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Impact of watershed management on soil organic carbon stock: Insights from Hiware bazar and Daithane semi-arid landscapes, Maharashtra

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Abstract
Soil organic carbon stock (SOCS) is a vital indicator of soil fertility, ecosystem functioning, and long-term carbon sequestration potential. This study evaluated the spatial and vertical variability of SOCS in two semi-arid watersheds of Maharashtra with contrasting management histories: Hiware Bazar (treated with soil and water conservation measures) and Daithane Gunjal (untreated). A total of 176 georeferenced samples were collected from 0-15 cm and 15-30 cm depths across major land-use types. SOC concentration was determined by the Walkley-Black method, bulk density by the Hilgard dish method, and SOCS was computed by integrating SOC, corrected bulk density, and soil depth. Results revealed that SOCS ranged from 1.58 to 34.82 t ha^{-1} in Hiware Bazar and 4.01 to 24.56 t ha^{-1} in Daithane Gunjal, with consistently higher values in the treated watershed. Forest lands contributed the highest SOCS, followed by croplands, fallows, and barren lands.

Across both watersheds, SOCS declined with depth, but the magnitude of reduction was lower in Hiware Bazar, reflecting improved soil resilience. The enhanced SOCS in Hiware Bazar underscores the effectiveness of long-term conservation interventions such as contour trenches, bunding, and vegetative barriers in promoting organic matter accumulation and carbon storage. Overall, the study highlights that watershed-based soil and water conservation practices substantially improve SOC sequestration in semi-arid ecosystems, thereby supporting soil health restoration, climate change mitigation, and sustainable land management.

Keywords: Watershed management, soil organic carbon stock, semi-arid landscapes, Hiware Bazar, Daithane Gunjal, soil fertility, carbon sequestration, land use, soil conservation, Maharashtra

Introduction

Soil organic carbon (SOC) is the foundation of soil health, driving nutrient cycling, water retention, and biological productivity, while also serving as the largest terrestrial carbon reservoir (Balal *et al.*, 2017) [1]. Globally, soils hold nearly three times more carbon than the atmosphere, which makes SOC a key determinant of climate stability and sustainable land use (IPCC, 2006) [8]. Even small changes in SOC stocks can substantially alter the global carbon cycle, highlighting the need for accurate quantification at regional and local scales (Lal, 2004) [13].

In India, SOC levels are generally lower than global averages due to intensive cultivation, residue removal, and land degradation (Bhattacharyya *et al.*, 2013) [3]. Declining SOC trends have been documented in semi-arid Maharashtra, where monocropping and excessive tillage reduce organic matter inputs and soil resilience (Fulpagare *et al.*, 2023; Suryavanshi, 2021) [5, 23]. However, soil and water conservation (SWC) measures such as contour trenches, bunding, and small water-harvesting structures have been shown to enhance vegetation cover, reduce erosion, and promote SOC accumulation (Jat *et al.*, 2019) [9].

The Hiware Bazar watershed in Ahilyanagar district represents a model for long-term SWC interventions, while the neighboring Daithane Gunjal watershed has largely remained untreated. These contrasting watersheds provide an opportunity to assess how conservation practices influence SOC storage under similar physiographic and climatic conditions. Therefore, the present study aims to estimate SOC stocks across treated and untreated watersheds, compare depth-wise variations, and evaluate the influence of land use on SOC distribution in semi-arid Maharashtra.

Materials and Methods
Study Area

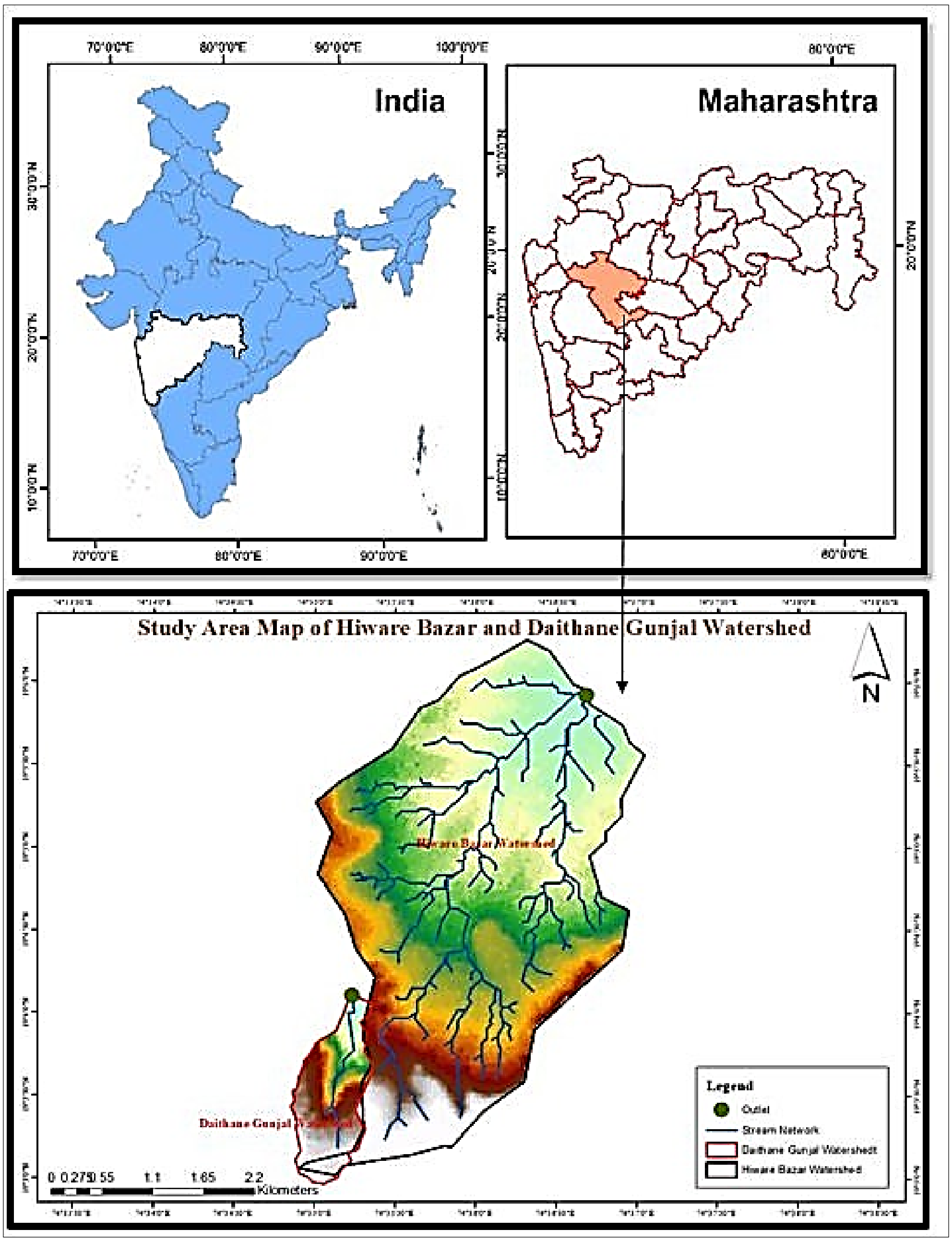

Fig 1: Location map of the Study Area

The research was conducted in two adjacent watersheds of Ahilyanagar district, Maharashtra, located in the rain-shadow region of the Western Ghats. The area is characterized by a semi-arid climate, with average annual rainfall of less than 400 mm. Topography is undulating, ranging from 600 to 720 m above mean sea level, with slopes varying between 3% and 25%.

The Hiware Bazar watershed (1287.60 ha) has undergone intensive soil and water conservation (SWC) interventions since the mid-1990s, including continuous contour trenches, compartment bunding, earthen nala bunds, storage ponds, and vegetative barriers. These measures transformed the village into a national model for watershed management by improving groundwater recharge, vegetation cover, and agricultural productivity.

In contrast, the neighboring Daithane Gunjal watershed (116.63 ha) has not SWC treatments, with visible soil erosion, poor vegetation cover, and seasonal water scarcity. Despite sharing similar climatic and physiographic settings, the two watersheds present stark contrasts in land-use intensity, vegetation, and soil quality, making them an ideal natural experiment to evaluate the role of conservation practices in enhancing SOC stocks.

Soil Sampling and Preparation
A systematic grid-based sampling approach was adopted to capture the spatial variability of soils in both watersheds. The treated Hiware Bazar watershed was covered with a 145-point grid, whereas the untreated Daithane Gunjal watershed was represented by 31 points, giving a total of 176 georeferenced sampling locations. At each grid point, soil samples were collected from two depth intervals: 0-15 cm and 15-30 cm using screw auger.

Estimation of Soil Organic Carbon (SOC)

Determining soil organic carbon is essential for assessing soil health, fertility, and its role in the global carbon cycle. Among the available analytical techniques, the Walkley-Black wet oxidation method (1934) is one of the most widely adopted because of its simplicity, reliability, and ease of application (Nelson and Sommers, 1982) [18]. In the present study, SOC was estimated following this method. Soil samples (< 2 mm fraction) were treated with potassium dichromate ($K_2Cr_2O_7$) and concentrated sulfuric acid (H_2SO_4) to oxidize organic carbon, and the residual dichromate was titrated against ferrous ammonium sulfate using diphenylamine as an indicator. Since the method does not fully oxidize all organic carbon, a correction factor of 1.33 was applied to the measured values to obtain realistic estimates of SOC concentration, expressed on an oven-dry basis.

Estimation of Bulk Density

Bulk density (BD) refers to the oven-dry weight of soil per unit of its bulk volume, including both soil particles and pore spaces. It is an important indicator of soil structure, compaction, and porosity, directly influencing root penetration, water infiltration, and overall soil health. Generally, higher BD values are associated with reduced pore space and poor soil conditions.

In this study, bulk density was determined using the Hilgard dish method (Keen and Raczkowski, 1921) [10]. The soil was filled into a flat-bottomed Hilgard dish by pressing it into the soil surface, trimming excess soil to match the dish's rim and weighing the soil-filled dish. The bulk density was then computed by dividing soil mass by the internal volume of the dish (BD = (B - A) / V), where B is the weight of the filled dish, A is the weight of the empty dish and V is internal volume.

Determination of Soil Organic Carbon Stock (SOC Stock)

Soil Organic Carbon stock (SOC stock) represents the total quantity of organic carbon stored in soils per unit area to a given depth. It serves as a key indicator of soil fertility, ecosystem functioning, and long-term carbon sequestration potential, while also reflecting the influence of land use and management on soil health. Beyond being a soil health index, it directly contributes to global carbon cycling, climate change mitigation, and the sustainability of agricultural systems by regulating nutrient availability, water retention, and resilience against degradation. Higher SOC stocks improve soil resilience, enhance crop productivity, and act as a natural sink for atmospheric CO_2.

In the present study, SOC stocks were calculated for two depth intervals 0-15 cm and 15-30 cm) and then aggregated to obtain cumulative stocks for the 0-30 cm soil layer. For each land-use category, the mean SOC stock was further scaled by the areal extent of that class to estimate total carbon storage within the watershed.

Soil Organic Carbon stock (SOC stock) refers to the amount of organic carbon retained in the soil profile per unit area to a specified depth. It is widely recognized as a key indicator for assessing soil carbon reserves, evaluating the effects of land-use practices, and determining the capacity of soils to function as long-term carbon sinks.

In this study, SOC stock was quantified on a volumetric basis by multiplying SOC concentration, corrected bulk density, and soil depth following the method proposed by Lal (1998) [11]. The calculation was expressed as:

$$SOC\ Stock = SOC/100 * Corrected\ bulk\ density * Soil\ sampling\ depth * 10^4$$

Where, soil organic carbon is in percent, corrected bulk density is in g/cm³, soil depth is in m and coarse fraction denotes soil particles greater than 2 mm in diameter.

The corrected bulk density is defined by:

$$Corrected\ Bulk\ density = Bulk\ density * ((100 - Coarse\ fraction))/100$$

This approach provides a robust and realistic estimate of SOC storage, enabling meaningful comparisons across land uses and supporting land management strategies aimed at improving soil health and enhancing carbon sequestration potential.

Results and Discussion

1. Spatial and Vertical Distribution of Soil Bulk Density Across Land Use Types

The bulk density (BD) of soils varied across land use land covers (LULC) and soil depths in the Hiware Bazar and Daithane Gunjal watersheds (Tables 4.4 and 4.5). Overall, BD ranged from 0.52 to 1.47 g/cc in Hiware Bazar and 0.74 to 1.68 g/cc in Daithane Gunjal, with higher values generally observed in the Daithane Gunjal watershed, reflecting greater soil compaction and degradation.

Forest lands exhibited the lowest BD in both watersheds, indicating better soil structure and higher organic matter content. In Hiware Bazar, BD ranged from 0.65-1.03 g/cc at 0-15 cm (mean 0.80 g/cc) and 0.72-1.24 g/cc at 15-30 cm (mean 0.88 g/cc). Daithane Gunjal showed slightly higher BD, with means of 0.88 g/cc (0-15 cm) and 0.91 g/cc (15-30 cm). Lower BD under forests suggests minimal disturbance and higher porosity due to continuous litter input and root activity. (USDA-NRCS, 2019) [25].

Croplands recorded moderate BD values. In Hiware Bazar, BD averaged 0.83 g/cc (0-15 cm) and 0.91 g/cc (15-30 cm), while Daithane Gunjal had slightly higher means of 0.91 g/cc (0-15 cm) and 0.99 g/cc (15-30 cm). Tillage and reduced organic matter input likely contributed to greater compaction compared to forests. (MDPI, 2020; Gassel, 1982) [14, 6].

Current fallow lands exhibited further increases in BD. In Hiware Bazar, BD averaged 0.89 g/cc (0-15 cm) and 0.99 g/cc (15-30 cm), whereas Daithane Gunjal recorded 0.99 g/cc and 1.18 g/cc at corresponding depths. Lack of continuous vegetation cover and exposure to erosive forces likely explain the increase. (Tesfaye & Lemma, 2019) [24].

Barren lands had the highest BD across both watersheds, reflecting severe soil degradation and compaction. In Hiware Bazar, BD averaged 1.03 g/cc (0-15 cm) and 1.15 g/cc (15-30 cm), while Daithane Gunjal exhibited even higher means of 1.03 g/cc (0-15 cm) and 1.26 g/cc (15-30 cm). These values suggest reduced soil porosity and poor physical conditions under barren areas.

Overall, bulk density increased with soil depth and was consistently higher in Daithane Gunjal than in Hiware Bazar, underscoring the positive impact of soil and water conservation measures in maintaining favourable soil physical properties in the treated watershed.

Table 1: Descriptive statistics Soil bulk densities (g/cc) in Hiware Bazar watershed under different LULC

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	0.65	1.03	0.80± 0.02	0.09
	15-30	0.72	1.24	0.88± 0.02	0.11
Crop land	0-15	0.52	1.10	0.83± 0.01	0.13
	15-30	0.56	1.17	0.91±0.01	0.14
Current fallow land	0-15	0.75	0.99	0.89±0.05	0.12
	15-30	0.84	1.14	0.99± 0.06	0.13
Barren land	0-15	0.77	1.36	1.03± 0.02	0.11
	15-30	0.94	1.47	1.15± 0.02	0.12

Table 2: Descriptive Statistics Soil Bulk Densities (G/Cc) In Daithane Gunajal Watershed under Different Lulc

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	0.77	1.05	0.88± 0.05	0.12
	15-30	0.83	1.04	0.91± 0.04	0.08
Crop land	0-15	0.78	0.98	0.91± 0.03	0.07
	15-30	0.74	1.23	0.99± 0.07	0.17
Current fallow land	0-15	0.88	1.10	0.99± 0.04	0.08
	15-30	0.95	1.33	1.18± 0.07	0.16
Barren land	0-15	0.85	1.37	1.03± 0.04	0.15
	15-30	0.99	1.68	1.26± 0.06	0.24

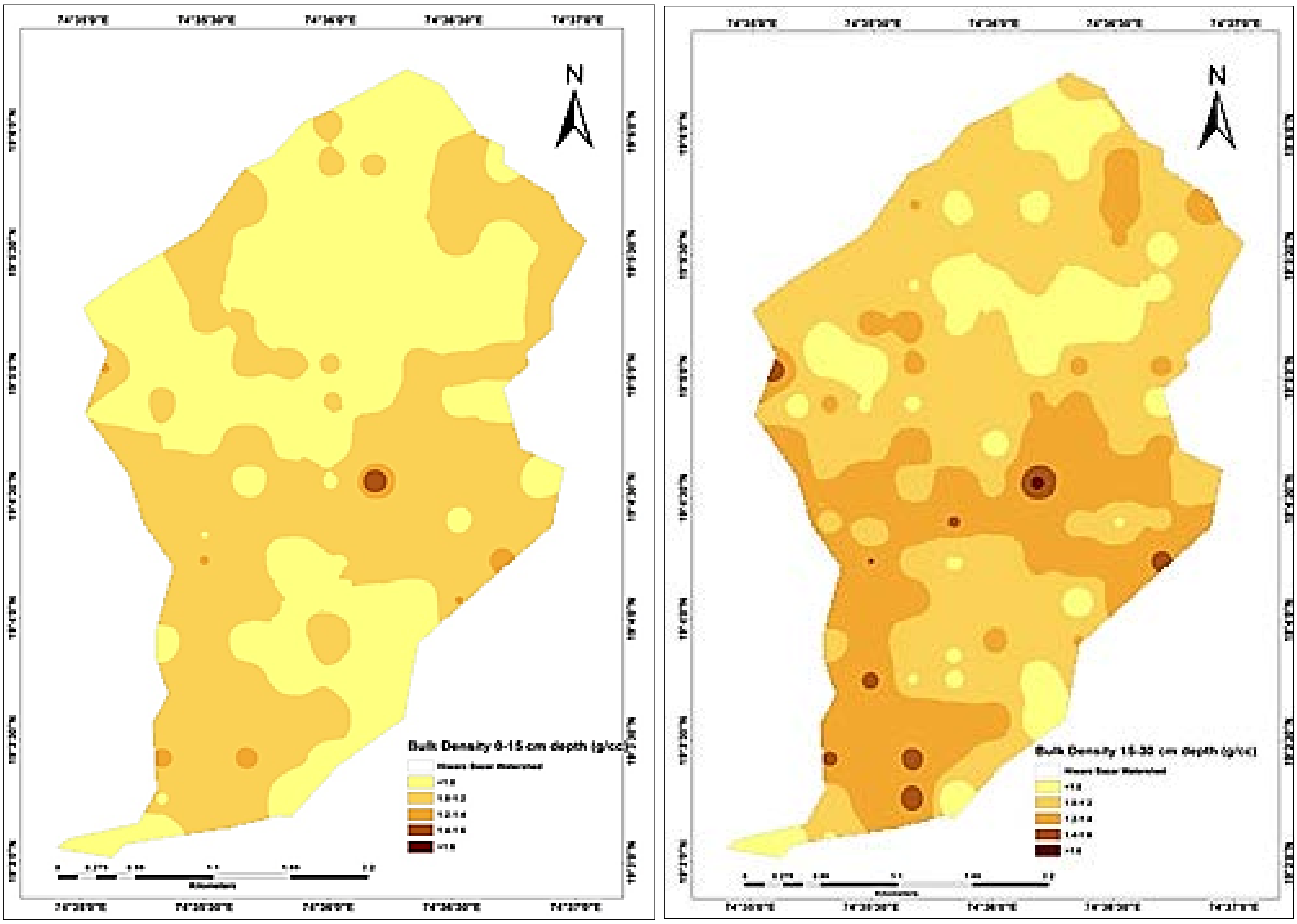

Fig 1 & 2: Spatial distribution maps of bulk density of Hiware Bazar watershed at 0- 15 cm and 15-30 cm depths

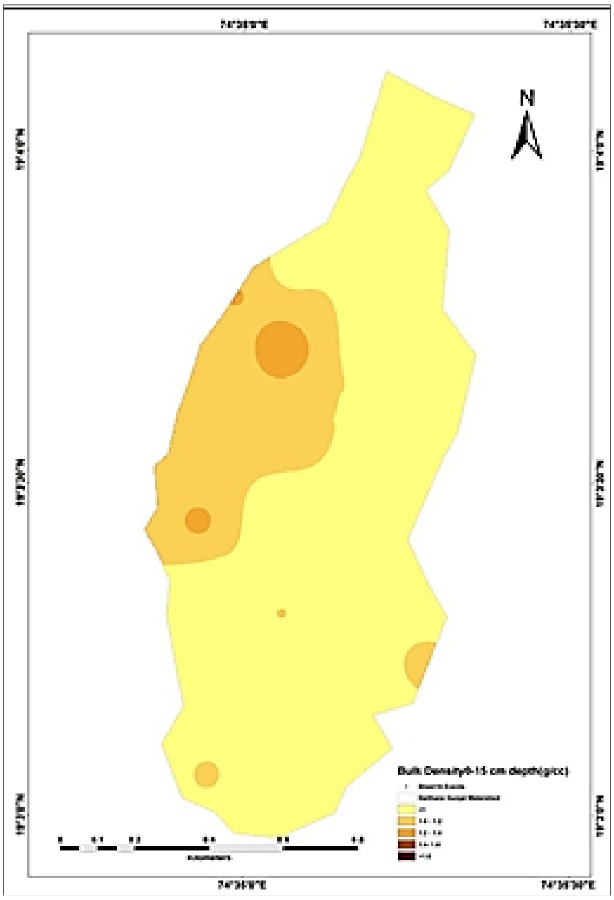
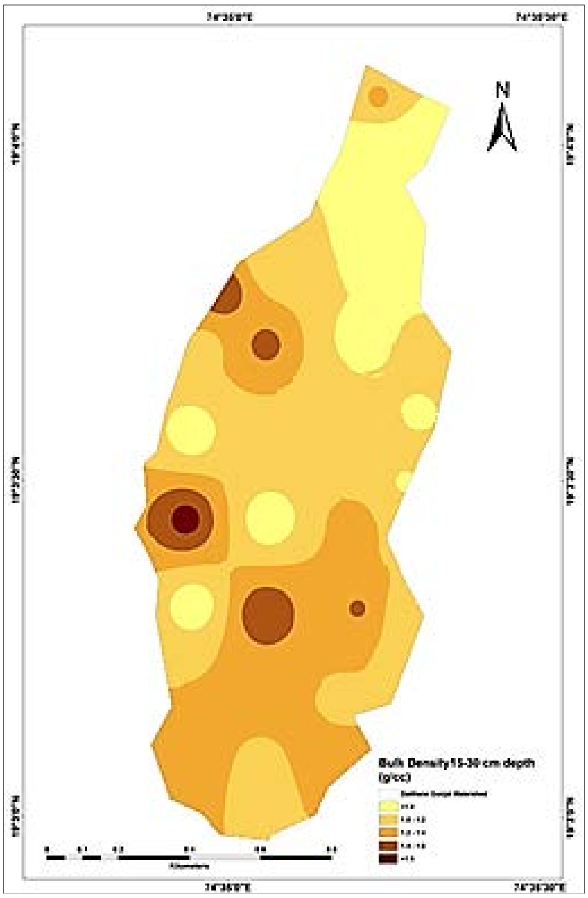

Fig 3 & 4: Spatial distribution maps of bulk density of Daithane Gunjal watershed at 0-15 cm and 15-30 cm depths

2. Spatial and Vertical Distribution of Soil Organic Carbon Across Land Use Types

The SOC content varied considerably across land uses in the two watersheds (Tables 3 and 4). Overall, SOC ranged from 0.21% to 2.24%, with higher values consistently observed in the treated Hiware Bazar watershed compared to the untreated Daithane Gunjal. Forest lands exhibited the highest SOC concentrations in both watersheds. In Hiware Bazar, SOC ranged from 0.98% to 2.24% with mean values of 1.43% (0-15 cm) and 1.20% (15-30 cm, while in Daithane Gunjal, values were comparatively lower, ranging from 0.88% to 1.26% at the surface (mean 1.03%) and 0.68% to 1.12% at the subsurface (mean 0.95%). The greater SOC under forest cover highlights the role of dense vegetation, continuous litter input, and minimal soil disturbance in carbon accumulation. (Giweta, 2020; Sun *et al*., 2024) [7, 22]

Croplands showed moderate SOC enrichment. Hiware Bazar recorded mean SOC of 1.12% (0-15 cm) and 0.88% (15-30 cm), with values ranging between 0.54% and 2.15%. In contrast, Daithane Gunjal had lower averages of 0.97% (0-15 cm) and 0.77% (15-30 cm), with a narrower range of 0.52% to 1.22%. Lower SOC compared to forests reflects frequent tillage, residue removal, and reduced organic matter input under cultivation. (Moussadek *et al*., 2014; MDPI, 2022) [17, 15]

Current fallow lands exhibited reduced SOC levels. In Hiware Bazar, SOC ranged between 0.47% and 1.12% at the surface (mean 0.82%) and 0.31% to 0.75% at 15-30 cm (mean 0.59%). Daithane Gunjal showed even lower values, with surface SOC of 0.55-0.74% (mean 0.67%) and subsurface values of 0.51-0.64% (mean 0.58%). The decline is attributed to limited biomass production and the absence of sustained vegetation cover.

Barren lands recorded the lowest SOC concentrations in both watersheds. In Hiware Bazar, surface soils contained 0.43-0.84% (mean 0.61%) and subsurface soils 0.21-0.39% (mean 0.48%). Daithane Gunjal exhibited slightly lower averages of 0.56% (0-15 cm) and 0.40% (15-30 cm). The depletion of SOC in barren areas is primarily due to soil degradation, lack of organic matter inputs, and susceptibility to erosion. (Lal, 2001) [12]. Overall, the results clearly demonstrate that Hiware Bazar maintained higher SOC levels across all land uses and depths, underscoring the effectiveness of long-term soil and water conservation measures in enhancing carbon storage potential.

Table 3: Descriptive Statistics Soil Organic Carbon (%) In Hiware Bazar Watershed Under Different Lulc

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	0.98	2.24	1.43 ±0.06	0.33
	15-30	0.86	1.95	1.20 ±0.05	0.25
Crop land	0-15	0.54	2.15	1.12 ±0.03	0.29
	15-30	0.48	1.73	0.88 ±0.02	0.22
Current fallow land	0-15	0.47	1.12	0.82 ±0.11	0.24
	15-30	0.31	0.75	0.59 ±0.08	0.18
Barren land	0-15	0.43	0.84	0.61 ±0.05	0.23
	15-30	0.21	0.39	0.48 ±0.04	0.19

Table 4: Descriptive statistics Soil organic carbon (%) in Daithane Gunajal watershed under different LULC

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	0.88	1.26	1.03 ±0.06	0.14
	15-30	0.68	1.12	0.95 ±0.08	0.19
Crop land	0-15	0.78	1.22	0.97 ±0.06	0.16
	15-30	0.52	1.17	0.77 ±0.03	0.20
Current fallow land	0-15	0.55	0.74	0.67 ±0.03	0.08
	15-30	0.51	0.64	0.58 ±0.03	0.06
Barren land	0-15	0.43	0.84	0.56 ±0.03	0.12
	15-30	0.21	0.60	0.40 ±0.03	0.10

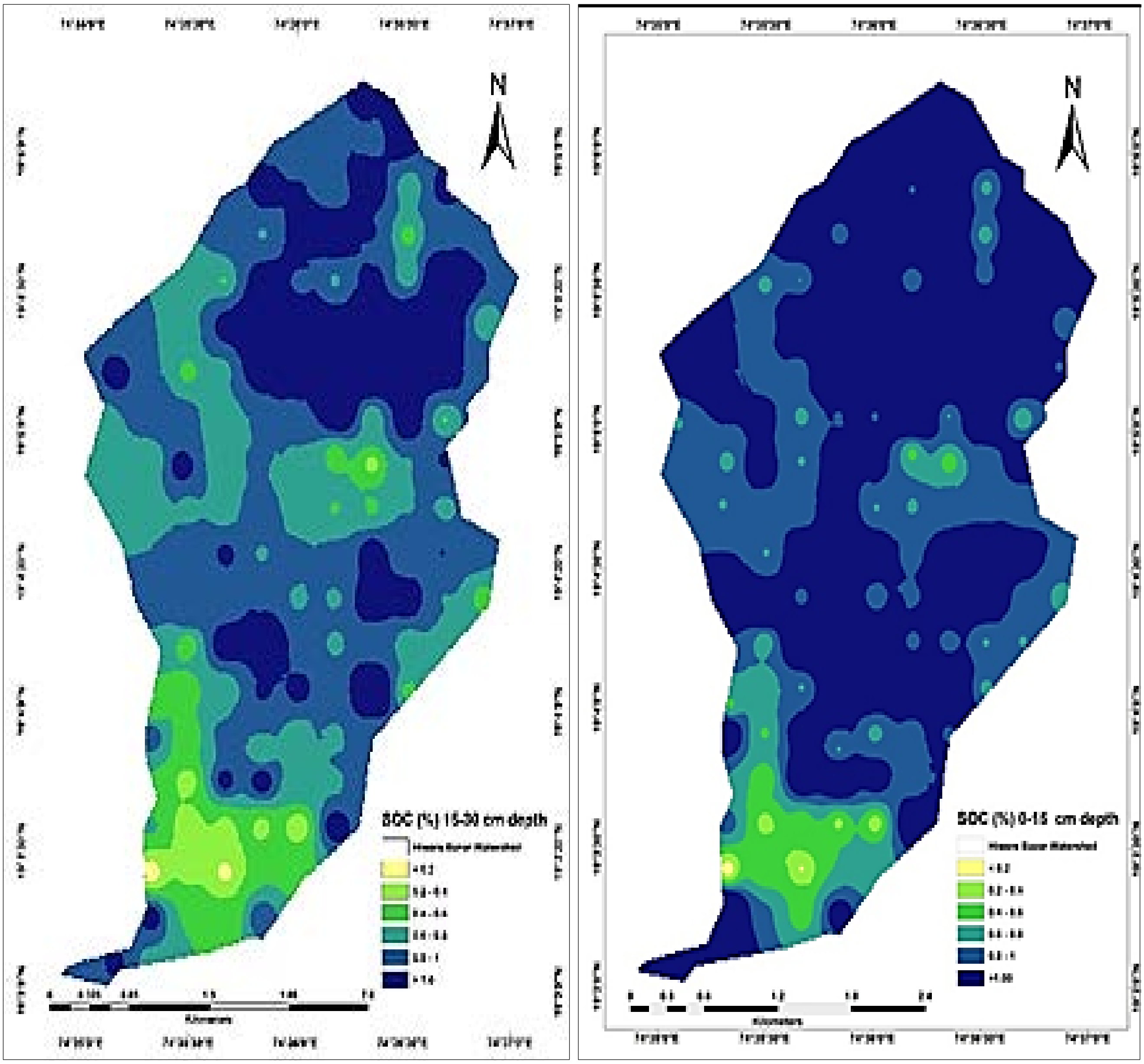

Fig 5 & 6: Spatial distribution maps of Soil organic carbon (%) of Hiware Bazar watershed at 0-15 cm and 15-30 cm depths

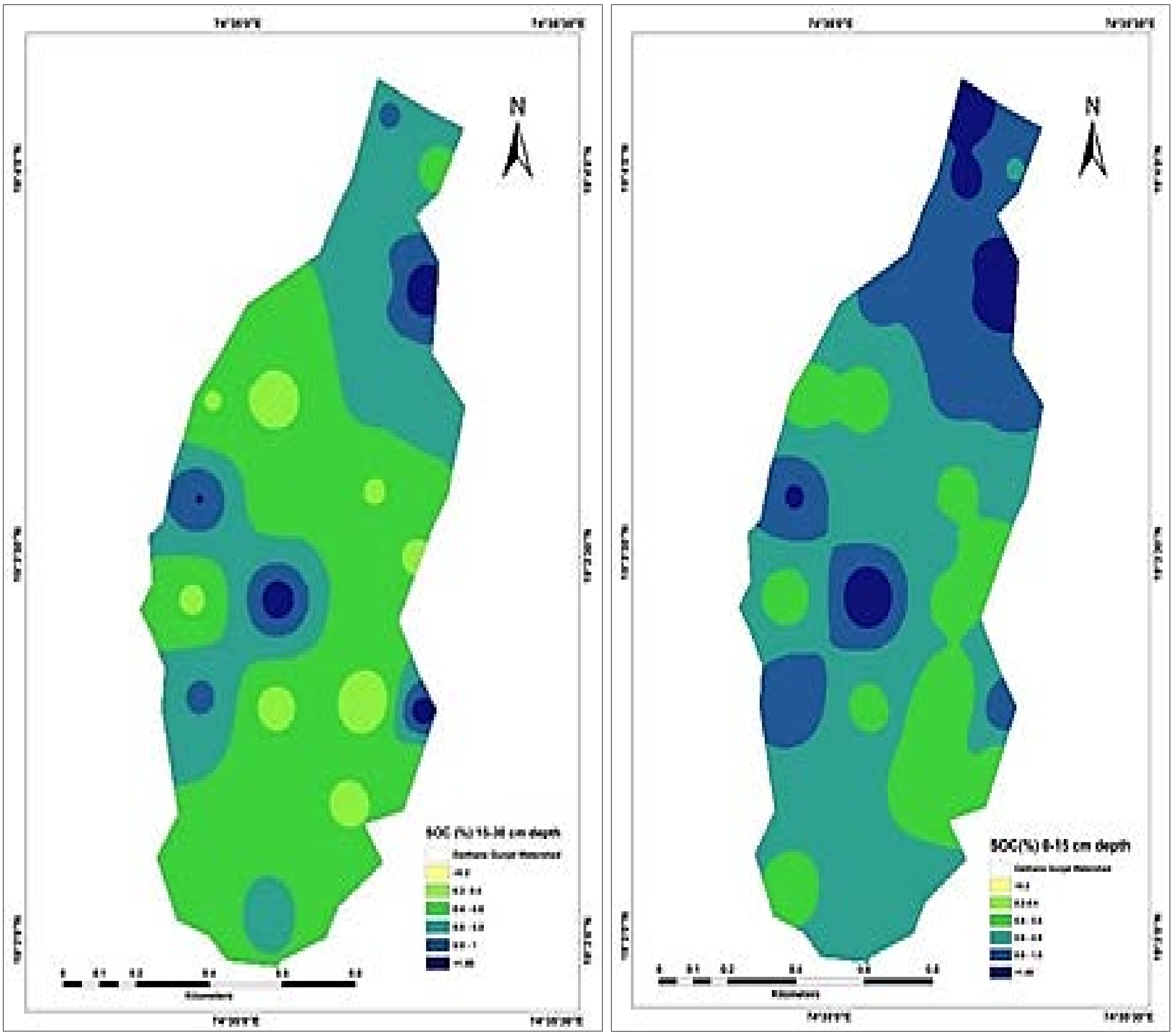

Fig 7 & 8: Spatial distribution maps of Soil organic carbon (%) of Daithane Gunjal watershed at 0-15 cm and 15-30 cm depths

Spatial and Vertical Distribution of Soil Organic Carbon Stock Across Land Use Types

The soil organic carbon stock (SOCS) varied considerably across land use land covers (LULC) and depths in the treated Hiware Bazar and untreated Daithane Gunjal watersheds (Tables 5 and 6). Overall, SOCS ranged from 1.58 to 34.82 t/ha in Hiware Bazar and 4.01 to 24.56 t/ha in Daithane Gunjal, with consistently higher values in the treated watershed, reflecting better soil carbon sequestration due to conservation practices.

Forest lands recorded the highest SOCS in both watersheds, highlighting the significant role of vegetation cover in enhancing soil carbon storage. In Hiware Bazar, SOCS ranged from 12.95-29.13 t/ha at 0-15 cm (mean 20.66 t/ha) and 10.79-24.55 t/ha at 15-30 cm (mean 17.83 t/ha). Daithane Gunjal showed slightly lower means of 19.49 t/ha (0-15 cm) and 15.53 t/ha (15-30 cm). The higher SOCS under forests is attributed to continuous litter input, root biomass, and minimal disturbance. (Sokol *et al.*, 2018; Mekonnen, 2020) [21, 16].

Croplands exhibited moderate SOCS values. In Hiware Bazar, SOCS averaged 16.85 t/ha (0-15 cm) and 14.13 t/ha (15-30 cm), with values reaching as high as 34.82 t/ha at the surface layer. Daithane Gunjal recorded slightly lower means of 16.75 t/ha (0-15 cm) and 12.29 t/ha (15-30 cm). Reduced carbon stocks compared to forests are likely due to tillage, crop residue removal, and intermittent cultivation practices. (Ren *et al*., 2023) [20]

Current fallow lands showed further reductions in SOCS. In Hiware Bazar, values averaged 14.44 t/ha (0-15 cm) and 12.03 t/ha (15-30 cm), while Daithane Gunjal recorded 14.06 t/ha (0-15 cm) and 10.04 t/ha (15-30 cm). Absence of continuous vegetation cover and reduced organic matter inputs explain the decline in SOCS. (Padbhushan *et al*., 2021) [19].

Barren lands exhibited the lowest SOCS in both watersheds. In Hiware Bazar, SOCS averaged 12.23 t/ha (0-15 cm) and 10.29 t/ha (15-30 cm), while Daithane Gunjal recorded 12.10 t/ha (0-15 cm) and 8.77 t/ha (15-30 cm). The depletion of soil carbon in barren areas is associated with severe land degradation, erosion, and lack of biomass inputs. (FAO, 1993; Bhandari & Bam, 2013) [4, 2].

Overall, SOCS decreased with depth and was consistently higher in Hiware Bazar across all land uses, underscoring the positive impact of soil and water conservation measures in improving long-term soil carbon sequestration potential

Table 5: Descriptive Statistics of Soil organic carbon stock (t/ha) in Hiware Bazar watershed under different LULC

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	12.95	29.13	20.66 ± 0.65	3.36
	15-30	10.79	24.55	17.83 ± 0.61	3.18
Crop land	0-15	8.89	34.82	16.85 ± 0.52	4.88
	15-30	7.22	32.26	14.13 ± 0.47	4.36
Current fallow land	0-15	8.87	17.52	14.44 ± 1.50	3.36
	15-30	7.39	14.60	12.03 ± 1.25	2.80
Barren land	0-15	1.90	19.92	12.23 ± 0.99	5.05
	15-30	1.58	17.80	10.29± 0.86	4.37

Table 6: Descriptive Statistics of Soil organic carbon stock (t/ha) in Daithane Gunjal watershed under different LULC

LULC	Depths (cm)	Min	Max	Mean ± SE	SD
Forest land	0-15	14.01	24.56	19.49 ± 1.86	4.17
	15-30	10.01	23.93	15.53 ± 2.35	5.25
Crop land	0-15	11.14	24.21	16.75 ± 1.83	4.84
	15-30	7.02	17.29	12.29 ± 1.56	4.12
Current fallow land	0-15	11.54	16.93	14.06 ±1.01	2.27
	15-30	8.24	12.09	10.04± 0.72	1.62
Barren land	0-15	5.62	19.07	12.10 ± 0.98	3.67
	15-30	4.01	13.62	8.77 ± 0.69	2.59

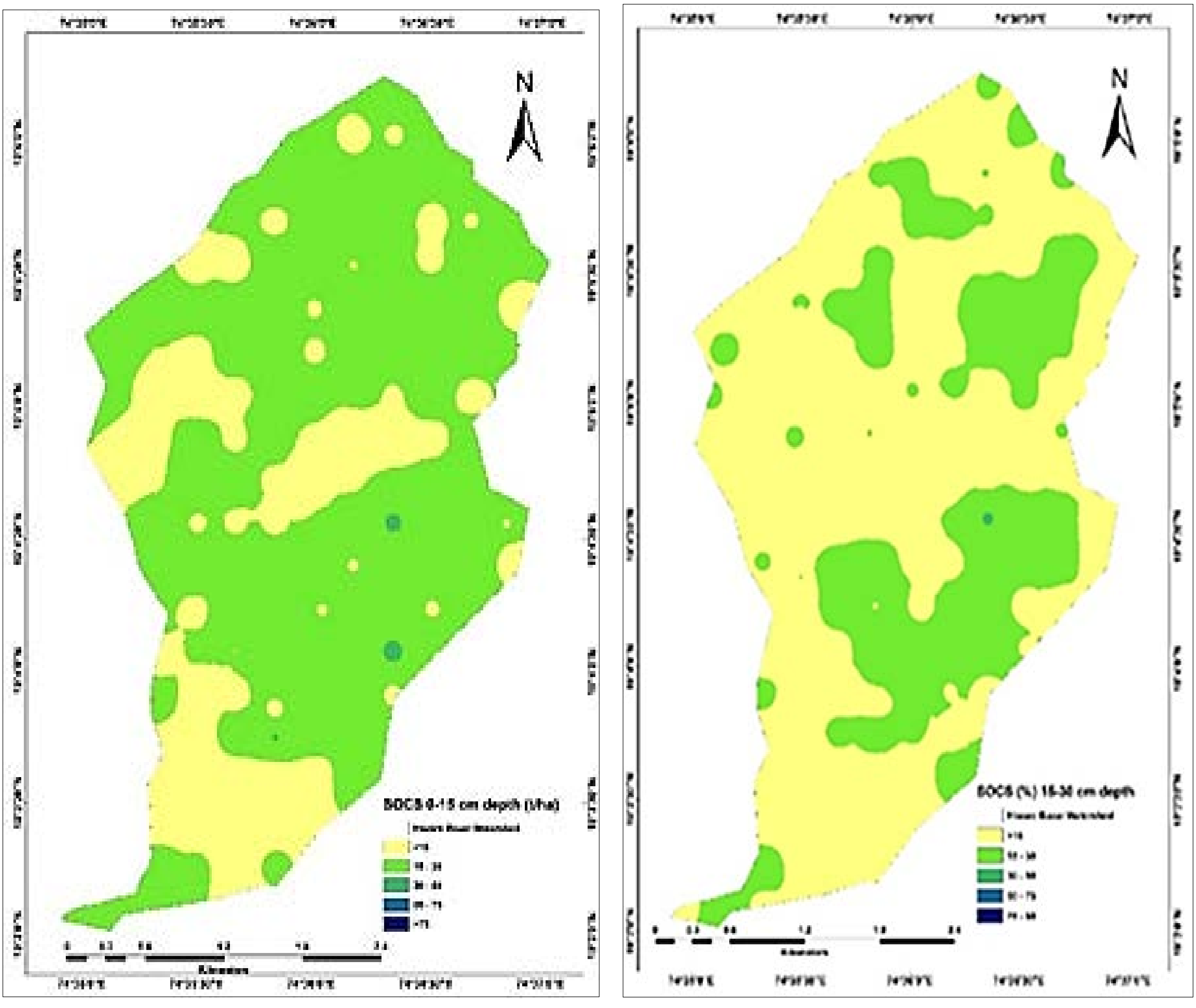

Fig 9 & 10: Spatial distribution maps of Soil organic carbon stock of Hiware Bazar at 0-15 cm and 15-30 cm depths

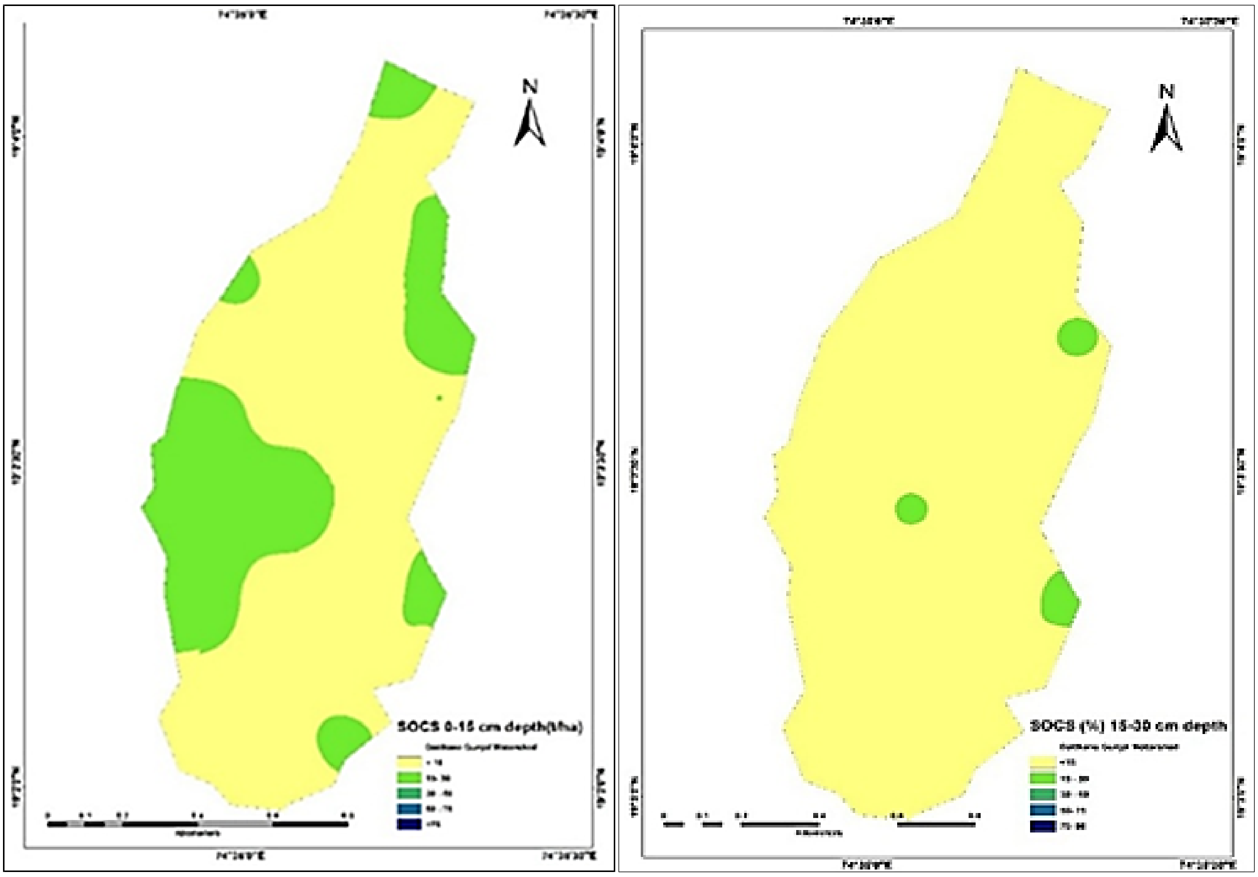

Fig 11 & 12: Spatial distribution maps of Soil organic carbon stock of Daithane Gunjal at 0-15 cm and 15-30 cm depths

Conclusion

The study evaluated the spatial and vertical variability of soil bulk density, organic carbon content, and carbon stocks under different land use land covers (LULC) in the semi-arid watersheds of Hiware Bazar and Daithane Gunjal, Maharashtra. Bulk density exhibited clear land use and depth-related patterns, being lowest in forested areas due higher organic matter, better aggregation, and minimal disturbance, while barren and fallow lands showed the highest values reflecting compaction and soil degradation.

Soil organic carbon (SOC) content ranged from 0.21% to 2.24%, with consistently higher levels in the treated Hiware Bazar watershed compared to the untreated Daithane Gunjal. Forest lands emerged as significant carbon reservoirs, followed by croplands, fallows, and barren lands, highlighting the importance of vegetation cover and organic matter inputs in carbon enrichment.

Soil organic carbon stocks (SOCS) varied between 1.58 and 34.82 t/ha, showing strong sensitivity to land use intensity and conservation measures. Hiware Bazar recorded higher SOCS across all depths and land use classes, underscoring the long-term benefits of soil and water conservation (SWC) practices in enhancing carbon sequestration potential.

Overall, the results indicate that SWC interventions improve soil physical health and carbon storage by reducing erosion, increasing vegetation cover, and enhancing organic matter accumulation. The findings emphasize the need to scale up practices such as agroforestry, residue retention, reduced tillage, and watershed-based soil conservation to sustain soil fertility, mitigate land degradation, and contribute to climate change adaptation in semi-arid ecosystems.

References

1. Balal Y, Guijian L, Ruwei W, Qumber A, Muhammad I, Ruijia L, *et al*. Investigating the biochar effects on C-mineralization and sequestration of carbon in soil compared with conventional amendments using stable isotope approach. GCB Bioenergy. 2017;9(6):1085-1099.
2. Bhandari S, Bam S. Comparative study of soil organic carbon (SOC) under forest, cultivated and barren land: a case of Chovar Village, Kathmandu. Nepal J Sci Technol. 2013;14(2):103-108.
3. Bhattacharyya R, Das TK, Pramanik P, Ganeshan V, Saad AA, Sharma AR, *et al*. Impacts of conservation agriculture on soil aggregation and aggregate-associated N under an irrigated agroecosystem of the Indo-Gangetic Plains. Nutr Cycl Agroecosyst. 2013;96:185-202.
4. FAO. Carbon sequestration in dryland soils. FAO Soils Bulletin. 1993.
5. Fulpagare DD, Ranshur NJ, Patil SR, Thakare RS. Aggregate stability in soils of Nandurbar district and their interaction with available nitrogen and soil organic carbon. Pharma Innov J. 2023;12(7):39-46.
6. Gassel DK. Tillage effects on soil bulk density and mechanical impedance. ASA Spec Publ. 1982;44:30-47.
7. Giweta M. Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: a review. J Ecol Environ. 2020;44:11-21.
8. Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC guidelines for national greenhouse gas inventories. Institute for Global Environmental Strategies (IGES); 2006.
9. Jat HS, Datta A, Choudhary M, Sharma PC, Yadav AK, Choudhary V, *et al*. Climate smart agriculture practices improve soil organic carbon pools, biological properties

and crop productivity in cereal-based systems of North-West India. Catena. 2019;181:104059.
10. Keen BA, Raczkowski H. The relation between the clay content and certain physical properties of a soil. J Agric Sci. 1921;11(4):441-449.
11. Lal R. Soil quality: For crop production and ecosystem health. J Environ Qual. 1998;27(6):15-52.
12. Lal R. Soil degradation by erosion. Land Degrad Dev. 2001;12:519-539.
13. Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004;304:1623-1627.
14. MDPI. The effects of soil compaction and different tillage systems on the bulk density and moisture content of soil. Agriculture. 2020;11:666-675.
15. MDPI. Organic amendments and reduced tillage accelerate harvestable C biomass and soil C sequestration in rice-wheat rotation in a semi-arid environment. Sustainability. 2022;15(8):6415-6427.
16. Mekonnen G. Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: a review. J Ecol Environ. 2020;44:11-21.
17. Moussadek R, Benzaazoua M, Zoughaib A, Touati N. Tillage system affects soil organic carbon storage and quality in Central Morocco. Appl Environ Soil Sci. 2014;2014:654796.
18. Nelson DW, Sommers LE. Total carbon, organic carbon and organic matter. Methods Soil Anal Part 2 Chem Microbiol Prop. 1982;9:539-579.
19. Padbhushan R, Kumar U, Sharma S, Rana DS, Kumar R, Kohli A, *et al*. Impact of land-use changes on soil properties and carbon pools in India: a meta-analysis. Front Environ Sci. 2021;9:794866.
20. Ren X, Fujisaki K, Tian H, Pan W. Organic amendment effects on cropland soil organic carbon and its implications: a global synthesis. Sci Total Environ. 2023;839:156871.
21. Sokol NW, Kuebbing SE, Karlsen-Ayala E, Bradford MA. Evidence for the primacy of living root inputs, not root or shoot litter, in forming soil organic carbon. New Phytol. 2018;221(1):233-246.
22. Sun D, Qiu X, Wan S. Forest types control the contribution of litter and roots to labile and persistent soil organic carbon. Biogeochemistry. 2024;167:1609-1617.
23. Suryavanshi A. Impact of agricultural practices on soil erosion and aggregate stability in Maharashtra. Soil Tillage Res. 2021;212:105071.
24. Tesfaye B, Lemma B. Effects of vegetation type and exposure on soil bulk density and aggregate stability in semi-arid savanna soils. Environ Dev Sustain. 2019;21:535-553.
25. USDA-NRCS. Soil Health - Bulk Density/Moisture/Aeration. USDA Natural Resources Conservation Service. 2019.
26. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37(1):29-38.