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The Effect of Different Patches and Interpatch on Infiltration Rate in an Arid Shrubland Ecosystem

[1]P. Lotfi Anari, [1]G.A. Heshmati and [2]A. Bahremand
[1]Department of Range and Watershed Management, Faculty of Range Management, Gorgan University of Agricultural Sciences and Natural Resources, Iran
[2]Department Range and Watershed Management, Faculty of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources, Iran

Abstract: Effect of different patches and interpatch on infiltration rate was specified in an arid rangeland ecosystem with 188 mm annual mean precipitation in Yazd Province, central part of Iran. Different patches and interpatch were determined in the study area (shrub, iris and grass patches and bare soil as interpatch). Initial (first 5 min), final (last 5 min) and total (30 min) infiltration rates measured by using ring method and then compared together with a completely randomize experimental design. The slope of infiltration rate curves in shrub, iris and grass patches and bare soil decreased, respectively. Infiltration rate increased in shrub patch partially and approximately fixed in the other patches and interpatch after 30 min. The infiltration rate variations in patches and interpatch were different significantly. Iris patch had highest final and total infiltration rates. Iris and shrub patches had highest initial infiltration rate. Initial infiltration rate of the grass patch was lower than the iris and shrub initial infiltration rates. Initial, final and total infiltration rates of the bare soil (interpatch) were lower than the patches. Regarding to shrubs dominance and their high infiltration rates in arid rangeland ecosystems, we concluded that shrub species are the best choice for restoration of these areas that as ecohydrological patterns have a prominent role on reducing runoff, redounded to lower transfer of initial resources out of ecosystem.

Key words: Patch, interpatch, infiltration rate, arid rangeland, ecosystem

INTRODUCTION

Arid and semi arid areas constitute over 30% of the world land surface (Saco *et al*., 2007). These areas function as tightly coupled ecological-hydrological systems with strong feedbacks and interactions occurring across scales (Noy-meir, 1973; Wilcox *et al*., 2003). In semi arid ecosystems, its already well established that hydrology exerts a profound influence over the abiotic components of landscape primarily erosion (Weinwright *et al*., 2000) and loss or redistribution of key plant-limiting nutrients such as nitrogen (Schlesinger *et al*., 1999; Parson *et al*., 2003).

Generally, the vegetation of semiarid and especially arid rangelands consist of mosaics or patterns composed of patches with high biomass cover interspersed within a low cover or bare soil components (interpatch). Soil hydrologic condition is the result of interaction between soil and vegetation. Infiltration rate and sediment yield integrate these factors and are good indicator of hydrologic condition.

Corresponding Author: Peyman Lotfi Anari, Department of Range and Watershed Management, Faculty of Range Management, Gorgan University of Agricultural Sciences and Natural Resources, Iran

A key condition for the development of these patterns is the emergence of a spatially variable field infiltration with low infiltration rates in the bare areas and high infiltration rates in the vegetated areas. The spatially variable infiltration has been observed in many field studies and is responsible for the development of a runoff-runon system (Saco *et al*., 2007). Several field studies have reported much higher infiltration rates (up to 10 times) under perennial vegetation patches than in interpatch areas (Bhark and Small, 2003; Dunkerley, 2002; Ludwing *et al*., 2005). The enhanced infiltration rates under vegetated patches are due to improve soil aggregation macro porosity related to biological activity and vegetation roots (Tongway *et al*., 1989; Ludwing *et al*., 2005). The amount of water received and infiltrated into the vegetation patches, which includes runon from interpatch, can be up to 200% of the actual precipitation (Wilcox *et al*., 2003; Dunkerley, 2002). This mechanism triggers a positive feedback that increases soil moisture and the vegetated patterns (Wilcox *et al*., 2003). The redistribution of water from bare patches (source area, interpatch) to vegetation patches (sink area) is a fundamental process with dry lands that may be disrupted if the vegetation patch structure is disturbed. So vegetation patterns play an important role in determining the location of runoff and sediment source and sink areas (Cammeraat and Imeson, 1999; Wilcox *et al*., 2003; Imeson and Prinsen, 2004). Consequently infiltration rates are often observed to be different under different life forms (Blackburn, 1975; Wood and Blackburn, 1981; Knight, 1984). Studies demonstrated the effect of increasing cover of ground-story plant, particularly grasses, on increasing infiltration rate and reducing runoff and erosion (Pressland and Lenane, 1982).

There is extensive literature showing interactions between infiltration rate and rangeland vegetation, but only infiltration rate of different vegetation life forms in various rangeland sites in comparison with bare soil were considered and relatively few studies specified effect of various patches on infiltration rate.

Therefore, the present study was conducted to determine effect of different vegetated patches and interpatch on infiltration rates (with different time periods) in an arid rangeland ecosystem. The effect of patches and interpatch areas in delaying fixation time of infiltration rate was investigated too.

MATERIALS AND METHODS

Study Area

The study area is located in Nodoshan arid rangeland ecosystems in the Yazd Province in the center of Iran (31°46’85” N, 53°43’04” W). According to Emberger method arid frigid climate with warm summers and cold winters prevails in the study area. The study site receives an average of 188 mm rainfall annual falling as rain and snow, concentrated in the period of autumn and winter of the year. The rainfall erosivity caused by the frequent storms of high intensity and short duration is high. Virtually no water exists on the surface, except locally after infrequent, heavy rainfall. The area consists primarily of sandy loam entisols with a low degree of development and moderate depth (30-70 cm). The elevation of the study site ranges from 1500 to 1900 above sea level. The Maximum and minimum mean temperatures of the hottest and coolest month are 36 and -15°C, respectively. This study has been done in April, 2008.

The study area includes shrubland in gently sloping alluvial fans that are dominated by *Artemiaia sieberi* and *Astragalus achrochlarus*, both are native species that have expanded considerably in extent and density and each has its unique growth pattern and distribution. Some other plant species are: *Astragalus candolleanus*, *Iris songarica*, *Acantholimun* sp., *Acanthphilum* sp., *Stachys inflate*, *Lactuca glaucifolia*, *Poa sinaica*, *Stipa barbata* and *Agropyron desertorum*.

Data Collection

Different kinds of patches and interpatch were reconnoitered in the rangeland study site. Plant species and interspaces between them were considered as microenvironments that have different functions on rangeland hydrological processes, such as infiltration. In this study area three kinds of patches were observed: shrub, grass, iris and one kind of interpatch: bare soil that was included spaces between vegetated patches. Shrub patches were included *Artemisia sieberi*, *Artemisia aucheri* and *Astragalus achrochlarus*. Grass patches were included *stipa barbata* and *Agropyron desertorum*. Iris patch was *Iris songarica*. In all of these patches and interpatch, infiltration rates were determined by using mono ring infiltrometer. ring diameter was 15 cm that is optimum size for ring method. Infiltration rate was determined in 5 min periods for 30 min as total infiltration rate. Infiltration rate in first 5 min period was considered as initial infiltration (sorption). And last 5 min period was considered as final infiltration (steady state flow). Various patches and interpatch areas were considered as infiltration treatments, than Initial infiltration rates, final infiltration rates and total infiltration rates were measured with 8 replications for every kind of patches and interpatch.

Data Analysis

Analysis of variance and mean comparison (Bewick *et al*., 2004) at the 95% confidence used to compare the effect of patches and interpatch on infiltration rate. The Minitab statistical software mainly used.

RESULTS

Infiltration Rate Curves

Different responses of patches and interpatch areas in infiltration process, during (30 min) time period are shown in Fig. 1. Results clearly indicated that patches and interpatch had different responses at the start of infiltrating process, So that the iris patch had highest infiltration rate (16 mm h^{-1}) and the bare soil had lowest infiltration rate (5 mm h^{-1}). Infiltration rate of the shrub patch (13.5 mm h^{-1}) was higher than infiltration rate of the grass patch (9 mm h^{-1}).

At the start of the second 5 min period, infiltration rate reduced in all of patches and interpatch. The Highest reduction in slope of infiltration rate curves, from first 5 min period to second, observed in the shrub patch and lowest reduction in slope of infiltration rate curves, observed in the bare soil. The slope of reducing infiltration rate curve in the iris patch was awhile higher than the grass patch. Reduction of infiltration rates from first 5 min period to second period was drastic in comparison with

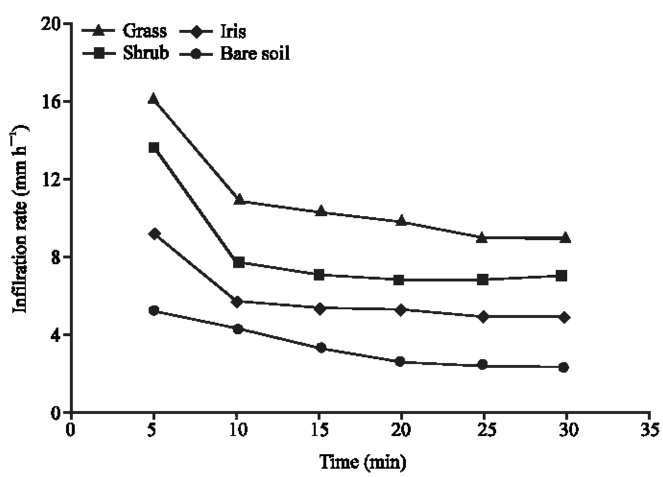

Fig. 1: Infiltration rate curves of different patches and interpatch

general reduction of infiltration rates in 30 min. Highest reduction of infiltration rate in second period to fourth period observed in bare soil and then in the iris patch. Reduction of infiltration rate in shrub and grass patches were almost equal and less than reduction of infiltration rate in iris patch. Reduction of infiltration rate in quintuplicate 5 min period in the iris patch was highest in comparison with other patches and interpatch. In this time period decrease of infiltration rates in the grass patch and bare soil were similar and less than the iris patch. Infiltration rate in shrub patch became stabilized at the last time period (25-30 min). Infiltration rate awhile increased in shrub patch and approximately fixed in the other patches and interpatch.

Initial Infiltration Rate

Results showed significant differences in initial infiltration rates between different patches and interpatch, but no significant difference between initial infiltration rates of the iris and the shrub patches (Fig. 2).

Initial infiltration rate of the bare soil was lowest (5.24 mm h^{-1}) and initial infiltration rate of the shrub and iris patches were highest.

Final Infiltration Rate

Results indicated that final infiltration rates of the different patches and interpatch were significantly different (Fig. 3). Final infiltration rate was highest in the iris patch (9.02 mm h^{-1}) and then in the shrub patch (7.01 mm h^{-1}), the grass patch (4.68 mm h^{-1}) and the bare soil (2.32 mm h^{-1}) decreased, respectively.

Total Infiltration Rate

Results obviously showed that differences in total infiltration rates, between different patches and interpatch were statically significant (Fig. 4).

Total infiltration rate in the iris patch was highest and in the shrub patch, grass patch and the bare soil decreased, respectively. The Iris patch recorded approximately 3 times higher average total infiltration rate (11.1 mm h^{-1}) than on bare soil (3.29 mm h^{-1}). The Shrub patch recorded approximately 2.5 times higher average total infiltration rate (8.16 mm h^{-1}) than on bare soil and total infiltration rate of the grass patch (5.69 mm h^{-1}) was about 2 times than on bare soil.

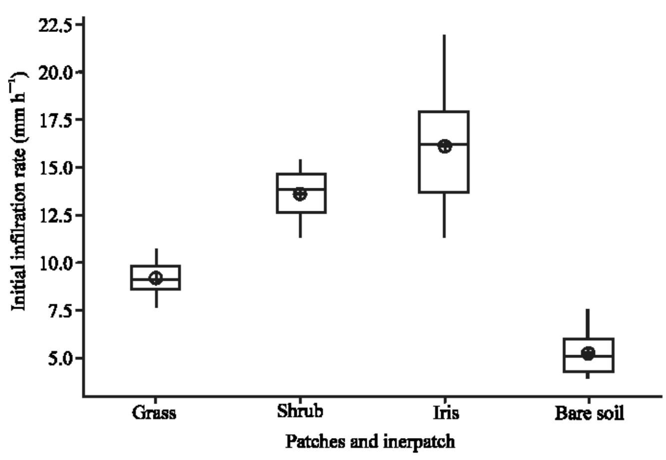

Fig. 2: Initial infiltration rate means of different patches and interpatch

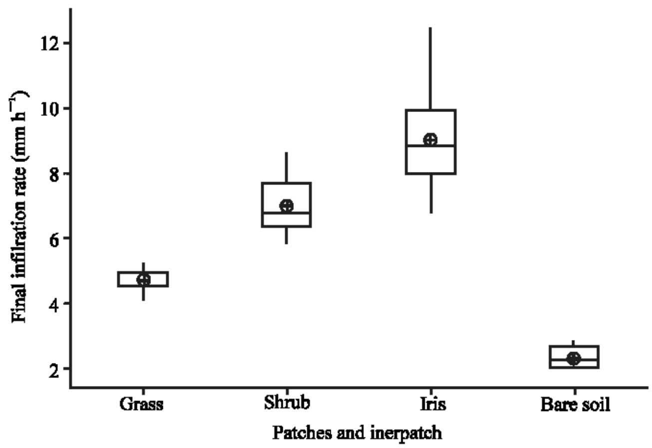

Fig. 3: Final infiltration rate means of different patches and interpatch

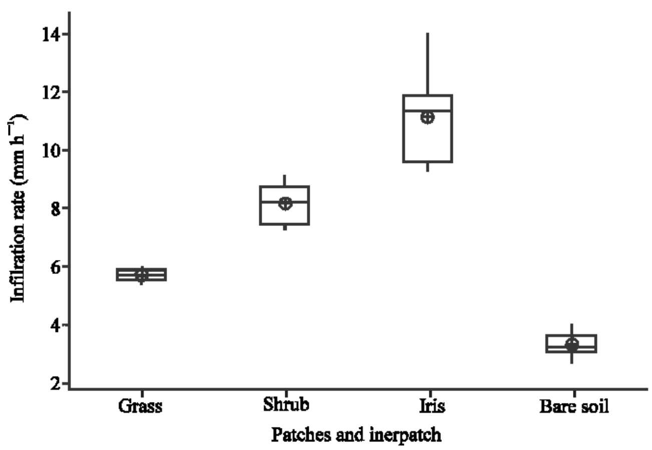

Fig. 4: Total infiltration rate means of different patches and interpatch

DISCUSSION

The results clearly showed that in study site, the areas treated with vegetated patches had higher initial, final and total infiltration rates than the bare soil, after 30 min. Infiltration rate decreased in iris, shrub, grass patches and bare soil, respectively.

Blackburn (1975), Wood and Blackburn (1981), Knight (1984), Dunkerley (2002), Ludwing *et al.* (2005) and Bhark and Small (2003) confirmed infiltration rates are often observed to be different under different life forms. Higher infiltration rates of the shrub patches in comparison with the grass patches are in contradiction with results that indicated by Pressland and Lehane (1982). This inconsistency is related to shrub root system in arid environments. In limiting water ecosystems, plant roots have wide extension especially in shrub life form and include higher rate of plant biomass in comparison with grass life form. This improves soil aggregate stability and soil porosity that infiltration rate is affected by these items. Final infiltration rate in the iris patch was higher than other patches that it can be related to its basal area bunch form. Thereby plant material residue remained from pervious years, accumulate around the patch and it causes increasing in humus, organic matter and soil aggregate stability that lead to rising final infiltration rate. Existence of cryptogam cover reinforce infiltration rate and in this patch cryptogam cover observed more than other patches and interpatch.

As water moves into the soil profile it is influenced by the matric forces of the soil (the force of attraction between soil and water molecules) and gravity. The initial infiltration of water into a soil profile is dominated by a period during which water is absorbed by the matric forces of the soil. Although the difference in initial infiltration rates of the iris and shrub patches was not significant, but high initial infiltration rates in these patches in comparison with the bare soil is so important; becaus it maximizes total infiltrated water into soil that indicated by Wilcox *et al*. (2003) and Dunkerley (2002). Thereby, plant seeds and residual materials do not loss and ecological patches will improve. Inversely, low initial infiltration rate causes to decrease in the total infiltrated water into the soil profile and increase in runoff and erosion.

Water infiltrating into a soil profile from saturated source, will reach a point where the rate of infiltration into the soil profile is constant and steady. At this point gravity and hydraulic conductivity has replaced the sorption as the dominant forces acting on the flow of water. This period of constant infiltration is expressed as the final rate and gives an indication of sub soil structure, water holding capacity and the drainage properties of the soil.

The low final infiltration rate of bare soil is related to the lack of soil biological crusts in interpatch. Inter spaces in arid rangeland ecosystems are not affected by microclimate of patches, thereupon there is no protection from splash erosion in bare soil areas. It leads to destroying soil aggregates and structure and reducing absorbed rain water. And is another major reason for low final infiltration rate. In this rangeland ecosystem there was no cryptogam cover in interpatch, which probably affect on decreasing final infiltration rate too.

Surface runoff can represent a serious loss of water from the ranch, resulting in significantly less sustainable forage production for livestock and/or wildlife. The erosive nature of runoff transports soil nutrients from the site. When erosion is severe, soil depth is reduced, which reduces the amount of water that can be stored in the soil profile. Reduced water storage within the soil profile results in the plants running out of water faster, thus increasing the frequency and severity of drought. Management can reduce runoff through manipulation of vegetated patch area.

Rangeland infiltration rates generally increase as total vegetated patches increases. Patch areas slows water movement across the soil surface, allowing more time for water to infiltrate before being lost down creeks and draws. Vegetated patches also protect the soil surface from raindrop splash. When raindrops hit unprotected soil surfaces, they tend to destroy soil structure, resulting in the pore spaces sealing and crusts forming. Stable soil pores allow water to move into the soil. Finally, patch areas provide organic matter to the soil, which maintains soil structure and aggregate stability, both of which positively influence rainfall infiltration rate.

CONCLUSION

This study demonstrated profound effect of vegetated patches on amount of infiltration rate. Infiltration is a key factor in hydrological processes, so ecological patches play a determinant role in hydrological processes that stated by Noy-Meir (1973) and Wilcox *et al.* (2003). Because of close relationship between patches and interpatch with infiltration rate in the rangeland ecosystem, we can call them ecohydrological spaces. Although, the iris patch has highest infiltration rates, Regarding to dominance shrubs and their high infiltration rates in arid rangeland ecosystems we concluded that shrub species are the best choice for restoration these areas that as ecohydrological patterns have a prominent role on reducing runoff, redounded to lower transfer of initial resources to out of ecosystem.

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