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The Critical Role Played by Soil Organic Carbon (SOC) in Terrestrial Ecosystem

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Abstract: ***Soil organic carbon (SOC) plays a critical role in terrestrial ecosystem functioning as the dominant energy source for microorganisms and as a fundamental control on soil structure and ecosystem productivity. It plays an important role in plant nutrition, roots, and overall plant development. Promotes active and diverse soil biology. Reactivates and sustains naturally occurring biological cycles. Increases soil exchange capacity. The present study work has been conducted for India. The study is purely GIS and Remote Sensing based, using imagery provided by EnvirometriX Ltd. The imagery contains the data from 1950 to 2018. Initially the imagery has been processed in Google Earth Engine and final image downloaded for the study area in tif form, further with the help of GIS the pixel value extracted. It is found that the average soil organic carbon (SOC) content in India is around 0.54%. However, the SOC content in India has decreased from 1% to 0.3% over the past 70 years. which is undoubtly on lower side and a matter of serious concern.***

Keywords: Organic carbon, Satellite imagery, microorganisms, TOC, GEE, GIS etc.

1. Introduction

Soil organic carbon (SOC) is the carbon component of organic matter and includes all living and dead organic material in the soil like plants, soil organisms and animal materials. At the same time it does not include fresh, undecomposed plant material on the surface. Organic matter is basically a source and store of plant nutrients, that binds soils aggregates together which makes them more resistant against soil erosion. It is also a source of energy for soil organisms, increasing their number and activity and their ability to cycle nutrients and compete with pests and pathogens. The microbial activity increases the biomass production by way of providing nutrients, and improves water infiltration, drainage and retention capacity in the soil for growing plants.

Plant photosynthesis is a biological process which converts carbon dioxide (CO2) of atmosphere into plant sugars which feed shoots and roots. When plants grow then roots and their associated beneficial fungi and other microorganisms build soil organic carbon. Carbon in root exudates provides a valuable food supply to soil biota. Bacteria, fungi and larger biota grow and reproduce, consuming organic carbo and transforming it into other forms and eventually into humus. Soil biota activity concentrates and recycles nutrients. Over half of the OC inputs are broken down by microbes and returned to the atmosphere as CO2. Some of the remaining OC stays in the soil as stable organic - mineral complexes. If plant production slows or stops, i. e. to do carbon inputs. Soil biota then consume stored soil carbon sources to satisfy their energy requirements so soil OC declines.

The key factors that affect the total amount of OC in the soil are soil type, climate, management and soil biota. All soils have a finite capacity to store OC. Sandy soils generally are less able to store OC than more clayey soils. Clay particles and aggregates can shield organic matter from breakdown by microbes, slowing the loss of OC through decomposition. However, a soil's potential to store OC based on its clay content is rarely achieved because climate and management practices also influence supply of OC to the soil. In dryland agriculture, rainfall has the greatest influence on plant production and hence input of OC to soil. Soils in areas of high rainfall tend to have greater OC storage than their counterparts in a lower rainfall region. Management influences the type and amount of organic material produced – crop selection, provision of nutrients and soil amendments, residue management, tillage practices and pest management strongly influence soil OC content. Losses of OC can occur from topsoil erosion and removal of plant and animal products

The potential of a soil to increase its OC content depends on the inherent capacity of the soil (clay content) to store more OC, the opportunity for increasing OC inputs so they exceed outputs, and the conversion of OC inputs into more stable forms of OC for longterm storage. The most effective strategy to re - build soil OC levels is to maximise inputs of OC into the soil by growing more biomass and / or supplying organic materials such as composts or manures while maximising the return of plant residues to the soil. Supplying additional organic material to that grown in situ means that OC is exported from its site of origin and this can incur additional costs in transportation and handling. The overall goal in OC management is to match rates of decomposition with soil type and climate rather than stopping decomposition and CO2 emissions altogether as effectively means the soil is biologically inactive and soil health and function with be impaired as a result.

Practices that can increase the amount of total OC stored in soil include: • Increased plant growth through use of sound agronomic practices – appropriate fertilisation and use of soil amendment; sowing at optimal time; selection of appropriate and diverse range of plants suited to soil type and rainfall; and management of pests and diseases. • Returning more organic material to the soil by managing grazing to maintain soil cover and increase plant growth; retention of crop and pasture residues. • Growing plants for longer periods each year, e. g. shorter fallow periods, conversion from cropping to pasture, conversion from annual to perennial pasture. • Minimising losses of OC from soil by decomposition and erosion, e. g.

retaining stubble, maintaining pasture ground cover • Stimulating plant growth rates through strategic grazing management practices Growing a more diverse range of plants for longer periods of time throughout the year

Soil organic carbon is a measureable component of soil organic matter. Organic matter has an important role in the physical, chemical and biological function of agricultural soils.

Organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, and carbon sequestration.

Soil organic carbon (SOC) refers only to the carbon component of organic compounds. Soil organic matter (SOM) is difficult to measure directly, so laboratories tend to measure and report SOC.

Sequestering carbon in SOC has been suggested as one way to mitigate climate change by reducing atmospheric carbon dioxide. The argument is that small increases of SOC over very large areas in agricultural and pastoral lands will significantly reduce atmospheric carbon dioxide. For the reduction to be long - lasting, organic matter would have to be in the more stable or resistant fractions (Table 1)

Table 1: The size, turnover time and composition of the 4 soil organic matter fractions

Fraction	Size micrometres (μm) and millimetres (mm)	Turnover time	Composition
Dissolved organic matter	<45 μm (in solution)	Minutes to days	Soluble root exudates, simple sugars and decomposition by - products. It generally makes up less than 5% of total soil organic matter.
Particulate organic matter	53 μm – 2 mm	2–50 years	Fresh or decomposing plant and animal matter with identifiable cell structure. Makes up 2–25% of total soil organic matter.
Humus	<53 μm	Decadal (10s to 100s of years)	Older, decayed organic compounds that have resisted decomposition. Can make up more than 50% of total soil organic matter.
Resistant organic matter	<53 μm – 2 mm	100s to 1000s of years	Relatively inert material, such as chemically resistant materials or organic remnants (e. g. charcoal). Can be up to 10% of soil organic matter.

SOM is composed mainly of carbon, hydrogen and oxygen, and has small amounts of other elements, such as nitrogen, phosphorous, sulfur, potassium, calcium and magnesium contained in organic residues. It is divided into 'living' and 'dead' components and can range from very recent inputs, such as stubble, to largely decayed materials that might be many hundreds of years old. About 10% of below - ground SOM, such as roots, fauna and microorganisms, is 'living' (Figure 1).

SOM exists as 4 distinct fractions which vary widely in size, turnover time and composition in the soil (Table 1):
1) Dissolved organic matter
2) Particulate organic matter
3) Humus
4) Resistant organic matter.

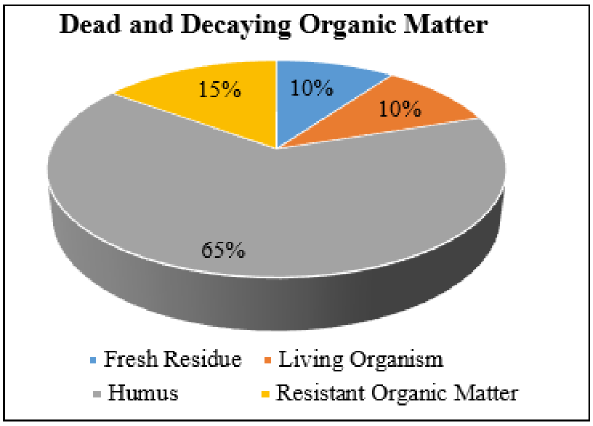


Figure 1: Most soil organic matter is dead or decaying, with living organisms making up about 10% of the soil organic matter pool

2. Literature Review

Soils are the largest terrestrial pool for organic carbon in the biosphere. Large-scale changes in land use like deforestation and agricultural activities, including biomass burning, plowing, drainage, and low-input farming have resulted in significant changes in soil organic carbon (SOC) pools (Lal, 2003).

Land use changes, however, may affect the SOC storage in deeper soil horizons. For example, by comparing data from 74 publications, Guo and Gifford (2002) observed that conversions of forest land to pasture or crop land had no effect on SOC stocks below 1 and 0.6-m depth, respectively. In contrast, conversion of crop land to pasture caused substantial C accumulation below 1-m depth. However, conclusions on the effects of land use changes on soil C stocks are hampered by the small global database (Klaus Lorenz, et al).

Investigated the stability of carbon in deep soil layers in one soil profile by combining physical and chemical characterization of organic carbon, soil incubations and radiocarbon dating. Here we show that the supply of fresh plant - derived carbon to the subsoil (0.6–0.8 m depth) stimulated the microbial mineralization of 2, 567 ± 226 - year - old carbon (Fontaine, S., Barot, S., Barré, P. et al).

In order to examine changes in deep SOC and quantify the relationship between SOC change rates in topsoil and subsoil. The results of the meta analysis indicated that the responses of SOC to afforestation were opposite for cropland than grassland. The SOC in soil depth layers of 0–10, 10–20, 20–40, 40–60 and 60–80 cm were reduced with afforestation of grassland but not significantly ($p > 0.05$), while conversion of cropland to forests (trees or shrubs) increased SOC significantly for each soil depth layer up to 60 cm depth ($p < 0.05$). Significant relationships of SOC change rate were found between topsoil (0–20 cm) and deeper soil layers (20–

40 and 40–60 cm). The linear regression showed that SOC change rate in 0–40 cm, 0–60 cm, and 0–100 cm soil profiles was 1.33, 1.49, and 1.55 times greater, respectively than the change rates in the corresponding 0–20 cm depth profile (Shengwei Shi, Wen Zhang, Ping Zhang, Yongqiang Yu, Fan Ding,)

The carbon - to - nitrogen (C/N) ratio is decreasing with soil depth, while the stable C and N isotope ratios of SOM are increasing, indicating that organic matter (OM) in deep soil horizons is highly processed. Several studies suggest that SOM in subsoils is enriched in microbial - derived C compounds and depleted in energy - rich plant material compared to topsoil SOM. However, the chemical composition of SOM in subsoils is soil - type specific and greatly influenced by pedological processes. (Rumpel et al).

Compared with topsoil, deep soil had lower soil OC stability and the highest value of soil OC mineralized was found in CF deep soils. Thus, soil depth and aggregate size were the important factors influencing soil OC stability, and reforested vegetation type might play an important role in soil OC storage by affecting ecosystem nutrient (especially N and P) cycling. (Xiang - Min Fang et al).

SOC content in the topsoil (0–0.2 m) decreased by 27% after desert soil was cultivated, total carbon stock within the soil profile (0–2.5 m) increased by 57% due to the significant increase in carbon stock at 0.2 - to 2.5 - m depth, and carbon efflux also markedly increased at 0 - to 0.6 - m depth. and the topsoil, the carbon process of the oasis was mainly dominated by consumption; in the subsoil (0.2–0.6 m) it was likely to be co - dominated by storage and consumption, and the greatest difference in SOC stock between the two soils also lay in this layer; while in the deep layer (0.6–2.5 m) of the oasis, with a more stable carbon stock, there was carbon storage dominated. Moreover, carbon stocks in the deep layer of the two soils contributed about 65% of the total carbon stocks, and correspondingly, microbial activities contributed 71% to the total microbial activity in the entire soil profile, confirming the importance of carbon cycling in the deep layer. Desert cultivation in this area may produce unexpectedly high carbon stocks from the whole profile despite carbon loss in the topsoil (Chenhua Li et al)

To determine the changes in deep SOC stock (to a depth of 400 cm) resulting from conversion of cropland to woodland, shrubland and grassland on the Chinese Loess Plateau, 469 observations from peer - reviewed publications and original measured data were synthesised. The results were as follows: (a) SOC stock increased significantly at 0–100 and 100–200 cm layers regardless of land - use conversion types. (b) Carbon loss occurred in the 200–400 cm layers due to land - use conversion. (c) Changes in SOC stock varied with restoration age, except for conversion of cropland to grassland. Specifically, SOC stock increased with restoration age in the upper 200 cm layers, whereas that in the 200–400 cm layers first increased and then decreased in the middle to later stages under conversion to woodland and shrubland. (d) Initial SOC stock and rainfall zones had significant effects on the changes of deep SOC stock. (e) Furthermore, an accumulation of 1 Mg ha−1 in the upper 100 cm was associated with an approximately 0.45 Mg ha−1 increase in the 100–400 cm soil layers. These results indicate that land - use conversion, particularly conversion of cropland to woodland, changes deep (>100 cm) SOC stock, and restoration age should be taken into consideration when assessing deep carbon sequestration. (Bin - Bin Li et al).

The various studies as referred emphasize the consideration of deep soil organic carbon as it is affected due to numerous kinds of human activities. Since, Soil carbon is recognized as central to soil functioning, plays a crucial role in maintaining the sustainability of soil to produce food, and acts as a large sink of carbon that can mitigate climate change.

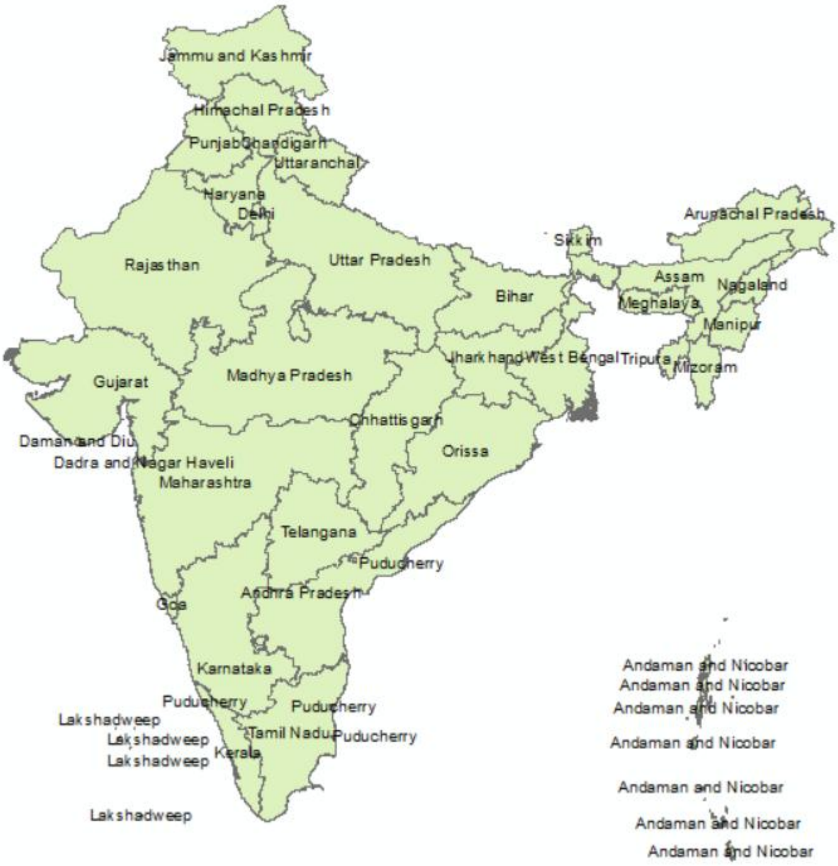
3. Methodology

3.1 Data and Methods

Total remote sensing and GIS approach has been considered in the study. Open LandMap Soil Organic Carbon Content (ee. Image ("OpenLandMap/SOL/SOL_ORGANIC - CARBON_USDA - 6A1C_M/v02") imagery used which contains six bands b0, b10, b30, b60, b100 and b200 providing Soil organic carbon content in x 5 g / kg at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution. (Tomislav Hengl, & Ichsani Wheeler. (2018). Soil organic carbon content in x 5 g / kg at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version v02) [Data set]. Zenodo. 10.5281/zenodo.1475457.

Harmonized Sentinel - 2 MSI: MultiSpectral Instrument, Level - 2A provided by European Union/ESA/Copernicus. Sentinel - 2 is a wide - swath, high - resolution, multi - spectral imaging mission supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas. having ee. ImageCollection ("COPERNICUS/S2_SR_HARMONIZED") considered for the period 2017 - 2024 using bands "B1 - B12) and processed for detecting the land use land cover considering various indices like NDVI, NDBI, BSI and NDWI

3.2 Study Area



India is located in Asia, north of the equator, and is the seventh - largest country in the world. It's bordered by the Bay of Bengal to the east, the Arabian Sea to the west, and the Indian Ocean to the south. The existence of soil organic carbon in India is 61%.

India's terrain is diverse, with the Himalayas in the north, the Thar Desert in the west, and jungles in the northeast. The Ganges Plain in northern India is a fertile area created by soil deposited by rivers from the Himalayas.

India has a tropical monsoon climate, with four seasons: winter, summer, monsoon, and post - monsoon. The climate varies from tropical in the south to temperate in the north.

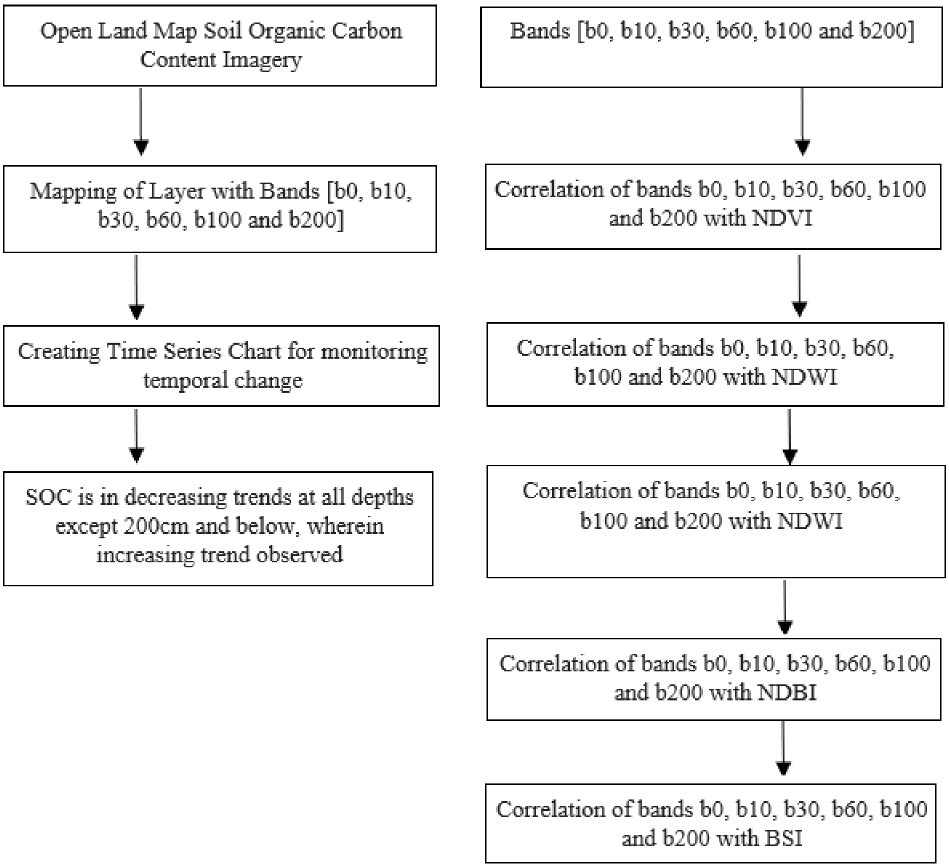
India has 12 major rivers, including the Ganges, which is the longest and considered a holy river.

India's highest point is Kanchenjunga at 28, 169 feet (8, 586 meters), and its lowest point is the Indian Ocean at 0 feet (0 meters).

India is one of the most climatically diverse countries in the world, with 23 different climate types. It's also ranked fifth in the world for reptiles.

3.3 Methods

The adopted methodology to derive meaningful insight from the satellite imageries is as below:



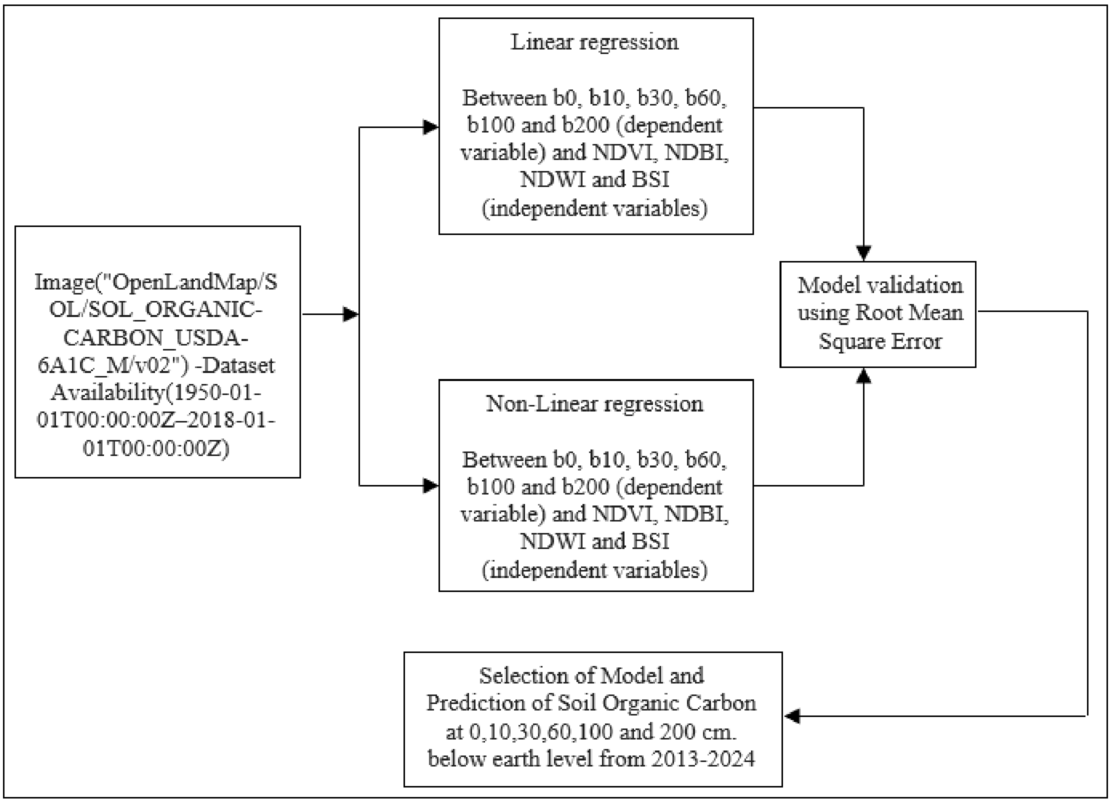


Image ("OpenLandMap/SOL/SOL_ORGANIC - CARBON_USDA - 6A1C_M/v02") processing:
Below shown image depicts the soil organic carbon levels in (X5gm/kg) for India.

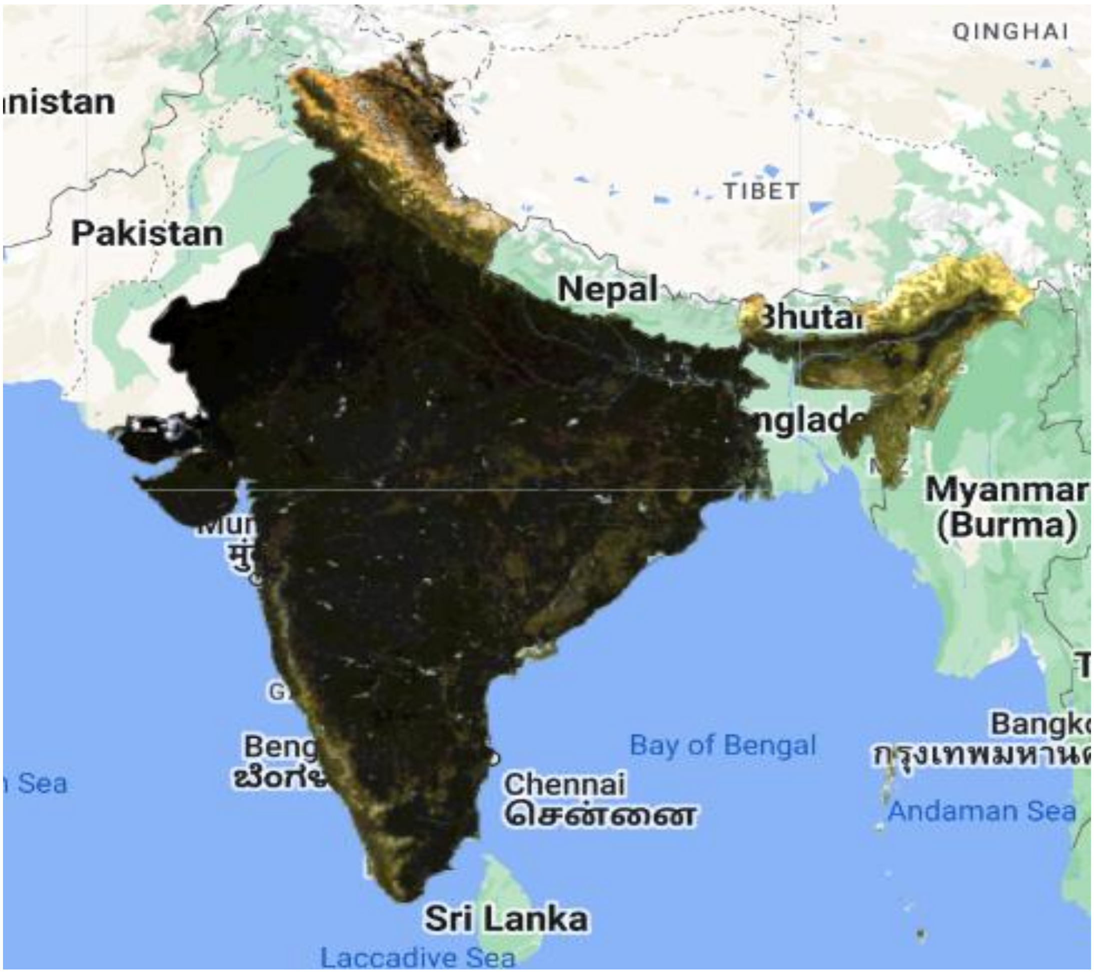
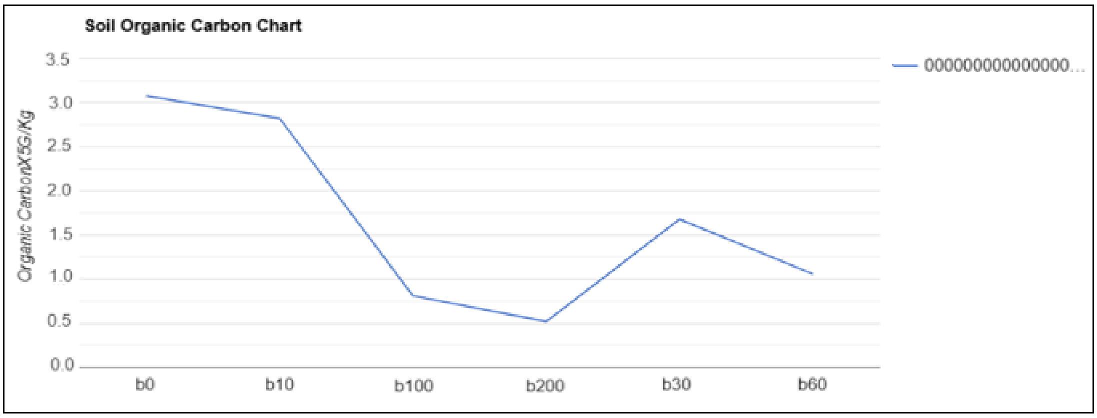


Figure 2



Normalized Difference Vegetation Index (NDVI):
The Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation index for observe greenery globally. Other commonly used vegetation indices Enhanced Vegetation Index (EVI), Perpendicular Vegetation Index (PVI), Ration Vegetation Index (RVI).

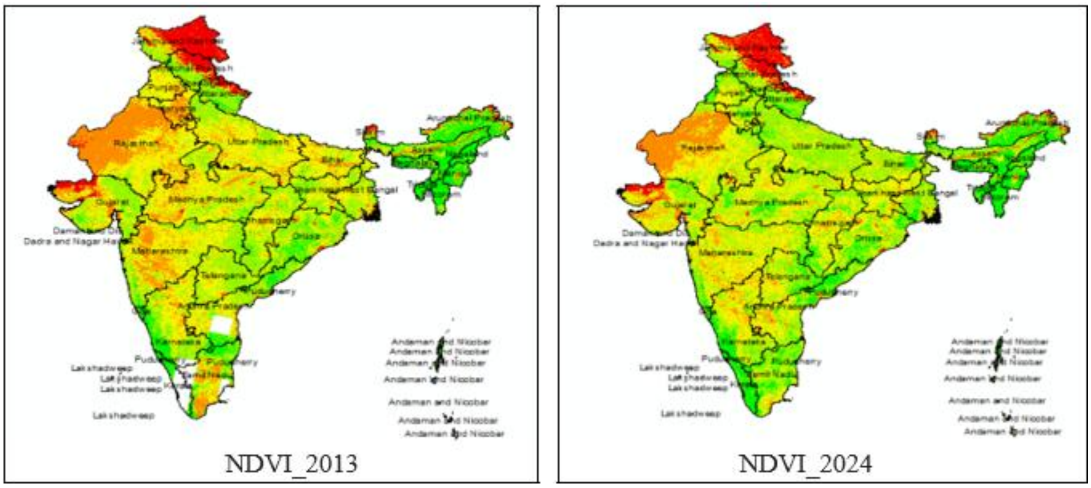


Figure 3

In general, Healthy vegetation is good absorber of electromagnetic spectrum in visible reason. Chlorophyll contains in a greeneries highly absorbs Blue (0.4 - 0.5 µm) and Red (0.6 - 0.7 µm) spectrum and reflects Green (0.5 – 0.6 µm) spectrum. Therefore, our eye perceives healthy vegetation as green. Healthy plants having high reflectance in Near Infrared (NIR) between 0.7 to 1.3 µm (fig.1). This is primarily due to internal structure of plant leaves. High reflectance in NIR and high absorption in Red spectrum, these two bands are used to calculate NDVI. So, following formula gives Normalized Difference Vegetation Index (NDVI).

NDVI = (NIR – Red) / (NIR + Red)

For Landsat 7 data, NDVI = (Band 4 – Band 3) / (Band 4 + Band 3)

For Landsat 8 data, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

The NDVI value varies from - 1 to 1. Higher the value of NDVI reflects high Near Infrared (NIR), means dense greenery. Generally, we obtain following result:

- NDVI = - 1 to 0 represent Water bodies
- NDVI = - 0.1 to 0.1 represent Barren rocks, sand, or snow
- NDVI = 0.2 to 0.5 represent Shrubs and grasslands or senescing crops
- NDVI = 0.6 to 1.0 represent Dense vegetation or tropical rainforest

Normalized Difference Built - up Index (NDBI)

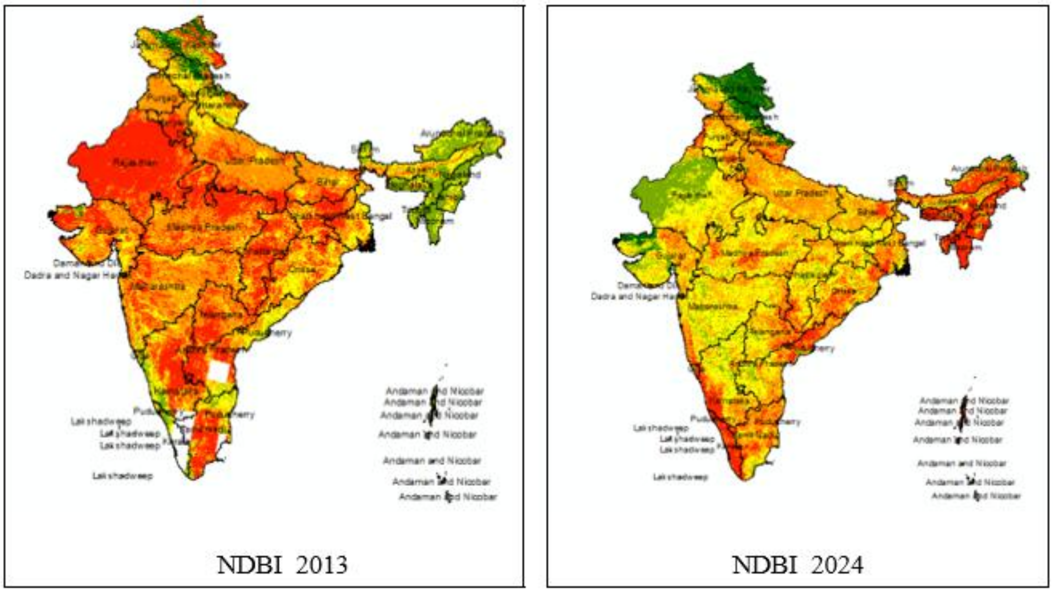


Figure 4

There are lots of indexes for the analysis of built - up area. Normalized Difference Built - up Index (NDBI), Built - up Index (BU), Urban Index (UI), Index - based Built - up Index (IBI), Enhanced Built - up and Bareness Index (EBBI) are most common indexes for analysis the built - up areas. These different indexes having their own formula, own calculation method. The build - up areas and bare soil reflects more SWIR than NIR. Water body doesn't reflect on Infrared spectrum. In case of greenie surface, reflection of NIR is higher than SWIR spectrum (Fig 1). For better result, you can use Built - up Index (BU). Build - up Index is the index for analysis of urban pattern using NDBI and NDVI. Built - up index is the binary image with only higher positive value indicates built - up and barren thus, allows BU to map the built - up area automatically.

BU = NDBI - NDVI

Image classification technique (supervised classification and unsupervised classification) is lengthy and complex process.

It requires compositive band & apply numbers of operation for the final result. The accuracy derived from image classification technique depends on the image analyst & method followed by analyst. However, NDBI calculation is simple and easy to derived. NDVI can be calculated by following formula.

NDBI = (SWIR – NIR) / (SWIR + NIR)
For Landsat 7 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4)
For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 + Band 5)

Also, the Normalize Difference Build - up Index value lies between - 1 to +1. Negative value of NDBI represent water bodies where as higher value represent build - up areas. NDBI value for vegetation is low.

Normalized Difference Water Index (NDWI):
Normalize Difference Water Index (NDWI) is use for the water bodies analysis. The index uses Green and Near infra - red bands of remote sensing images. The NDWI can enhance water information efficiently in most cases. It is sensitive to build - up land and result in over - estimated water bodies. The NDWI products can be used in conjunction with NDVI change products to assess context of apparent change areas.

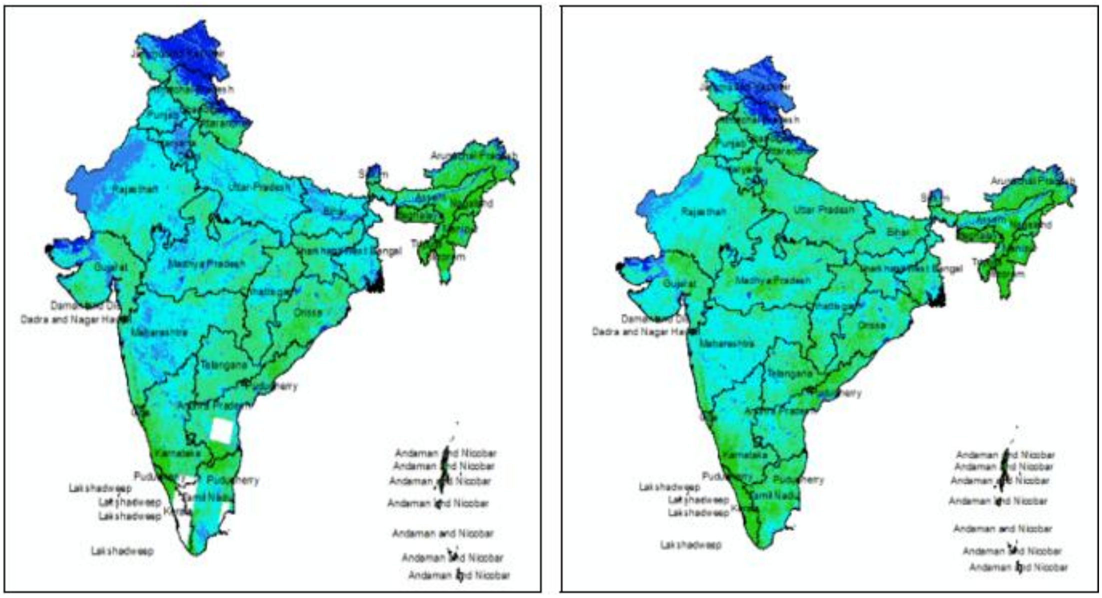


Figure 5

Water bodies having low reflectance. It only reflects within visible portion of the electromagnetic spectrum. Water bodies in their liquid state are generally high reflectance on Blue (0.4 - 0.5 µm) spectrum than Green (0.5 - 0.6 µm) and Red (0.6 – 0.7 µm) spectrum. Clear water having greatest reflectance in the blue portion of the visible spectrum. So, water appear blue. Turbid water has higher reflectance in visible spectrum. There is no reflection in Near Infrared (NIR) and beyond. NDWI is developed by Gao (1996) to enhance the water related features of the landscapes. This index uses the near infrared (NIR) and the Short - Wave infrared (SWIR) bands. NDWI can be calculated by following formula:

NDWI = (NIR – SWIR) / (NIR + SWIR)
For Landsat 7 data, NDWI = (Band 4 – Band 5) / (Band 4 + Band 5)
For Landsat 8 data, NDWI = (Band 5 – Band 6) / (Band 5 + Band 6)

Bare Soil Index (BSI):
Bare Soil Index (BSI) is a numerical indicator that combines blue, red, near infrared and short wave infrared spectral bands to capture soil variations. These spectral bands are used in a normalized manner. The short wave infrared and the red spectral bands are used to quantify the soil mineral composition, while the blue and the near infrared spectral bands are used to enhance the presence of vegetation.

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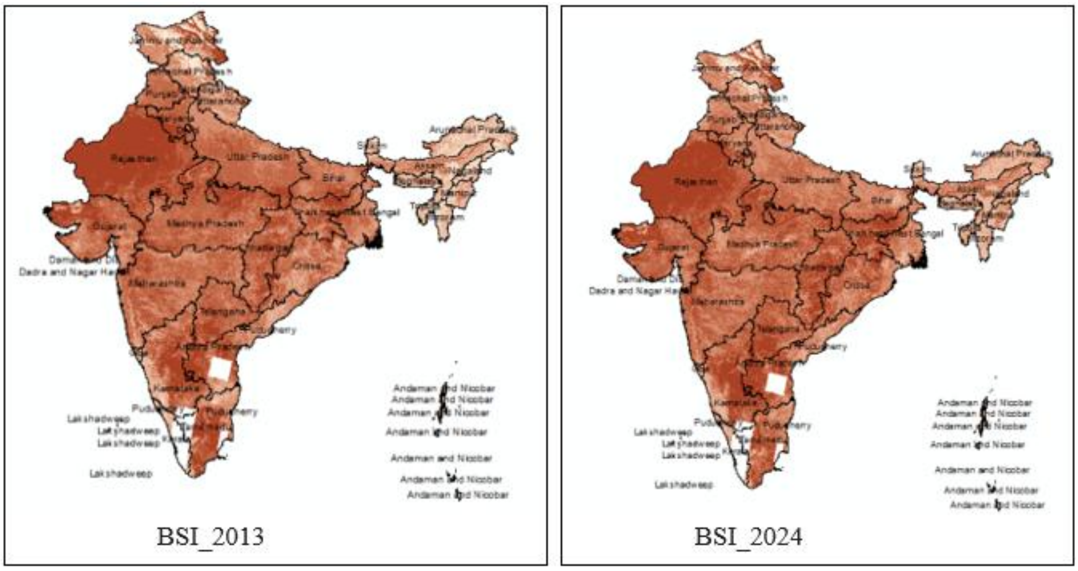


Figure 6

- Formula of **BSI = ((Red+SWIR) – (NIR+Blue)) / ((Red+SWIR) + (NIR+Blue))**
- BSI (Landsta 8) = (B6 + B4) – (B5 + B2) / (B6 + B4) + (B5 + B2)
- BSI (Landsta 4 – 7) = (B5 + B3) – (B4 + B1) / (B5 + B3) + (B4 + B1)
- BSI (Sentinel 2) = (B11 + B4) – (B8 + B2) / (B11 + B4) + (B8 + B2)

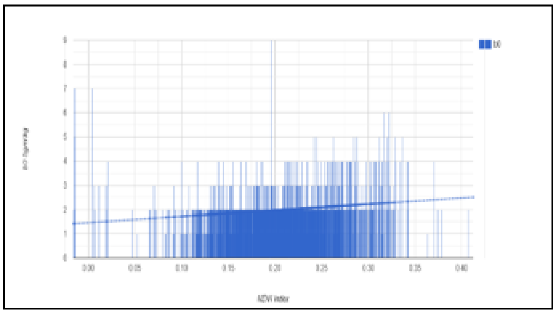
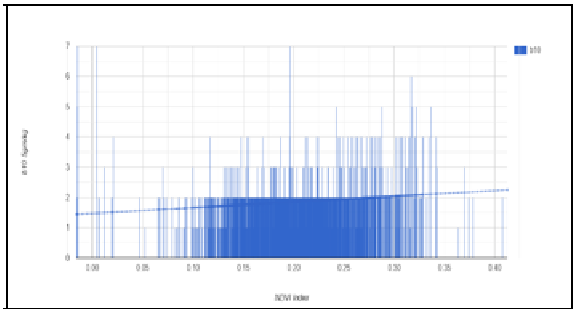
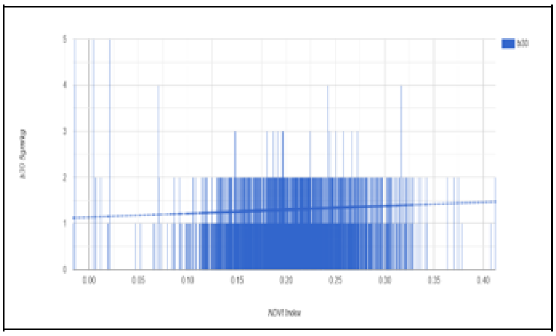
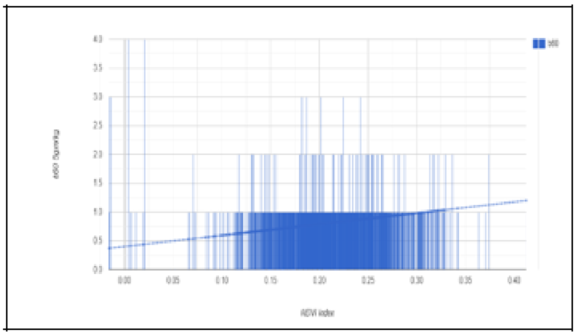
In this study, initially it was considered prudent to understand the relationship between soil organic carbon bands i. e. b0, b10, b30, b60, b100 and b200 with various indices like NDVI, NDBI, NDWI and BSI, accordingly each band was correlated with indices independently in Google Earth Engine, which gave a fair idea of variation pattern.

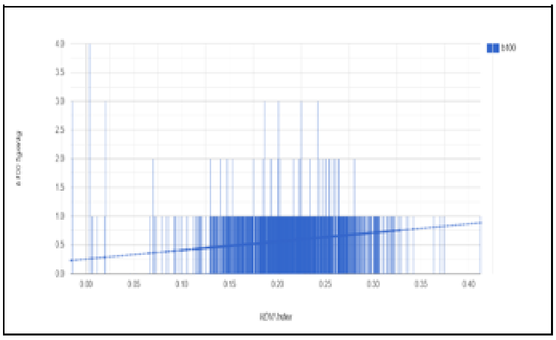
Further, the combined effect of NDVI, NDBI, NDWI and BSI on each soil organic carbon band was envisaged through linear regression. Depending upon the data availability for Image ("Open Land Map/SOL/SOL_ORGANIC - CARBON_USDA - 6A1C_M/v02") - Dataset Availability (1950 - 01 - 01T00: 00: 00Z–2018 - 01 - 01T00: 00: 00Z), NDVI, NDBI, NDWI and BSI calculated for the year 2013 and 2024 and a prediction module was developed in Google Earth Engine which can predict the soil organic carbon at different depths i. e.0, 10, 30, 60, 100 and 200 cm below earth for the year 2024.

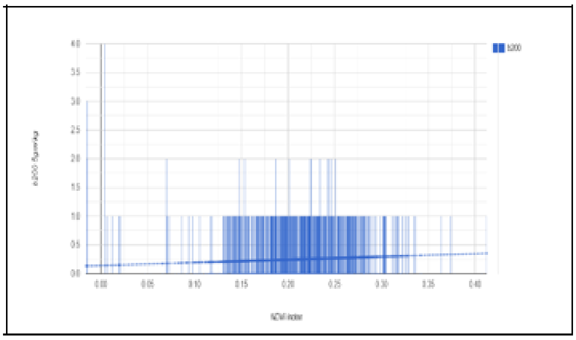
4. Results and Discussions

With the help of correlation algorithm, the variation pattern of various bands with different indices is shown as below:

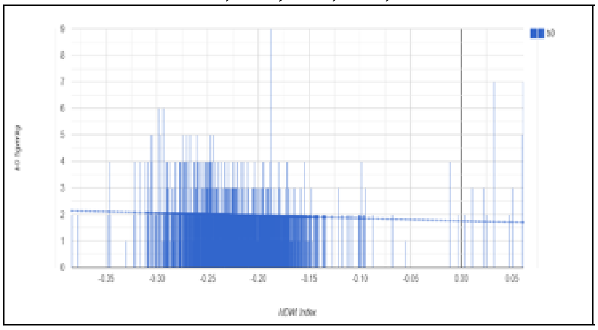
Results of Correlation for b0, b10, b30, b60, b100 and b200 with NDVI:

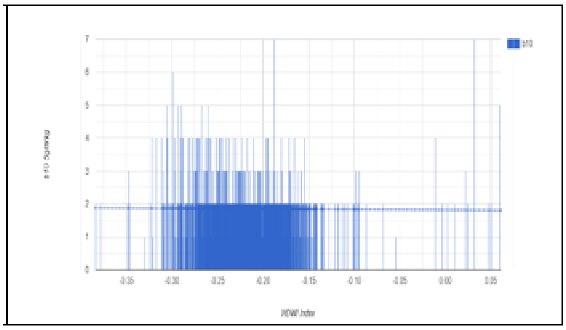





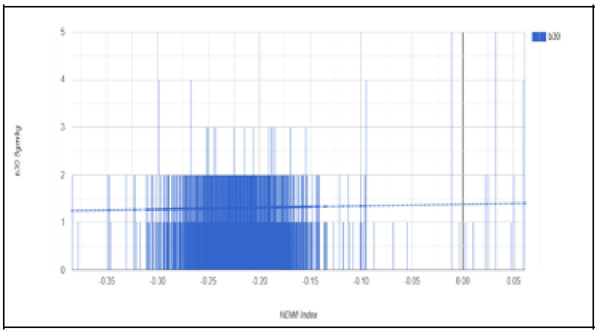


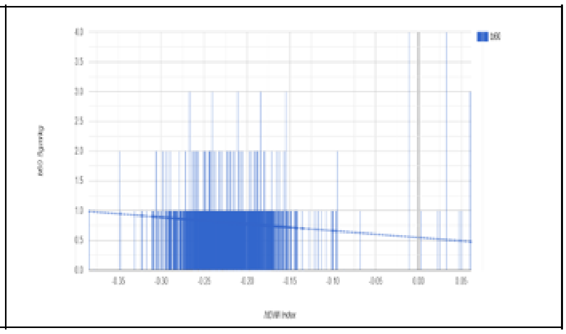


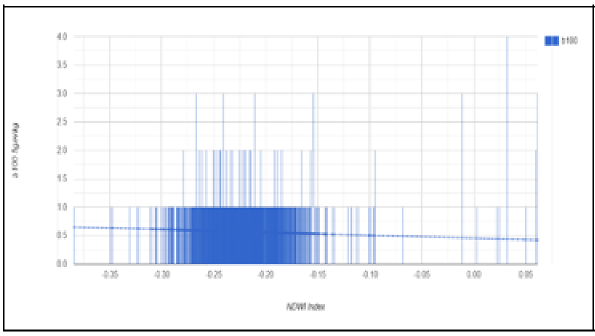
Results of Correlation for b0, b10, b30, b60, b100 and b200 with NDWI:

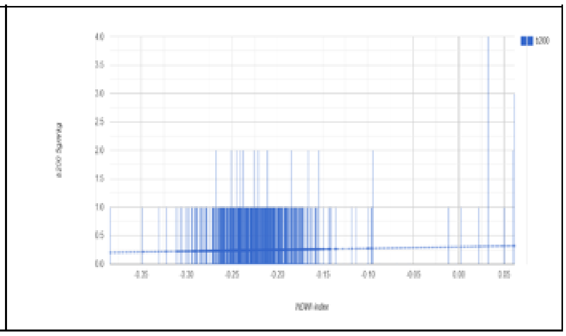




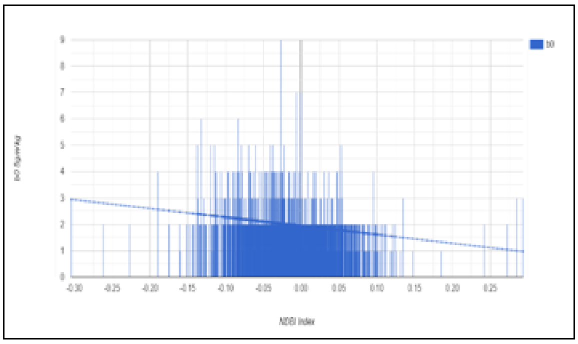


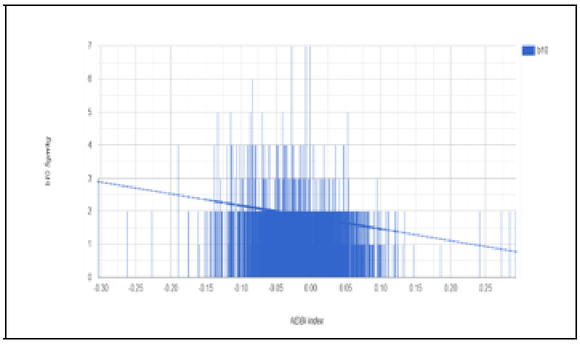


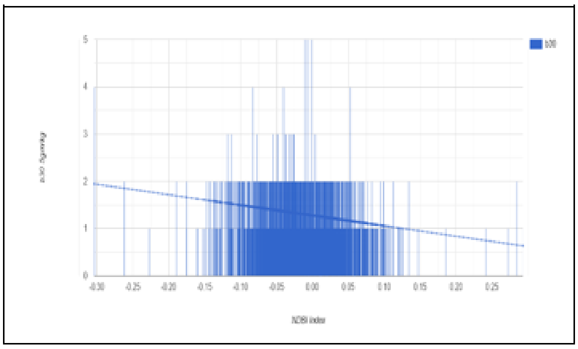


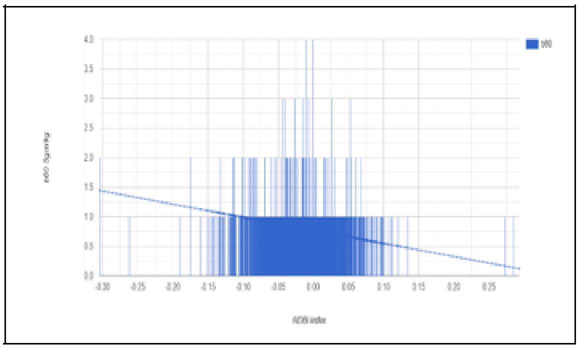


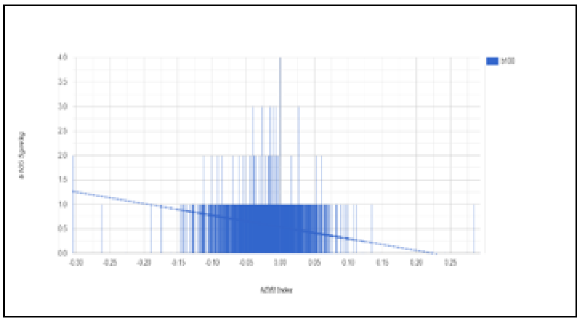
Results of Correlation for b0, b10, b30, b60, b100 and b200 with NDBI:

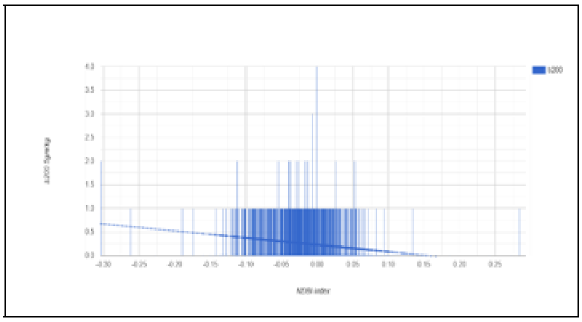




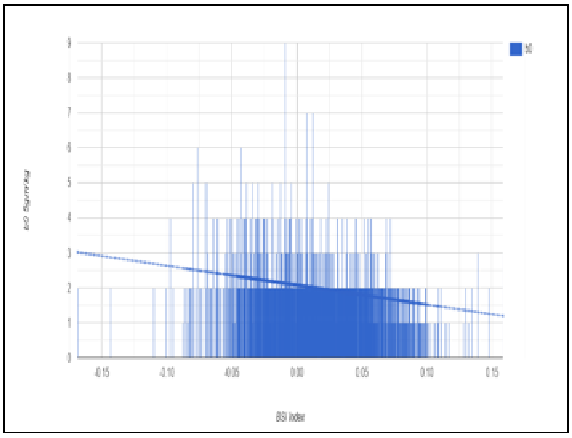


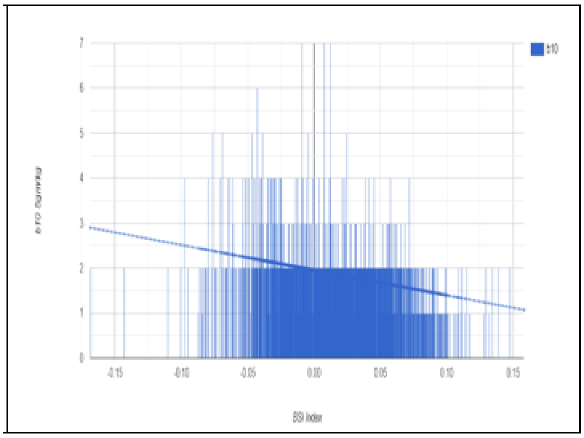


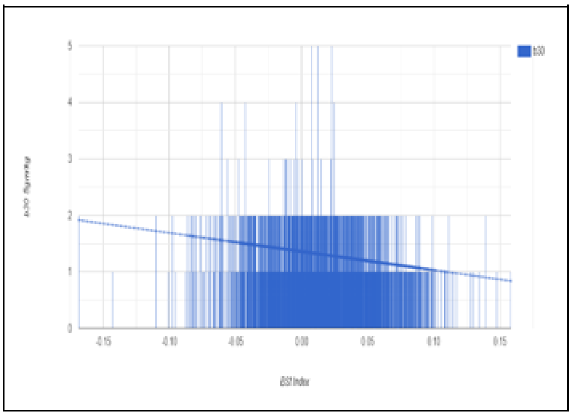


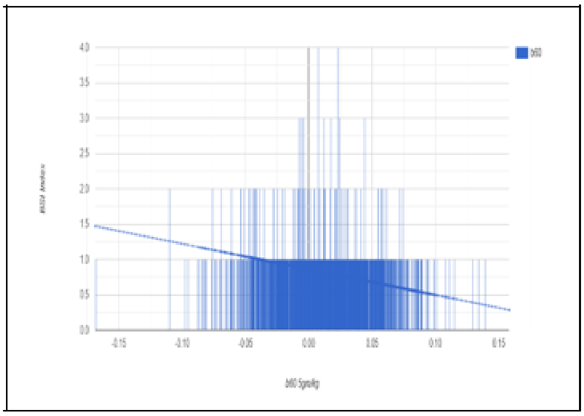


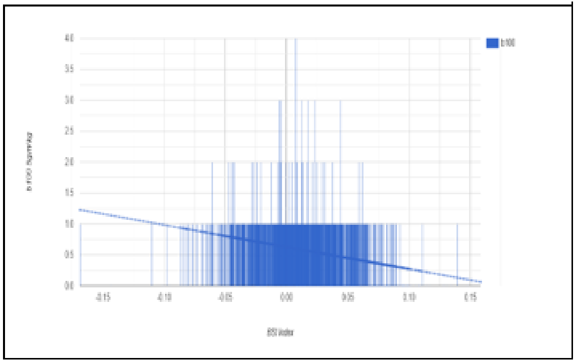
Results of Correlation for b0, b10, b30, b60, b100 and b200 with BSI:

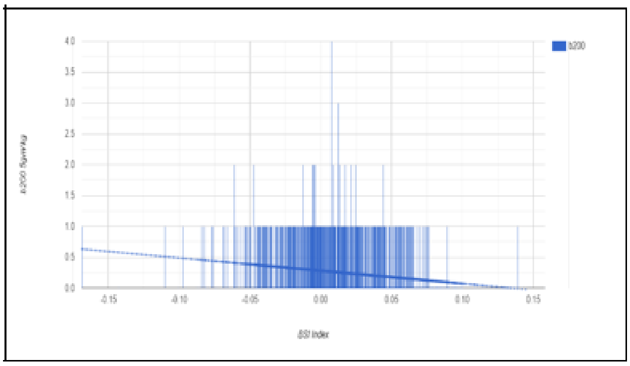












It is observed from Fig.2 and 3 that average soil organic carbon at surface level in India is 15.4 gm/kg, at 10 cm depth 14.12 gm/kg, at 30 cm depth 8.39 gm/kg, at 60 cm depth 5.29 gm/kg, at 100 cm depth 4.06 gm/kg and at 200 cm depth is 2.6 gm/kg. It is also observed that maximum soil organic carbon deposits exist in Kashmir region and North - East, especially upper portion of NE, relatively the existence in coastal areas is also better.

Fig.9.0 clearly indicates that there is positive increasing trend of soil organic carbon with Normalized Vegetation Index (NDVI) up to 100 cm and this increasing trend is substantially reduced at 200 cm. More vegetation leads to higher SOC levels. Growing crops and roots add biomass above and below the soil surface, which decomposes and increases organic carbon levels. Since, percolation of decomposed carbon at more depth is not so significant, therefore increasing trend of SOC at more depth is reduced.

Fig.10.0 shows the variation of soil organic carbon with Normalized Water Index (NDWI). The Normalized Difference Water Index (NDWI) is a satellite image index that highlights open water features. Soil organic carbon (SOC) levels can be affected by a number of factors, including:

Sufficient irrigation can increase soil carbon in a short time, but it can also lead to SOC loss in deep soil over time.
Clay has a greater potential to store SOC than sandy soil.

Different land uses, such as farming, can significantly affect SOC levels.

SOC content increases with elevation.

Precipitation and temperature can have a negative effect on SOC at lower altitudes, while they can have a positive effect at higher altitudes.

Abundant vegetative litter can cause SOC to accumulate.

However, this type of abnormal patterns of soil organic carbon at different depths is a matter of advanced research and community engaged in this area may certainly contribute to this specific observation.

Fig.11.0 shows the variation of soil organic carbon with Normalized Building Index (NDBI). Normally, the trend of soil organic carbon with Normalized Building Index (NDBI) is decreasing at all level of depths. However, Rapid urbanization can lead to a significant loss of SOC, which is a major part of the global carbon stock. This can be due to soil sealing for construction and infrastructure development, which cuts and translocates the topsoil layer.

But, urbanization can also increase SOC storage in some cases because human activities and climate change can lead to vegetation changes that positively correlate with SOC changes.

Urbanization can also change the way SOC accumulates in soil. For example, in urban forests, SOC content is more correlated with litter C stock than soil microbial biomass, which suggests that urbanization may have changed the accumulation mode of SOC.

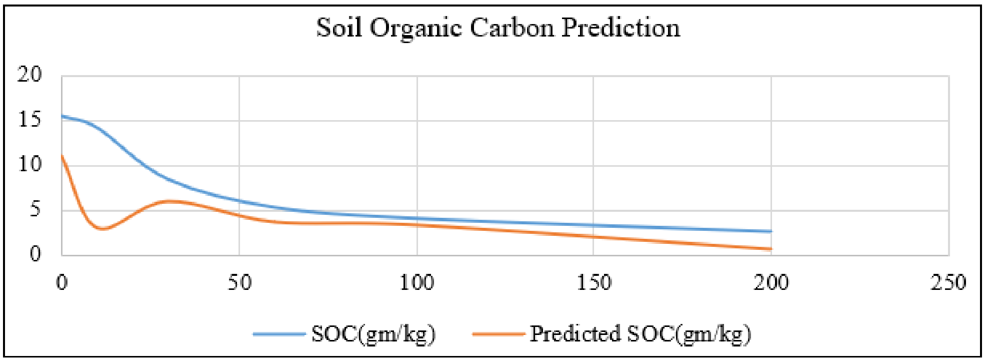
Temperature can also affect SOC mineralization in urban areas. In warmer climates, more C is released from urban green spaces. However, SOC stored in soils under grass and young plantations is less susceptible to climate warming than SOC in soils under trees.

Fig.12.0 shows the variation of soil organic carbon with Bare Soil Index (BSI). Bare soil has lower SOC levels than other land uses, such as forests and bushlands. In one study, found that bare land had 3.82 times lower SOC stock than bushland. Bare soil loses SOC at a higher rate than other land uses as visible in graphs under fig.12.0. Afforestation can increase SOC sequestration in degraded land

Results of Linear and Non - Linear Regression:

Sr. No.	Dependent Variable (Band)	Interdependent Variable (Bands)	Linear Regression (RMSE)	Non- Linear Regression (RMSE	Predicted Value of Soil Organic Carbon as per Linear Regression	Predicted Value of Soil Organic Carbon as per Non - Linear Regression
1	b 0	NDVI, NDBI, NDWI and BSI	2.5904	3.2393	10.915 gm/kg at surface level	5.00 gm/kg at surface level
2	b 10	NDVI, NDBI, NDWI and BSI	2.6394	3.1181	3.035 gm/kg at 10 cm depth level	5.00 gm/kg at 10 cm depth level
3	b 30	NDVI, NDBI, NDWI and BSI	1.1954	1.6857	5.945 gm/kg at 30 cm depth level	5.000 gm/kg at 30 cm depth level
4	b 60	NDVI, NDBI, NDWI and BSI	0.9002	1.1443	3.673 gm/kg at 60 cm depth level	5.000 gm/kg at 60 cm depth level
5	b 100	NDVI, NDBI, NDWI and BSI	0.8960	1.1620	3.335 gm/kg at 100 cm depth level	2.078 gm/kg at 100 cm depth level
6	b 200	NDVI, NDBI, NDWI and BSI	0.8910	1.1526	0.6685 gm/kg at 200 cm depth level	0.000 gm/kg at 200 cm depth level

It is observed from the above results that Linear regression model is more authenticated as compared to Non- linear regression model depending upon the RMSE values. Moreover, linear regression model is more robust particularly in predicting SOC at 60, 100 and 200 cm. depths as RMSE values approaching to zero.



5. Conclusion

Conclusion is drawn from the study that during the period of prediction, NDVI and NDWI are in increasing trend, which are favorable for increase in soil organic carbon level, however, NDBI and BSI are more steeply increasing resulting to showing detrimental effects on soil organic carbon levels at different depths.

Organic carbon in deep soils remains stable because of a lack of fresh carbon supply, an essential source of energy for soil microbes, thus soil at the surface is relatively unstable. Xu et al. The instant study contradicts this statement as soil organic carbon is found to be reducing at all depths level, hence remedial measures need to be taken in over - all perspective irrespective of depth of soil.

6. Recommendations

Optimising pasture growth through selection of grass, legume, brassica and herb species, fertiliser management (including manures), irrigation and grazing management are all strategies to improve SOC under pasture.

Cover crops can take many forms and are grown in between main crops to keep the soil covered. In turn the Normalized Vegetation Index would remain on higher side promoting the soil organic carbon.

Pasture cropping minimizes soil disturbance, minimizing soil disturbance helps to maintain soil structure which physically protects SOC.

Increasing the frequency or duration of well - managed pastures (particularly by including legumes) in a cropping rotation can increase SOC, improve soil nutrition and water infiltration.

Soil compaction, surface crusting or sodicity may be overcome with the application of gypsum. However longer - term strategies include increasing and maintaining higher levels of SOM.

Carbon - rich or organic soil amendments such as manure, biosolids and compost, provide nutrient, carbon and microbial inputs to the soil. Decisions to apply these types of amendments will depend on the nutrient requirements for the crop and soil and whether it is economically viable to provide nutrition in this form. Often practised with minimum till, retaining stubble (crop residue) on the paddock is a popular method of not only retaining soil moisture, but increasing SOC.

Changing land use to repair land degradation is site specific and depends on the type and cause of degradation. Repairing damage and addressing the cause of degradation are both required.

Acknowledgement

The completion of this research paper would not have been possible without the support of my family members and colleagues. The dedication and overwhelming attitude towards helping me is solely responsible for completing my study paper. The encouragement and insightful feedback were instrumental in accomplishing this task.

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