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PREFERENTIAL FLOW : A HOT SPOT FOR BIOLOGICAL ACTIVITY IN SOILS - A CASE STUDY

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ABSTRACT

Land degradation is highly dependent on a preferential flow path, which is influenced by plant roots, the surrounding rhizosphere and the surrounding landscape features. Plant roots within soil profiles constitute a complicated macropores network that influences soil water flow. Specific microbes were mobilised selectively in preferential flow paths along root channels. The effects of the plant roots on preferential flow and soil water and its influence on soil microbial biomass carbon built up in semi-arid regions were assessed. Tracer experiments were carried out in Oct-Dec 2020 by Blue FCF dye. At each site, two 1m ×1m flat plot was selected, and an iron frame with a volume of 0.20 m and 0.5 cm thick was embedded into the soil. Soil Microbial Biomass Carbon (SMBC) in the flow path was in the range of 200 to 300 µg g^{-1}, while in the soil matrix, it varies 50 to 150 µg g^{-1}. Finer roots play a vital role in deciding the flow path than coarse roots. The study shows that preferential flow paths are hot spots for various biological *vis à vis* microbial activities in soils of the study area.

(Key words: Preferential flow, flow path, blue FCF dye)

INTRODUCTION

Soil preferential flow, one of the essential hydrological processes, influences various environmental issues, specifically land degradation and groundwater resource security. It is studied on different scales from field to catchment area (Beven & Germann, 2013; Keesstra *et al.,* 2016). Soils with more continuity of vertically oriented preferential flow paths promote water flow, and these flow paths change the soil hydrological process (De Boever *et al.,* 2014; Wang *et al.,* 2016). During plant root growth, channels formed by plant roots and root-soil interfaces affect soil hydrological responses, such as water uptake, nutrient acquisition, solute retention, and soil conservation. Plant roots sometimes grow into soil pores to form continuous preferential root channels (Tracy *et al.,* 2011), supporting the flow path to below horizons in soil. Moreover, preferential flow can promote water flow and solute transportation with significantly less resistance (Bogner *et al.,* 2010). Studies on the role of plant roots to preferential flow and soil water flow, which tend to characterise land degradation, are hot spots in pedological research (Zhao *et al.,* 2016). Preferential flow at the pore scale arises from different controlling factors: soil biota (Cerdà *et al.,* 2009); land use (Zema *et al.,* 2012; Leh *et al.,* 2013; Liu *et al.,* 2014; Wildemeersch *et al.,* 2015); vegetation (Zhao *et al.,* 2016); plant roots (Bargués Tobella *et al.,* 2014; Zhang *et al.,* 2015a) are few of them. The evaluation of plant root hydrological responses has been hindered by the associated mechanisms of soil water flow and solute transportation, particularly preferential flow (Ola *et al.,* 2015). Plant roots and preferential flow relationship were described by Ceccon *et al.* (2011); Bargués Tobella *et al.,* (2014), and Zhang *et al.*, (2015a). Land degradation is highly dependent on preferential flow path, which is influenced by plant roots and the surrounding rhizosphere, which plays a deciding factor in various landscapes. The chemical and biological activities in the rhizosphere and the physical action of plant roots form stable channels of preferential flow (Ghestem *et al.,* 2011).

When there is more variability in the soil water flow, it is essential to consider preferential flow properties because of the interaction between plant roots and soils (Vannoppen *et al.,* 2015). Plant roots within soil profiles constitute a complicated macropores network, which significantly influences soil water flow. Specific microbes were mobilised selectively, likely due to the preferential flow of seepage water along root channels. This fact can determine various microbial environments within the same soil. Preferential flow paths have increased microbial biomass compared with the soil matrix since locations along

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flow paths are more exposed to drying and wetting and have a better nutrient supply (Bundt *et al.,* 2001). Consequently, preferential flow paths might be locations with an enhanced turnover of soil organic carbon and nutrients.

With this background, the study was conducted to evaluate the fine root distribution in response to preferential flow paths and quantitatively identify the relation between plant root distribution and soil water flow. So that the preferential flow and soil water flow can be observed with the soil microbial biomass carbon build up in semi-arid soils

MATERIALS AND METHODS

Hayathnagar micro-watershed issituated in Hayathnagar village, Rangareddy district of Telangana, lying between $17^0$20' 18.00" to $17^0$21' 8.94 N latitude and 78^0 35' 26.14" to $78^0$36' 4.890" E longitudes. The total area of the micro-watershed is 154 ha (fig.1a). The area has been divided into three units upper-reach, middle and lower-reach based on their elevation (fig.1 b).

Tracer experiments were carried out in Oct – Dec. 2020. At each site, two 1m ×1 m flat plot was selected, and an iron frame with a volume of 0.20 m and 0.5 cm thick was embedded into the soil. The soil surface within 5 cm at the inner and outer sides of the iron wall was compacted to keep the dye from leaving the frame. Brilliant Blue FCF in water was applied manually at a concentration of 4 g l^{-1} with a backpack sprayer. The infiltration capacity of the soil determined the application rate because ponding was to be prevented. The application took 1.2 hours. After 24 hours, a profile was dug beside the dye application area, and the plot was excavated. The stained area was defined as the preferential flow path, whereas the unstained area was considered the soil matrix.

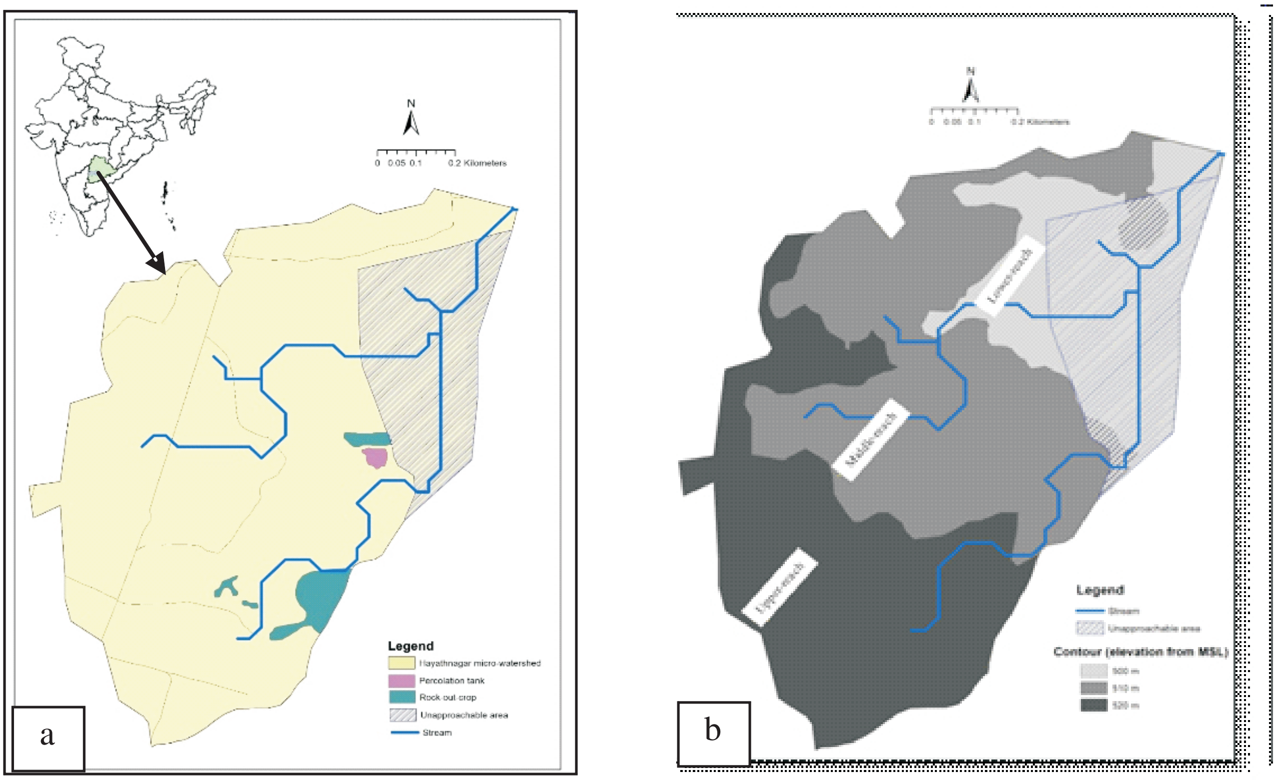

Figure1: Location map (a) and elevation map (b) of the study area

RESULTS AND DISCUSSION

Soil Microbial Biomass Carbon (SMBC) in the flow path was in the range of 200 to 300 µg g^{-1}, while in the soil matrix, it varies 50 to 150 µg g^{-1}. These findings were similar to Bundt *et al.,* (2001), which shows that SMBC was 9 to 92% higher in the flow path than in the soil matrix. Lower reach shows much variation in SMBC between the land use. Fallow land at middle reach was observed least SMBC while cropped land shows least differences of SMBC between flow path and soil matrix.

Planted forest at lower reach observed to have higher (300 µg g^{-1}) SMBC followed by plantation crop at upper reach (210 µg g^{-1}) and planted forest (200 µg g^{-1}) at middle reach. Yao *et al.,* (2000), Padalia *et al.,* (2001) and Singh et al. (2021) also observed that cropped land had less SMBC compared to fallow and forest land (Fig. 2).

Roots play an essential role in soil preferential flow (Table 1), which agrees with Perillo *et al.* (1999), who found that decaying and living roots were pivotal for preferential flow pathways. Cui *et al.* (2019) found that fine roots were the main factors affecting the potential soil infiltration in semi-arid tropics. While, studying the number of soil profile roots, the roots in the flow path and soil matrix were counted. The finer roots (d" 5 mm) and the coarser roots (e" 5mm) were counted. At upper reach, cropped land had maximum roots (90%) in the flow paths. All the roots were not in the flow path. One-way ANOVA and Spearman's correlations were done to know the relation between the number of roots (fine/coarse) and its significance with dye coverage. In the study, the fine root density (d"5 mm diameter) decreased with increasing depth except for plantation crop, which covers up to the soil profile depth. Zhang *et al.* (2015) also found the same results. Sandy loam and sandy clay loam will enhance plant roots growth in macropores (Zhang, 2015). The soil was very compact at 30 to 40 centimetres depth in middle reach, leading to few roots penetrating. Thus, most of the roots were confined to a depth of 20 to 30 centimetres, even in forest land. The lateral flow was observed in these soils.While in lower reach, most of the roots (85 to 90%) were observed in the flow path (Fig. 3), Table 1 shows that fine roots at upper reach were maximum for fallow land. A correlation between dye coverage and the number of roots (fine/coarse) (Table 1 and 2) reveals a higher correlation of fine roots (at the significance level of 0.001) with dye coverage in fallow land and plantation crop but planted forest having significance at 0.05 level. Fine roots in the cropped plants have a high correlation coefficient (r=0.96), with dye coverage found to be statistically insignificant. The variable proportions of the stained area show the importance of preferential flow at our site (Fig. 2). Based on experimental evidence from other studies (Ritsema and Dekker, 2000; Hagedorn and Bundt, 2002), we suppose that many preferential flow paths remain stable down to the subsoil. Indeed, preferential flow along root channels dominates the flow system in the top soil. In the sub soil, root density diminishes and in homogeneous infiltration from preferential flow paths into the soil matrix takes place (Bogner *et al.,* 2010). Consequently, as root channels remain stable for a long time (Hagedorn and Bundt, 2002), infiltration into the soil matrix in the subsoil is likely to occur at the exact location.

In soils, preferential flow is the rule rather than the exception. Understanding the well-established preferential flow mechanism in this system is important to understand the soil-water flow, especially at rainfed areas in semi-arid tropics. From this study, it is concluded that the preferential flow paths are hot spot for various microbial activities, indicated by a high difference in the amount of SMBC(> than 30 to 40 per cent) in all land use except in cropped land of middle and lower reach where the difference is low (10-20 per cent) between flow path and soil matrix. However,roots play an essentialrole in deciding vertical preferential flow path;where lateral flow prevails (as in middle reach), the significance of roots for determining flow paths was not established.

Table 1. Dye coverage and fine roots

Land Use	**Planted forest**			**Fallow land**			**Cropped land**			**Plantation**
Elevation	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower	Upper
DC (%)	33	29.14	67.7	28.8	37.07	64.9	19.5	44.6	60.4	50.7
Fine roots (no.)	11	11	27	36	23	37	12	20	20	9
Correlation coefficient	0.82	0.6	0.9	0.96	0.91	0.91	0.96	0.95	0.96	0.7
P-value	0.032*	0.08	0.02*	0.007**	0.07	0.033*	0.109	0.11	0.21	0.008**

* significant difference at the level of P<0.05, ** significant difference at P<0.01

*** significant difference at the level of P<0.001

Table 2. Dye coverage and coarse roots

land Use	**Planted forest**		**Plantation**	
Elevation	Upper	Middle	Lower	Upper
DC (%)	33	29.14	67.7	50.7
Fine roots	7	6	8	21
Correlation coefficient	-0.71694	0.5	0.9	-0.27702
P-value	0.025*	0.054	0.004*	0.001*

* significant difference at the level of P<0.05, ** significant difference at P<0.01

*** significant difference at the level of P<0.001

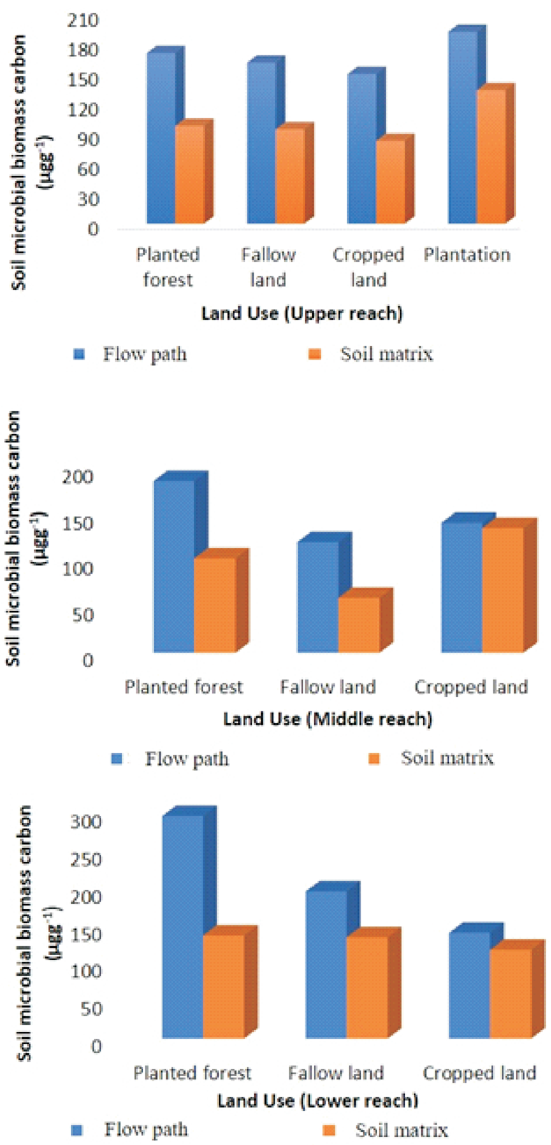

Figure 2. **Soil microbial biomass carbon under different elevation and land use**

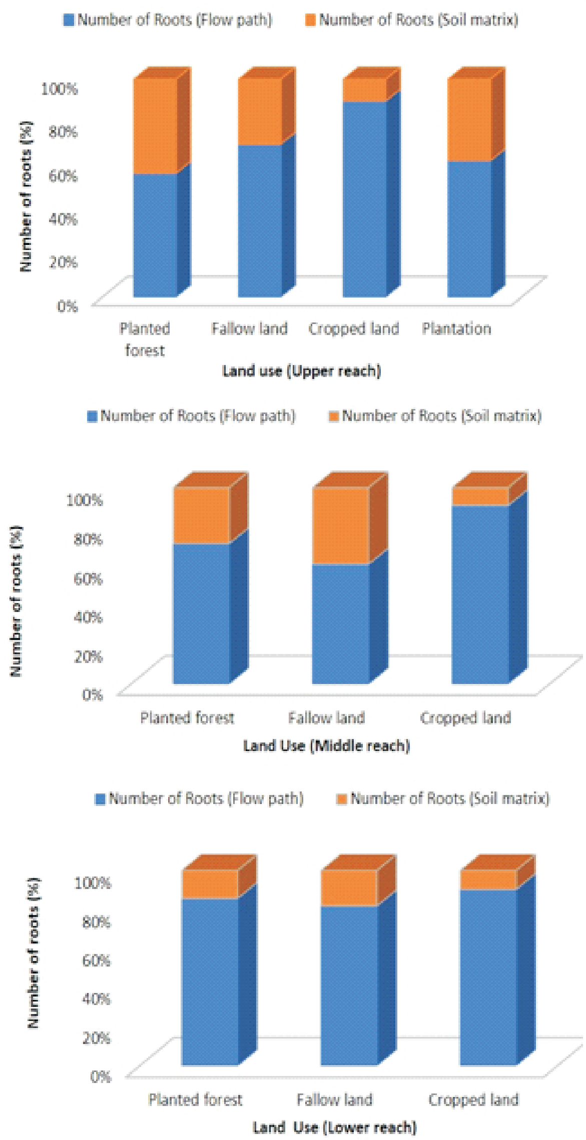

Figure 3. **Roots (in percentage) under different elevations and land use**

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