INFILTRATION CHARACTERISTICS OF SOIL UNDER EUCALYPTUS PLANTATION FOREST IN HEADWATER OF VIETNAM

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SUMMARY

To determine soil infiltration characteristics of eucalyptus plantation forest, we used double rings infiltrometer in 15 different locations (5 times for one part) of up-hill, mid-hill and down-hill parts from August 2015 to March 2016. Dye pouring method was also used to determine spatial distribution of infiltration in two plots (Eucalyptus tree plot and reference plot- no eucalyptus trees). Some other factors that can impact on soil infiltration such as soil physical, understory vegetation were determined. Main findings of this study include: (1) Infiltration rate tended to be decreased over time, the rate was highest at the downhill and lowest at the middle hill; (2) Spatial infiltration distribution of dye in two plots was different, dye tended to be infiltrate deeper and bigger area into soil at reference plot; (3) Infiltration rate did not have close relationship with soil moisture and porosity but it strongly depended on understory vegetation. However, infiltration rate have close relationship with overall factors (vegetation cover, soil moisture and porosity). These findings suggest that water demand of Eucalyptus tree for growth has limited deeper infiltration capacity and make drier soil under Eucalyptus forest.

Keywords: Dye infiltration, infiltration rate, soil under Eucalyptus forest, understory vegetation.

I. INTRODUCTION

Infiltration is the process in which water entries downward into the immediate surface of soil or other materials (Bouma and Dekker, 1978). Infiltration rate is one of the most critical parameters for hydrologic behavior and watershed management. Characteristics of infiltration process control the forming of surface flows and subsurface flows, which affect peak flow rates, runoff volumes, surface erosion and plant-available water. Because in the area that has high infiltration rate, soil has high infiltration capacity, there will be little or no overland flows (Horton, 1933). Hence, surface erosion does not occur or occurs with very low frequency. In this situation, water resource is regulated so soil can be conserved. On the other hand, soil has low infiltration rate and low infiltration capacity leads to more overland flows. When there is rainfall, erosion and landslides will occur. In conclusion, infiltration rate plays a crucial role in watershed management (Haw et al., 2004).

There are many factors affecting infiltration rate of soil such as precipitation, soil texture, soil structure, terrain and vegetation. Soil factors that control infiltration rate are vegetation cover, root development, organic content (Dune et al., 1991). In general, soil with high vegetation cover has high infiltration rate (Hiraoka et al., 2010; Dung, 2016). Furthermore, some factors such as soil moisture, bulk density, porosity, permeability soil texture and structure also have significant effects on infiltration rate. Soil that has low moisture content, high proportion has higher infiltration rate than the one with high moisture and high proportion of clay (Sharma et al., 2016). Another important factor is precipitation. The characteristics affecting infiltration are depth of storm, storm intensity, and duration. Infiltration rate is low if storm intensity is high (Onda et al., 1995; Hiraoka et al., 2010). However, in reality, precipitation is the most difficult factor to control.

In terms of vegetation cover factor, one type of plants that has strong impact on infiltration process is eucalyptus. Eucalyptus belongs to Myrtaceae family. This type of tree has high value on economy because of its timber, especially eucalyptus oil extracted from the leaves. However, some hypothesis proposed that Eucalyptus trees make upper soil layer drier and understory vegetation cannot grow. The loss of understory vegetation can reduce infiltration capacity of soil and leads to some serious problems such as Horton overland flow and soil erosion. In this study, experiment on spatial infiltration was carried out to see the water movement inside the soil particles under eucalyptus trees compared to the reference plot that does not have tree to conclude this hypothesis is right or wrong. The measurement of infiltration experiment also was conducted by using double-ring infiltrometer to identify the soil infiltration characteristics of eucalyptus plantation forest.

In the world, there have been many researches carried out on infiltration since 1930s of 20th century by many researchers (Horton, 1933; Haw et al., 2004). Most of researchers concerned about factors that affect to infiltration rate of soil such as soil, precipitation, vegetation cover to find out the rules of infiltration. However, spatial infiltration is a new experiment that is concerned in recent year with the aim of figuring out the effects of tree roots in water inside the soil. By now, in Vietnam there has been no survey about this field. So that, we decided to do research with the title: "*Infiltration characteristics of soil under Eucalyptus plantation forest in headwater of Vietnam*". Main objectives of this study is including: (1) characterize infiltration's characteristic of soil in Eucalyptus Forest; (2) point out the impact of Eucalyptus's root system on infiltration process; (3) identify the correlation between infiltration rate and other factors.

II. STUDY SITE AND METHOD

2.1. Study site

This research was conducted in a small catchment at Luot mountain, located in Xuan Mai (20^{o}58' N, 105^{o}05' E), Hanoi, Vietnam (Fig 2.1). There are two distinct seasons: wet season and dry season. Wet season spin out from April to October, dry season is from November to March next year. Mean annual precipitation is 2268.4 mm. Mean annual temperature and relative humidity are 22.7^{o}C and 82%, respectively (Kim Boi meteorological station). Plantation in Luot mountain is very diversity with the total area of forest is 130 ha, in which Eucalyptus occupies 9.5 ha (14%).

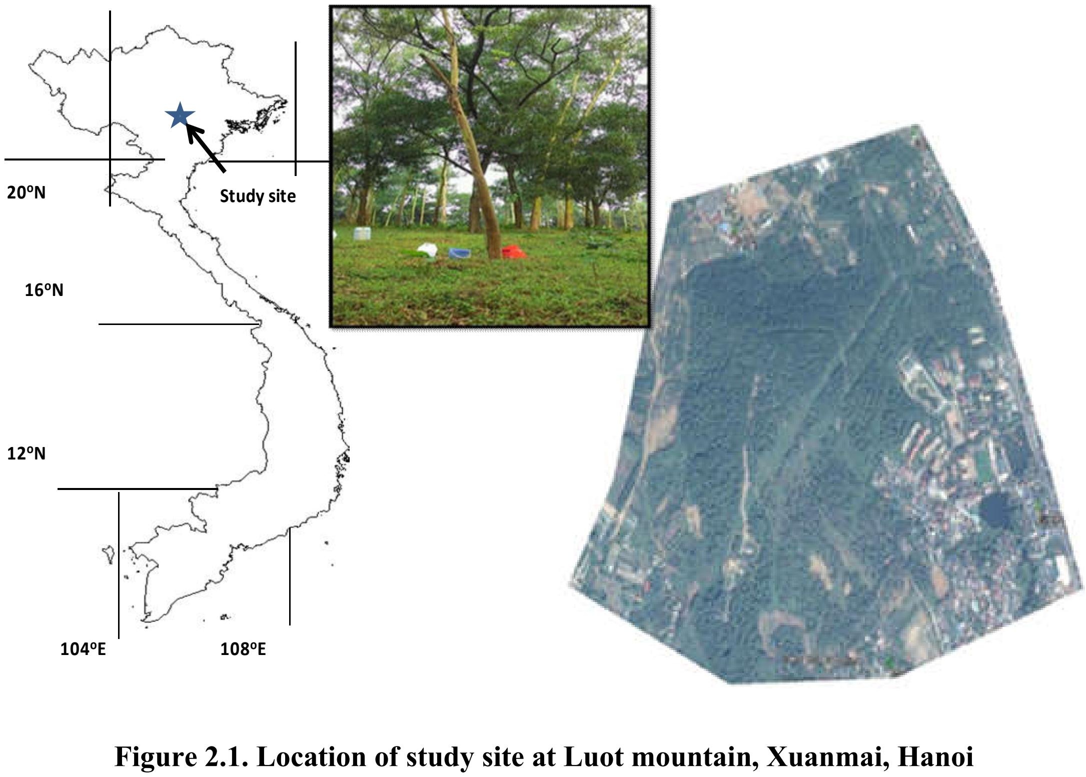

Figure 2.1. Location of study site at Luot mountain, Xuanmai, Hanoi

2.2. Method

Infiltration rate was measured by using double-ring infiltrometer with the diameter of inner and outer ring are 20 cm and 25 cm, respectively. Infiltration measurements were conducted with 5 locations in the uphill part, 5 locations in the middle hill part and 5 locations in the downhill part from August 2015 to March 2016 (fig. 2.2). On the other hand, understory vegetation cover was also measured by taking pictures. Soil samples were taken at each location where measuring in filtration rate by using dry bulk density tube. Finally, the physical characteristics of soil (moisture and porosity) were measured in the laboratory. Microsoft excel and R-studio were used to process data in order to find the correlation between Infiltration rate and other factors.

The spatial experiment was conducted at two plots that have the same characteristics of soil texture, soil moisture and slope. One has a eucalyptus tree and another does not have. Four soil layers at each plot were dug after 24 hrs dye pouring to see how the dye moved (fig. 2.3). In all, four layers were dug. Each layer was 10 cm far from the previous layer. The furthest layer (first layer) was dug firstly, which was about 40 cm far from the place and the dye was poured there where the dye was poured. Pictures were taken for each layer to be analyzed by photoshop software to determine infiltrated cover area. The similar steps were also implemented for the other plot (fig. 2.3).

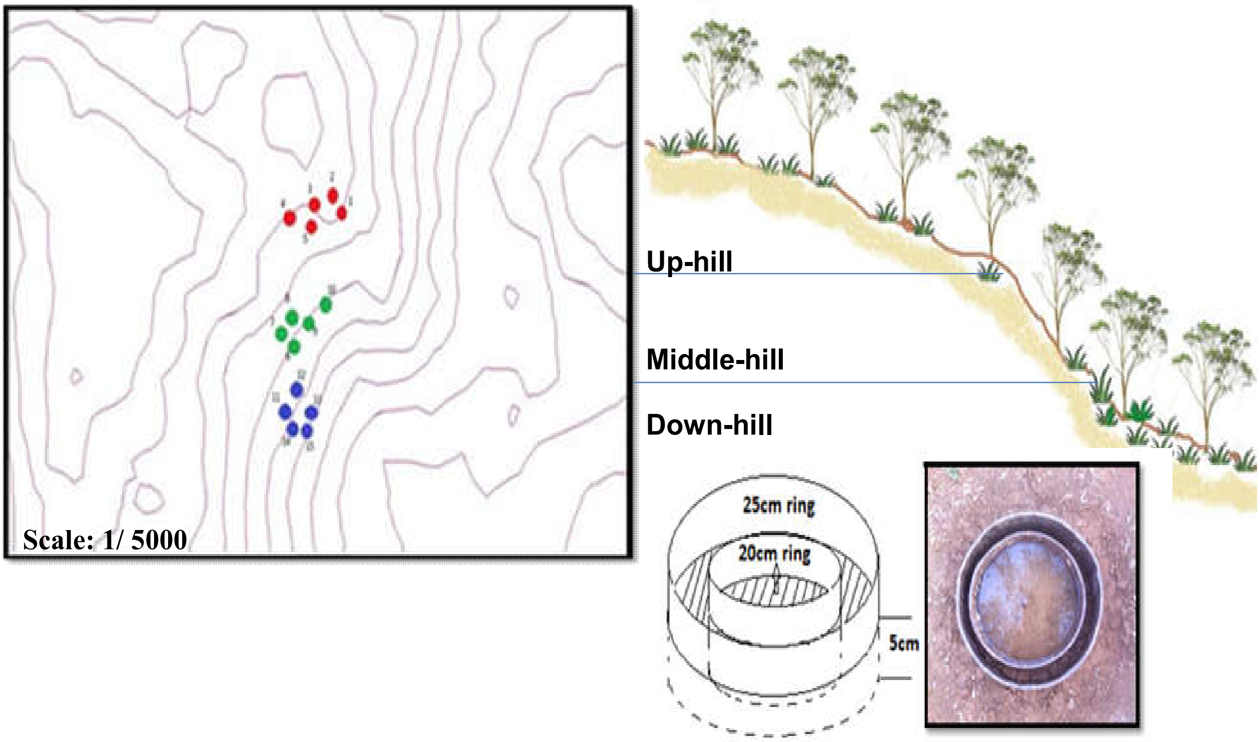

Figure 2.2. Location and infiltration design for measuring soil infiltration

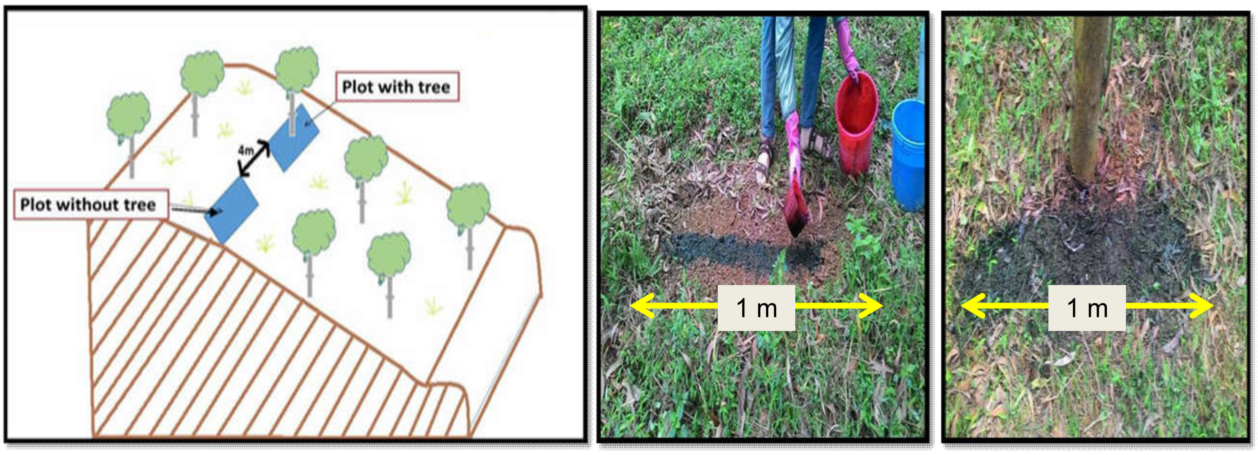

Figure 2.3. Dye experiment at two plots (Eucalysptus forest and no tree) at study site

III. RESULT AND DISCUSSION

3.1. Soil infiltration rate at Eucalyptus forest

3.1.1. Infiltration at different parts of hillslope

Infiltration rate at uphill was various in different times. Mostly, initial rate was very high, ranged from 108 to 350 mm/5min (averaged 212 mm/5min). Stable infiltration rate ranged from 9 - 32 mm/5min (averaged 21 mm/5min). All time measured showed the same tendency, which was the infiltration rate decreased over time and reached to stable value after 120 minute (fig. 3.1).

The infiltration rate in the middle-hill was quite high and decreased over time. The initial rate got the minimum (62 mm/5min) and maximum (217 mm/5min) value at the 9th time and 6th time (averaged 110 mm/5min). However, the stable infiltration rates did not change so much over time, it varied from 12 mm/5min (9th time) to 22 mm/5min (6th and 10th time), averaged 19 mm/5min. Infiltration rate in all 5 times tended to be stable from 140th minute (fig. 3.2). Because the middle of the hillslope was quite steep, it would be harder for water to infiltrate into soil. After the 100th minute, infiltration rate changed not very remarkable.

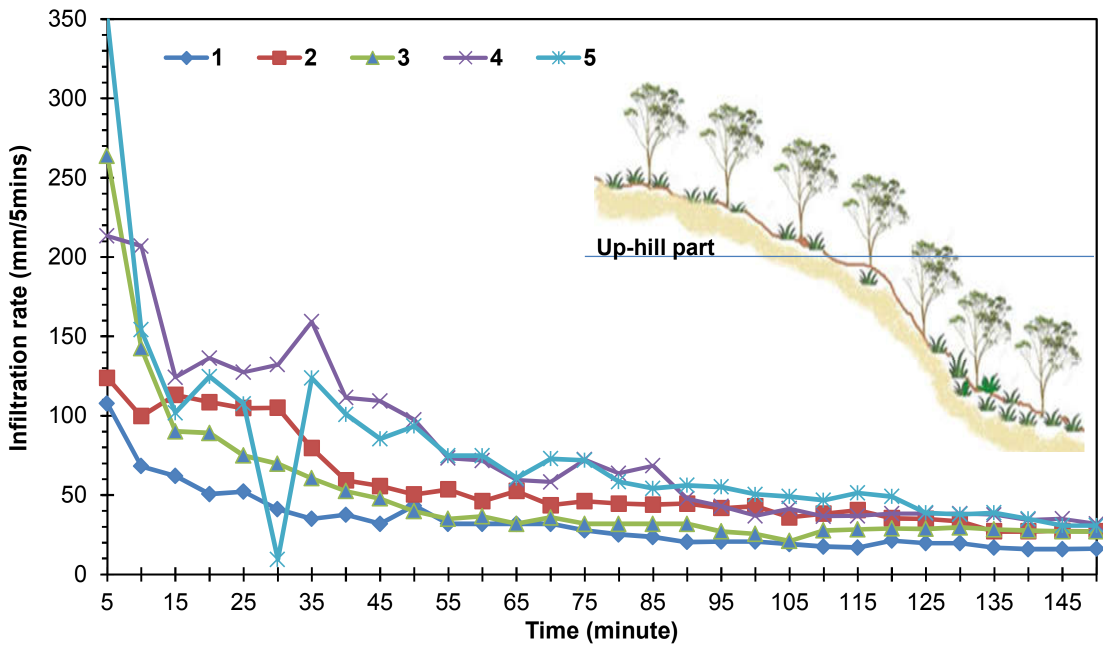

Figure 3.1. Infiltration rate at up-hill part of the study site

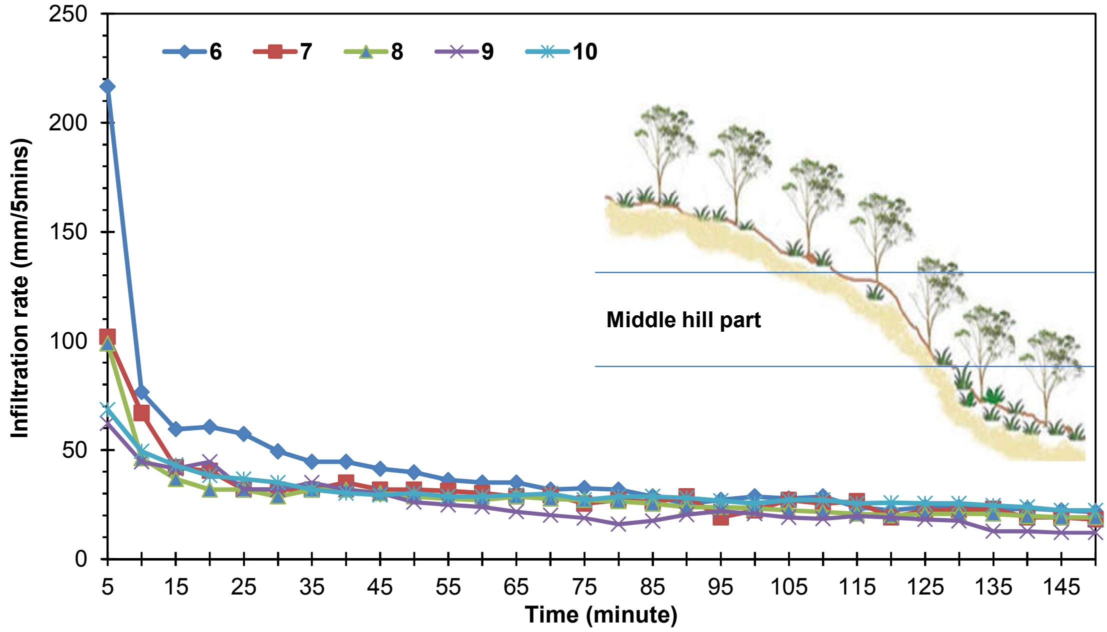

Figure 3.2. Infiltration rate at middle hill part of the study site

The infiltration rate in the downhill was the highest compared to infiltration rates in uphill and middle hill. The results showed the same trend, particularly, the initial rate was very high at the first time and then decreased overtime. Infiltration rates of all 5 times tended to be stable after 150 minutes; actually, it changed very slowly after 90 minutes. The initial infiltration rate ranged from 191 mm/5min (15th time of measurement) to 149 mm/5min (11th time), averaged 171 mm/5min. The stable infiltration rate was 26-60 mm/5min, averaged 46 mm/5min (fig. 3.3).

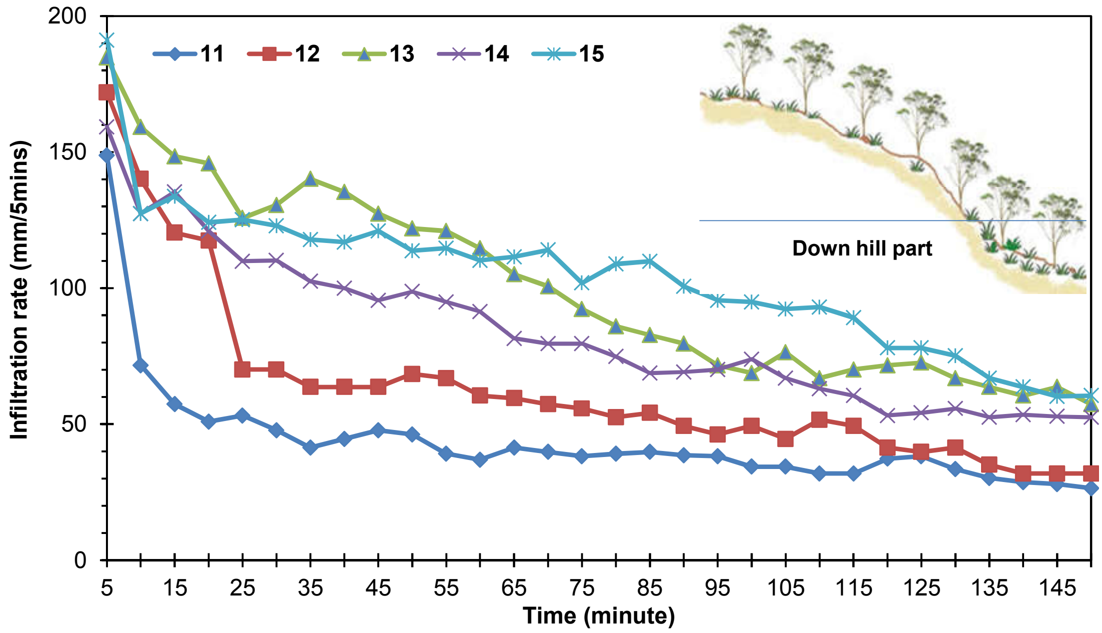

Figure 3.3. Infiltration rate at down-hill part of the study site

Infiltration rate tended to be decreased from down-hill (averaged 79 mm/5min) to up-hill (averaged 59 mm/5min) and lowest at middle-hill (averaged 31 mm/5min) (fig. 3.4). These differences may be caused by the different features of elevations, terrains and vegetation cover. The middle hill is very steep, so infiltration is hard to occur. The infiltration rate in downhill was higher than uphill because uphill had infiltration and Horton overland flow (caused by terrain and big potential energy), but the downhill had only infiltration and saturated overland flow occurred there.

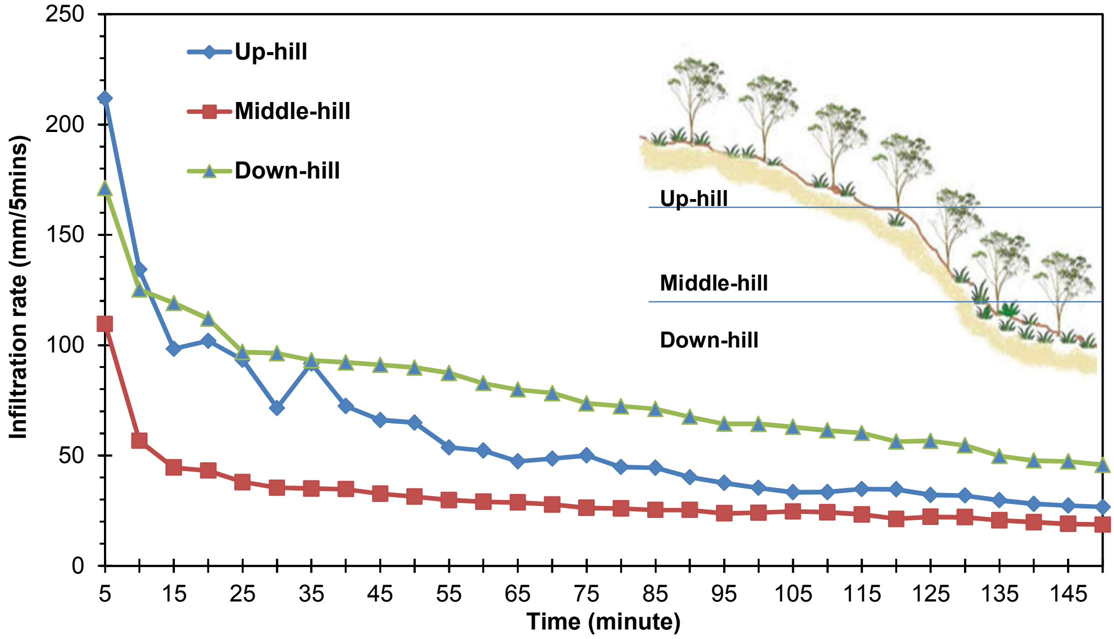

Figure 3.4. Average infiltration rate at different parts of hillslope

3.1.2. Total water infiltrate into soil for 1 hour

Total water infiltrated for one hour in both 3 parts of the hillslope was very high. But the highest was in down-hill part (ranged from 671-1661, averaged 1254 mm/hr), then up-hill part (ranged from 593-1536, averaged 1014 mm/hr) and the lowest was middle-hill part (ranged from 428-761, averaged 519 mm/hr) (fig. 3.5). Hence, the middle-hill part is more likely to have overland flow and erosion. In the uphill and downhill part, with such a large amount of water can infiltrate in 1 hour, overland flow is hard to occur.

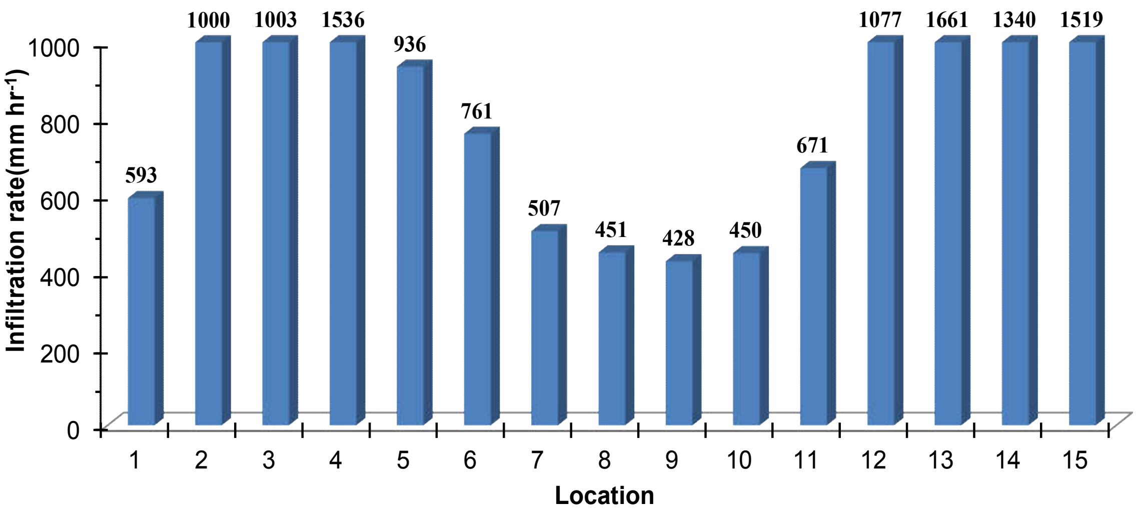

Figure 3.5. Amount of water infiltrated into soil under Eucalyptus forest at the study site

We compared the result of water infiltrate in 1 hour in Eucalyptus forest with other types of forest from previous study (Dung et al. 2015), the Eucalyptus forest in our study site had highest value. These results may be due to the difference of soil physical and understory vegetation among land use types. Understory vegetation cover of this study was really high from 50-95, averaged 80% that enhanced water infiltrated into soil. This result was contrast with the hypothesis that Eucalyptus forest makes soil become dryer and reduce infiltration rate (fig. 3.6). On the later part, we will define the correlation between infiltration rate and other factors to explain for this result.

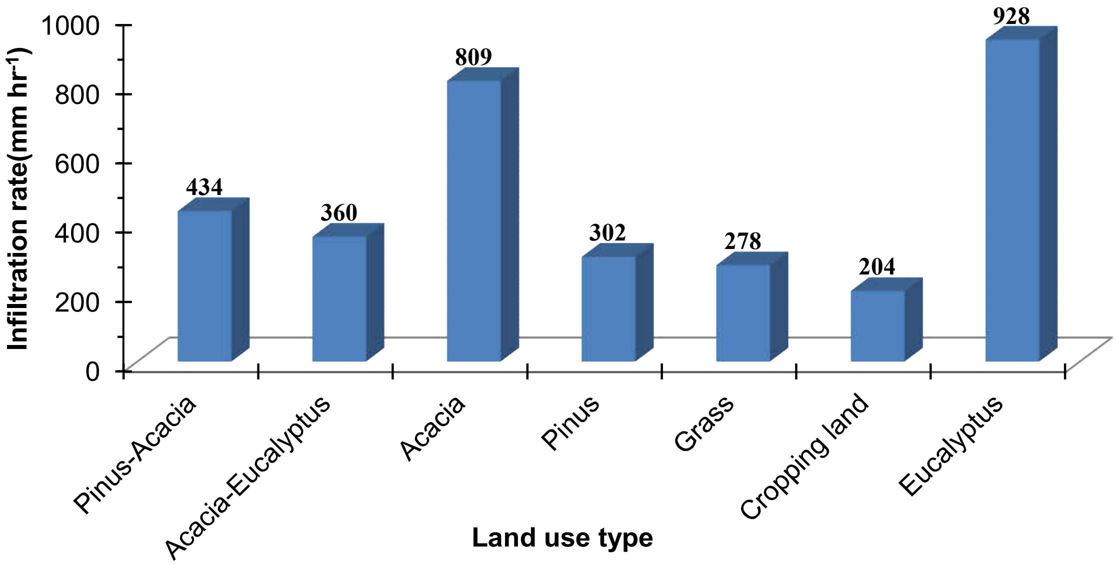

Figure 3.6. Amount of water infiltrated into soil under different land use type at the study site

3.2. Spatial distribution of soil infiltration over time at the study site

The first layer was 40 cm far from the dye tracer. In the plot which has Eucalyptus tree, it was found that a little dye appeared along the tree roots but it existed in a very small proportion (13 cm^2/m^2) (fig. 3.7). In the plot which has no Eucalyptus trees, a little more dye in soil appeared (21 cm^2/m^2). Both were not considerable. The second layer was about 30 cm far from the dye tracer. The plot which has eucalyptus tree, had some dye along the roots that in the upper part of soil layer and a little more along the root in lower layer (56 cm^2/m^2). In comparison to the plot without tree, the reference plot had more infiltrated dye into the soil (70 cm^2/m^2). In the third layer of soil (20 cm far from dye tracer), the reference plot had a significant amount of dye infiltrate observed (581 cm^2/m^2). The dye in this plot gathered in part of soil which has large pores and infiltrated quite deep into the soil (50 cm) compared with the plot of Eucalyptus tree. In the fourth layer (10 cm far from dye tracer), in plot has tree the dye area was about 430 cm^2/m^2 and the deepest point was 30 cm, while in the reference plot was twice time larger at 917 cm^2/m^2 and the deepest point was 65 cm (fig. 3.7).

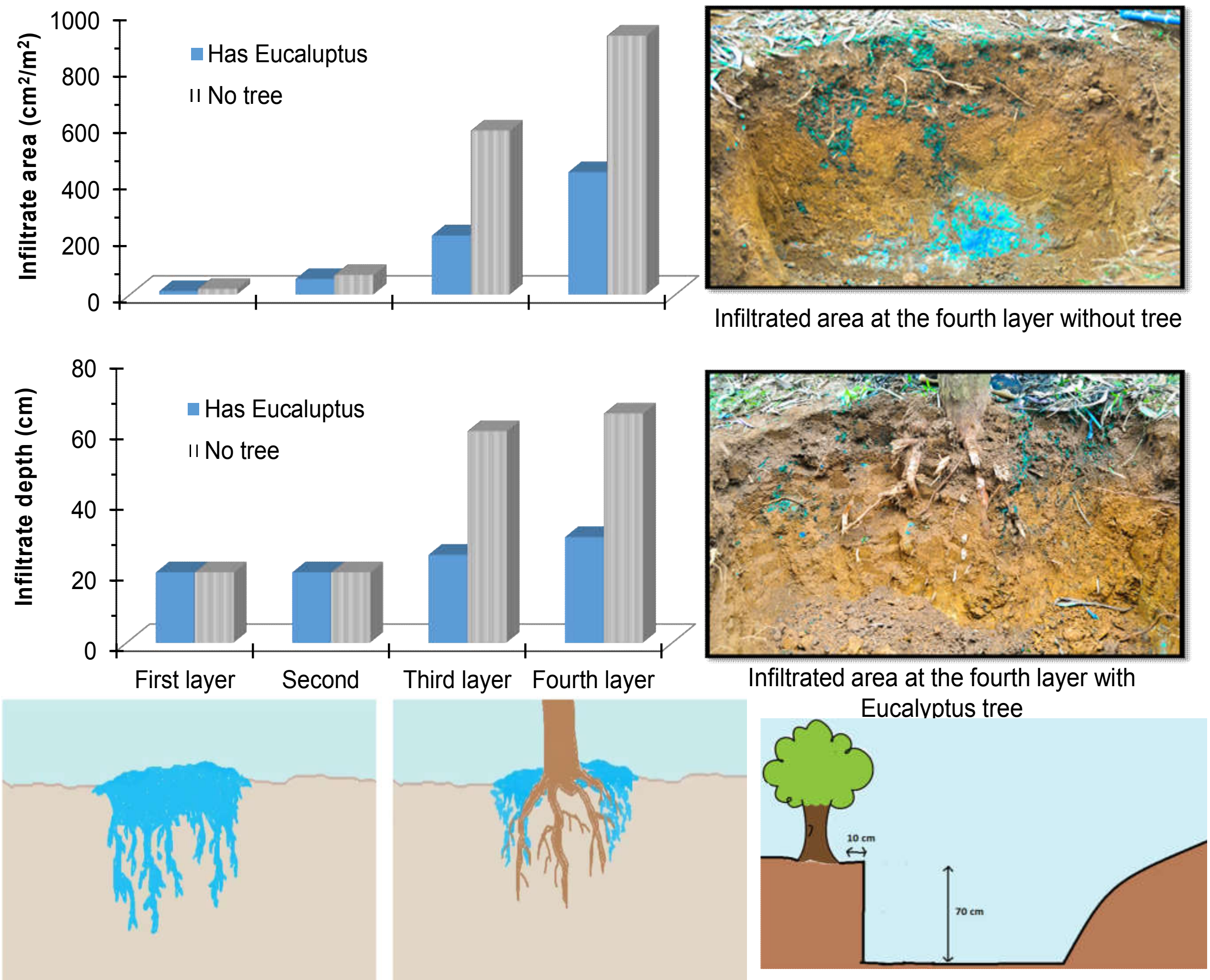

Figure 3.7. Infiltrated area (area and depth) with/without Eucaluptus tree at the study site

3.3. Relationship between infiltration rate and understory vegetation cover, moisture, porosity

3.3.1. Soil physical and understory vegetation characteristics of the study site

Understory vegetation cover was from 50-95, averaged 80% (fig. 3.8a). Soil moisture at 15 locations was quite low (fig. 3.8b). The average value of soil moisture was 6.2%, the fifth location had the highest value (10.4%) and the sixth location was lowest (3.6%). The values of porosity were pretty high, ranged from 39-69%. The average value of porosity was 64% (fig. 3.8c).

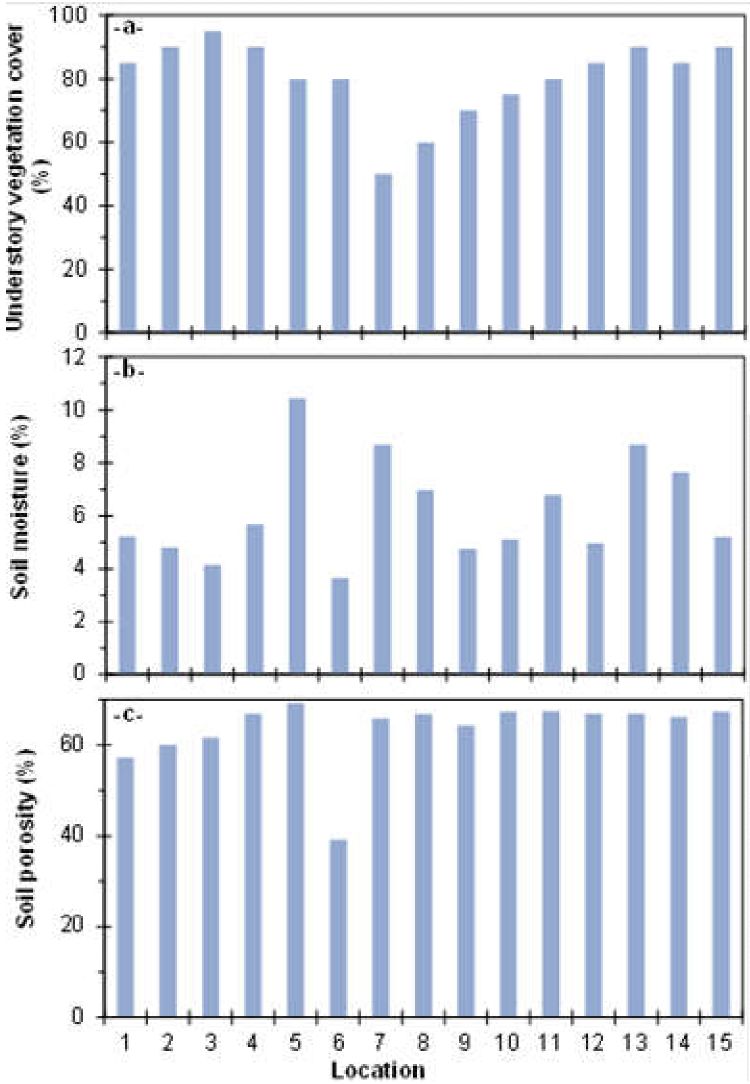

Figure 3.8. The characteristics of a- understory vegetation cover; b- soil moisture and c- soil porosity of the study site

3.3.2. The correlation between infiltration rate and understory vegetation, porosity, soil moisture

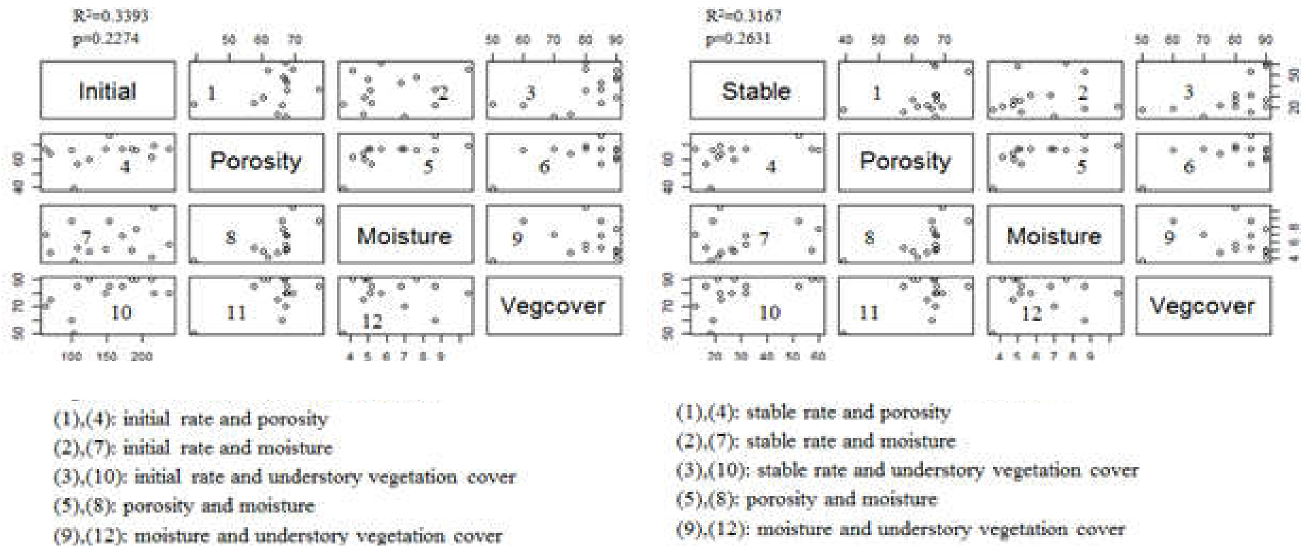

Figure 3.9. The relationship among parameters of soil physical, understory vegetation cover and infiltration

Effect of various soil physical (porosity and moisture) and understory vegetation cover on initial and stable infiltration was mentioned not only in a separate factor but also in overall factors. Therefore, we considered the relationship among all of parameter investigation using R commander software. The result shows that there was relationship between understory vegetation cover on initial and stable infiltration. Meanwhile, we could not find a clear relationship between porosity and soil moisture on initial and stable infiltration (fig. 3.9, showed in graph 3 and 10). To evaluate the relationship among understory vegetation ground cover, initial and stable infiltration, we focused on the relationships between understory vegetation and initial, stable infiltration in detail. The concrete results will be presented at following part below (fig. 3.10).

Initial and stable infiltration rate have relationship with understory vegetation cover (fig. 3.10). The graphs described correlation between independent variables and this correlation is not linear through a straight line. The relationship exists due to understory vegetation cover under Eucalyptus forest. When the infiltration rate and the amount of water infiltrated in one hour is very high, the Horton overland flow will rarely occur. Because the density of trees in this area is not very high (221 trees/ha), distance from one tree to one another is large enough, the infiltration does not heavily depend on eucalyptus trees. Moreover, soil in Eucalyptus forest in the research site does not have tendency of repellency (impervious soil does not occur here).

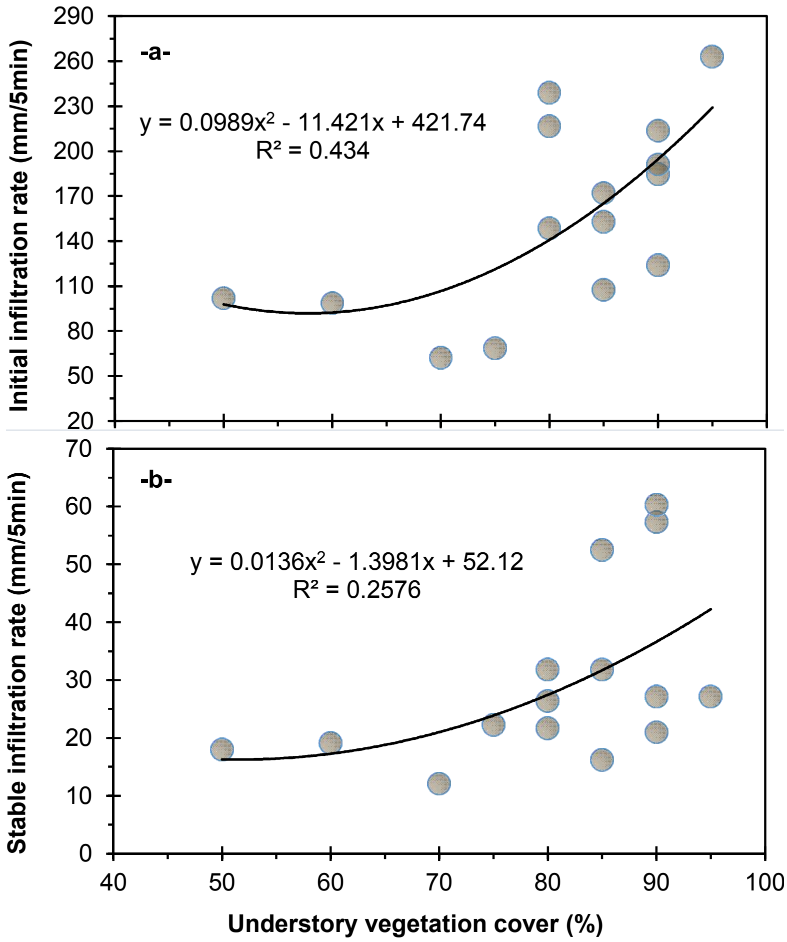

Figure 3.10. The relationship between a - initial infiltration rate and understory vegetation cover and b - stable infiltration rate and understory vegetation cover

Results of multivariate analysis showed that initial and stable infiltration rate have close relationship with soil moisture, porosity and understory vegetation cover with specific equation such as: Initial infiltration rate = 3.95 veg cover + 18.43 moisture – 3.34 porosity – 60.53 (relationship coefficient: R = 0.75); Stable infiltration rate = 0.74 veg cover + 2.82 moisture + 0.37 porosity – 71.62 (relationship coefficient: R = 0.70). Relationship coefficient of model ranged from 0.7 - 0.75, suggests that infiltration rate also depend on other factor such as soil depth, deeper layer soil porosity and moisture.

IV. CONCLUSION

Main findings of this study includes: (1) Soil infiltration in Eucalyptus forest decreased over time. The initial and stable infiltration rate at up-hill, middle-hill and down-hill parts were different; (2) Dye in plot has no Eucalyptus tree infiltrated deeply into the soil (i.e., 65 cm without tree and 30 cm with tree). Infiltrated area of soil under Eucalyptus tree (917 cm^2/1 m^2) was higher than one of area without tree (434 cm^2/1m^2); (3) Infiltration characteristic did not have strong relationship with porosity and soil moisture. However, they depended on understory vegetation cover. Otherwise, infiltration rate also have close relationship with overall factors (vegetation cover, soil moisture and porosity); (4) Findings of this study suggest that water demand of Eucalyptus tree keep water around root but not deeply percolated into soil that make soil become drier.

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ĐẶC TÍNH THẤM NƯỚC CỦA ĐẤT DƯỚI RỪNG TRỒNG BẠCH ĐÀN Ở VÙNG ĐẦU NGUỒN VIỆT NAM

Bùi Xuân Dũng[1], Nguyễn Thị Mỹ Linh[2], Trần Thị Thủy[3], Lê Nguyên Kha[4], Phạm Thùy Linh[5], Phạm Thị Thu Trang[6]

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TÓM TẮT

Với mục đích xác định được đặc tính thấm của đất dưới rừng trồng Bạch đàn, thí nghiệm nghiên cứu tốc độ thấm được thực hiện từ 8/2015 đến 3/2016 bằng ống vòng khuyên kép. Độ thấm được đo ở 15 địa điểm khác nhau trên 3 phần của đồi bạch đàn: 5 điểm ở đỉnh đồi, 5 điểm ở sườn đồi, 5 điểm ở chân đồi, mỗi điểm được tiến hành đo 30 lần trong thời gian 150 phút. Thí nghiệm đổ thuốc nhuộm đã được tiến hành để xác định được quy luật thấm của đất dưới rừng trồng bạch đàn theo không gian tại 2 ô tiêu chuẩn (ô có cây bạch đàn và ô không có cây bạch đàn). Chúng tôi đã xác định và phân tích một số nhân tố có ảnh hưởng đến tốc độ thấm như độ ẩm, độ xốp và thảm thực vật che phủ nhằm tìm ra mối tương quan giữa tính thấm của đất và những nhân tố này. Những kết quả tìm được bao gồm: (1) Tốc độ thấm có xu hướng giảm theo thời gian, đạt giá trị cao nhất ở khu vực chân đồi và thấp nhất ở vùng sườn đồi; (2) Sự phân bố thuốc nhuộm theo không gian ở hai ô tiêu chuẩn là khác nhau, thuốc nhuộm có xu hướng thấm sâu hơn, diện tích thấm lớn hơn vào đất ở ô tiêu chuẩn không có cây bạch đàn; (3) Tốc độ thấm không có mối quan hệ rõ ràng với độ ẩm và độ xốp nhưng phụ thuộc mạnh vào thảm thực vật che phủ. Ngoài ra, tốc độ thấm còn có quan hệ đồng thời với các biến che phủ thực vật, độ ẩm và độ xốp theo hàm hồi quy tuyến tính đa biến (hệ số quan hệ: R = 0,7 – 0,75). Kết quả nghiên cứu cho thấy rằng, vì nhu cầu sử dụng nước lớn để phục vụ cho sinh trưởng nên cây Bạch đàn đã giữ nước lại quanh vùng rễ, nước không thấm sâu và rộng vào trong đất được. Điều này làm cho đất thiếu nước, đất vì thế trở nên khô hơn so với đất không trồng Bạch đàn.

Từ khóa: Đất rừng trồng Bạch đàn, thấm nước của đất, thí nghiệm thấm không gian, tốc độ thấm ban đầu, tốc độ thấm ổn định.

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