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Full Length Research Paper

Soil organic carbon stock potential of shrubs, occupying natural *Anogeissus latifolia* forest in sub-tropical belt of Garhwal Himalaya

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The soil organic carbon (SOC) stock in three pure shrub species was compared with the adjacent growing *Anogeissus latifolia* tree stand to understand the changes occurring in SOC stock as a consequence of degradation of *A. latifolia* forests. Among the shrubs, *Rhus parviflora* (168.00 ± 1.60 t ha^{-1}) and *Lantana camara* (164.16 ± 2.08 t ha^{-1}) showed higher values of SOC as compared to *A. latifolia* forest (161.28 ± 3.04 t ha^{-1}). However, *Carissa spinarum* showed lower values (152.64 ± 2.24 t ha^{-1}) of SOC compared to *A. latifolia*. The soils were dominated by sand particles in all shrubs and *A. latifolia* forest. Forest floor litter mass of *R. parviflora* and *L. camara* was 140.4 ± 10.3 g m^{-2} and 150.3 ± 9.23 g m^{-2}, respectively which was higher compared to *A. latifolia* (98.8 ± 6.82 g m^{-2}) forest. The litter mass of *C. spinarum* was the lowest 60.7 ± 6.0 g m^{-2} which has reflected lowest SOC stock. The water holding capacity of soil was recorded the highest (36.08 ± 4.57%) under *R. parviflora* and the lowest under *L. camara* (23.66 ± 8.65%). The higher amount of litter input enhanced the SOC stock in the soil. The shrub species are occupying the gaps created by villagers in the *A. latifolia* forest and subsequently the shrub species restoring the degraded forest areas from land sliding and soil erosions.

Key words: Shrub, soil carbon stock, soil erosion, degradation.

INTRODUCTION

Anogeissus latifolia occur throughout the tropical and subtropical regions of India except arid parts of North-West India and moist region of North-East India (Champion and Seth, 1968). It often forms pure stands in the sub-Himalayan tract and Shiwalik hills (Luna, 2005; Gaur, 1999). In the sub-tropical region of Garhwal Himalaya, *A. latifolia* is very important in providing various ecosystem services to local people (Kumar et al., 2010). Due to heavy biotic pressure, natural regeneration and seedling establishment of *A. latifolia* as well as associated tree species viz., *Acacia catechu, Lannea coromandelica, Terminalia* spp., *Emblica officinalis* have been affected and shrubs species like *Carrisa spinarum, Lantana camara, Rhus parviflora* etc., have been occupied by the tree-less degraded lands and dominated by shrubs in many places (Kumar et al., 2010). The early successional shrubs like *L. camara* has rapidly invaded deforested hill slopes around human settlements and abandoned crop fields up to 1500 m a.m.s.l. in outer ranges of Central Himalaya (Bhatt et al., 1994). The *L. camara, C. spinarum, R. parviflora* shrubs have occupied the natural *A. latifolia* forest over large areas forming pure or mixed species with the understory of forests. Although, these shrubs form a thick cover on barren landscape and occupying the area of forest ecosystem. These shrubs also plays an important role by reducing land sliding and soil erosion, as well as maintaining soil organic carbon (SOC) stock, by reducing atmospheric carbon level.

In the forest ecosystem, soils and plants are the main sources of organic carbon stocks. The concentration of carbon in soil has an effect on the above ground and below forest production. It has been estimated that soil in the forest ecosystem accumulates the largest form of SOC more than 1500 pg c arbon or approximately two

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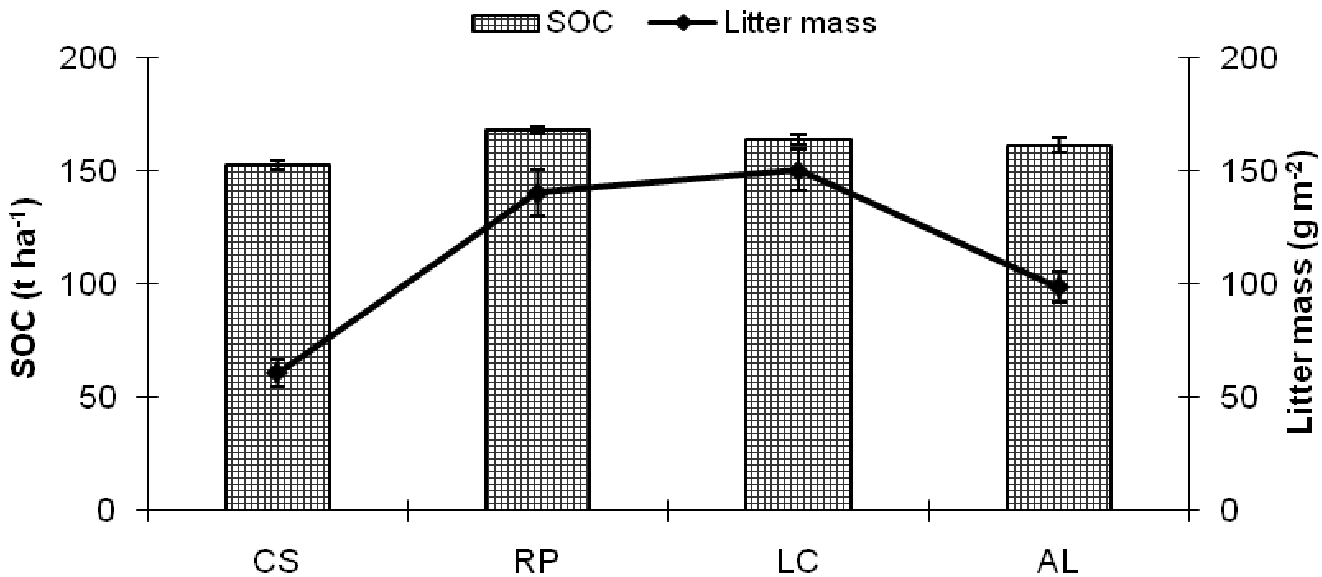

Figure 1. Litter mass (g m^{-2}) and SOC (t ha^{-1}) in *A. latifolia* forest stand and shrub (CS=*Carrisa spinarum,* RP=*Rhus parviflora*, LC=*Lantana camara*, AL=*Anogeissus latifolia*,) patches.

times as much as carbon in the air, and more than two and a half times carbon in plant structure (Schimel, 1995). These, changes the composition and structure of tree species, of forest ecosystem and the degraded area of trees, is occupied by shrubs due to heavy biotic pressure. Few ecosystem studies address the function of secondary vegetation, which develops after the destruction of mature ecosystems, such as forests, and this is particularly true for the Himalayan forests (Singh and Singh, 1987; Bhatt et al., 1994). Therefore, the present study was undertaken to estimate the soil carbon stock of shrub species and the occupied gaps, created by biotic pressure in *A. latifolia* degraded forests in Garhwal Himalaya; and this may be also helpful to identify suitable shrub species for promoting soil carbon storage in degraded forests of this area.

MATERIALS AND METHODS

Soil characteristics and climate

The present study was conducted in *A. latifolia* forest located between 30° 29' N and 78° 24' E at an elevation range of 700 to 1000 m above mean sea level (a.m.s.l.). The site experiences a monsoonic climate and can be divided into three different seasons; rainy (mid June to September), winter (October to February) and summer (march to mid June). The forest has anthropogenic pressure ranges, from low to high in different aspect and is accessible to the villagers. In the nutrients, phosphorus ranged from 9.67 to 10.56 kg ha^{-1}, potassium ranged from 141.87 to 172.48 kg ha^{-1} (Kumar et al. 2010). The pH of the soil in this forest is slightly acidic in nature. The approximate age of the forest is 20 to 30 years, although, all girth classes trees are available but majority of trees are of lower girth classes and hardly few trees reaches to the higher girth class.

Approach

One *A. latifolia* dominated stand and three pure shrub patches viz., *R. parviflora L. camara* and *C. spinarum* were selected for estimation of soil organic carbon stock of tree and shrubs dominated patches within the degraded *A. latifolia* forest. Five sample plots (each of 5 × 5 m size) were randomly placed for the measurement of density and total basal cover of each species (tree and shrubs) and among the five plots, three plots were selected randomly for soil sampling. The nested plot sampling technique was used for collection of forest floor litter mass; three sample plots (1 × 1 m size each) were nested randomly within plots of 5 × 5 m in each species. The density and basal cover were calculated following standard methods (Misra, 1968). The soil samples were collected randomly from three plots of 0 to 30 cm depth. Prior to analysis, the soil samples were air-dried, ground and sieved to < 0.2 mm diameter. The SOC was determined as per the method described by Walkley and Black (1934). To get the actual organic carbon content, the values obtained by Walkley and Black method were multiplied by a correction factor (2.4) given by Krishan et al. (2009) for the Himalayan soils. The correction factor is based on the relationship between Walkley and Black estimate and that from oxidative combustion-infrared analysis method using total organic carbon analyzer. The soil organic carbon stock was estimated by method described by Jha et al. (2003).

RESULTS AND DISCUSSION

The organic carbon stock in the soil of *A. latifolia* forest was 161.28 ± 3.04 t ha^{-1}. Among the shrub patches, the SOC in *R. parviflora* and *L. camara* was 168.00 ± 1.60 and 164.16 ± 2.08 t ha^{-1}, respectively, which was higher compared to the SOC of *A. latifolia* (Figure 1). However, the SOC stock under *C. spinarum* patch was 152.64 ± 2.24 t ha^{-1}, which was lowest among the shrubs and tree (Figure 1). Soil of each patch was dominated by sand

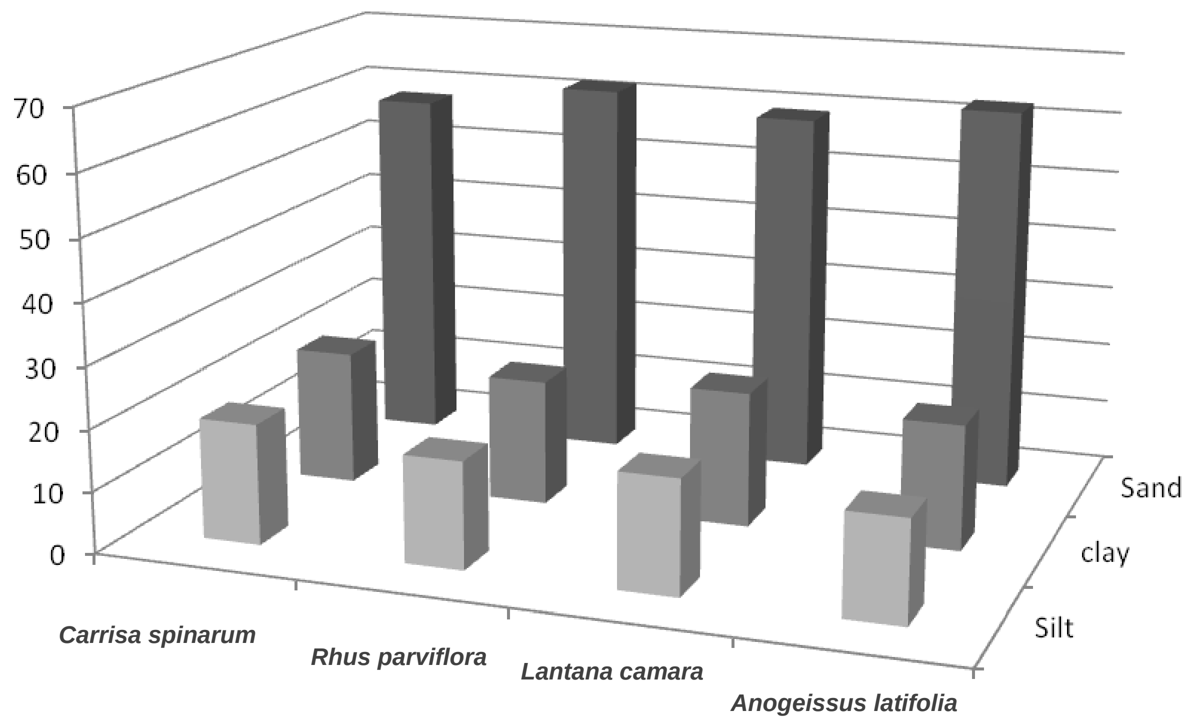

Figure 2. Soil texture (%) in *A. latifolia* forest stand and shrub (CS=*Carrisa spinarum,* RP=*Rhus parviflora*, LC=*Lantana camara*, AL=*Anogeissus latifolia*,) patches*.*

Table 1. Density, TBC and WHC in *A. latifolia* forest stand and shrub (CS=*Carrisa spinarum,* RP=*Rhus parviflora*, LC=*Lantana camara*, AL=*Anogeissus latifolia*,) patches.

Species	Category	Density (plant/25 m^2)	TBC (cm^2/25 m^2)	WHC (%)
Carrisa spinarum auct non. L.	Shrub	14 ± 1.58	55.2 ± 10.68	26.79 ± 2.98
Rhus parviflora Roxb.,	Shrub	32.6 ± 2.07	114.4 ± 13.70	36.08 ± 4.57
Lantana camara L.	Shrub	55 ± 11.18	183.0 ± 52.50	23.66 ± 8.65
Anogeissus latifolia Wall ex Bedd.	Tree	7.4 ± 3.28	392.0 ± 180.99	30.90 ± 1.38

(Figure 2). The water holding capacity of soil was highest (36.08 ± 4.57%) in *R. parviflora* and lowest (23.66 ± 8.65) in *L. camara* (Table 1). Bhatt et al. (1994) reported that *L. camara* grows well in nutrient deficient areas and its net primary productivity is similar to net primary productivity of forests. The presence of allelochemicals and its release in soil, affects germination and growth of many other species and forms pure patches. It has also, the capacity to prevent natural regeneration of some tree species which block succession and replace natural species (Morton, 1994; Ambika et al., 2003).

It was interesting to note that most of the *A. latifolia* degraded sites have been occupied by the shrub patches; after the loss of this *A. latifolia* forest by various degrees of biotic pressure by the villagers for fuel, fodder and small timbers. Therefore, these shrubs are playing an important role in maintaining and conserving soil organic carbon stock by occupying existed *A. latifolia* forest areas. Among the shrubs, *R. parviflora* occupy the *A. latifolia* forest after deforestation and holds the largest amount of organic carbon stock in the soil. Although, these shrubs could not have attained above ground biomass/carbon similar to *A. latifolia*.

The main reason for higher values of SOC stock of shrubs might be because of negligible use of green leaves of these shrubs as fodder, except leaves of *R. parviflora* used as bedding materials for cattle during rainy season. Kumar et al. (2010) have reported that all the associated tree species of *A. latifolia* forests in this belt are severely lopped by the villagers for various purposes. However, relative lopping intensity was significantly higher for *A. latifolia* (45 to 57%) as compared to associated species (4 to 33%). Thus, higher anthropogenic pressure on *A. latifolia,* in terms of lopping for fodder might be low as compared to un-lopped shrubs and thus, the litter input. Higher water holding capacity, which enriches the soil moisture content, results in greater rate of decomposition of organic carbon under shrubs and this may be based on the assumption that high moisture content enhances SOC level in the soil. The low values of SOC in *C. spinarum* might also be due to the lowest water holding capacity results and low amount of moisture in the soil.

Forest management strategies may have great potential to mitigate carbon dioxide emissions to the atmosphere (Johnson, 1992; Eriksson et al., 2007) and the selection of species could be an important factor in such strategies (Stendahl et al., 2010). Although, shrub species established after deforestation in the *A. latifolia* forest cannot fulfill the above ground biomass requirement of carbon sequestration including the villagers demand, but it could be helpful in reducing land sliding and possibly, can compensate the SOC stock requirement of the area. Therefore, these shrubs can play an important role in the restoration of treeless areas by minimizing landslides, erosion of soil due to heavy rainfall, providing shelter to fauna and enhancing soil organic carbon stock. Thus, shrubs growing in degraded lands have good potential of carbon sink, which accelerate the natural recovery processes of succession after tree loss and probably, change to recover forest in due course of time.

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