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Abstract. Research on water infiltration and retention will be an important basis for identifying flow generation and suggesting solutions to water regulation, soil protection, erosion prevention. The study was based on sample plots with an area of 400 m^2/plot (20m×20m) for three states: grassland (I_A), brushland (I_B), shrubs and regeneration trees (I_C) after shifting cultivation in mountainous areas of Nghe An province. Results showed that the initial infiltration rate (V_o) of the three states (I_A, I_B, I_C) were 5.08 - 6.74 mm/min. The steady infiltration rate (V_c) increased as I_A was 2.69 mm/min, I_B was 2.86 mm/min, and I_C was 3.11 mm/min. The time to reach V_c of I_A was 34.9 - 36.8 min, I_B was 43.4 - 45.2 min, and I_C was 68.4 - 74.4 min. Totals water infiltration up to 80 minutes from 206.32 mm to 255.70 mm, according to $I_A < I_B < I_C$. The water storage in the capillary pore was 135.91 - 275.32 mm; water storage in non-capillary pore was 49.23 - 122.76 mm; saturated water content increased $I_A < I_B < I_C$. Research results are an important foundation for influencing measures based on the water infiltration and retention of forest land.

1. Introduction

Erosion is occurring seriously, every year thousand tons of fertile soil eroded into streams and downstream. This situation causes the loss of cultivation ability [1-3].

Infiltration is the process by which water on the ground surface enters the soil. Soil infiltration is one of the important hydrologic components and processes in water balance [4], and depends on many factors such as rainfall features, soil properties, topographic features and surface cover (expressed by forms of using soil) [5]. Of the three main factors affecting soil infiltration, rainfall factor is the most difficult to intervene because they are out of people' expectation. We can only predict negative phenomena related to it for preparation. The rest of them (soil and vegetation characteristics) can be controlled to regulate the source of water and protect soil. Dune (1991) indicated the effects of rainfall, vegetation cover, and terrain conditions on soil infiltration [6]. Besides the characteristics of rainfall, the form of using land also has the great impact on the infiltration of the soil. Surface coverage criteria, land use patterns of different types will directly affect the infiltration of the soil [7]. In terms of research methodology on the soil infiltration, two methods should be used: ring knife method and artificial rain test in the experimental plots [8-9]. For the ring knife method, it can be applied in two ways: simple ring or double ring. Although this research topic has been studied in many countries in the world, there has not been much research in Vietnam. As one of the few researchers interested in this topic, Pham Van Dien (2008) determined the infiltration characteristics of some forest soils depending on the porosity, thickness and humidity of the soil layer [10]. Do Thi Lan (2010) suggested that the water infiltration rate is proportional to soil porosity and inversely proportional to soil

humidity [11]. Bui Xuan Dung (2016) assesses the infiltration under some states of land use, the results follow (1) The infiltration of the soil follows the law of the highest value at the beginning and decreases over time. The time to reach a steady stream of the forest is often faster than grassland-shrubs and vacant land; (2) the initial penetration rate of land use type depends on the soil surface humidity and the average relationship (R = 0.4). The initial infiltration rates are not very closely related to soil bulk density and porosity. In turn, the steady infiltration rate does not depend on soil surface humidity, but has a close relationship with bulk density and porosity [12].

The forest in Nghe An province are mainly located in 10 mountainous districts in the West. With mountainous high terrain, complicated division, difficult transportation and severe weather; it is the place where the about five hundred thousand ethnic minorities (Thai, H'Mong, Kho Mu, Tho, E de, Dan Lai, etc.) are gathered. The area of forest land is 1,178,182 ha (accounting for 72.5%), including forest area: 777,359 hectares (covering for 47%) and 400,823 hectares without forest and the shifting cultivation area is 50,000 ha. The vegetation is dominated by grasslands and brushland on the fallow swidden. This is the target for development and rehabilitation measures in the coming period to promote the forest protection function. The study of infiltration of soil after shifting cultivation, which is a scientific basis for suggesting appropriate measures for upstream forest is necessary.

2. Research methods

The study area is a mountainous district located in the southwest of Nghe An province, coordinates 19°18'28"N 104°28'36"E. The terrain is mixed, mountainous and is difficult for transportation and traffic. Climate and weather are harsh. Natural resources are quite abundant. Tuong Duong is directly affected by the tropical monsoon climate with two distinct seasons: rainy season from April to October, dry season: from November to March next year. The average temperature varies from 23 - 25oC; the highest temperature is July: 39 - 41oC; the lowest temperature is January: 8oC. Average rainfall is 1,450 mm, but unevenly distributed in space and time.

The vegetation cover on the land after shifting cultivation is studied in three states: grassland (I_A), brushland (I_B), shrubs and regeneration trees (I_C). A total of 18 sample plots, each with an area of 400m^2 (20m×20m). The ring knife method and double-ring infiltrometer was used to measure the infiltration of forest soil, measured at different times from February to June, and two times per month.

Calculating soil infiltration: $V = (Q \times 10)/(S \times T)$

where: V is the water infiltration rate of soil (mm/min); Q is the amount of water absorbed (cm^3); S is ring cutter cross-section area (cm^2); T is penetration time (minute).

Based on the above formula we calculated the initial infiltration rate (V_o, mm/min) for the first 5 minutes, and calculated the infiltration rate (V_c, mm/min) during an irrigation until the absorbed water in the tube is constant.

Calculating water retention: Capillary porosity X_{mq} (%) = W_{drbn} (%) + W_{ch} (%)

W_{drbn} (%): field moisture is determined by moisture analysis after 24 hours watering. W_{ch} (%): wilting point is determined by 1.5 times the maximum hydroscopic water, W_{ch} (%) = 1.5×H_{ymax}

Non-capillary porosity X_{nmq} (%) = X (%) - X_{mq} (%)

Water storage in capillary pore (I_{mq}) of soil is calculated according to the layer thickness (H_d) and capillary porosity (X_{mq}): $I_{mq} = H_d \times X_{mq}$

Water storage in non-capillary pore: $I_{nmq} = H_d \times X_{nmq}$

3. Results and analysis

3.1. Initial and steady infiltration rate

The infiltration of soil is the flow of water through a unit of cross-section of soil in a unit of time with a certain pressure difference. In upstream regions with from medium to high rainfall, water infiltration is important for soiling protection and watering retention. Soil infiltration was assessed by initial infiltration rate (Vo, mm/min) and steady infiltration rate (Vc, mm/min).

According to Table 1, the initial infiltration rate of the three states (IA, IB, and IC) were 5.08 - 6.74 mm/min. Steady infiltration rate Vc of 2.58 - 3.20 mm/min in all plots, obviously the vegetation was one of the factors influencing the variation, the time to reach (Vc) was the highest in IC (74.4 min); compared to Do Thi Lan (2011), the steady infiltration rate in grassland, brushland was very low of 0.27 - 0.30 mm/min, and the time to reach Vc was 38 min [11]. Vo Dai Hai (1996) has determined the rate of basaltic soil in grassland, brushland was 2.13 mm/min, and the forest regeneration after cultivation was 10.23 mm/min [13]. Meanwhile, Pham Van Dien (2009) showed that the Vc of the IA and IB states were 2.5 - 2.6 mm/min, and the time to reach Vc was 30 - 45 min [14]. It can be seen that the infiltration of forest soil is influenced by many factors.

Table 1. Water infiltration rate of 3 states of study sample plot

State	Layer thickness (H_d, cm)	Soil porosity (X, %)	V_o (mm/min)	V_c (mm/min)	Time to reach V_c (minutes)
I_A	47	41.36	5.08	2.61	34.9
I_A	48	42.54	5.15	2.60	36.1
I_A	60	42.69	5.16	2.58	36.7
I_A	66	42.63	5.20	2.63	35.6
I_A	50	44.07	5.61	2.78	36.8
I_A	55	44.17	5.62	2.87	36.7
I_B	75	44.57	5.78	2.81	45.2
I_B	67	45.68	5.83	2.90	43.9
I_B	78	43.64	5.60	2.81	43.3
I_B	70	44.56	5.78	2.84	45.1
I_B	78	44.22	5.77	2.89	43.4
I_B	70	44.31	5.78	2.84	43.5
I_C	78	49.66	6.61	3.15	68.4
I_C	89	46.43	6.32	3.07	72.4
I_C	78	47.77	6.38	3.18	71.7
I_C	87	46.60	6.25	3.04	74.4
I_C	78	49.72	6.74	3.20	72.9
I_C	72	46.08	6.34	3.03	72.7

The steady infiltration rate depends on the initial infiltration rate, where the equation was Vc = 0.383Vo + 0.644 (R2 = 0.963, P < 0.01). The relationship between these two values is strongly correlated with R2 = 0.963 (Figure 1).

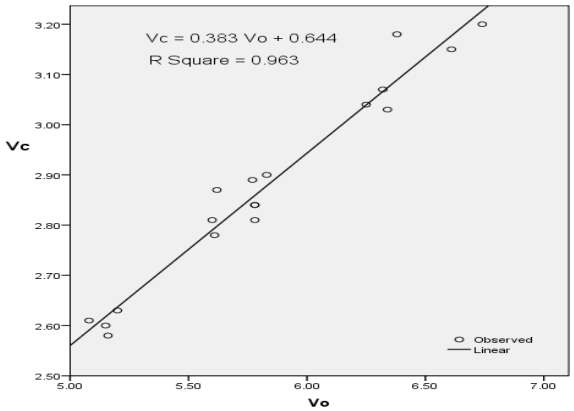

Fig. 1. The relationship between steady infiltration rate (Vc) and initial infiltration rate (Vo).

3.2. The influence of some factors on the soil infiltration

The linear relationship between initial infiltration rate (Vo), steady infiltration rate (Vc) and porosity (X) and layer thickness (Hd) is obtained from Table 1: y = a + bx (a, b constant).

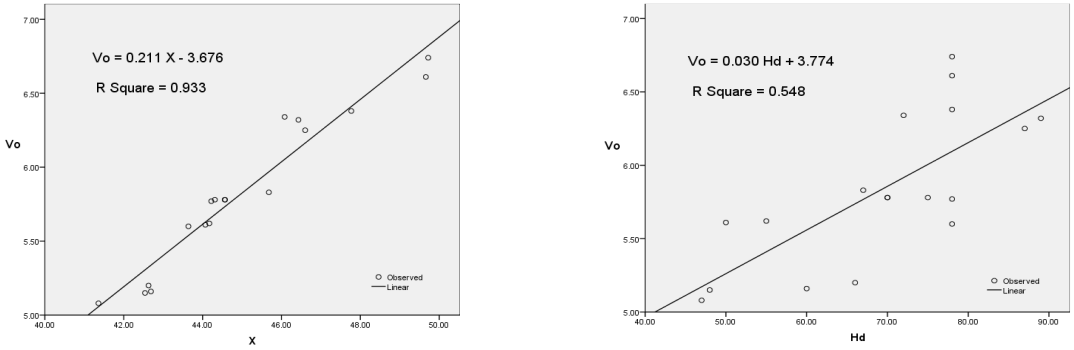

Fig. 2. A linear relationship between (Vo) and porosity (X), layer thickness (Hd)

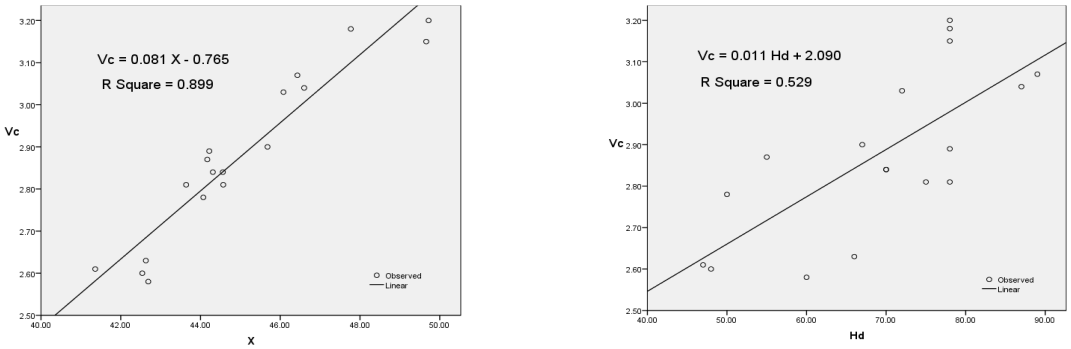

Fig. 3. A linear relationship between (Vc) and porosity (X), layer thickness (Hd)

3.3. Soil infiltration process

According to the maximum infiltration rate and the infiltration time in the experimental standard plots (80 min), a totals water infiltration was determined in Table 2.

Table 2. Total water infiltration of 3 states

Stade	Water infiltration (mm)	Stade	Water infiltration (mm)	Stade	Water infiltration (mm)
I_A	208.87	I_B	224.48	I_C	251.79
I_A	208.17	I_B	232.18	I_C	245.80
I_A	206.32	I_B	225.18	I_C	254.18
I_A	210.07	I_B	226.92	I_C	242.93
I_A	222.48	I_B	231.09	I_C	255.70
I_A	229.52	I_B	227.34	I_C	242.55

The total amount of water infiltration in the states were different, the difference about 40 – 50 mm between IA and IC. Total water infiltration into the soil within 80 minutes has fluctuated from 206.32 mm to 255.70 mm and increased IA < IB < IC. Research results are an important basis for influencing measures based on the infiltration of forest land.

3.4.Water retention of soil after shifting cultivation

The capillary pores of different thickness in the soil are connected together to form a complex capillary system. When the water content of the soil increases gradually, the part of the water which exceeds the maximum water holding capacity is kept in the capillary pore of the soil without the control of the gravity action. The water which is kept in the capillary pore of the soil by capillary force is called capillary water.

The results showed that the water storage in the capillary pores is different, shrubs and regeneration trees (IC) was the highest (275.32mm), and then gradually reduced, and the lowest was the grassland (IA) 135.91mm. Water storage in non-capillary pore was 49.23 - 122.76 mm in the states. Saturated water indicated that soil moisture was the highest when capillary pores were filled with water. This water content is equal to the total of capillary and non-capillary water content, according to IA < IB < IC, ranged 194.39 - 413.22 mm (Table 3).

Table 3. Water storage in capillary and non-capillary pore

State	H_d (cm)	H_{ymax} (%)	X (%)	W_{drbn} (%)	W_{ch} (%)	X_{mq} (%)	I_{mq} (mm)	X_{nmq} (%)	I_{nmq} (mm)	I_{bh} (mm)
I_A	47	6.19	41.36	21.60	9.29	30.89	145.16	10.48	49.23	194.39
I_A	48	4.41	42.54	21.70	6.62	28.32	135.91	14.22	68.28	204.19
I_A	60	4.28	42.69	22.00	6.42	28.42	170.52	14.27	85.62	256.14
I_A	66	5.73	42.63	21.65	8.60	30.25	199.62	12.39	81.76	281.38
I_A	50	4.42	44.07	21.75	6.63	28.38	141.90	15.69	78.46	220.36
I_A	55	5.43	44.17	21.80	8.15	29.95	164.70	14.22	78.23	242.93
I_B	72	6.19	44.57	22.95	9.98	32.93	237.06	11.64	83.82	320.88
I_B	67	4.41	45.68	23.20	14.97	38.17	255.74	7.51	50.33	306.07
I_B	69	4.28	43.64	22.80	14.37	37.17	256.47	6.47	44.67	301.14
I_B	70	5.73	44.56	22.55	13.38	35.93	251.51	8.63	60.41	311.92
I_B	73	4.42	44.22	23.25	12.30	35.55	259.52	8.67	63.27	322.78
I_B	70	5.43	44.31	23.70	7.74	31.44	220.08	12.87	90.12	310.20
I_C	78	7.59	49.66	23.60	11.39	34.99	272.88	14.67	114.46	387.34
I_C	89	4.89	46.43	23.60	7.34	30.94	275.32	15.49	137.90	413.22
I_C	78	7.32	47.77	23.60	10.98	34.58	269.72	13.19	102.85	372.57
I_C	87	6.69	46.60	23.85	10.04	33.89	294.80	12.72	110.62	405.42
I_C	78	6.89	49.72	23.65	10.34	33.99	265.08	15.74	122.76	387.85
I_C	77	6.47	46.08	23.55	9.71	33.26	256.06	12.82	98.74	354.81

H_d: Layer thickness; H_{ymax}: Maximum hydroscopic water; X: Soil porosity; W_{drbn}: Field moisture; W_{ch}: Wilting point; X_{mq}: Capillary porosity; X_{nmq}: Non-capillary porosity; I_{mq}: Capillary water content; I_{nmq}: Non-capillary water content; I_{bh}: Saturated water content

4. Conclusion

The infiltration rate increases by the state, from the grassland soil (IA) was the lowest, and then the brushland (IB) to shrubs and regeneration trees (IC) were the highest. The IA state reached the steady infiltration in the shortest time was 34.9 - 36.8 min, IB was 43.4 - 45.2 min, and IC was 68.4 - 74.4 min. It can be seen that the coverage is proportional to the infiltration rate of the forest land.

The infiltration rate depends on the porosity and the thickness of the soil, which is a increasing correlation. The effect of forest water source scheduling is achieved through soil water retention. The results mentioned above indicate that the water storage in non-capillary pores (Inmq) has been less than the water storage in capillary pores (Imq), especially in sloping land with a thin soil, and it will be low, so the protection capacity is limited, it is also necessary to combine other measures to protect soil and water.

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References

[1] Do Thi Lan, Nguyen Tuan Anh and Hoang Tien Ha 2010 GIS application and modeling of soil erosion in Son Dong district, Bac Giang province *J. Agri. Rural Dev.* **11** 162 (in Vietnamese with English abstract).
[2] Do Thi Lan and Nguyen The Dang 2003 Land degradation in traditional cultivation on sloping land in northeastern Vietnam *J. Soil Sci.* **19** 201 (in Vietnamese with English abstract).
[3] Pham Van Dien 2011 Characteristics of soil erosion in *Hevea brasiliensis* forest in Ha Tinh province *J. Agri. Rural Dev.* **11** 95 - 101 (in Vietnamese with English abstract).
[4] Horton R E 1933 The role of infiltration in the hydrologic cycle *Eos Trans. Amer. Geo. Union* **14** 446.
[5] Bouma J and Dekker L W 1978 A case study on infiltration into dry clay soil I. Morphological observations *Geoderma* **20** 27.
[6] Dunne T, Zhang W and Aubry B F 1991 Effects of rainfall intensity, vegetation, and microtopography on infiltration and runoff *Water Res. Res.* **27** 2271.
[7] Onda Y and Yukawa N 1995 The influence of understories on the infiltration rate in Chamaecyparis obtsusa plantations (II): experimental results using mist type rainfall simulator *Japan. J. For. Soc.* **77** 399.
[8] MacDonald L H 2001 Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range *Hyd. Proc.* **15** 2931.
[9] ImRan Hawking 2011 *The effects of prescribed burning on infiltration rates on heather Moorland: Holnicote Estate Exmoor National Park* (Thesis report) pp. 22 - 26.
[10] Pham Van Dien 1999 Water retention capacity of some vegetation status in Hoa Binh reservoir *J. For.* **3+4** 45 (in Vietnamese with English abstract).
[11] Do Thi Lan 2011 Research on the water infiltration and retention ability of forest soil in Bien Nhieu commune, Dinh Hoa district, Thai Nguyen province *J. Sci. Tech.* **86** 149 (in Vietnamese with English abstract).
[12] Bui Xuan Dung 2016 The water infiltration under some types of land use in Luot mountain, Xuan Mai, Hanoi *J. For. Sci. Tech.* **4** 47 (in Vietnamese with English abstract).
[13] Vo Dai Hai 1994 The ability to prevent erosion of vegetation types *J. For.* **5** 8 (in Vietnamese with English abstract).
[14] Pham Van Dien 2009 *Forest water protection function from research to production* (Hanoi Agricultural Publishing House).