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Research Article

FINE ROOT BIOMASS AND NUTRIENT AVAILABILITY IN A COMMUNITY MANAGED FOREST

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ABSTRACT

Fine root production and soil parameters in community managed forest consisting of *Quercus leucotrichophora* (*Banj* or Oak) and *Pinus roxburghii* (*Chir* or Pine) were measured. Fine root biomass has an important implication for individual plant growth and carbon nutrient cycling. Fine root biomass and carbon varies widely within and among species and across various seasons. The total fine root biomass across four sites varied from 4.33 t ha $^{-1}$ to 6.65 t ha $^{-1}$. Fine root biomass declined with increasing soil depth. The fine root biomass in the present study was higher during the rainy season (59.2%) followed by summer and winter seasons (26% and 14.8%, respectively). Soil organic carbon values of the present study ranged from 1.00±0.29 to 2.73±0.51% and declined with increasing soil depth. Fine root acts as a medium for transfer of atmospheric carbon into the soil in the form of carbon containing compounds. Root necrosis and exudates contribute significant quantities of carbon deposited in sub surface soil. These deposits have the potential for a greater contribution to long term soil carbon sequestration in reducing atmospheric CO_2 concentration.

Key Words: *Community Managed Forest**,** Fine Root, Carbon Sequestration Rate*

INTRODUCTION

Fine root production represents a varying proportion of the total accumulated organic matter of forest stands, and plays an important role in soil carbon and nutrient cycling (Vogt *et al.*, 1986; Aerts *et al.*, 1992; Trumbore and Gaudinski, 2003). Fine roots exert a significant influence on the soil profile development and contribute substantially to the soil organic pool through their turnover (Persson, 1982). Fine root biomass is constantly renewed, and its productivity often exceeds aboveground productivity despite the fact that living fine root biomass constitutes only a small fraction of the total stand biomass (Helmisaari *et al.*, 2002). Globally, 33% of the global annual Net Primary Productivity is estimated to be used for the production of fine roots (Jackson *et al.*, 1997). The distribution of fine roots in different soil layers is assumed to be related to climate and site characteristics, such as soil structure, compactness and aeration, and differs between different plant species. The rate of growth of fine roots is affected by the availability of nutrients and environmental factors such as soil temperature and moisture contents. Fine roots of trees and understory vegetation play an important role in the carbon and nutrient dynamics of forest soils. Their C input into the soil in the form of fine root litter may be several times larger than the corresponding inputs from aboveground litter (Ruess *et al.*, 1996; Scheffer and Aerts, 2000). However, there is insufficient quantitative information available about their contribution to the carbon and nutrient budgets (Trumbore and Gaudinski, 2003). Fine root biomass varies over the growing season, and because of influences from site characteristics, fine root dynamics differ between forests across the world. Fine roots exert an important influence between atmosphere and soil because they are the link between the aboveground C pool and the soil C pool. This is why we need robust estimates of fine root biomass and production. An effort has been made in the present study to understand the seasonal dynamics of fine root biomass and the role of fine roots in carbon transfer from the atmosphere into the soil in community managed forest.

MATERIALS AND METHODS

The study was conducted in the Anriyakot Van Panchayat forests of Lamgara block of Almora districts situated between 29º 32′ 98″ N Latitude and 79º 41□□' 45□□" E Longitude. The site characteristics are given in table 1.

Table 1: Site Characteristics of the Anriyakot Van Panchayat Forest

Parameters	Anriyakot Van Panchayat
Altitude (m)	1500-1800
Dominant Vegetation	*Quercus leucotrichophora* and *Pinus roxburghii*
Total Tree density (in/ha)	150 to 490
Total seasonal litter fall (t/ha)	5.61 to 6.83
Sand (%)	45.57±6.92 to 76.07±2.95
Silt (%)	9.02±1.94 to 22.25±3.64
Clay (%)	13.1±1.79 to 41.90±1.61
Soil bulk density gcm^{-3} (0-100cm)	1.15±0.006 to 1.44±0.22
Soil carbon (%)	0.38±0.09 to 2.73±0.51
Annual range of soil moisture (%)	7.53±1.06 to 29.72±1.15

The basic climate pattern is governed by the monsoon rhythm with an average annual rainfall between 274.5 mm and 463.2 mm. The mean maximum temperature varies from 17.31°C (December) to 27.87°C (June), while the mean minimum temperature varies from 2.18°C (January) to 14.87°C (June). The parent material forming the soils in the study area mainly comprises of schist, micaceous quartizimeta morphism, plutonic bodies of granodiorites and granites (Valdiya, 1980). The vegetation type mainly comprises Himalayan moist temperate oak forest and subtropical pine forest. Fine root biomass (< 1 mm in diameter) was estimated following the ingrowth core method. The soil cores were obtained by driving a sharp edged steel tube (8.5 cm internal diameter) in to the soil up to a depth of 1m (0-20, 20-40, 40-60, 60-80, 80-100 cm soil depths). A total of 360 soil samples were taken for each depth class in three seasons (winter, summer and rainy). Fine roots were excavated from the soil core with the help of a steel tube and the hole refilled afterwards with soil. Samplings were carried out in three directions from the measured trees and a sample point was located at 1⁄2m, 1⁄4m and 1⁄8m of the distance away from the neighbouring trees. Root samples collected from different directions and different depths were kept in separate polythene bags and brought to the laboratory. Roots were separated from other organic material by passing the soil core through a sequence of sieves. Soil samples were collected from 5-6 pits dug to 100 cm depth in different locations for each site. From each pit 300 to 500 g soil samples were collected from 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm, 90-100 cm soil depths. Soil texture was determined after removing the gravel particles, air drying the soil samples and passing through a series of sieves following Jina (2009). Soil moisture was determined on fresh weight basis following Jackson (1958). Soil carbon content was based on rapid titration method of Walkey and Black following Jackson (1958). For total Nitrogen (N), available Phosphorus (P) and available Potassium (K), three composite samples at different soil depths (0-30, 30-60, 60-100 cm) were taken. The total nitrogen content (%) was determined by micro-Kjeldahl assembly (Peach and Tracey, 1956). Soil phosphorous and potassium were extracted by wet ashing of 1 g soil material in acid mixture consisting of 10 ml H_2SO_4 +3 ml HNO_3 + ml $HCLO_4$ (Jackson, 1958). Soil potassium was determined using a flame Photometer, and phosphorous was determined using spectrophotometer following Jackson (1958). To determine soil bulk density, soil samples were collected by means of a special metal core-sampling cylinder of known volume from different layers considered for soil carbon estimation for different soil depths. Samples of soil were brought to the laboratory and oven dried at 60°C till constant weight and soil bulk density was calculated following Misra (1968). Analysis of variance (ANOVA) and Standard errors were calculated by using SPSS version 16 software.

RESULTS

Site I

The total fine root biomass at site I over the whole year was 6.15 t ha $^{-1}$. It was maximal in the rainy season (3.93 t ha $^{-1}$) followed by summer and winter seasons (1.56 t ha $^{-1}$ and 0.65 t ha $^{-1}$, respectively). Fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 67.4% to the total fine root biomass; 38.5% was observed in the 0-20 cm interval, 28.9% in the 20-40 cm interval, 16.6% in the 40-60 cm interval, 8.8% in the 60-80 cm interval and 7.2% was recorded in the 80-100 cm interval (Figure 1).

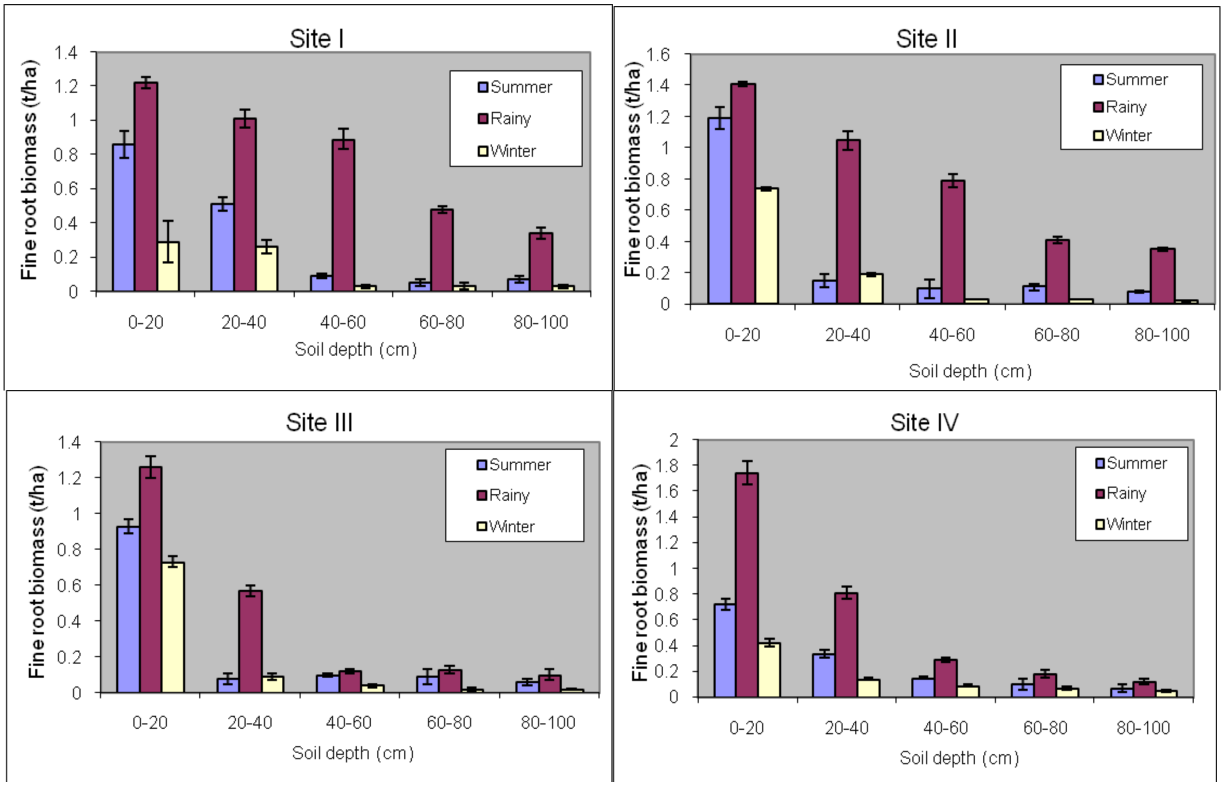

Figure 1: Fine Roots Biomass (T Ha $^{-1}$) Of Anriyakot Van Panchayat across Different Sites and Seasons

The total fine root carbon stock across the three seasons at this aspect was 3.07 t ha $^{-1}$. The contribution of fine root carbon stock was highest in rainy season (1.97 t ha $^{-1}$), followed by summer and winter seasons (0.78 t ha $^{-1}$ and 0.33 t ha $^{-1}$, Figure 2).

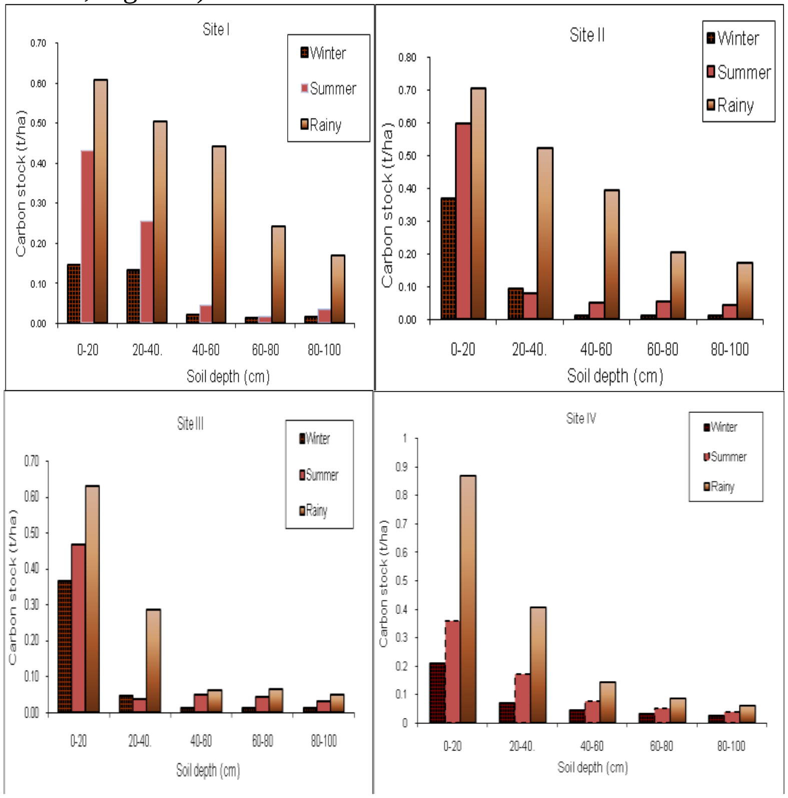

Figure 2: Fine Roots Carbon Stock (T Ha $^{-1}$) of Anriyakot Van Panchayat across Different Sites and Seasons

The organic soil carbon percent varied from 1.34±0.19 to 2.23±0.31 across all the soil depths (Figure 3).

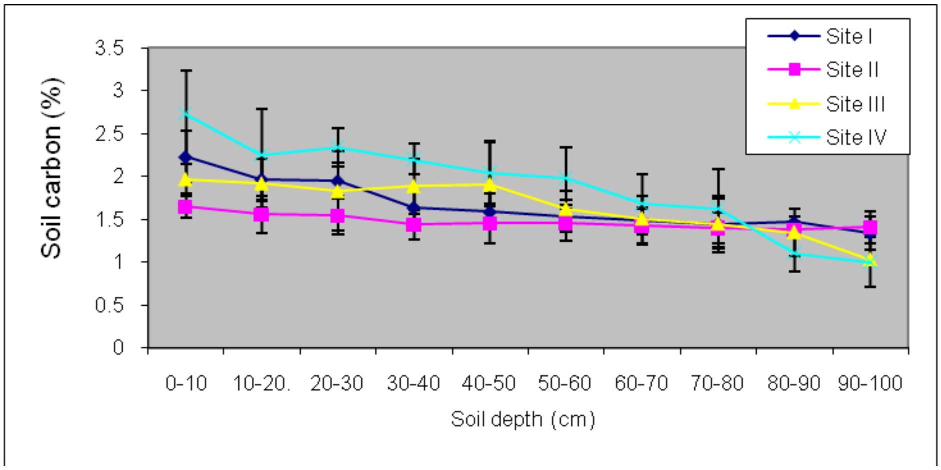

Figure 3: Soil Organic Carbon Percent of Anriyakot Van Panchayat along Different Soil Depth and Sites

Contrary to this, the soil bulk density followed a reverse trend and varied from 1.18±0.03 g cc^{-3} to 1.44±0.22 g cc^{-3} across different soil depths. Soil nitrogen, phosphorus and potassium value varied from 0.18 to 0.22%, 0.0008 to 0.0018% and 0.0072 to 0.0108%, respectively across different soil depths (Figure 4).

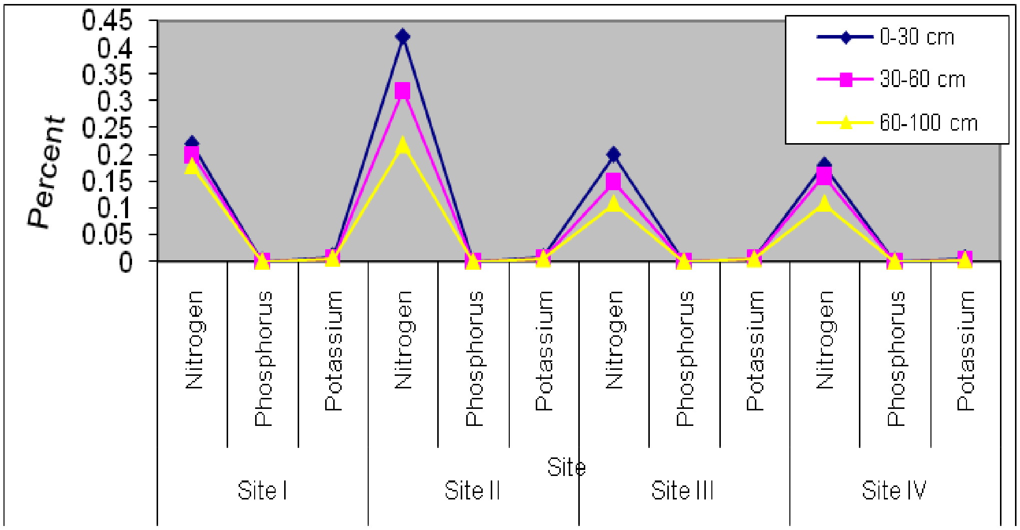

Figure 4: Nitrogen, Phosphorus and Potassium of Anriyakot Van Panchayat along Different Soil Depths and Sites

Site II

The total fine root biomass at site II over the whole year was 6.65 t ha $^{-1}$. It was maximal in the rainy season (4.00 t ha $^{-1}$) followed by summer and winter seasons (1.64 t ha $^{-1}$ and 1.01 t ha $^{-1}$, respectively). Fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 85% to the total fine root biomass; 50.3% was observed in the 0-20 cm interval, 20.9% in the 20-40 cm interval, 13.7% in the 40-60 cm interval, 8.2% in the 60-80 cm interval and 6.9% was recorded in the 80-100 cm interval (Figure 1). The total fine root carbon stock across the three seasons at this aspect was 3.33 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (2.00 t ha $^{-1}$) with lower but similar value in summer and winter seasons (0.82 t ha $^{-1}$ and 0.51 t ha $^{-1}$, Figure 2). The organic soil carbon percent varied from 1.38±0.09 to 1.65±0.13 across all the soil depths (Figure 3). The soil bulk density varied from 1.17±0.01 g cc^{-3} to 1.36±0.03 g cc^{-3} across all the soil depths. Soil nitrogen, phosphorus and potassium value varied from 0.22 to 0.42%, 0.0006 to 0.0013% and 0.0056 to 0.0083%, respectively across various soil depths (Figure 4).

Site III

The total fine root biomass at site III over the whole year was 4.33 t ha $^{-1}$. It was maximal in rainy season (2.18 t ha $^{-1}$) followed by summer and winter seasons (1.25 t ha $^{-1}$ and 0.90 t ha $^{-1}$, respectively). Fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 84.4% to the total fine root biomass; 67.4% was observed in the 0-20 cm interval, 17% in the 20-40 cm interval, 5.9% in the 40-60 cm interval, 5.5% in the 60-80 cm interval, and 4.2% was recorded in the 80-100 cm interval (Figure 1). The total fine root carbon stock across the three seasons at this aspect was 2.16 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (1.09 t ha $^{-1}$) with lower but similar value in winter season and summer seasons (0.44 t ha $^{-1}$ and 0.63 t ha $^{-1}$, Figure 2). The organic soil carbon percent varied from 1.03±0.71 to 1.97±0.17 across all the soil depths (Figure 3). The soil bulk density varied from 1.15±0.006 g cc^{-3} to 1.30±0.01 g cc^{-3} across all the soil depths. Soil nitrogen, phosphorus and potassium values varied from 0.11 to 0.20%, 0.0008 to 0.0010% and 0.0055 to 0.0068%, respectively across various soil depths (Figure 4).

Site IV

The total fine root biomass at site IV over the whole year was 5.30 t ha $^{-1}$. It was maximal in rainy season (3.14 t ha $^{-1}$) followed by summer and winter seasons (1.39 t ha $^{-1}$ and 0.77 t ha $^{-1}$, respectively). Fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 88.89% to the total fine root biomass; 54.4% was observed in the 0-20 cm interval, 24.4% in the 20-40 cm interval, 10.1% in the 40-60 cm interval, 6.4% in the 60-80 cm interval, and 4.7% was recorded in the 80-100 cm interval (Figure 1). The total fine root carbon stock across the three seasons at this aspect was 2.65 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (0.38 t ha $^{-1}$) followed by summer and winter seasons (0.69 t ha $^{-1}$ and 0.39 t ha $^{-1}$, Figure 2). The organic soil carbon percent varied from 1.00±0.29 to 2.73±0.51 across all the soil depths (Figure 3). The soil bulk density followed an inverse trend and varied from 1.09±0.07 g cc^{-3} to 1.42±0.01 g cc^{-3} across all the soil depths. Soil nitrogen, phosphorus and potassium value varied from 0.11 to 0.18%, 0.0006 to 0.0018% and 0.0035 to 0.0065%, respectively across various soil depths (Figure 4).Analysis of variance (ANOVA) test showed that fine roots biomass varied significantly ($P<0.05$) between season, forest site, soil depth. The combined effects of season x forest site and season x soil depth, soil organic carbon, site and soil depth also varied significantly at $P<0.05$.

DISCUSSION

The present study shows that about 82% of the fine roots were in the upper 40 cm of soil depth. The growth of fine roots was greater in the surface root mats. The leaf litter forms a shelter for the surface roots by providing a moist microclimate for the developing new fine roots. The nutrients that are released from the litter are not leached down to the soil but are transferred directly to the surface roots which are growing intermingled with the decaying matter (Went and Stark, 1968). Singh *et al.*, (1990) and Upadhyay and Singh (1989) reported that the more microbial activity in the upper layers of the soil accelerates decomposition. Also, the temperature is favourable throughout the year which ensures a supply of nutrients to the top soil through litter decomposition; these are the reasons for higher fine root biomass in the top soil layers in the present study. The fine root production in the present study was higher during the rainy season (63.51%) compared to summer and winter seasons (18.24%, each). Similar seasonal patterns of fine root biomass were also observed by Keys and Grier (1981) for a spruce sub-alpine forest in British Columbia and for Central Himalayan high altitude forests of India by Adhikari (1992) and Garkoti (1992). The fine root biomass was higher during rainy season due to rapid nutrient release. The seasonal change could be attributed to changes in environment such as temperature and moisture. The fine root biomass in the present study was generally comparable to the fine root biomass of different forests of the World (Table 2). Evidently fine root biomass mass varied greatly with respect to sampling depth and diameter class under consideration besides the forest types and their locations. The average N concentration across four aspects was 0.82% and the mean P and K concentration was 0.01 and 0.02%, respectively. These values are comparable to those of the seven forest sites in south India, where it ranged from 0·53 to 1·11% (Parthasarthy, 1986) and also in the tropical forests of Africa and South America where it ranged from 0·47 to 1·01% (Klinge, 1976). Soil organic carbon values of the present study ranged from 0.38 to 2.73%, while the soil bulk density ranged from 1.15±0.006 g cc^{-3} to 1.44±0.22 g cc^{-3}. These values are generally comparable with the values reported earlier for the surrounding community managed forests (Singh, 2009, Jina, 2006). Significantly greater soil organic carbon might be due to greater inputs of organic matter through above and below ground litter. Fine root biomass was inversely proportional to the soil bulk density. According to Nambiar and Sands (1992) when bulk density increases, soil strength increases and aeration decreases leading to adverse effects on root growth.

It is evident that greater accumulation of fine roots in the managed forests helps in microbial colonization and immobilization of nutrients. Root necrosis and exudates contribute significant quantities of carbon deposited in sub surface soil.

Table 2: Comparison of Fine Root Biomass from Different Forests of the World

Forest	Location	Diameter	Fine root Biomass (t ha $^{-1}$)	Reference
Dry deciduous forest	Varanasi (India)	<6	4-5.5	Singh and Singh (1981)
Evergreen forest	Western Ghat	<2	3.4	Parthasarathy (1988)
Semi evergreen forest	Western Ghat	<2	3.5	Parthasarathy (1988)
Mixed deciduous forest	Kalakad Western Ghat	<2	1.8	Parthasarathy (1988)
Central Amazonian forest	Brazil	<2	8.4	Klinge (1973)
Terra firm forest	Latosol of Amazonian	<6	16	Klinge (1973)
Terra firm forest	Podzol of Amazonian	<6	10	Klinge (1973)
Central Himalayan oak and pine forest	Nainital	<1	3.7-5.3	Usman (1999)
Anriyakot Panchayat forest	Lamgara	<1	4.33-6.65	Present study

The root deposits have the potential for a greater contribution to long term soil carbon sequestration in reducing atmospheric CO_2 concentration.

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