International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(6): 1481-1484

Received: 01-09-2017
Accepted: 02-10-2017

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Assessment of soil infiltration characteristics under micro-watershed in North Eastern part of Karnataka, India

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Abstract
In order to assess the soil infiltration characteristics, a standard field-test method was conducted by means of double-ring infiltro-meters under Patapura micro-watershed in Manvi taluk, Raichur district representing north-eastern dry zone (Zone-2) of Karnataka. The rate of infiltration in a micro-watershed was estimated under representative three different land forms *viz.*, upland, midland and lowland topography. The results were shown that the steady infiltration rates of a micro-watershed in these land forms were decreased from the initial measurement upto the end of 360th minutes, the values of infiltration rate remained firmly stable at 2.1, 1.4, and 0.7 cm hr^{-1} for upland, midland and lowland soils, respectively. The cumulative infiltration (26.3 cm) and terminal infiltration rate (2.1 cm hr^{-1}) were observed highest in case of upland area. Similarly, in midland and lowland areas were recorded lower amount of cumulative infiltrations (22.0 cm and 11.8 cm) and infiltration rates were also showed lowest *i.e.*, 1.4 cm hr^{-1} and 0.7 cm hr^{-1}, respectively compared to upland area. The terminal infiltration rate followed the order: lowland < midland < upland physiographic locations. The factors influencing infiltration rates are soil texture, soil organic matter, soil sodicity, porosity, bulk density, topography and initial soil moisture content in the testing area. Therefore, increasing of soil infiltration, reducing runoff velocity and volume are the main aims for soil and water conservation in the watershed area for management and development of soil profile

Keywords: Infiltration rate, cumulative infiltration, land forms, micro-watershed.

Introduction

Water is one of the most important resource. As far as the watershed is concerned, the main source of water is rainfall. When the rainfall takes place, then various hydrologic processes will be taking place and that rainfall to transform into runoff. Interception, evapo-transpiration, infiltration, percolation, like that so many processes actually decide how much will be the runoff for the given rainfall condition. The hydrologic information, when we deal with the water as a resource for the watershed planning and management. So, we have to mainly deal with, how much will be the rainfall intensity, how much will be the runoffrate, how much is the channel flow and how much is the soil erosion and then how much is the subsurface flow components ultimately the soil infiltrability factors.

Infiltration is the process by which water on the soil surface penetrates the soil. But, rate of infiltration (cm hr^{-1}) is the volume of water flux flowing into soil profile through a unit soil surface area (Savalia *et al*., 2009) [7]. Infiltration can be quantified by the soil infiltrabilityand/or cumulative infiltration. It is related to overland flow and groundwater determining the fraction of the irrigation or rain water entering the soil and thus, affecting the amount of runoff responsible for subsequent soil erosion (Lei Zhidong *et al*., 1988) [4]. Soil infiltration rate and the cumulative infiltration are comparatively very high initial soil infiltrability decreasesrapidly with time. The rate of decrease slows down exponentially and the infiltration rate gradually reaches asteady state. The final soil infiltration rate is equal to or very close to the saturated hydraulic conductivity. It usually takes five to six hours for the soil infiltration process to reach the final infiltration rate.

Soil infiltrability is determined by the matric potential gradient at the soil surface. The high initial soil infiltration rate is related to the relatively high matricpotential gradient of an initially dry soil. The soil suction gradient decreases with the increase of wetted soil depth. The soil infiltrability is affected by time, soil texture and structure, antecedent soil moisture content, topography, soil surface cover conditions, soil depth, rainfall intensity *etc.* The soil infiltration rate is closely related to soil conditions including soil texture, aggregate stability, cracks and crusts at the soil surface. Sandy soils and soils with stable aggregates have much higher infiltrability than the silty soil. The swelling in clay soils can further reduce the soil infiltrability. The presence of macro pores and the consequent high soil porosity promotes the infiltration process (Mao Lili *et al*., 2008) [5].

The topography of a watershed or a hill-slope refersto generally as slopes, and the combinations of soilsurface properties, the orientation of the slopes and the micro-topography of the soil surface also affect soil infiltration processes (Qin Yaodong, 2003) [9].

Materials and Methods

The study area located in Patapura micro-watershed (WS-code: 4D3A4B1e), Manvi taluk, lies on the SH-20 about 63 km away from the Raichur district and representing north-eastern dry zone (Zone- 2) of Karnataka covers an area of 542.4 ha and lies between 16º 07'35.9" N and 16º 08'22.3" N latitudes and 76º 51'33.3"E and 76º 53'27.7" E longitudes. Patapura micro-watershed covers Gudidinne, Chikkahanige, Goldinni and Patapura villages. The adjacent black and red soils were seen in this area with the red sandy soils being limited to hill-tops which are also a feature of the micro-watershed. The study area belongs to semi-arid tropical climate of Southern India. The slope and soil texture both are limiting factors for crop production that in turn are determined by topo-sequence.

Infiltration rate was determined by double ring infiltro-meter as described by Black (1965) [1]. The double ring infiltro-meter with inner ring of 30 cm and outer ring 50 cm diameter each had a height of 30 cm above the ground. Infiltration test was carried out in each land forms of upland, midland and lowland situation. The infiltro-meter was driven into the soil at a depth of 10 cm with the aid of a sledge hammer and care was taken to ensure that it creates minimum disturbance to the soil. The outer ring acts as a buffer ensuring a vertically downward movement of water. The infiltro-meter was flooded at a constant 5cm depth throughout the duration of each test run. The observation on subsidence of water level was taken at the end of 1, 3, 5, 10, 20, 30, 40, 60, 80, 100 and 120 minutes and thereafter at hourly intervals up to 360th minutes or the process continued until a steady state was reached.

Results and Discussion

The data furnished in Table.1 pertaining to evaluation and assessment of water infiltration rate and cumulative infiltration studied in three topo-sequential locations of Patapura micro-watershed indicated that, infiltration rates decreased from the initial measurement at 1 minute to upto 360th minutes. But the cumulative infiltration increases from initial measurement and up to the end of 360th minutes.

Infiltration rate is the capacity of soil for letting water to percolate through a unit soil surface area in a given period of time. The steady rate of infiltration decreased from 30.0 to 2.1 cm hr^{-1} in upland, 15.0 to 1.4 cm hr^{-1} in midland and 6.0 to 0.7 cm hr^{-1} in lowland from the initial measurement at 5 minutes upto 360th minutes. At 300th minute and onwards upto the end of figures, the values of infiltration rate remained firmly stable at 2.1, 1.4 and 0.7 cm hr^{-1} for upland, midland and lowland soils, respectively. The highest amount of cumulative infiltration of 26.3 cm was observed in upland area. Similarly, in midland and lowland situation, the cumulative infiltrations were examined and result showed that 22.0 cm and 11.8 cm, respectively.

When water is supplied to an initially dry soil, the large suction gradient across the soil surface becomes very high which leads to high initial infiltration rate. As the wetting front moves downward, the suction gradient across the soil profile decreases, then the rate of water infiltration becomes steady gravity driven flow and is equal to saturated hydraulic conductivity (Ks) of those soils (Rathan Lal and Shukla, 2004) [6].

The higher infiltration rate in upland area was due to the lower soil organic matter content and per cent clay. Due to coarse soil texture, since leaching/eluviations of fine clayey soil particles through runoff water during rainy season, which ultimately leads to formation of large number of macro-pores with coarse texture, the movement of waterin soil profile is more in case of upland soils. Thus, type of soil texture seemed to play a major role for variation of infiltration rate. Similar results were stated by Demelash and Stahr (2010) [2] in assessment of integrated soil and water conservation measures on key soil properties in South Gonder, North-Western Highlands of Ethiopia.

The midland area has medium infiltration rate and their characteristic properties were intermediate between upland and lowland soils, because of slight sodicity development that leads to formation of impervious layer like hard pans which can declines the water movement in the soil profile, ultimately reduces infiltration rate of the soil.

Similarly, the lowland area has very poor infiltration rate but its soil properties were very different from other land forms, because of development of more alkalinity and water stagnation which were resulted by illuviations of high amount of organic matter and clay particles through runoff water from upland and midland areas in the study area (Fig. 1). The decrease in infiltration rate caused by dispersion of aggregates or slaking, soil compaction and surface sealing or clogging of soil pores (Shukla *et al*., 2003) [8].

In the soil profile, development of alkaline nature leads to dispersion of soil colloids and blocking of macro pores as well as formation of crust in the soil surface layer. Therefore, lowland soils has very poor infiltration rate because, those soils containing swelling type of clay minerals like montmorillonite. These observations were in accordance with the findings of Gulati and Rai (2013) [3] in soil and organic matter characterization of an agrarian micro-watershed in lowland areas of Chotanagpur highlands.

Conclusion

The infiltration refers to the process of downward entry of water in the soil. The assessment and evaluation of infiltration is an important process because its rate often determines the amount of accumulation or runoff over the soil surface during heavy rainfall in the study area. Therefore, hazard of soil erosion or water stagnation during heavy precipitation is determined by the process of rate of infiltration. So, the upland area has higher value of infiltration rate than midland and lowland soils.

However, in the field conditions, if ponding on soil surface continues for a long time, the gradual decrease in infiltration rate with time may be attributed due to the swelling of clay and dispersion of fine soil particles which might have gradually narrowed down the pore diameter resulting in gradual lowering of infiltration rate. The terminal infiltration rate followed the order: lowland < midland < upland physiographic locations. Therefore, lowland sodic soils have very less infiltration rate than non-sodic soils *i.e.* upland and midland soils. Usually, infiltration rates of these landforms are varied with the intensity of sodicity development, type of clay minerals and its content but, these factors are confirmed by land topography. Therefore, increasing soil infiltration, reducing runoff velocity and volume are the main aims for soil and water conservation in the watershed area for management and development of soil profile.

Table 1: Infiltration rates of different locations in toposequence of Patapuramicro-watershed

Cumulative time (minutes)	Upland		Midland		Lowland	
	Cumulative infiltration (cm)	Infiltration rate (cm hr^{-1})	Cumulative infiltration (cm)	Infiltration rate (cm hr^{-1})	Cumulative infiltration (cm)	Infiltration rate (cm hr^{-1})
0	0.0	0.0	0.0	0.0	0.0	0.0
1	2.0	120.0	1.7	102.0	2.6	156.0
3	3.5	45.0	2.2	15.0	3.6	30.0
5	4.5	30.0	2.7	15.0	3.8	6.0
10	6.0	18.0	3.6	10.8	4.4	7.2
20	8.4	14.4	5.1	9.0	5.1	4.2
30	10.4	12.0	6.6	9.0	5.9	4.8
40	12.2	10.8	7.5	5.4	6.2	1.8
60	14.4	6.6	9.2	5.1	6.8	1.8
80	16.2	5.4	10.8	4.8	7.2	1.2
100	17.9	5.1	12.4	4.8	8.1	2.6
120	19.2	3.6	13.8	4.2	8.7	2.0
180	22.0	2.8	17.1	3.3	9.4	1.2
240	24.2	2.2	19.2	2.1	10.4	0.8
300	26.3	2.1	20.6	1.4	11.1	0.7
360	-	-	22.0	1.4	11.8	0.7

Measurement of infiltration rate in the study area

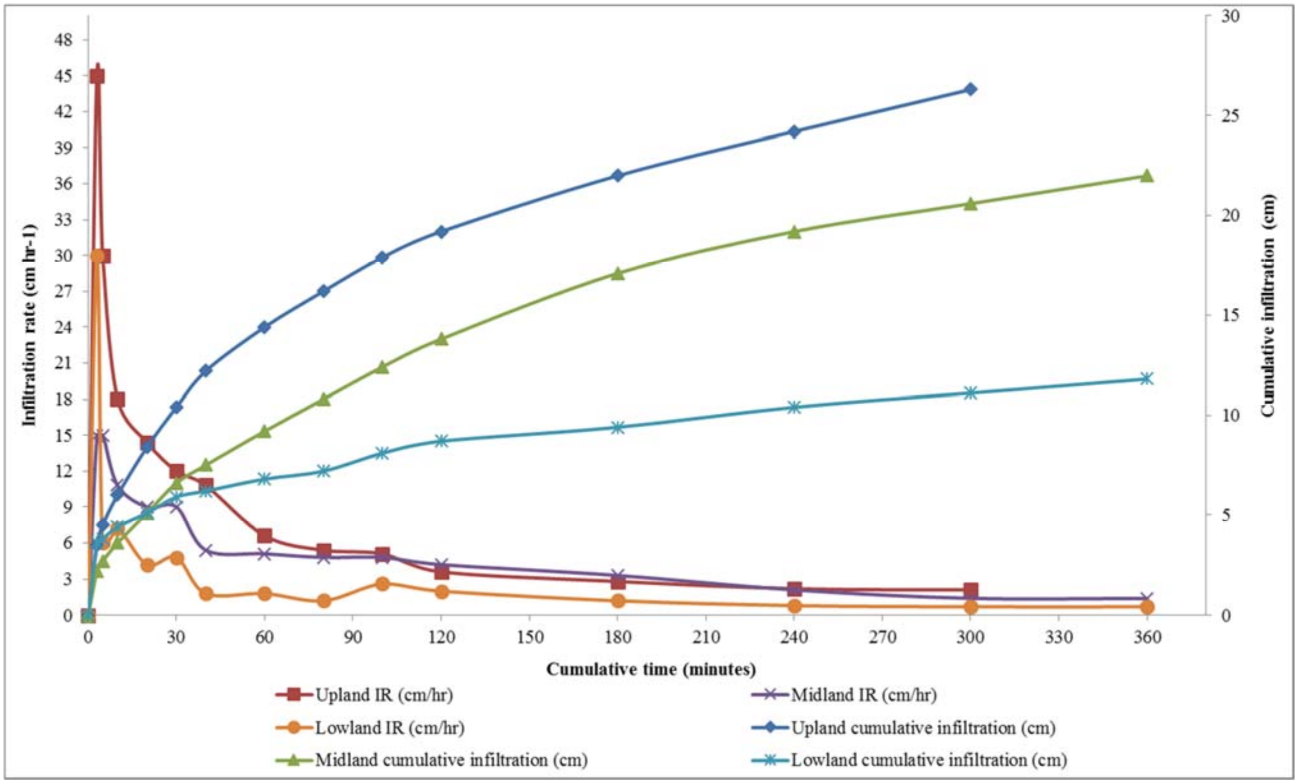

Fig 1: Soil infiltration characteristics of different topo-sequencial locations in Patapura micro-watershed

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