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Soil Organic Carbon Stocks Assessment under different Land use Land Cover in Morna Watershed, India using GIS Technique

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Abstract

Soil organic carbon (SOC) content is a key component of the global carbon (C) cycle which is highly variable concerning space and time. The main objective of this study was to provide an assessment of soil organic carbon (SOC) stock variability in Morna Watershed, Maharashtra. In Morna Watershed, SOC stocks were estimated from the SOC contents, bulk density values from soil depth up to 30 cm. It was found that the bulk density values ranges from 1.17 g/cm^3 to 1.46 g/cm^3 with average bulk density of soil 1.35 g/cm^3. Soil organic carbon of the study area ranges from 0.12 to 3.05 per cent with an average value of 1.16 per cent. An increase in SOC value increases the soil carbon density. SOC stock value for Morna watershed ranged between 3.81 to 67.64 mg/ha. Forest land contained 1.26 and 2.27 times more SOC stock than agricultural land and bare land in 30 cm soil depth. Such differences can be observed due to the higher tree/shrub density, shrub/herb biomass and forest litter in the forest areas as compared to agriculture and barren land. Hence, converting degraded land to forest or protected land in the study area will enhance the SOC-stock is an effective way to mitigate climate change.

Keywords : Carbon sequestration, RS, GIS, Soil organic carbon storage

Greenhouse gases (GHGs) emission from anthropogenic activities is most significant driver of observed climate change since the mid-20th century. Soil organic carbon (SOC) content is key component of the global carbon (C) cycle which is highly variable with respect to space and time. Soil is a basic source to produce food, fodder, fuel and fiber and other necessities of the human being. It is made up of three main components-minerals that come from rocks below or nearby, organic matter (OM) and the living organisms that reside in the soil. Soils are critically important in determining global carbon cycle dynamics because they serve as the link between the atmosphere, vegetation and oceans. Soil plays a crucial role in the global carbon cycle, serving as a significant source of carbon to the atmosphere and storing more carbon than biomass. Soil organic carbon (SOC) is the main constituent of soil organic matter. It is one of the most important indicators of soil fertility, productivity and quality. Globally, the soil carbon pool (also referred to as the pedologic pool) is estimated at 2,500 Gt (Gt = 1 billion tons) up to a 2-m depth (The world bank, 2012). Out of this, the soil organic carbon pool comprises 1,550 Gt, while the SOC and elemental pools make up the remaining 950 Gt (Batjes 1996). The soil carbon pool is more than 3 times the size of the atmospheric pool (760 Gt) and about 4.5 times the size of the biotic pool (560 Gt). The first estimation of organic carbon (OC) stock in Indian soils was 24.3 Pg (1 Pg = 1015g) based on 48 soil series taking into account of a few major soils (Bhattacharyya *et al*., 2000). The present OC stock has been estimated as 63 Pg in the first 150 cm depth of soils (Bhattacharyya *et al*., 2000). The SOC concentration in most cultivated soils is less than 5 g/kg compared with 15 to 20 g/kg in uncultivated soils (Lal, 2004). SOC storage has been widely considered as a measure for mitigating global climate change through C sequestration in soils (Huang *et al*., 2010). Carbon sequestration implies transferring atmospheric CO_2 into long-lived pools and storing it securely so it is not immediately reemitted. Promoting soil carbon sequestration is an effective strategy for reducing atmospheric CO_2 improving soil quality (Lal *et al*., 1998, 1999). The build-up of each ton of soil organic matter removes 3.667 tons of CO_2 from the atmosphere (Bowen and Rovira, 1999). Watershed is an area covering all the land that contributes runoff water to a common point. The SOC is preferentially removed from soil by wind and water borne sediments through erosional processes. Severe depletion of the SOC pool in watersheds degrades soil quality, reduces biomass productivity and has a negative impact on water quality. So, assessing and managing natural carbon sources and sinks has proven to be the most vital and practical approach to regulating GHGs levels in the atmosphere. The main objective of this study was to provide soil organic carbon (SOC) stock variability in different land use land cover and slope positions of Morna Watershed, Maharashtra. The information generated in this study will be useful for policy-makers and environmentalists for undertaking appropriate conservation plans.

Material and Methods

Study Area

Morna is tributary of Koyna River, which is one of the major tributaries of river Krishna in Maharashtra. As shown in Fig. 1, this catchment lies in Patan Tehsil of Satara district of Maharashtra state in western India, lies between 17º 24' N to 17º 50' N latitude and 73º

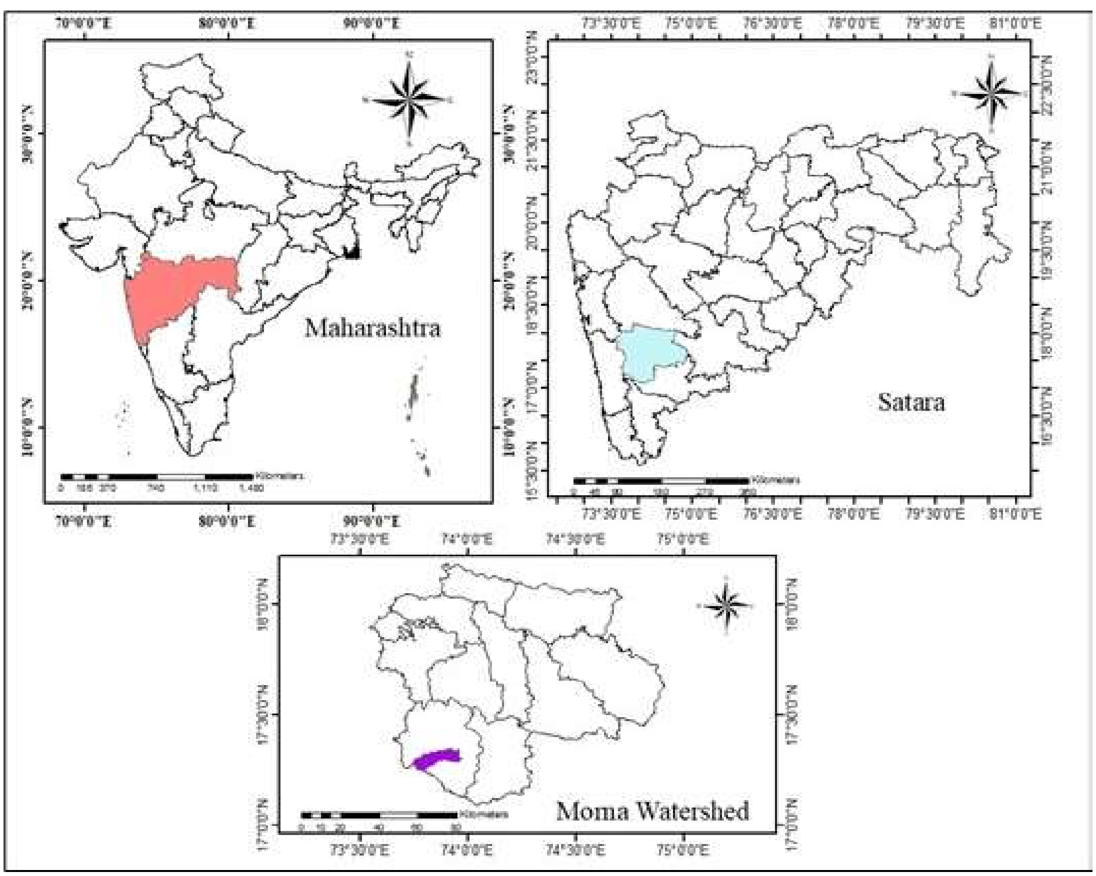

Fig. 1 : Location of Morna Watershed in Maharashtra state, India

46' E to 74° 0' E longitude. The total area of the watershed is 132.85 km^2. In this watershed, area under agriculture is about 65.37 km^2. Majority of area is covered under II, III, IV, VI and VII land capability classes. The average minimum and maximum temperatures are 7.5°C to 38.5°C, respectively and May is the hottest month. The average annual rainfall is 2012 mm. The soil is laterite having dark reddish to yellowish red color. The textural class is clay-to clay loam and has pH value between 4 to 5.8. The catchment area under this project is 55.94 sq. km. Cropping pattern of the watershed is dominated by cereals, paddy and millets which are major *kharif* crops.

Data Collection

Soil sample data such as percentage of coarse fractions, organic carbon and bulk density were collected for each village of Morna Watershed from District soil survey and soil testing lab (Government of Maharashtra) at Hamdabaj in Satara. Standard protocol of data collection and analysis approved by Government of Maharashtra has been followed at all District Soil Testing Laboratories including Satara district. Soil organic matter tends to concentrate in the upper soil horizons with roughly half of the soil organic carbon of the top 100 cm of mineral soil being held in the upper 30 cm layer (IPCC, 2003). A random soil sampling method was used to collect the soil sample data up to 30 cm depth. Soil samples were collected from 161 locations under different land use cover from Morna basin.

Estimation of Bulk Density

Bulk density (BD) is a physical parameter of soil. It reflects the total porosity of the soil. It also describes soil quality and ecosystem functions. High BD indicates poorer conditions for plant root growth, low aeration and adverse changes in hydrologic functions such as compact water infiltration (FAO, 2006). For mapping purpose of this parameter, we collected the secondary data of physical soil characteristics of bulk density from the District soil survey and soil testing lab (Government of Maharashtra) at Hamdabaj in Satara. It includes soil samples from 161 locations, which includes sampling locations inside and surrounding to Morna River watershed.

Estimation of Carbon Stock in Soil

Soil organic carbon is a major determinant and indicator of soil fertility and is highly related to crop productivity (Jia, *et al*., 2006). The total amount of carbon present within the soil depends on bulk density, stoniness and depth of soil. SOC content below 1 per cent creates problem to obtain potential crop yields with sustainability and SOC less than 2 per cent makes soil aggregates unstable (Korschens, *et al*., 1998). Corrected bulk density values were estimated by using equation 2. Carbon stock in the soil was calculated using equation 1 (Ramachandran *et al*., 2007).

SOC density = SOC X corrected bulk density x layer depth x 10 .... (1)

Corrected bulk density = Bulk density X {(100-% coarse fraction)}/100 .... (2)

where, soil organic carbon in per cent, corrected bulk density in Mg/m^3, layer depth in m, bulk density in Mg/m^3, soil organic carbon density in Mg/ha. Carbon stock values were estimated based on samples of Morna Watershed.

Land Use/Land Cover Map of the Study Area

Changes in land use/land cover play a major role in the study of global climate change. Land has become scarce resource due to immense agricultural and demographic pressure. Land use refers to man's activities and the various uses which are carried out on land. Land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others resulting due to land transformations. Land use/land cover reflects the importance of land as a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, water catchment and storage. For sustainable utilization of the land ecosystems, it is essential to know its natural characteristics, extent and location, quality, productivity, suitability and limitations of various land uses. Information on land

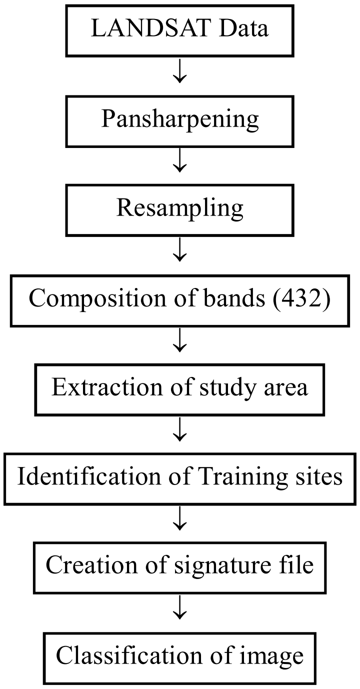

Fig. 2 : Flow chart for generation of LU/LC map

use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare.

For the present study land use/land cover map was derived from satellite images. The cloud free satellite data downloaded from LANDSAT imageries (Row No.147, Path No.48) was used to prepare LU/LC map of Morna Watershed. Interpretation of multi-season satellite data was carried out to generate the land use/ land cover map of study area. Thematic mapping of the different land use/land cover classes was achieved through supervised classification. Soil carbon stock values for different land use land cover were estimated using Arc GIS.

Generation of Slope Map of the Study Area

Remote sensing (RS) based Digital Elevation Model (DEM) of 30 m spatial resolution data was downloaded from the United States Geological Survey (USGS) Earth Explorer to understand the study region's topography. A slope map of the study area was prepared using the spatial analyst tool in Arc GIS. The slope map was divided into three classes mainly lower slope 0-10 per cent, middle slope 10-30 per cent, and upper slope > 30 per cent. Soil carbon stock values for different slopes were observed in this study.

Generation of Bulk Density Map

Bulk density values were assigned in the attribute table to each village in Arc GIS 9.3 and bulk density map was generated using the Inverse Distance Weighted interpolation method.

Generation of Organic Carbon Map

Organic Carbon values were assigned in the attribute table to each village in Arc GIS 9.3 organic carbon map was generated using the Inverse Distance Weighted interpolation method.

Generation of Soil Organic Carbon Storage Map

Soil organic carbon storage was calculated for each village of Morna watershed. These values were assigned in the attribute table to each village of Morna watershed in Arc GIS 9.3 and soil carbon stock map for soil was generated.

Results and Discussion

Bulk Density Map

Bulk density map of the study region was portrayed in Fig. 3. It was found that the bulk density values ranges from 1.17 g/cm^3 to 1.46 g/cm^3 with average bulk density of soil 1.35 g/cm^3. Hydrologically, the higher bulk density (BD) of soil in the lower catchment as compared to the upper catchment is due to the attribution of surface runoff. The southwest part of the watershed shows the highest value which also depicts that, this region was quite unsuitable for plant root growth. It was also evident from the elevation data that, due to the gravitational rolling of soil particles and surface runoff the low elevated areas were observed high bulk density. Soil organic carbon of the study area ranges from 0.12 per cent to 3.05 per cent with an average value of 1.16 per cent. Soil organic carbon map was shown in Fig. 4.

TABLE 1

Bulk density and Soil organic carbon values of Morna watershed

Parameter	Min.	Max.	Mean	Median	SD	CV
Bulk density (g/cm^3)	1.17	1.46	1.35	1.35	0.06	4.27
SOC (%)	0.12	3.05	1.16	1.20	0.51	44.07

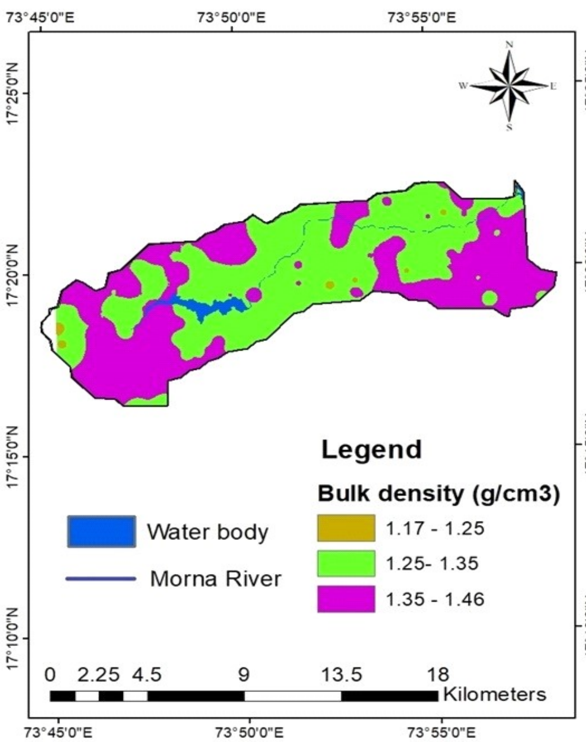

Fig. 3 : Bulk density map of Morna Watershed

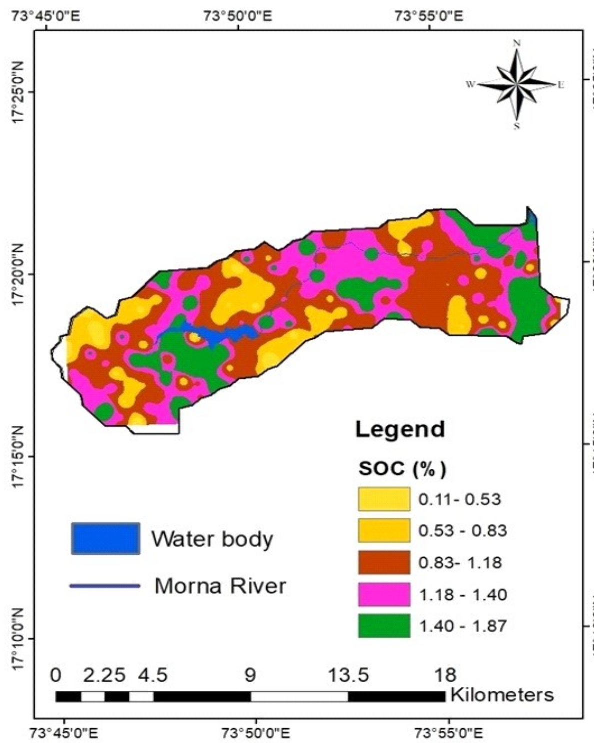

Fig. 4 : Soil organic carbon map of Morna Watershed

Land Use Land Cover of Study Area

The land use/land cover characteristics were described using land use/land cover (LU/LC) maps of Morna watershed. Study area was classified into five land use/land cover classes: (i) Agriculture (ii) Water body (iii) Forest area (iv) Bare land (v) Built up area. Spatial coverage of land use land cover classes of Morna basin are shown in Table 2 and Fig. 5.

Majority of land in Morna Watershed comes under agriculture 65.37 km^2 (49.21%). Next dominating land use/land cover class was bare land which covers 37.76 km^2 (28.43%) followed by forest area 22.13 km^2 (16.66%), built-up area of 5.23 km^2 (3.94%) and water body 2.35 km^2 (1.77 %). It was found that almost 65.87 per cent of the land is covered under major two classes; agriculture and forest. There is no

TABLE 2

Spatial coverage of land use land cover of Morna watershed

Land use/land cover	Area covered (km^2)	Area (%)
Agriculture	65.37	49.21
Water body	2.35	1.77
Forest	22.13	16.66
Bare land	37.76	28.43
Built up	5.24	3.94
Total	132.85	100

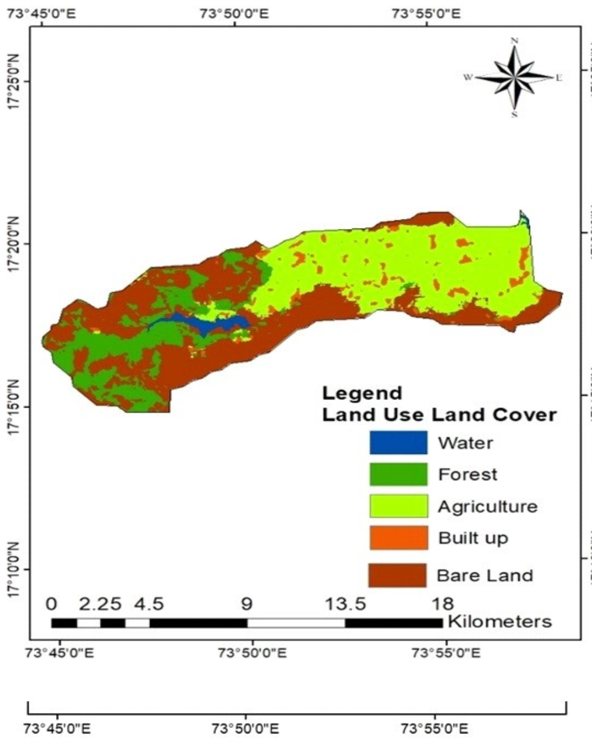

Fig. 5 : Land use land cover map of Morna Watershed

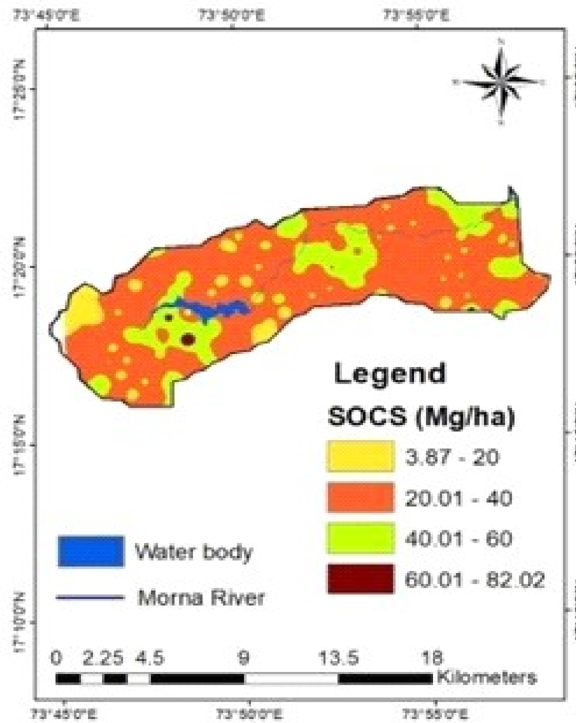

Fig. 6 : Soil organic carbon stock map of Morna Watershed

urbanization and industrialization in this watershed. So, the residential area is scattered and is not very significant.

Soil organic carbon stock values for agricultural land ranges from 14.62 Mg/ha to 60.94 Mg/ha with a mean value of 38.11 Mg/ha. Soil organic carbon stock values for forest land ranges from 35.99 Mg/ha to 67.64 Mg/ha with a mean value of 47.85 Mg/ha. Soil organic carbon stock values for bare land ranges from 3.81 Mg/ha to 36.19 Mg/ha with a mean value of 21.12 Mg/ha and soil organic carbon stock values for built up land ranges from 14.22 Mg/ha to 30.61 Mg/ha with a mean value of 18.50 Mg/ha. Organic carbon values in percent, bulk density values in gm/cm^3 and soil organic carbon stock values in Mg/ha for different land use land cover are shown in Table 3.

The lowest values are observed on built-up land or barren land. These results match with the study done by Sreenivas *et al.* (2016). From the results, it was revealed that the highest soil organic carbon stock

Table 3

Land use land cover and respective statistics of soil organic carbon, bulk density and SOC stock in the Morna Watershed

LULC type	Organic carbon (%)				Bulk density (g/cm^3)				SOC stock (Mg/ha)			
	Min.	Max.	SD	Mean	Min.	Max.	SD	Mean	Min.	Max.	SD	Mean
Agriculture	0.43	1.98	0.33	1.29	1.32	1.45	0.05	1.34	14.62	60.94	9.45	38.11
Forest	1.20	2.40	0.34	1.24	1.46	1.48	0.06	1.47	35.99	67.64	9.28	47.85
bare land	0.12	1.05	0.18	0.62	1.17	1.15	0.06	1.17	3.81	36.19	11.95	21.12
Built up	0.55	1.01	0.19	0.73	1.25	1.29	0.03	1.28	14.22	30.61	6.64	18.50

values were observed in forest land situated in the upper catchment. Agricultural land has low SOC stock values as compared to forest land but has high values than barren land and built-up land. Forest land contained 1.26 and 2.27 times more SOC stock than agricultural land and bare land in 30 cm soil depth. LULC changes have considerable contributions toward the SOC-storage and/or CO_2 emission. Observably, LULC changes can influence soil properties, including SOC stock and SOC content, because of anthropogenic activities (agricultural intensifications, overgrazing, fertilizer application, harvesting, planting, etc.). Cultivated land and bare land have lower organic carbon stocks and contents than other land-uses ecosystems since cultivated-land increases the soil's aeration, microbial-mobility, enhances decomposition, removal with crop residues, and bare land might be exposed to removal of organic carbon with topsoil by erosion and evaporation from soil surface due to lack of land cover. The lowest SOC stock and SOC content in the study area were recorded in bare land which may cause land degradation and environmental pollution.

This study revealed that the transformation of natural vegetation to anthropogenic land uses (grassland, cultivated land and bare land) could cause a deterioration effect on SOC stock. This result is in line with a study by (Alemayehu and Sheleme, 2013), that reported that alteration of natural forests into human-managed land uses (cropland, grazing land, and eucalyptus plantation) had more harmful effects

TABLE 4

Soil sample data and soil organic carbon stock values of Morna Watershed

Village Name	LULC	VF Sand (%)	O. C (%)	B.D (g/cm^3)	Corrected B.D.	SOC (t/ha)
Malharpeth	Bare land	29.36	0.49	1.34	0.94	13.73
Tarale	Bare land	9.34	0.38	1.17	1.06	12.14
Jalu	Forest	17.63	1.24	1.24	1.02	37.92
Natoshi	Forest	22.72	1.27	1.28	0.99	37.68
Nune	Forest	20.23	1.2	1.37	1.09	39.35
Nune	Forest	31.12	1.23	1.45	1.00	36.83
Nune	Bare land	29.56	0.8	1.37	0.97	23.27
Maneri	Bare land	22.82	0.23	1.4	1.08	7.45
Devran	Forest	14	1.2	1.27	1.09	39.32
Kumbhargaon	Forest	14.76	1.34	1.26	1.07	43.01
Chafal	Bare land	28.5	0.9	1.41	1.01	27.23
Rahude	Bare land	27.49	0.55	1.4	1.01	16.56
Rahude	Bare land	25.41	0.43	1.37	1.02	13.24
Bambavade	Forest	23.34	1.24	1.38	1.06	39.38
Tarale	Bare land	29.56	0.29	1.38	0.97	8.34
Yelavewadi	Bare land	29.56	0.37	1.41	0.99	11.08
Navasarwadi	Bare land	28.27	0.75	1.35	0.97	21.68
Navasarwadi	Bare land	27.49	0.43	1.39	1.01	13.05
Mandrul haveli	Bare land	17.12	0.66	1.28	1.06	21.05
Malharpeth	Bare land	28.53	0.98	1.35	0.96	28.23
Marali	Forest	25.93	1.31	1.34	0.99	38.87
Marali	Bare land	28.53	0.86	1.34	0.96	24.71
Marali	Bare land	23.34	1.26	1.31	1.01	38.09
Gavhanwadi	Forest	24.38	1.23	1.35	1.02	37.65

Continued....

TABLE 4 Continued....

Village Name	LULC	VF Sand (%)	O. C (%)	B.D (g/cm^3)	Corrected B.D.	SOC (t/ha)
sulewadi	Bare land	19.19	0.62	1.31	1.06	19.69
Divashi bk.	Forest	25.41	1.8	1.42	1.06	57.08
Divashi bk.	Bare land	19.19	0.59	1.36	1.1	19.4
Dhanagarwadi	Bare land	25.41	1.15	1.34	1	34.2
Divashi bk.	Bare land	27.49	0.74	1.37	0.99	21.92
Adul	Forest	27.49	2.09	1.26	0.91	57.2
Adul	Forest	25.41	1.5	1.39	1.04	46.59
Adul	Bare land	17.12	0.38	1.3	1.08	12.4
Adul	Agriculture	18.15	1.1	1.28	1.04	34.44
Padekarwadi	Bare land	17.12	0.54	1.26	1.05	16.97
Nade	Bare land	18.15	0.5	1.29	1.06	15.84
Choparwadi	Bare land	29.56	0.94	1.38	0.97	27.4
Sangwad	Bare land	28.53	0.15	1.43	1.02	4.49
Padekarwadi	Forest	27.49	1.54	1.36	0.99	45.64
Paparde	Built up	17.89	0.76	1.33	1.1	25.14
Nadoli	Forest	24.38	1.5	1.34	1.01	45.65
Marul haveli	Bare land	16.6	0.56	1.28	1.07	17.93
Marul haveli	Bare land	18.15	0.41	1.29	1.05	13.01
Marul haveli	Agriculture	22.3	1.2	1.35	1.05	37.83
Marul haveli	Bare land	19.71	1.03	1.27	1.02	31.55
Koriwale	Bare land	18.15	0.94	1.27	1.04	29.32
Koriwale	Bare land	17.12	0.12	1.3	1.08	3.81
Majgaon	Bare land	15.04	0.56	1.28	1.09	18.21
Majgaon	Bare land	24.38	0.35	1.31	0.99	10.51
Majgaon	Forest	15.04	1.56	1.26	1.07	50.18
Majgaon	Agriculture	18.15	1.23	1.28	1.05	38.79
Majgaon	Agriculture	19.19	1.2	1.31	1.05	37.97
Chafal	Agriculture	19.71	1.1	1.28	1.03	33.87
Chafal	Agriculture	24.9	1.15	1.29	0.97	33.35
Chafal	Agriculture	19.71	1.4	1.3	1.05	43.94
Chafal	Agriculture	24.9	1.7	1.3	0.98	49.88
Devran	Built up	22.3	1.01	1.3	1.01	30.61
Devran	Agriculture	15.04	1.6	1.3	1.1	53.02
Devran	Agriculture	20.23	1.4	1.37	1.09	45.76
Shinganwadi	Bare land	22.56	0.7	1.36	1.05	22.05
Abdarwadi	Bare land	21.21	0.6	1.3	1.02	18.44
Vihe	Agriculture	22.3	1.24	1.29	1	37.22
Shedgewadi	Bare land	31.12	0.9	1.39	0.95	25.9
Vihe	Agriculture	19.19	1.63	1.24	1	48.76
Vihe	Agriculture	18.15	1.78	1.28	1.05	55.97
Nisrale	Agriculture	20.23	1.9	1.34	1.07	60.94
Shedgewadi	Bare land	17.63	0.6	1.23	1.01	18.26
Vihe	Bare land	17.12	0.72	1.27	1.05	22.9

Continued....

TABLE 4 Continued....

Village Name	LULC	VF Sand (%)	O. C (%)	B.D (g/cm^3)	Corrected B.D.	SOC (t/ha)
Abdarwadi	Agriculture	18.15	1.3	1.31	1.08	41.96
Navadi	Agriculture	28.53	1.2	1.39	1	35.89
Vetalwadi	Agriculture	16.86	1.2	1.27	1.06	38.11
Garawade	Agriculture	22.3	1.5	1.35	1.05	47.28
Khilarwadi	Agriculture	20.75	1.1	1.34	1.06	35.14
Khilarwadi	Agriculture	23.6	1.03	1.4	1.1	33.69
Bahule	Bare land	15.04	0.9	1.23	1.05	28.26
Jarewadi	Agriculture	18.15	1.01	1.32	1.08	32.83
vetalwadi	Agriculture	23.34	1.23	1.41	1.08	39.81
Garawade	Agriculture	24.38	1.34	1.34	1.01	40.65
Garawade	Agriculture	25.41	1.6	1.34	1	47.85
Bagalwadi	Agriculture	23.34	1.32	1.4	1.07	42.53
Bagalwadi	Agriculture	20.23	1.15	1.32	1.05	36.42
Bagalwadi	Agriculture	18.15	0.94	1.28	1.04	29.36
Bagalwadi	Agriculture	31.12	1.23	1.37	0.94	34.88
Bagalwadi	Agriculture	29.51	1.23	1.37	0.96	35.58
Bagalwadi	Agriculture	22.82	0.83	1.35	1.04	25.77
Mhavashi	Built up	21.78	0.55	1.36	1.06	17.6
Mhavashi	Bare land	24.9	0.6	1.32	0.99	17.81
Mhavashi	Bare land	24.12	0.67	1.34	1.02	20.54
Mhavashi	Agriculture	20.75	1.34	1.33	1.06	42.51
Mhavashi	Agriculture	24.9	1.2	1.23	0.93	33.37
Mhavashi	Built up	20.23	0.89	1.36	1.08	28.84
Mhavashi	Agriculture	23.86	1.41	1.31	1	42.06
Mhavashi	Agriculture	14.52	0.43	1.33	1.14	14.62
Mhavashi	Agriculture	16.6	1.04	1.28	1.07	33.42
Mhavashi	Agriculture	18.15	1.26	1.28	1.05	39.36
Mhavashi	Agriculture	18.15	0.92	1.28	1.05	28.85
Mhavashi	Agriculture	19.45	1.5	1.25	1.01	45.26
Mhavashi	Agriculture	27.75	1.47	1.3	0.98	43.11
Mhavashi	Agriculture	29.05	1.74	1.42	1.01	52.63
Mhavashi	Forest	23.34	2.05	1.36	1.04	64.22
Mhavashi	Agriculture	28.53	1.26	1.37	0.98	36.75
Mhavashi	Agriculture	25.16	1.34	1.29	0.97	38.93
Mhavashi	Forest	19.97	1.9	1.35	1.08	61.42
Mhavashi	Agriculture	30.34	0.95	1.22	0.85	24.17
Mhavashi	Agriculture	25.41	0.86	1.34	1	25.72
Mhavashi	Agriculture	27.75	0.52	1.36	0.98	15.37
Mhavashi	Agriculture	23.34	0.92	1.31	1.01	27.71
Mhavashi	Agriculture	19.19	1.01	1.32	1.07	32.42
Mhavashi	Agriculture	21.78	0.83	1.33	1.04	25.77
Mhavashi	Agriculture	23.7	1.08	1.34	1.03	33.23
Maloshi	Agriculture	28.53	0.99	1.36	0.97	28.81

Continued....

TABLE 4 Continued....

Village Name	LULC	VF Sand (%)	O. C (%)	B.D (g/cm^3)	Corrected B.D.	SOC (t/ha)
Maloshi	Agriculture	29.3	0.71	1.38	0.97	20.81
Bambavade	Bare land	30.34	0.51	1.4	0.97	14.76
Banpuri	Forest	27.75	2.3	1.36	0.98	67.64
Padekarwadi	Bare land	19.97	0.67	1.29	1.03	20.8
Banbavade	Agriculture	19.19	1.2	1.35	1.09	39.2
Sakhari	Agriculture	25.67	1.34	1.4	1.04	41.8
Jalu	Agriculture	22.3	1.34	1.36	1.06	42.42
Kadoli	Built up	24.38	0.62	1.33	1.01	18.61
Vajroshi	Agriculture	44.61	1.1	1.41	0.78	25.81
Goshatwadi	Agriculture	35.89	1.8	1.4	0.9	48.34
Goshatwadi	Agriculture	33.82	1.8	1.42	0.94	50.73
Goshatwadi	Agriculture	40.77	1.41	1.45	0.86	36.26
Goshatwadi	Forest	41.7	2.14	1.46	0.85	54.8
Goshatwadi	Agriculture	37.24	1.86	1.42	0.89	49.76
Goshatwadi	Agriculture	41.49	1.98	1.4	0.82	48.49
Goshatwadi	Agriculture	39.73	1.15	1.37	0.83	28.54
Goshatwadi	Agriculture	30.81	1.86	1.41	0.98	54.48
Goshatwadi	Agriculture	34.54	1.52	1.42	0.93	42.24
Goshatwadi	Forest	38.8	1.98	1.43	0.88	52
Goshatwadi	Bare land	39.63	0.67	1.42	0.85	17.22
Goshatwadi	Built up	41.39	0.58	1.4	0.82	14.22
Goshatwadi	Agriculture	42.63	1.13	1.37	0.78	26.51
Goshatwadi	Bare land	40.04	0.53	1.4	0.84	13.3
Goshatwadi	Agriculture	33.61	1.15	1.36	0.9	31.21
Goshatwadi	Forest	38.17	1.67	1.38	0.86	42.87
Goshatwadi	Agriculture	42.22	1.55	1.39	0.8	37.43
Goshatwadi	Forest	31.33	1.78	1.4	0.96	51.45
Goshatwadi	Forest	23.03	1.69	1.39	1.07	54.15
Goshatwadi	Forest	33.92	2.4	1.4	0.92	66.43
Goshatwadi	Bare land	24.17	0.91	1.3	1.04	28.5
Kalgaon	Forest	36.62	1.6	1.4	0.88	42.45
Kalgaon	Forest	24.9	1.89	1.32	0.99	56.22
Kalgaon	Bare land	27.49	1.45	1.33	0.96	41.96
Kalgaon	Forest	38.9	1.45	1.4	0.86	37.25
Kalgaon	Forest	31.02	1.35	1.45	1	40.56
Kalgaon	Forest	28.63	1.38	1.46	1.04	43.09
Kalgaon	Bare land	31.02	3.05	1.3	0.9	82.19
Kalgaon	Forest	42.84	1.51	1.39	0.79	35.99
Kalgaon	Bare land	41.18	0.5	1.44	0.85	12.61
Kalgaon	Forest	31.02	1.98	1.42	0.98	58.32
Kalgaon	Forest	42.95	1.67	1.44	0.82	41.18
Kalgaon	Forest	36.93	1.99	1.42	0.9	53.46
Kalgaon	Forest	32.88	1.91	1.4	0.94	53.98

Continued....

TABLE 4 Continued....

Village Name	LULC	VF Sand (%)	O. C (%)	B.D (g/cm^3)	Corrected B.D.	SOC (t/ha)
Kalgaon	Bare land	40.98	1.49	1.37	0.81	35.99
Kalgaon	Bare land	33.82	0.42	1.45	0.96	12.05
Kalgaon	Bare land	42.84	1.15	1.39	0.8	27.4
Kalgaon	Agriculture	31.74	1.73	1.32	0.9	46.64
Kalgaon	Bare land	30.91	0.68	1.32	0.91	18.54
Kalgaon	Bare land	32.68	0.76	1.43	0.97	21.92
Kalgaon	Forest	22.1	1.44	1.33	1.04	44.9
Kalgaon	Agriculture	41.18	1.9	1.41	0.83	47.43

on SOC in Northwestern Ethiopia. The increment of SOC and ecosystem improvement have been achieved by converting degraded lands to protected areas across different agroecological zones in Ethiopia (Werner, 1997). Correspondingly Xiaoyu *et al*., 2019, confirmed that SOC stock increased by community-based water and soil conservation practices. Hence, converting degraded land to forest or protected land in the study area will enhance the SOC-stock is an effective way to mitigate climate change. Such approaches that enhance SOC increment in farming ecosystems systematically improve atmospheric CO_2 sequestration and organic-matter pools restoration, which is critical to soil quality and health.

Soil Organic Carbon Stock under Different Slope Conditions

The result revealed that SOCs was higher on the lower slope than in other slope classes in the study area due to the removal of topsoil from upper and middle slope classes and deposited in the lower slope position, the presence of more vegetation on the lower slope and less exposed for sunlight.

From the results it was found that the increasing trend of SOC stock in slope position was observed within the depth of 30 cm in the order: lower slope > middle slope > upper slope. In most land uses, middle-slope and upper-slope classes have lower SOC stock and SOC content than lower-slope positions in the Morna watershed. This could be caused by a decrease in upper and middle slope position due to the removal of top soil by accelerated erosion. This result is in agreement with McLauchlan (2006), where SOC content and SOC stock might be affected by topographic factors.

Soil organic carbon stock values for agricultural land ranges from 14.62 Mg/ha to 60.94 Mg/ha with a mean value of 38.11 Mg/ha. Soil organic carbon stock values for forest land ranges from 35.99 Mg/ha to 67.64 Mg/ha with a mean value of 47.85 Mg/ha. Soil organic carbon stock values for bare land ranges from 3.81 Mg/ha to 36.19 Mg/ha with a mean value of 21.12 Mg/ha and soil organic carbon stock values for built up land ranges from 14.22 Mg/ha to 30.61 Mg/ha with a mean value of 18.50 Mg/ha. Forest land contained 1.26 and 2.27 times more SOC stock than agricultural land and bare land in 30 cm soil depth. LULC changes have considerable contributions toward the SOC-storage and/or CO_2 emission. The research plays a pivotal role in soil carbon management, contributing to the goal of sustainable agriculture. RS-based datasets, such as land cover layer and slope derived from DEM, are crucial in understanding the impact of regional entities on soil's physical and chemical properties. Conversion of land use from cultivated to managed perennial plantation can enhance soil carbon stock in Morna Watershed.

This study highlights the importance of assessing watershed level carbon stock for better and carbon friendly land use decision making.

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