SPATIAL DISTRIBUTION OF SOIL ORGANIC CARBON FOR SUSTAINABLE FOREST CONSERVATION

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ABSTRACT: Climate change is a serious global threat to be addressed by rapid reduction of atmospheric greenhouse gases. Subsequent to the 1997 Kyoto protocol, there was a consensus among environmental and natural scientists that increasing green cover is the only realistic way to reduce carbon dioxide emission due to anthropogenic interferences. Reduction of emission through deforestation and degradation (REDD) emerged as a prime agenda to be adopted through Clean Development Mechanism (CDM). In 2007, the UNFCCC COP 13 held at Bali, Indonesia appreciated the conservation strategies of developing countries like India, China, Thailand, etc., and recommended adding Enhanced Carbon storage and came up with the concept of REDD+.

In its unique conservation efforts to protect the forests, India strengthened its legal framework and has also undertaken several field conservation measures. It has shown an increase in the forest cover despite massive human and cattle population. It is imperative to measure the carbon stock (both biomass and soil carbon) in the forest in order to estimate the enhanced carbon stock. The enhanced carbon stock in the forest is helpful in compensating the emission reduction activities of India as envisaged in INDC (Intended Nationally Determined Contribution). Eastern Ghats of Tamil Nadu (Javadi hill) in India are taken in the present study and the status of the soil organic carbon (SOC) stock and Normalized Difference Vegetation Index (NDVI) classification are taken up for analysis using sampling techniques and Geospatial technology. The LANDSAT data was analyzed to assess the NDVI and the soil samples were analyzed to estimate the SOC using CN analyzer. All the gridded point samplings were interpolated spatially by Kriging tools. The variations in the NDVI and SOC are spatially estimated for the whole area and the low SOC coupled with low green cover are identified, and precise forest degradation was estimated in the study. As per the Sustainable Development Goals (SDG) 15, reversal of land degradation and eco-restoration are prime components to be addressed with adequate eco-restoration works in conjunction with the agenda of INDC.

1. INTRODUCTION

The Emission of Greenhouse Gases (GHG) due to fossil fuel burning in the post-industrial era is considered as the prime reason for climate change affecting the globe. The Western nations have been responsible for bulk of the historic emission and the concentration of carbon dioxide in the atmosphere has risen from 277 parts per million (ppm) at the beginning of the industrial era (Joos & Spahni, 2008) to 414.47 ppm as of August, 2021 (NOAA-ESRL, 2021). The present five major emitting economies of China, the European Union (EU), India, Japan and the United States accounted for 55% of global GHG emissions in 2018, including those caused by land use, land-use change and forestry (LULUCF) (FAOSTAT 2019; Olivier & Peters, 2019). The Paris Agreement adopted in 2015 (Paris Agreement, 2015) has countries committing to keep the average global warming increase to well below 2° C above pre-industrial levels and pursue efforts to limit it to 1.5° C to prevent dangerous impacts of climate change. The agreement mandates the global stock-taking to assess the collective progress towards the goal, and the first assessment is to begin in 2023 and then be repeated every five years.

The 2015 Paris Climate Agreement also included the role of forests in removing additional carbon dioxide from the atmosphere, specifically emphasizing reducing emissions by forest protection and by avoiding deforestation and forest degradation (UNFCCC 2015). As forests are a great potential source as well as sink for carbon, quality of forest management could have a major impact on the level of greenhouse gases in the atmosphere. So, assessing the carbon emission and sequestration potential of forests is an essential commitment of the signatories. In order to meet the Paris Agreement goals, the net carbon dioxide emissions need to be reduced by 7.6% per year below 2010 levels for the next ten years starting from 2020 and this requires a simultaneous reduction in carbon emissions and increasing sequestration (Moomaw *et al.* 2020). Through carbon sequestration in plant biomass and soils, forests and soils can play a greater role in meeting these goals (Moomaw *et al.* 2020). Accurate monitoring, Reporting and Verification of carbon stocks and flows are essential as per UNFCC guidelines (Goetz *et al.*, 2015) and in respect of forests, accurate accounting of carbon dioxide emissions to the atmosphere from land-use change, forest management practices, soil loss and forest sequestration rates by trees, forest soils and forest products (Moomaw *et al.* 2020).

The importance of tropical forests in climate change mitigation cannot be overemphasized and is a key component in the policy addressing Reducing Emissions from Deforestation and Forest Degradation (REDD+) consistent with the Paris Agreement (Moomaw et al., 2020). Recent literature indicates that natural forests are much better at storing carbon in biomass and soils than in managed forests or forest products (Moomaw et al., 2020). Accurate accounting of forest carbon is essential for any country that seeks to manage carbon dioxide in the atmosphere (Moomaw et al., 2020). Remote sensing has been identified as a vital tool to identify changes in carbon density in tropical and other forests to comply with REDD+(Goetz et al. 2015). Forest Survey of India (FSI), an organization of the Government of India, is responsible for regular assessment and monitoring the country's forest resources. Its primary objectives are to prepare the State of Forest Report biennially, providing assessment of the latest forest cover and also conduct inventory in forests and non-forest areas and develop database on forest tree resources including forest carbon. FSI using remote sensing as well as ground inventory has fairly standardized the methodology in the carbon assessment in the above-ground and below-ground biomass. Regarding the assessment of the forest SOC, considerable refinement and more extensive sampling are required to be undertaken. Since as much as two-thirds of the terrestrial C in forest ecosystems is contained in soils (Dixon et al., 1994), mapping of SOC in forests, understanding the reasons for the variation and ameliorative steps to sequester carbon in the poor carbon soils is paramount in the steps to tackle climate change. Hence, a study of the SOC and its distribution in the forests of the Javadi hill, Eastern Ghats of Tamil Nadu coupled with the NDVI assessment of the same area was undertaken.

1.2 Study Area – Javadi Hill

The Eastern Ghats in the state of Tamil Nadu in India is a rugged and discontinuous hilly terrain, which starts from Javadi Hill and extends to Alagar Hill. Javadi, Sirumalai, Elagiri, Shevaroy, Chitteri, Kalrayan, Bodamalai, Kolli, Pachaimalai, Semmalai, Aiyalur, Karandamalai, and Alagar are the major hills. The mean temperature ranges from 17°C to 33°C, and the mean rainfall ranges from 800 and 1600 mm. Many tributaries of major peninsular rivers originate in these hills. (Jayakumar et al., 2008).

The Javadi hill, the present study area is the northernmost hill range of the Eastern ghats in Tamil Nadu and lies in the districts of Tirupattur, Tiruvannamalai and Vellore in the state of Tamil Nadu, India. The Javadi hill is about 80 km wide and 32 km long and is divided into eastern and western segments by the Cheyyar and Agaram rivers, which ultimately flow into the Palar river. The hill is generally forested with settlements and agricultural lands of tribes interspersed in the valley portions. The degraded extent of forest cover in the Javadi hill was 43.06 % (Ramachandran et al., 2016).

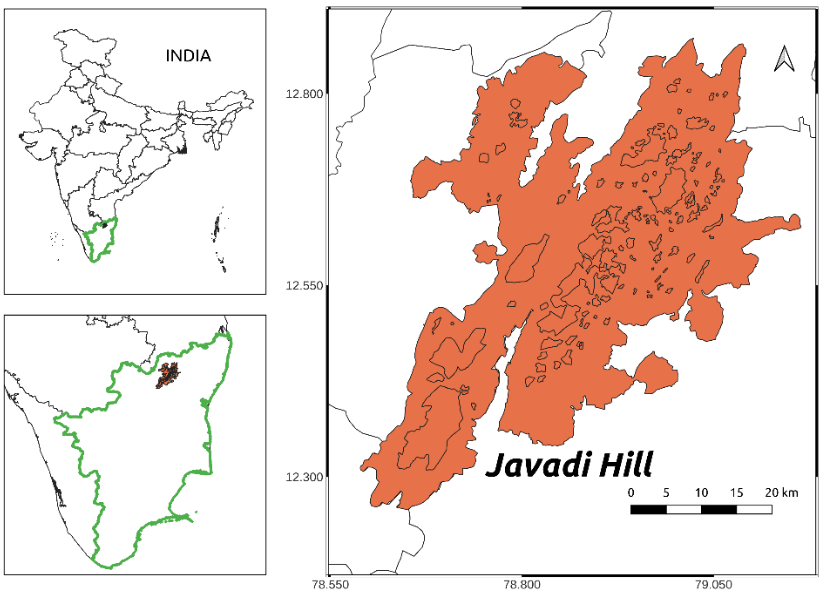

Figure 1: Study area – Javadi Hill, Eastern Ghats, Tamil Nadu, India

2. METHODOLOGY

The Javadi hill range was divided into five km^2 grids by overlaying five km^2 grids on digital forest maps of Javadi hill and 104 grid squares were obtained. Randomly chosen latitude and longitudes were taken within the forest area of each grid and the corresponding profile sites were located. From each such site in the grids, one soil profile was examined to assess the organic carbon status of soil. The organic litter above the mineral layer to an extent of 1 sq. m was removed and a pit of size 30 x 30 x 30 cm was excavated. The soil from the pit was taken out and kept aside. Then one entire side of the pit was sliced to an extent of 5 cms width so that the soil from that entire slice falls into the pit. Using hands, the fallen soil in the pit was nicely mixed and about 1 kg of the nicely mixed soil was collected in a polythene bag which was already numbered for that grid sampling point, sealed and taken to the laboratory for analysis.

The soil samples were shade-dried, were sub-sampled and ground to fine powder using an agate pestle and mortar and sieved through 0.5 mm sieve. The samples were repeatedly ground and sieved until no residue was left out on the sieve. The soil organic carbon content in the 0.5 mm sieved soil samples were estimated using the CHSNO Elemental Analyser (Wang & Anderson, 1998).

The NDVI assessment, spatial mapping of the SOC and subsequent GIS processing was carried out using the ERDAS Imagine software. The NDVI assessment of the Javadi hill was carried out on LANDSAT 8OLI image of January 20, 2020.

3. RESULTS

The SOC content (in %) for the 104 locations were plotted on the map of Javadi hill in a GIS platform and gridded point samplings were interpolated spatially by Kriging tools and the distribution map of the SOC of the Javadi hill was generated (Fig 2).

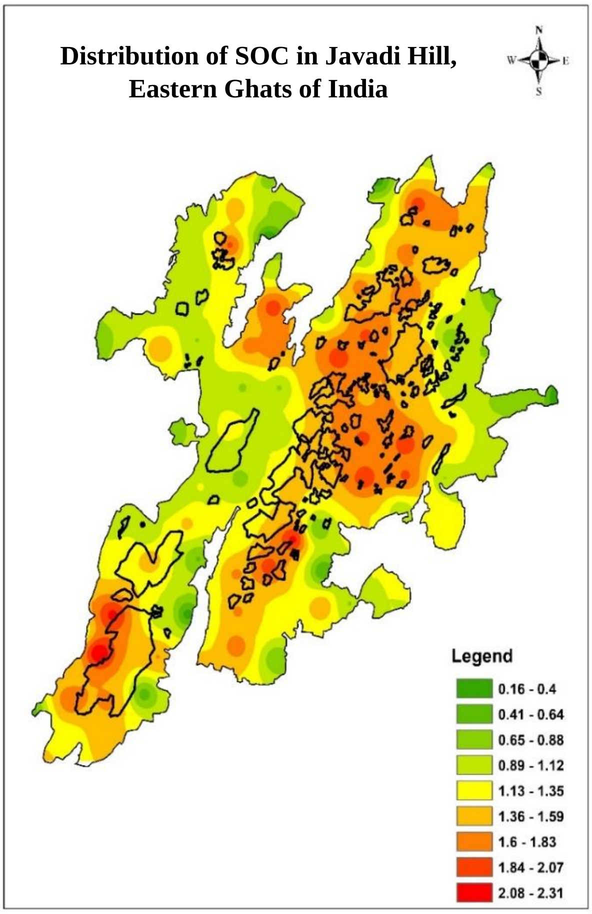

Figure 2: The soil organic carbon content (in %) in the Javadi hill, Eastern ghats, Tamil Nadu

The image of the Javadi hill classified using NDVI is provided in Fig 3. The extent of the area in the various NDVI classes is shown in Table 1.

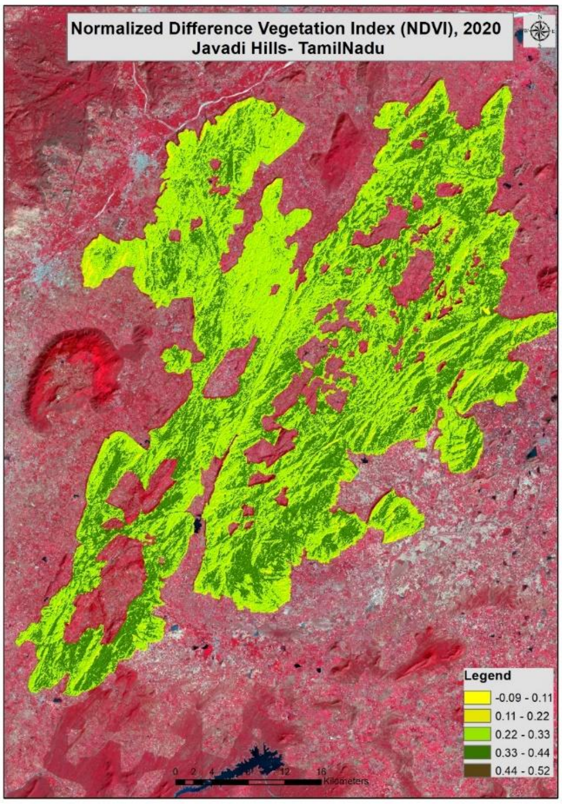

Figure 3: The NDVI image (January 2020) of the Javadi Hill, Eastern ghats, Tamil Nadu

Table 1: The NDVI classes using 2020 satellite imagery and the corresponding area in the Javadi Hill, Eastern ghats, Tamil Nadu

Sl. No.	NDVI class	Area (in ha)
1	-0.14 – 0.11	221.7
2	0.11 – 0.22	6061.8
3	0.22 – 0.33	95049.5
4	0.33 – 0.44	59923.1
5	0.44 – 0.54	250.9
	Total	**161507.0**

4. DISCUSSION

4.1 SOC and NDVI in forests of Javadi hill

Natural and anthropogenic factors affect the forest soil carbon (C) stock (Larionova et al., 2002). Anthropogenic factors affecting SOC in forests include forest management activities, deforestation and other biotic factors like grazing and biomass removal. Fire is another major disturbance affecting soil C stock in a forest ecosystem (Lal, 2005). Soil carbon is the prime indicator to address climate mitigation and delivering ecosystem services through land-based efforts to prevent carbon emissions, sinking atmospheric carbon dioxide (Bossio, 2020).

The SOC in the forests of Javadi hill is grossly low as compared to the global levels and this indicates a problem in the efforts to sequester carbon at a high rate. The existing SOC is additionally under threat due to the rapidly changing precipitation and other climate parameters due to climate change acting on the rugged terrain of the Javadi hill. At the same time, with proper forest management techniques, the low SOC could turn out as a great potential for the forests to sequester and stock more C in the future. SOC is a crucial parameter for optimum above-ground and below-ground

biomass. Hence, it is imperative that appropriate scientific techniques are applied especially in the identified low SOC areas in the forests of Javadi hill to enhance the carbon levels of both biomass as well as SOC.
The NDVI map of the Javadi hill indicate considerable degraded vegetation and the presence of dense canopy forests is seen only in the higher reaches of the hill. Comparison of the SOC classes map and the NDVI classified map of the Javadi hill indicate fair amount of correlation between low SOC and low NDVI indicating severe degradation. Field verification carried out in the forest areas in Javadi hill indicated thorn and deciduous forest to be the primary forest types present. The forest areas with SOC being lower than 1% indicated clear and visible signs of severe degradation primarily devoid of trees. Shrub species like *Lantana camara, Strychnos potatorum, Pterolobium indicum, Dodonaea viscosa, Strychnos nux-vomica, Pavetta indica, Acacia intsia, Clausena dentata* were commonly noticed in such areas indicating various stages of degradation.

4.2 Achieving India's Nationally Determined Contribution

In the Intended Nationally Determined Contribution (INDC) for the period 2021 to 2030, India has agreed to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent by 2030 through additional forest and tree cover (India's first INDC, 2015). In order to meet the country's INDC targets, it is obligatory to increase the carbon sequestration and increase the carbon stock in the forests. For this to happen, it is crucial to consider the SOC content in the soils, tackle the low SOC degraded areas through eco-restoration measures like replenishment of nutrients, increasing SOC, soil conservation and afforestation. The addition of compost and manure, application of single super phosphate and ammonium sulphate in the large-sized pits for afforestation would increase the microbial activity and help in proliferation of root system to achieve rapid but robust tree growth. In addition to soil amendments, soil conservation measures to prevent erosion and planting nitrogen-fixing legume species would be important strategies to sequester C at a faster rate (Ramachandran et al., 2007).

5. CONCLUSIONS

Reversal of land degradation and eco-restoration are prime components of Sustainable Development Goals (SDG) to be addressed with adequate eco-restoration works in conjunction with the agenda of INDC. Based on the above study, it is amply clear that substantial and sustained efforts to enhance the SOC in the forests need to be undertaken to meet India's INDC targets. The above efforts would also go a long way in also achieving the Sustainable Development Goals dealing with the reversal of land degradation and eco-restoration. Effective afforestation and sequestration of C will only be possible when the degradation status of forests has been accurately identified and quantified based on SOC and tackled with appropriate restoration techniques.

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