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Assessment of soil carbon pool using geospatial techniques

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Abstract
Soil carbon holds a key part on the Carbon-cycle, as at a 1 m depth, soils store the largest terrestrial carbon pool. Therefore, carbon sequestration could potentially mitigate climate change. In this context present investigation of soil carbon pool was carried out at Tanda, Bhakda and Pipalpadao forest ranges of Tarai Central Forest Division, Western Circle, Uttarakhand, India during 2013-14. Random sampling was done in all the three forest ranges. Total soil sampling was done at 23 sites of Tanda, Bhakda, and Pipalpadao range in the month of February 2014. The average carbon values for Tanda, Bhakda and Pipalpadao ranges were 1.290%, 1.277% and 1.205% respectively at 0-15cm depth of soil profile and 1.047%, 1.053% and 1.007% respectively at 15-30 cm depth of soil profile. The spatial interpolation method, IDW (Inverse Distance Weighting) used to estimate soil organic carbon of unsampled locations with Geographical Information Systems (GIS) modeling. Tanda, Bhakda, and Pipalpadao forests were having soil organic carbon 0.303 million ton, 0.302 million ton and 0.284 million ton respectively.

Keywords: GIS, IDW, carbon pool, GPS, soil organic carbon

Introduction
Carbon is the 15th most abundant element in the Earth's crust and the fourth most abundant element in the universe by mass after hydrogen, helium, and oxygen. Most carbon in the terrestrial biosphere is stored in forests: they hold 86% of the planet's terrestrial above-ground carbon and forest soils also hold 73% of the planet's soil carbon. The total amount of C present in the Earth is almost constant, except for the small gains and losses produced by falling meteorites, and the losses of low molecular weight C compounds to space. The global C budget can therefore be considered constant, and C conservation follows the first law of thermodynamics. However, the total concentration of atmospheric CO_2 has increased greatly since 1750 (from 280 to 385 ppmv) as a result of human activities, and now far exceeds pre-industrial values (IPCC, 2007) [1]. Soil contains both inorganic and organic forms of carbon. Major inorganic forms are carbon dioxide and carbonates, organic carbon ranges from plant and animal residuals, microbial biomass and dead tissues. In most soils both the soil inorganic carbon (SIC) and soil organic carbon (SOC) plays a critical role in many geochemical or biochemical process. Soil humification process leads to sequestration of organic carbon (Lal *et al.*, 1998) [4]. Interest in SOC has greatly increased in recent years because terrestrial organic carbon can be a key factor in understanding the effect of carbon emission on global climate change (Schlesinger, 1991) [7]. Satellite remote sensing is providing an increasing variety of spatial data layers that are potentially usable as model input or for validation of model output. The integration of process models and remote sensing is particularly effective for monitoring at landscape to regional scales, because at fine spatial and temporal resolutions it can resolve the major near term controls on carbon fluxes, including land use, foliar biophysical characteristics, topography, and climatic gradients. Research challenges in this field include optimizing spatial and temporal resolution for specific applications, differentiating the relative influences of structural and chemical variables on ecosystem carbon fluxes, and systematically validating model based flux estimates (Turner *et al.*, 2004) [11].Current Remote Sensing technology offers acquisition and analysis of georeferenced data from assorted platforms and can be operationally linked with spatial data layers and models within a GIS. The effortless ability of integrating Remote Sensing data with other sources of information makes geospatial technology a powerful contemporary instrument (Kohl *et al.*, 2006) [3]. Remote sensing may be the only feasible way to acquire forest stand parameter information at a reasonable cost with acceptable accuracy and feasible efforts because of its data advantages which included repeated data collection, multi spectral and multi temporal images, synoptic view.

Fast digital processing of large quantities of data and compatibility with GIS**.** Soil organic carbon pool is one of the important parameters for studying carbon pool of forest. Soil is a source and sink of the carbon, which plays important role in carbon pool of the ecosystem. Soils not only nourish the plant but also mineralize and store the nutrients including carbon. Soil organic carbon was estimated by using QGIS (Quantum Geographic Information System) software.

Material and Methods

Field experiment was conducted at Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar during 2013 to 2014 to evaluate the Assessment of soil carbon pool using geospatial techniques. Field study was conducted in three forest ranges namely Tanda range is situated at 29º2′-29º6´N latitude, 79º21′-79º31´E longitude and elevation about 250 meter from mean sea level. Bhakda range is situated at 29º5´-29º13´N latitude, 79º22´-79º28´E longitude and elevation about 320 meter from mean sea level. Pipalpadao range is situated at 29º5´-29º13´N latitude, 79º14´-79º26´E longitude and elevation about 260 meter from mean sea level.

The climate of study sites are humid subtropical in nature. The average annual rainfall was about 1400 mm; 80-90 per cent of which was received during wet season from June to early October. It experiences a mean maximum temperature of 38.4^{0}C in May and mean minimum temperature of 4.3^{0}C in January

Soil sampling and analysis

Random sampling was done in all the three forest ranges. Total soil sampling was done at 23 sites of Tanda, Bhakda, and Pipalpadao range in the month of February 2014. At the sampling site surface litter was removed with the help of *Khurpi.* Then made the 'V' shape cut with the help of Spade, removed the soil of the pit. Then, 1 cm soil had been scrapped from the surface upto 15 cm depth and again 15-30 cm depth from the both side with the help of *Khurpi*. These scrapped soils were collected in plastic bags (Primary sample). At the one sampling site, there were 3 sites within 100 m^2 from where sample had been taken and mixed thoroughly and drawn about ½ to 1 Kg composite sample by quartering method. Soil samples were labelled and recorded in the sampler's record book to identify the field's sample.

Determination of organic carbon in soil samples

Organic carbon in soil samples of each site (depth- 0-15 cm and 15-30 cm) was determined by Walkley and Black method (Walkley and Black, 1934) [13]. The most common method of measuring soil Bulk Density was used by collecting a known volume of soil using a metal ring pressed into the soil (intact core), and determining the weight after drying (McKenzie *et al.*, 2004) [5].

GPS Software: GPS was used for geographic position (latitude and longitude) of the sampling sites, which was used at the time of image processing as a ground truth and also in GIS to create soil surface layer.

GIS software

Geographic Information System (GIS) is a technological tool that incorporates geographical features with tabular data in order to map, analyze, and assess real-world problems. The key word to this technology is Geography which means that the data (or at least some portion of the data) is spatial; in other words, data that is in some way referenced to locations on the earth. On the most basic level, GIS is used as computer cartography, *i.e.* mapping. The real power of GIS is, using spatial and statistical methods to analyze attribute and geographic information. The end result of the analysis can be derivative information, interpolated information or prioritized information.

Quantum GIS software was used to create, retrieve and analyse soil and developed the soil layer and estimated the soil carbon of Tanda, Bhakda and Pipalpadao ranges of "Tarai" forest of Uttarakhand.

Vector layer (shape file) was selected through browsing an open the shape file in QGIS. The sample data of carbon along with latitude and longitude were saved in comma delimiter in Microsoft excels. Then created a layer from a delimited text file by browsing the Microsoft excels delimited file and selected coordinate reference system WGS 84 with authority id EPSG:4326, then IDW interpolations were carried. The soil surface layer of carbon of all three forest range was clipped. In the metadata of all forest ranges minimum, maximum, mean, standard deviation value of carbon were extracted.

Results and Discussion

Soil organic carbon

The data presented in (Table 1.) on soil organic carbon (%) show variation in soil profile depth (0-15 cm) the soil organic carbon (%). At soil profile depth 0-15 the soil organic carbon was observed maximum 1.78 and minimum 0.71%. At the depth 15-30 soil organic carbon ranged from 0.38-1.67%. Semwal *et al.* (2009) [8] reported 1.78-2.83% range of organic carbon content in undisturbed Uttarakhand forest soil under cedar and pine cultivation. Usmana *et al*. (2000) [12] reported 3.06% to 2.54% organic carbon in Banj oak and Chir pine forest in Central Himalayas respectively. In a mixed deciduous forest of teak plantation soil organic carbon was found to be decreasing from 1.35 to 0.52, 0.35, 0.29 at 0-15, 15-30, 30-50, 50-100 cm soil depth, respectively (Tangsinmankong *et al.,* 2007) [10]. Analyzed soil carbon concentration up to 70 cm depth in young plantations of *Dalbergia sissoo* and *Eucalyptus* hybrid in Tarai region of Central Himalaya. Soil carbon percent in *Dalbergia sissoo* forest ranged between 0.50 to 2.66, and 0.46 to 1.85% in *Eucalyptus* hybrid forest (Joshi, *et al.*, 2013) [2].

Table 1: Soil organic carbon (%) at two soil profile depth (0-15 and 15-30 cm)

Plot No.	Soil Organic Carbon (%)	
	0-15 cm	**15-30cm**
1	1.78	1.32
2	0.79	0.64
3	1.36	1.27
4	1.55	1.12
5	1.55	1.34
6	1.33	1.15
7	1.52	1.5
8	1.67	0.88
9	1.02	0.38
10	1.69	1.67
11	1.25	0.65
12	1.66	1.6
13	1.55	1.4
14	0.98	0.99
15	1.43	1.17
16	0.71	0.48
17	0.97	0.29
18	0.71	0.71
19	1.2	1.02
20	1.71	1.62
21	1.1	0.97
22	1.28	0.92
23	1.62	1.32

Estimation of soil nutrients using GIS

Estimation of forest soil organic carbon: Soil Organic Carbon (SOC) is strongly influenced by soil type, and different environmental variables. Geostatistical methods have been used effectively to spatially interpolate SOC using different spatial interpolation methods such as IDW (Inverse Distance Weighting). These spatial interpolation methods estimate the values of a point source data (SOC in this case) at unsampled locations with Geographical Information Systems (GIS) modeling.

Soil carbon was estimated in percentage for 0-15 cm and 15 - 30 cm (table 2.) separately and then converted into the tons per hectare (table 4.14). The average carbon values for Tanda, Bhakda & Pipalpadao ranges were 1.290%, 1.277% & 1.205% respectively at 0-15 cm depth of soil profile and 1.047%, 1.053% & 1.007% respectively at 15-30 cm depth of soil profile. The soil carbon in tons per hectare was calculated by using bulk density and depth. At 0-15 cm soil depth carbon in tons per hectare was 24.96, 24.71 & 23.32 and at 15-30 cm it was 21.04, 21.16 & 20.24 for Tanda, Bhakda & Pipalpadao ranges respectively. Negi *et al.* (2013) [6] found that natural forests of Uttarakhand had the soil organic carbon pool under Fir & Spruce forests maximum i.e., 140.76 t/ha, followed by Deodar forests (118.09 t/ha), *Quercus* forests (96.44 t/ha), Kail forests (67.66 t/ha), Chir forests (61.10 t/ha), miscellaneous forests (58.95 t/ha) and the minimum SOC pool was found under Sal forests (58.45 t /ha) and under plantation forests it was estimated that maximum soil organic carbon pool was in the soils under Cypress, i.e., 66.32 t/ha, followed by Eucalyptus (42.73 t/ha), Khair(41.67 t/ha), Teak (40.71 t/ha) and Shisham (32.96 t/ha) at soil profile depth upto 30 cm. Sevgi and Tecimen (2008) [9] observed that soil organic carbon pool was higher under natural forests as compared to planted forests. This may be due to production and return of higher amount of litter in natural forests. The release of nutrients from litter decomposition is a fundamental process in the internal biogeochemical cycle of an ecosystem, and decomposers recycle a large amount of carbon that was bounded in the plant or tree to the atmosphere.

Total soil organic carbon was calculated by using total forest area (evergreen and deciduous forest) estimated from classification of satellite image of study area. Tanda, Bhakda, and Pipalpadao forests were having soil organic carbon 0.303 million ton, 0.302 million ton and 0.284 million ton respectively. Images of soil surface layer of carbon are shown in fig. 1, 3 and 5 for soil profile depth 0-15 cm and 2, 4 and 6 for soil profile depth 15-30 cm.

Table 2: Estimated value of soil carbon of forest at depth 0-15 cm and 15-30cm

Parameter	Carbon in % (0-15 cm)			Carbon in % (15-30 cm)		
	Tanda	Bhakda	Pipalpadao	Tanda	Bhakda	Pipalpadao
Minimum	0.808	0.808	0.82	0.803	0.424	0.395
Maximum	1.738	1.671	1.702	1.497	1.489	1.421
mean	1.29	1.277	1.205	1.047	1.053	1.007
SD	0.098	0.118	0.113	0.087	0.162	0.129

Table 3: Estimated value of total soil carbon of forest in million ton

Soil depth	Study Area	Average C (%)	Bulk Density (g/cm³)	Total C (t/ha)	Area (ha)	Total C (10^6t)
0-15 cm	Tanda	1.29	1.28	24.9615	6592	0.164546
	Bhakda	1.277		24.70995	6596	0.162987
	Pipalpadao	1.205		23.31675	6517	0.151955
15-30 cm	Tanda	1.047	1.34	21.0447	6592	0.138727
	Bhakda	1.053		21.1653	6596	0.139606
	Pipalpadao	1.007		20.2407	6517	0.131909

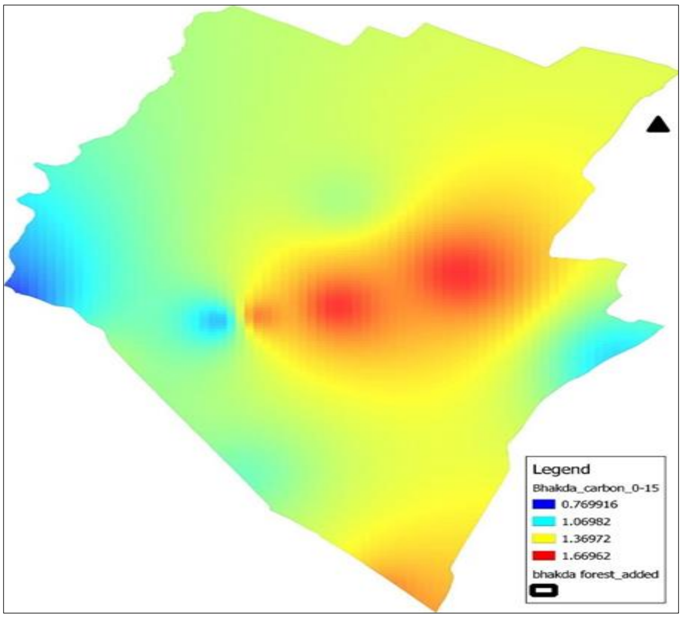

Fig 1: Soil surface carbon (0-15 cm depth) layer of Bhakra Rnage

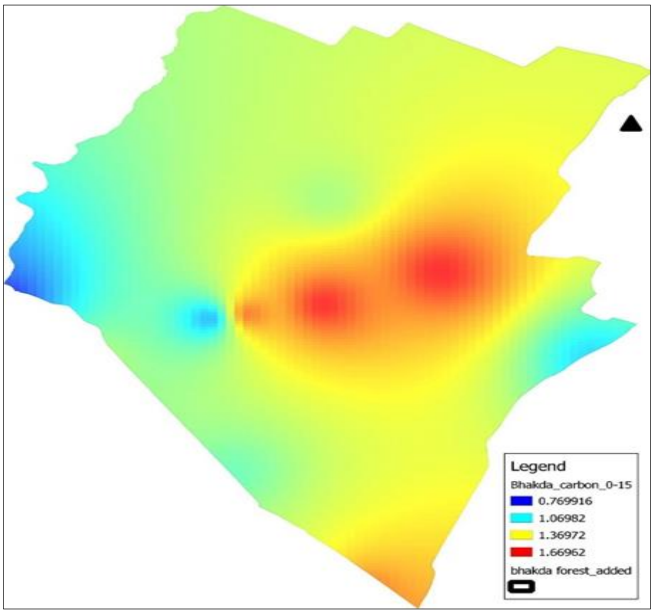

Fig 2: Soil surface carbon (15-30 cm depth) layer of Bhakra Rnage

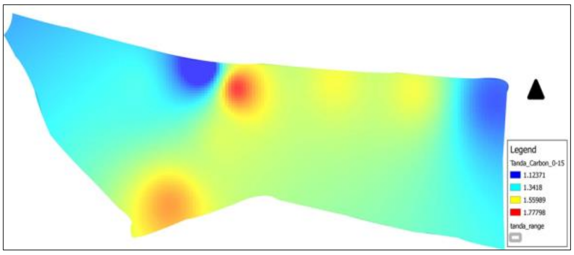

Fig 3: Soil surface carbon (0-15 cm depth) layer of Tanda Rnage

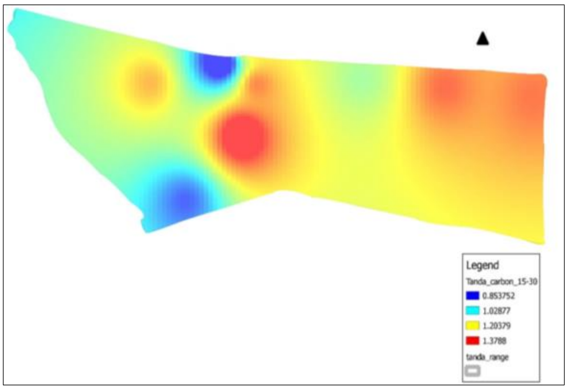

Fig 4: Soil surface carbon (15-30 cm depth) layer of Tanda Rnage

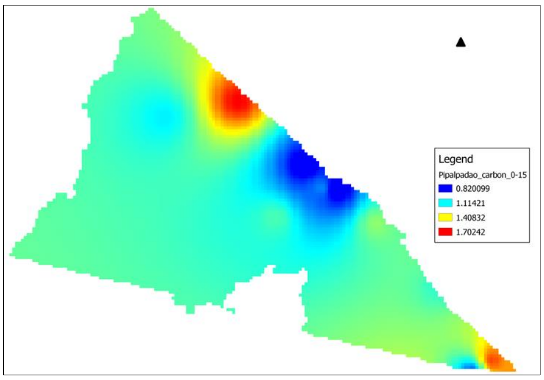

Fig 5: Soil surface carbon (0-15 cm depth) layer of Pipalpadao Rnage

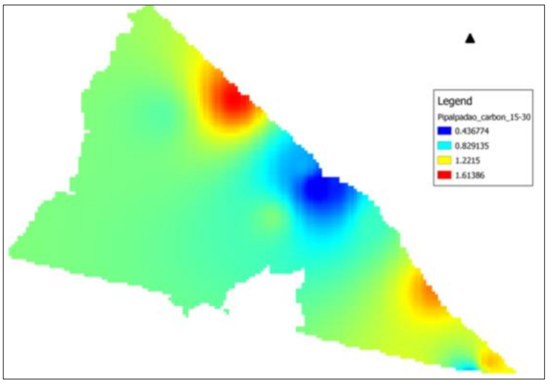

Fig 6: Soil surface carbon (15-30 cm depth) layer of Pipalpadao Rnage

Conclusion

Geostatistical methods have been used effectively to spatially interpolate SOC using spatial interpolation method IDW (Inverse Distance Weighting). Total soil organic carbon was calculated by using total forest area (evergreen and deciduous forest) estimated from classification of satellite image. At soil profile depth 0-15 the soil organic carbon was observed maximum 1.78 and minimum 0.71%. At the depth 15-30 soil organic carbon ranged from 0.38-1.67%. The average carbon values for Tanda, Bhakda & Pipalpadao ranges were 1.290%, 1.277% & 1.205% respectively at 0-15 cm depth of soil profile and 1.047%, 1.053% & 1.007% respectively at 15-30 cm depth of soil profile. Tanda, Bhakda, and Pipalpadao forests were having soil organic carbon 0.303 million tons, 0.302 million tons and 0.284 million tons respectively. Soils of Pipalpadao had lowest carbon because it occupied minimum forest area as compared to Tanda and Bhakda range.

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