rugose thallus, oblong to lirellate apothecia and 18–20 × 4–7 μm sized spore. In spore size, the species is close to *Schismatomma ceylanicum* Tehler, but the latter differs in having corticolous habitat and presence of psoromic acid in thallus. In white thallus colour, the species is close to *Schismatomma melastigmum*, but the latter differs in punctiform to submoniliform linear ascocarps. *Schismatomma kurzii* (Krempelh. in Nyl.) Zahlbr, *Schismatomma gregantulum* (Müll. Arg.) Zahlbr and *Schismatomma cinereum* (Müll. Arg.) Zahlbr also have whitish to grey thallus, but differ in having corticolous habit and bigger spores (40–60 μm long).

Specimens examined: India: Jammu and Kashmir State; Doda district; Tehsil Bhaderwah, Nalthi, on rock. April, 2012, alt.1945 m, Reema LWG, 011-019718.

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Soil organic carbon pool under different land uses in Achanakmar Amarkantak Biosphere Reserve of Chhattisgarh, India

Global climate change caused by rising levels of carbon dioxide (CO_2) and other greenhouse gases (GHGs) is recognized as a serious environmental issue of the 21st century. The role of land-use systems in stabilizing CO_2 levels and increasing carbon (C) sink potential of the soils has attracted considerable scientific attention in the recent past[1,2]. Type of land-use system is an important factor controlling soil organic matter (SOM), since it affects the amount and quality of litter input, litter decomposition rates and processes of organic matter stabilization in the soils[3]. SOM which contains more reactive soil organic carbon (SOC) than any other single terrestrial pool, plays a major role in determining C storage in ecosystems and moderating atmospheric concentrations of CO_2 (ref. 4). Soil C sequestration is the process of transferring CO_2 from the atmosphere into the soil in a form that is not immediately re-emitted, and this process is being considered as a strategy for mitigating climate change[5–7]. It is a natural, cost-effective and environment-friendly process[8]. Once sequestered, C remains in the soil as long as restorative land use, no-till farming and other recommended management practices are developed[8]. Land misuse and soil mismanagement can cause depletion of SOC stock with an attendant emission of CO_2 into the atmosphere[7–9]. In contrast, an appropriate land use and proper soil management can increase SOC stock, thereby reducing net emission of CO_2 to the atmosphere[10,11] and increase sustainability of land-use systems to reduce vulnerability to climate change[12].

Soils are the largest carbon reservoirs of the terrestrial carbon cycle. About three times more carbon is contained in the soils than in the world's vegetation and soils hold double the amount of carbon that is present in the atmosphere. Worldwide the top 30 cm of soil holds 1500 Pg ($1 \text{ Pg} = 10^{15}$ g) carbon[13]; for India the figure is 9 Pg (ref. 14). The first estimate of the organic carbon stock in Indian soils was 24.3 Pg based on 48 soil samples[15]. Jenny and Raychaudhuri[16] conducted comprehensive studies on the distribution of SOC in Indian soils in relation to the prevailing climate. Dadhwal and Nayak[17] using ecosystem areas and representative global average carbon density, estimated organic carbon at 6.8 Pg in the Indian soil. Chhabra *et al.*[18] estimated organic carbon pool at 6.8 Pg C in the top 1 m using estimated SOC density and remote sensing-based area under forest. Gupta and Rao[19] reported SOC stock at 24.3 Pg for the soil ranging from surface to an average subsurface depth of 44–146 cm based on 48 soil series. Based on a much broader national database, Velayuthum *et al.*[20] reported on total mass of SOC pool, while Bhattacharya *et al.*[21] reported on both organic and inorganic carbon pools.

In the tropical regions of Central India, few studies have been conducted on C pool of soils. The knowledge and study of the impact of different land uses on soil carbon pool at greater depths, more than 30 cm in India and particularly in Chhattisgarh is limited. Therefore, the purpose of the present study was to generate knowledge and develop conservation strategies for efficient storage of C pool in the soils. To achieve this objective, study of SOC pool was under taken under four land uses, viz. forest land, agriculture land, grassland and wasteland.

The study was conducted in Achanakmar Amarkantak Biosphere Reserve (AABR), Chhattisgarh. AABR lies between 81°48′–82°24′E long. and 22°8′–23°7′N lat. (Figure 1). The Reserve covers a huge area of 3835.51 sq. km. It has varied topography and climatic conditions which provide congenial habitat for a unique diversity of vegetation. The vegetation of the forest area of the Reserve represents tropical deciduous and is classified into Northern Tropical Moist

Deciduous and Southern Dry Mixed Deciduous forests. In the former, Sal is the dominant species followed by mixed forest, teak and bamboo forest. The Reserve has typical monsoon climate with three distinctly defined seasons and a short post-rainy season. The mean daily maximum temperature ranges from 24°C to 39°C and mean daily minimum temperature ranges from 10°C to 25°C depending upon season. A few showers generally occur in every season throughout the year. The average rainfall is 1322–1624 mm.

The various land uses of AABR include forest land, agriculture land, grassland, wasteland, settlements and water bodies. Among these, four major land uses (as mentioned above) were selected for the estimation of SOC pools. Settlements and water bodies were not considered for the estimation of SOC pool because of the negligible area covered under these land uses. Soil sampling was carried out at four selected sites, viz. Achanakmar, Chapparwa, Lamni and Surhi based on the availability of land uses at these sites (Figure 1). At each sampling site, 10 soil sampling points were selected randomly to collect soil samples at three different soil depths of 0–20, 20–50 and 50–100 cm using a stainless steel cylinder[22]. Roots, stones and debris were removed before sampling. The samples were packed in zip-lock polythene bags and tagged with the geo-morphological information (location of site, elevation, latitude and longitude) using GPS (Garmin etrex-30). Soil samples were returned to the laboratory and air-dried for 2–3 days. The dried soil samples were sieved through a 2 mm mesh. A total of 120 soil samples (4 sites × 3 depths × 10 replicates = 120) were collected and analysed for estimation of SOC. The SOC was estimated using the standard Walkley and Black[23] method.

Bulk density at each site was estimated by standard core method[24]. Five randomly selected replicates of soil samples were collected at different soil depths of 0–20, 20–50 and 50–100 cm at each land use to determine the value of mean soil bulk density. Soil samples brought to the laboratory were oven-dried at 60°C till constant weight. The weight of the oven-dried soil samples was then taken. This weight was divided by its volume to estimate bulk density. Carbon pool in each soil depth of different land uses was estimated by multiplying the mean SOC pool in each unit area (tonnes/ha) by the total area covered by it. Summation of SOC pool in three soil depths gave the total SOC pool (t) in each land use.

The area-wise distribution of different land uses in AABR is: forest land (238,129.38 ha), agricultural land (88,805.07 ha), grassland (37,500.72 ha) and wasteland (8656.92 ha). Depth-wise bulk density of different land uses was found to estimate the SOC pool density variation among different soil depths. The mean soil bulk density values of forest land (1.02, 1.12 and 1.19 g cm^{-3}), agricultural land (1.04, 1.13, 1.21 g cm^{-3}), grassland (1.12, 1.18, 1.23 g cm^{-3}), wasteland (1.20, 1.26, 1.34 g cm^{-3}) were observed in 0–20, 20–50 and 50–100 cm soil depths respectively (Figure 2). The result shows that bulk density values increase with increasing soil depth among all land uses. The wasteland has higher values of bulk density followed by grassland, agricultural land and least bulk density values are found in forest land. This may be due to the lack of organic matter in agricultural and wasteland compared to the forest and grassland.

Based on the results, it was found that the forest land had a highest mean SOC pool of 52.72, 41.69 and 28.04 t ha^{-1} in 0–20, 20–50 and 50–100 cm soil depth respectively. Agriculture land had a mean SOC pool of 31.21, 23.40 and

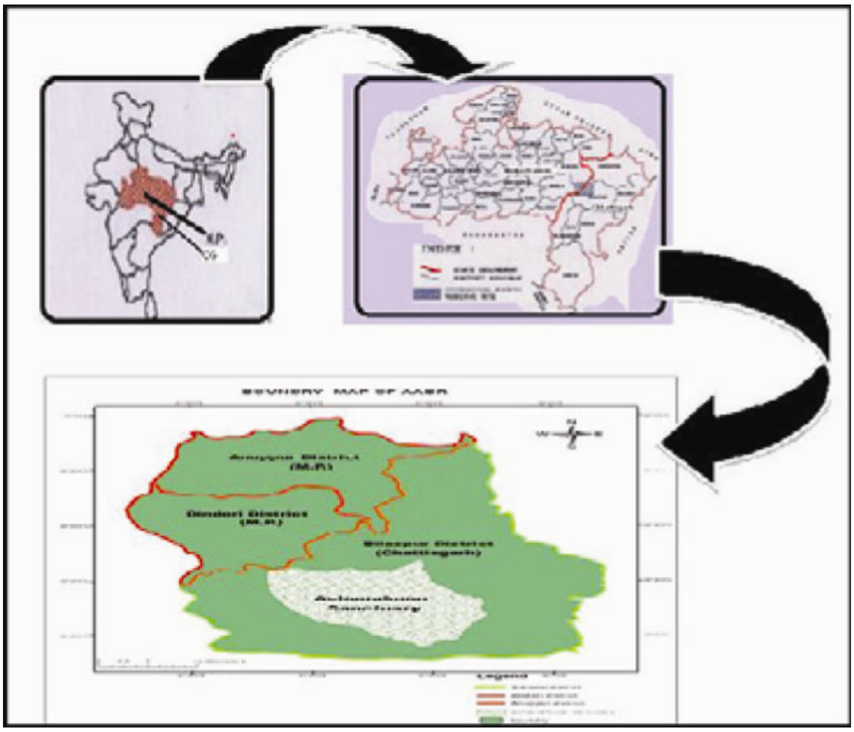

Figure 1. Map of Achanakmar Amarkantak Biosphere Reserve (AABR), Chhattisgarh, India.

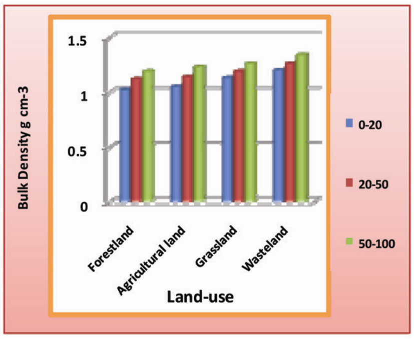

Figure 2. Bulk density (g cm^{-3}) of land uses in AABR.

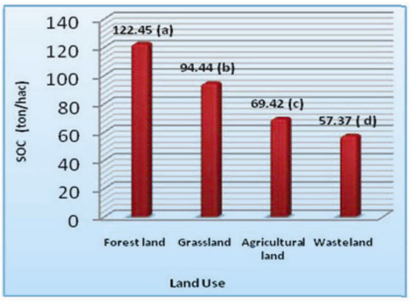

Figure 3. Depth-wise soil organic carbon (SOC) pools (t ha^{-1}) in AABR.

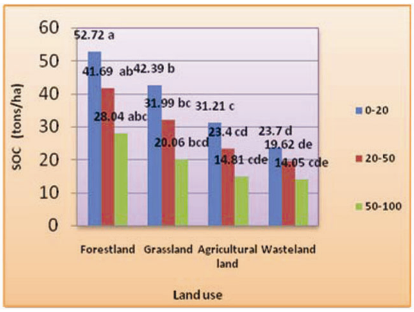

Figure 4. SOC (t ha^{-1}) under land uses in AABR.

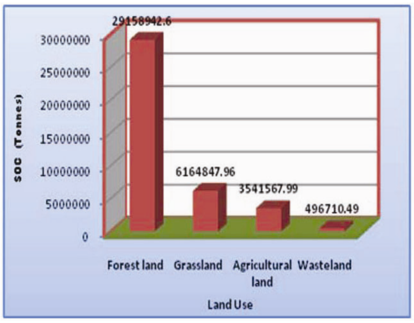

Figure 5. Total SOC (t) under land uses in AABR.

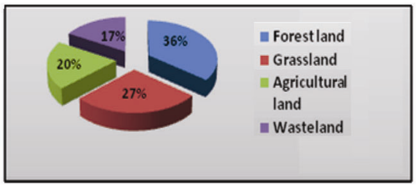

Figure 6. Percentage share of SOC in AABR.

14.819 t ha^{-1}; grassland had 42.39, 31.99 and 20.06 t ha^{-1} and wasteland had mean SOC pool of 23.70, 19.62, and 14.05 t ha^{-1} in 0–20, 20–50 and 50–100 cm soil depth respectively. In all land uses, carbon density decreased with increase in soil depth (Figure 3). Thus, total SOC pool (0–100 cm depth) of forest land was highest (122.55 t ha^{-1}), followed by grassland (94.43 t ha^{-1}), agricultural land (69.42 t ha^{-1}) and least for wasteland (57.35 t ha^{-1}) (Figure 4). Data revealed that highest SOC pool was found in the upper 0–20 cm soil depth, followed by 20–50 cm and least in 50–100 cm soil depth among all land uses. Similarly, total SOC pool (tonnes) was found highest under forest land (29,158,942.6), followed by grassland (6,164,847.96), agricultural land (3,541,567.99) and wasteland (496,710.49) (Figure 5). Forest land had 36% of the total SOC followed by grassland, agricultural land, and wasteland with 27%, 20% and 17% respectively (Figure 6).

The organic carbon pool at three different depths under forest land use was much higher compared to the other land uses. This is because of the maximum litter fall and plant residues associated with microbial activities observed in the forests, which show the interlinkage of forest ecosystems in storage or sequestration of SOC pools compared to other land uses. Sharma *et al.*[25] estimated the SOC pool under different land uses in Arnigad watershed of Doon valley, Uttarakhand. They found that agriculture land had SOC pool of (116.57 t ha^{-1}), forests (112.31 t ha^{-1}), and degraded wasteland (108.1 t ha^{-1}). The results of our study are comparable to those of Sharma *et al.*[25]. Forests are thus rich not only in terms of biodiversity but also in terms of ecosystem services like carbon sequestration.

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