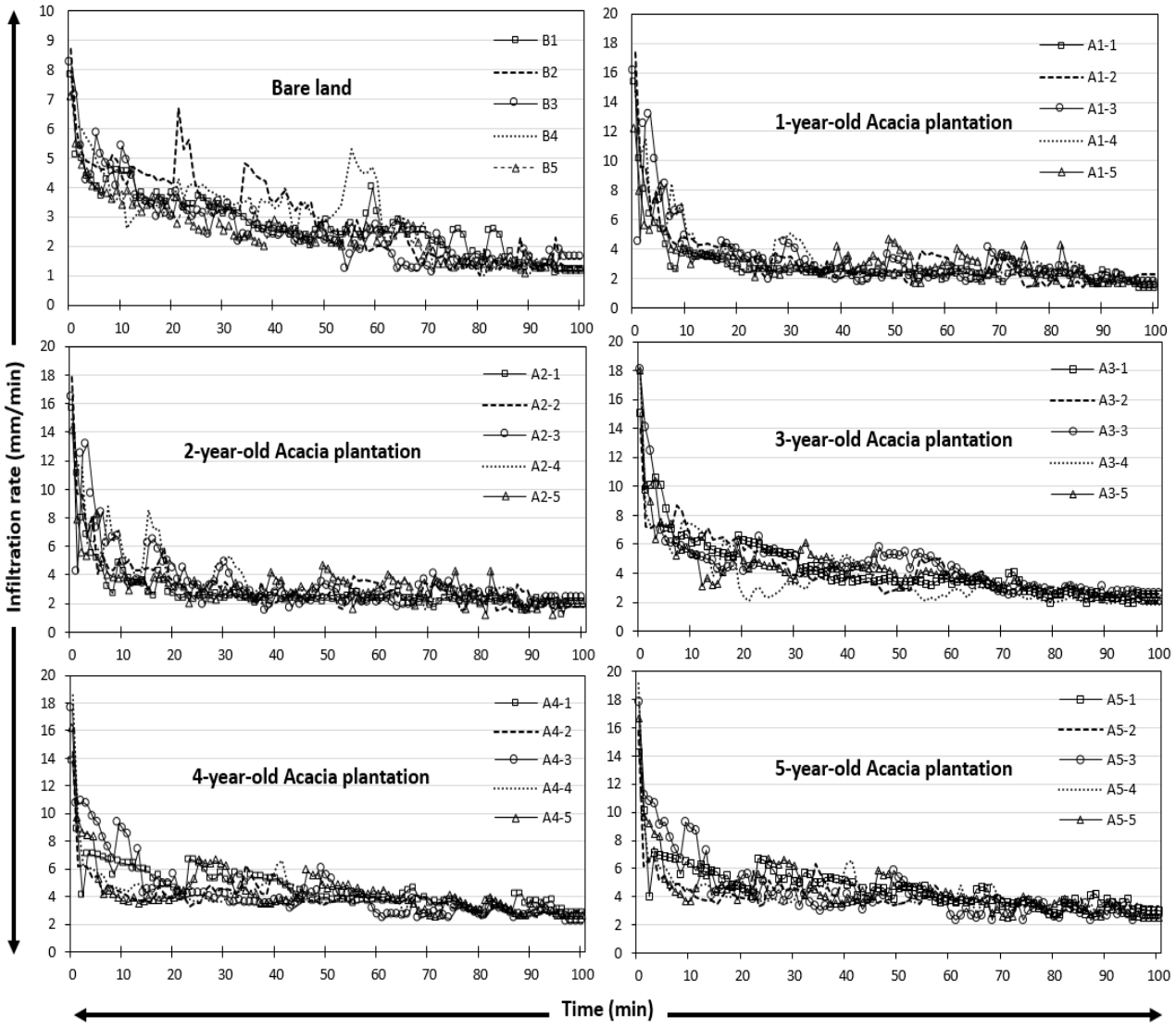

Figure 3. Temporal infiltration rate of soil under bare land and different ages of Acacia plantation

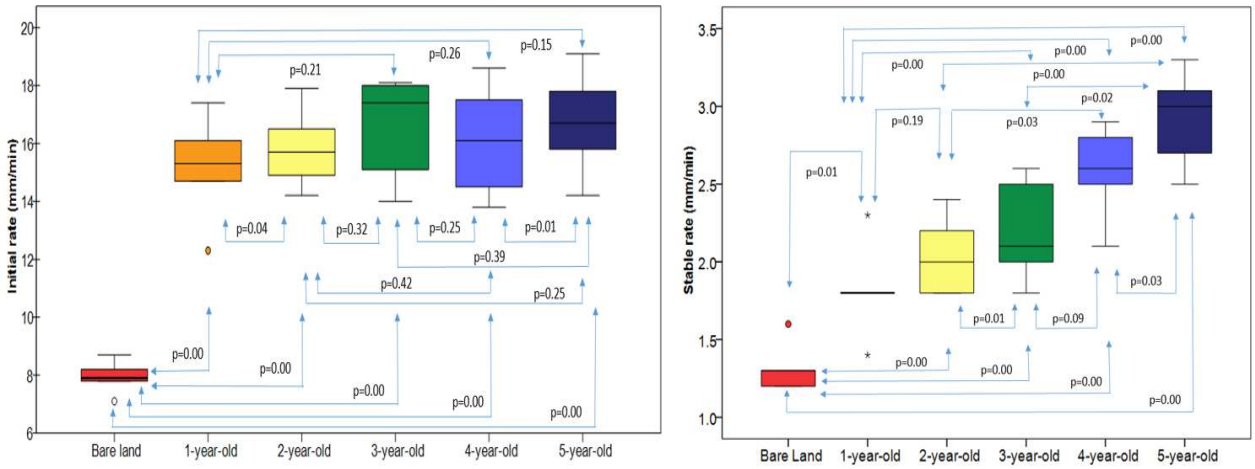

Figure 4. Box-plot results of initial and stable infiltration rate of 6 different condition covers

Table 2. Summary of the paired mean comparison of initial rate and stable rate at different ages of Acacia plantation

Correlation	Initial rate			Stable rate		
	t	df	p	t	df	p
Bare land & 1-year-old	-12.215	4	0.00	-3.371	4	0.01
Bare land & 2-year-old	-19.448	4	0.00	-7.426	4	0.00
Bare land & 3-year-old	-8.5021	4	0.00	-6.487	4	0.00
Bare land & 4-year-old	-8.4407	4	0.00	-6.178	4	0.00
Bare land & 5-year-old	9.91347	4	0.00	9.396	4	0.00
1-year-old & 2-year-old	-2.2016	4	0.04	-0.961	4	0.19
1-year-old & 3-year-old	-0.8955	4	0.21	-6.487	4	0.00
1-year-old & 4-year-old	-0.6833	4	0.26	-4.209	4	0.00
1-year-old & 5-year-old	-1.2106	4	0.15	-6.957	4	0.00
2-year-old & 3-year-old	-0.5033	4	0.32	-3.138	4	0.01
2-year-old & 4-year-old	-0.202	4	0.42	-2.355	4	0.03
2-year-old & 5-year-old	-0.7389	4	0.25	-3.844	4	0.00
3-year-old & 4-year-old	0.739	4	0.25	-1.572	4	0.09
3-year-old & 5-year-old	-0.3064	4	0.39	-2.930	4	0.02
4-year-old & 5-year-old	-3.4989	4	0.01	-2.563	4	0.03

Infiltration rate at bare land and five different ages Acacia plantation have a similar trend of decrease over time. Infiltration rate of the soil follows the law of the highest value at the beginning and decreases until reaching the stable rate with the oscillation range of the 95th-100th minute. Initial and stable rate in five locations of bare land is lowest (about 7.9 mm/min and 1.3 mm/min, respectively), that of Acacia plantation forest intend to increase when the age of tree is older. The highest initial and stable infiltration rate (about 19.1 mm/min and 3.3 mm/min, respectively) is under 5-year-old Acacia tree (Fig. 5).

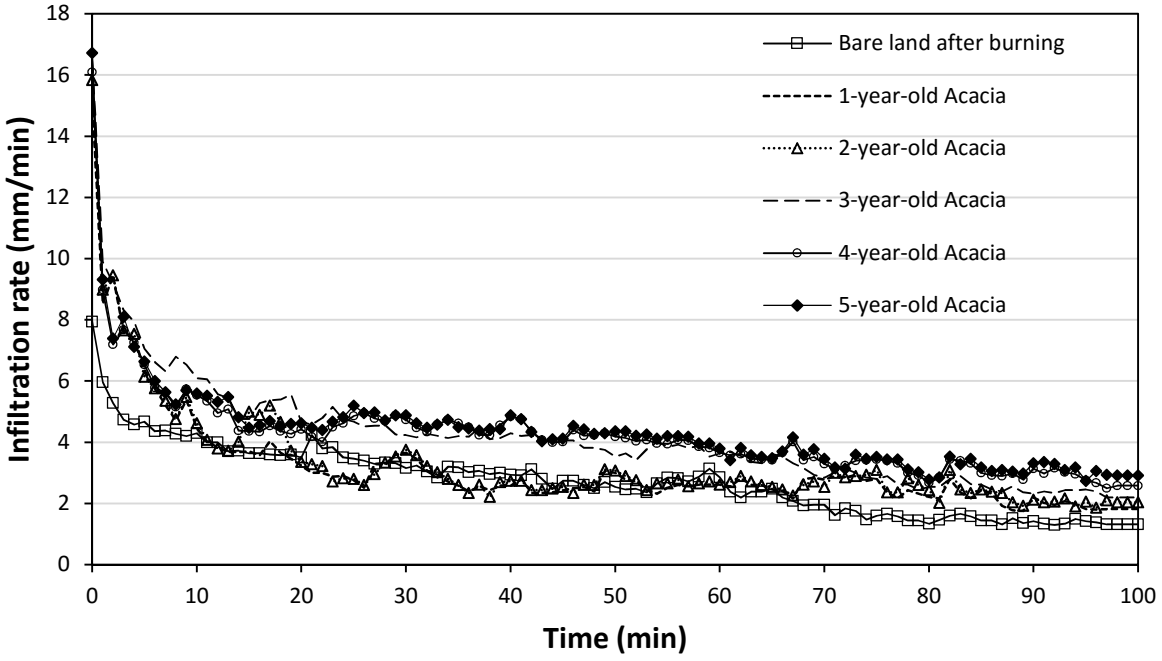

Figure 5. Average infiltration rate at different ages Acacia plantation

Comparison with the research of Horton, 1933, the curves of infiltration rate of bare land, 1-year-old, 2-year-old 3-year-old, 4-year-old and 5-year-old of Acacia plantation tend to be similar to the typical curve for wet able soil. This shows that the infiltration capacity in study site is quite good and has the ability to protect and regulate water well, the surface flow and

soil erosion can be controlled effectively.

The infiltration rate is higher at the beginning and decreases over time because soil is still dry and gets wetter later. The distance between the soil particles of dry soil is large, so when water is poured into the ring, the water is permeable quickly into soil. By seconds, the holes and pores in the soil is saturated, the swelling of the soil particles reduced the size of holes so the infiltration rate decreases over time. The infiltration rate will reach stable level when the soil layer is completely saturated with water. At this time water can permeate into soil because of gravity.

3.1.2. Total water infiltrated in one hour at different ages of Acacia plantation

Total infiltration in 1 hour in six locations varied from 212 mm/hour to 310 mm/hour. The total infiltration in 1 hour of bare land is the lowest. That of Acacia plantation covers have trend to increase when the age of tree gets older. In particular, the total infiltration in 1 first hour in bare land, 1-year-old Acacia tree, 2-year-old, 3-year-old Acacia tree, 4-year-old Acacia tree and 5-year-old Acacia tree is 212 mm/hour, 227 mm/hour, 236 mm/hour, 310 mm/hour, 301.2 mm/hour and 310 mm/hour, respectively (Fig. 6).

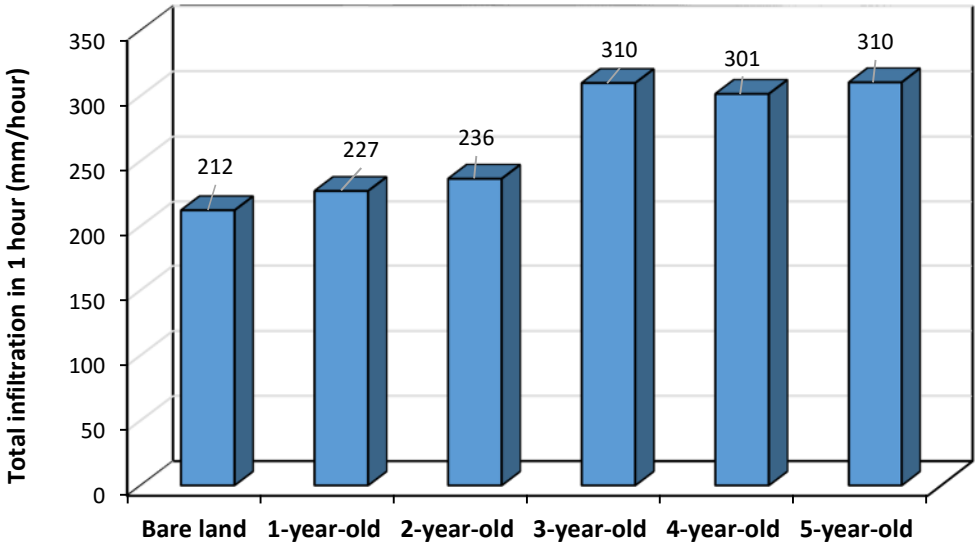

Figure 6. The amount of total infiltration in 1 hour under different vegetation cover types

Compared to the total water infiltrated in one hour reported by other researches at different locations, the amount of water in the Acacia ranged from 59 mm/hr to 809 mm/hr. In previous studies, the hourly infiltration rate in the area with Pine was within 302 - 434 mm/hr. The relative high infiltration rate per hour of the research might be explained by quite high proportion of understory vegetation cover and porosity. In addition, previous studies have proved that the positive relation between porosity and understory vegetation with infiltration capacity, therefore, it also follows the trend to negative correlation between infiltration capacity and possibility of generating overland flow (Hiraoka, 2010). The average total infiltration rate in 1 hour of bare land is 212 mm, higher than bare land, Acacia and Cinnamon in Yen Bai location (Linh et al., 2018). The average range total infiltration rate in 30 locations of Acacia plantation is lower than that of Pinus, Acacia in Quang Ninh location; and the mixed forest in Luot mountain, such as Pinus-Acacia and Acacia-Eucalyptus (Dung et al., 2019). Regarding high amounts of water infiltrated in one hour, the soil under different ages of Acacia trees are expected to reduce the relative amount of saturated overland flow.

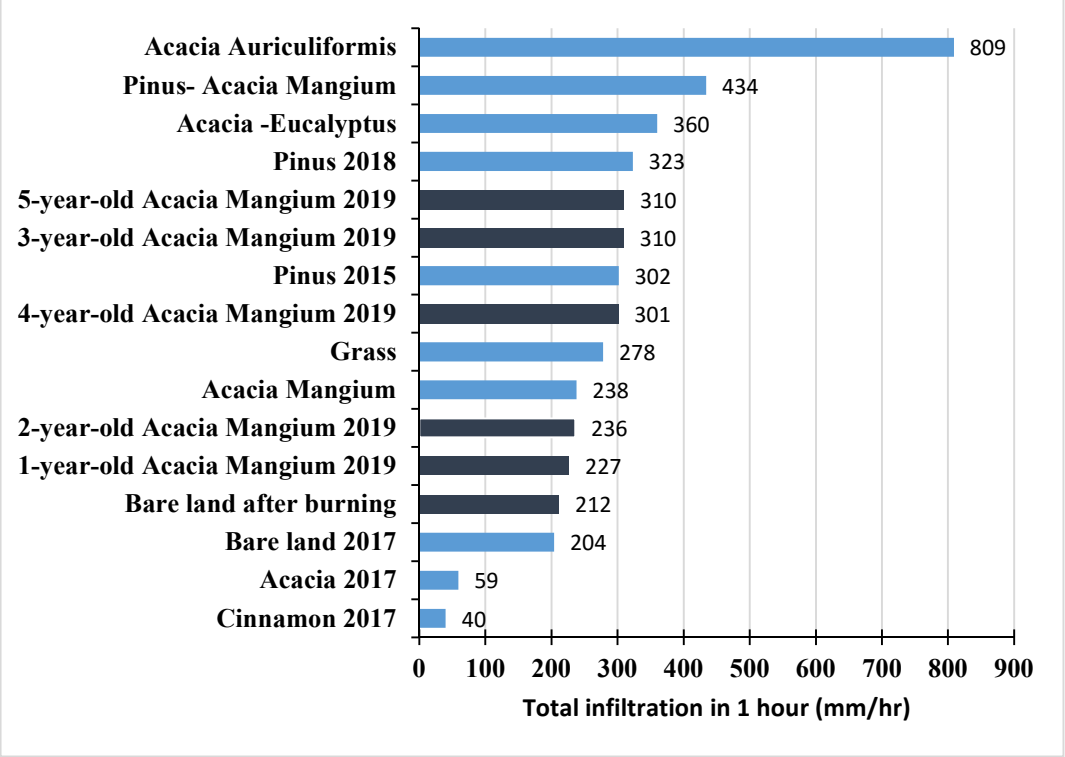

Figure 7. Comparing total infiltration in 1 hour of soil under different ages of Acacia plantation with those from other previous studies (Dung, 2016; Dung et al., 2016; Linh et al., 2018; Dung et al., 2019)

3.2. Relationship of infiltration rate with other factors

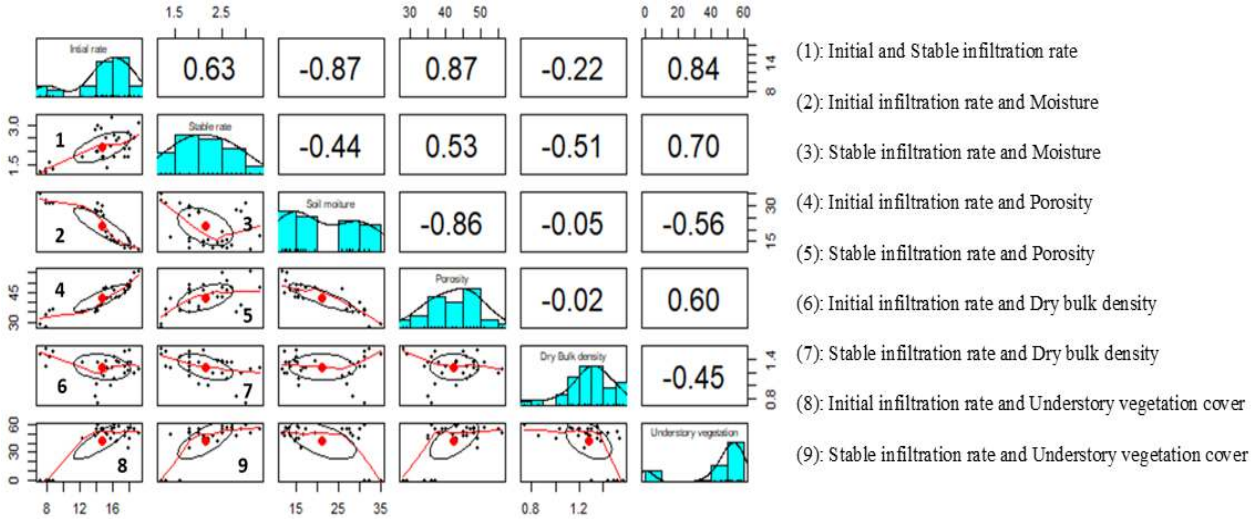

Figure 8. Affecting factors on infiltration of soil

The initial soil infiltration rate has a strong negative relationship with the soil moisture (correlation coefficient R:-0.87). Otherwise, the stable rate does not have a significant relationship with soil moisture with the R=-0.44. Porosity has a strong positive relationship with initial rate with the correlation coefficient R=0.87. Otherwise, the stable rate has moderate relationship with porosity and dry bulk density with R=0.53 and -0.51 respectively. Initial rate has a strong positive relationship with understory vegetation with the correlation coefficient R=0.84. Stable rate also has a positive relationship with understory vegetation

coverage with the correlation coefficient and R= 0.7. Comparing with other researches, they have the same results that vegetation has a critical impact on infiltration characteristic of soil and it also can be the reason to reduce rain plash. With the same low understory coverage, the soil may be detached by rain drop and it can lead to overland flow and soil erosion. Dung et al. 2017 also indicated that initial and stable infiltration rates have a strong positive relationship with understory vegetation cover. There is evidence that under the cover of vegetation, the accumulation of organic matter and the regulation of microclimate (Kittredge, 1948). In other words, understory vegetation cover and little fall play an important role in improving the infiltration capacity of soil.

4. CONCLUSION

To determine the temporal soil infiltration characteristics at different ages of Acacia plantation, a double-ring infiltrometer was used. In addition, the software such as Microsoft Excel, IBM SPSS, and R-studio was applied to analyzed data. The main findings were:

- The temporal soil infiltration rate at different ages of Acacia plantation tend to be decreased with increasing of ages. Higher age of Acacia trees tended to increase of infiltration capacity due to increase of canopy cover and understory vegetation cover. The highest rate was recorded under 5-year-old of Acacia plantation and the lowest rate under bare land. Time to reach the stable rate of the type range from 95 to 97 minutes. In addition, the total infiltration for 1 hour of soil very large, range from 212mm/hour (bare land after burning) to 310mm/hour (3-year-old Acacia tree and 5-year-old Acacia tree).

- Both initial and stable infiltration rates have strong positive relationship with understory vegetation cover. Initial infiltration rate of soil also has a strong relationship with porosity and soil moisture, but do not have significant relationship dry bulk density. While stable rate has a moderate relationship with porosity, dry bulk density and soil moisture.

Findings of this study estimated increasing of soil infiltration with increasing of Acacia plantation ages and lowest at bare land after cutting. Thus, manager of Acacia plantation should consider about solutions to protect soil through increasing of soil infiltration, especially in stage of soil treatment and 1-year-old Acacia plantation.

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ĐẶC TÍNH THẤM NƯỚC THEO THỜI GIAN CỦA ĐẤT DƯỚI CÁC TUỔI KHÁC NHAU CỦA RỪNG TRỒNG KEO TẠI LƯU VỰC LƯƠNG SƠN, HOÀ BÌNH, VIỆT NAM

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[2]Trường Đại học Lâm nghiệp

TÓM TẮT

Với mục đích xác định đặc tính thấm nước theo thời gian của đất dưới rừng trồng Keo ở các tuổi khác nhau tại vùng đầu nguồn Lương Sơn, tỉnh Hoà Bình, Việt Nam. Thí nghiệm đo tốc độ thấm nước của đất bằng phương pháp ống vòng khuyên (loại kép) được thực hiện tại các điều kiện che phủ thực vật khác nhau (bao gồm đất trống sau đốt, keo 1 năm tuổi, keo 2 năm tuổi, keo 3 năm tuổi, keo 4 năm tuổi và keo 5 năm tuổi) từ tháng 7 tới tháng 9 năm 2019. Một số nhân tố tiềm năng ảnh hưởng tới độ thấm nước của đất đồng thời được xác định gồm những tính chất vật lý của đất và điều kiện che phủ thực vật của rừng trồng keo. Những kết quả chính cho thấy: (1) Tốc độ thấm theo thời gian của rừng trồng keo có xu hướng giảm theo thời gian. Cả tốc độ thấm ban đầu và tốc độ thấm ổn định đều tăng từ đất trống (tương ứng là 7,9 mm/phút và 1,2 mm/phút) đến rừng keo trồng 5 năm tuổi (tương ứng là 14,2 mm/phút và 2,5 mm/phút); (2) Tốc độ thấm theo thời gian có mối quan hệ rõ ràng với tính chất vật lý của đất và độ che phủ thực vật. Tốc độ thấm ban đầu có mối quan hệ chặt với độ che phủ thực vật (R = 0,84), độ xốp (R = 0,87) và độ ẩm của đất (R = -0,87), nhưng không có mối quan hệ đáng kể với tỷ trọng đặc (R = -0,22). Tốc độ thấm ổn định cũng có quan hệ rõ ràng với độ che phủ thực vật (R = 0,70), trong khi nó không có mối quan hệ đáng kể với độ xốp (R = 0,53), tỷ trọng (R = -0,51) và độ ẩm của đất (R = -0,44); (3) Kết quả nghiên cứu cho thấy rằng tốc độ thấm nước dưới rừng trồng keo cao hơn ở ô đất trống sau đốt. Điều đó có thể được giải thích rằng rễ cây và độ che phủ thực vật có ảnh hưởng quan trọng tới đặc tính thấm nước của đất.

Từ khoá: đất trống sau đốt, đầu nguồn, điều kiện che phủ thực vật, độ thấm nước, mô hình rừng trồng keo.

Received : 02/10/2020
Revised : 08/11/2020
Accepted : 16/11/2020