# Spatial Patterns of Soil Organic Carbon Stock in Different Land Use System in Salcete Taluka of Goa

**Sanjay D. Gaikwad*[1], Eripogu Kiran Kumar*[1] and Shubham Gude[2]**
[1]Dept. of Geography and Research Centre, Parvatibai Chowgule College of Arts and Science (Autonomous),
[2]Bharatiya Vidhyapeeth Institute of Environmental Education and Research
*Mailing address: Parvatibai Chowgule College of Arts and Science (Autonomous), Gogol, Margao-Goa.
*Email: drsanjaygaikwad@gmail.com, kirankumareripogu@gmail.com

**Abstract:** Soil organic carbon (SOC) stock acts as a major part of the terrestrial carbon reservoir with storage of about 1,500 Pg to 2,000 Pg C in the top layer in the world soils. Land Use Land Cover (LULC) changes directly affect the carbon sequestration rate in soil. Remote sensing, Geographical Information System (GIS) and GPS are used for spatial analysis and preparation of SOC distribution map.The present study aims to quantify SOCS of different land use and land cover classes include agriculture, mangrovesand wetlands. The study was conducted in Salcete taluka of South Goa district. Randomly soil samples were collected at a depth of 0-10cms and analyzed for SOC using Loss on Ignition (LOI) and Revised Walkley-Black method. Sentinel 2A satellite image of year 2016 was used to prepare thematic map of LULC of different land use system with ground truth data obtained from GPS coordinates. The distribution patterns of SOCS were plotted using SOC values obtained from soil health card portal and Indian Council for Agricultural Research (ICAR).The results indicated that the SOC in soils of different land use classes are significantly different. The mean SOC content in agricultural, mangroves and wetlands are 1.24% $\pm$ 0.43; 4.1% $\pm$ 1.15 and 2.16% $\pm$ 1.21 respectively. The total carbon stock of different land use systems from Salcete taluka of Goa is 5,47,626.15 tonnes.

**Keywords**: Soil Organic Carbon, LULC, GIS, Salcette.

## Introduction

Carbon (C) sinks plays an important role in meeting the challenge of climate change. More recently scientists have been analyzed soil organic carbon to measure the net exchange of C between soil and atmosphere (Janzen, 2005). Soil is considered as the largest pool of terrestrial organic carbon in the biosphere storing more $CO_2$ (2,200Pg) than is contained in plants (Batjes, 1996), so small changes in the size of this flux can have a large effect on atmospheric $CO_2$ concentrations (Schlesinger & Andrews, 2000) and thus constitute a powerful positive feedback to the climate system. Carbon sequestration is the process of capture and long-term storage of atmospheric carbon dioxide (Roger & Brent, 2012; Watson *et al*., 2000) in soil, vegetation, oceans and geologic formation. Through the process of photosynthesis, plants assimilate carbon and return to the soil as litter and stored as soil organic matter (Negi & Gupta, 2010). Soil store 2.5 to 3.0 times higher as that stored in the plants (Post *et al*., 1990) and two to three times more than the atmospheric as $CO_2$ (Davidson *et al*., 2000). The first estimate of the organic carbon pool in the Indian soils done in the year 1984 and it was 24.3Pg (1 Pg = 1015 g) based on 48 soil samples (Gupta *et al., 1994*). Approximately 1500Gt of organic carbon is stored in the world's soils to a depth of 1m, with a further 900Gt between 1-2m (Kirschbaum, 2004).

Land Use and Land Cover (LULC) changes directly affect the carbon sequestration rate in soil (Lal, 2004) and other factors including climate, vegetation type, anthropogenic activities and land use land management practices (Six & Jastrow, 2002; Baker, 2007). The practices of carbon sequestration in soil help to reduce concentration of atmospheric $CO_2$ and in turn help plant growth as well as increasing crop yield (Shachi & Venkatramanan, 2009). The remote sensing technologies are being used for real time LULC data analysis and area estimation under different land use practices. Geographical information system (GIS) technology is useful for preparation of maps.

## Materials and Methods

**Study area:** The study was conducted in Salcete taluka which is located in the heart of central coastal plains of South Goa district (12°39'-13°18'N and 77°22'-77°52'E), with a geographical area of 292.94 sq.km at an elevation range of 0-360m above mean sea level. In 2016,Salcetereceived an average rainfall of 2,635mm. Agriculture is one of the important economic activities of the taluka.Rice is the staple food and paddy is the principal agricultural crop (a Glance, G.A., 2000. Statistics Section. Directorate of Education, Government of Goa). The study area has been shown in Fig.1

## Methodology

**Remote sensing and GIS:** Sentinel 2A satellite image (Source: USGS) of year 2016 was used for the LULC classification. Satellite images were analyzed using Arc GIS and ERDAS software with the help of ground truth data collected from GPS and LULC classes viz., Agriculture, Settlements, Wetlands, Mangroves and Other vegetation were identified. By using ERDAS software, LULC thematic map and their area estimation was done by supervised classification. Agricultural, Wetland and Mangrove areas were extracted from LULC map. Interpolated map was created using SOC stock values in ERDAS software. The SOC stock map was overlayed on the extracted maps to view the distribution.

**Soil Collection and Analysis:** Soil samples at 0-10cm depth were collected from different LULC areas viz., Agro-ecosystems such as Paddy fields, Barren land, Coconut plantation, Cashew plantation and Current Fallow land; Wetlands; Mangroves; and Open forest areas. Bulk density of each soil sample was estimated. The collected samples were dried, crushed into pieces and were passed through 40mm sieves using electrical sieve shaker. The sieved samples were analyzed in Soil Laboratory for SOC and Soil Organic Matter (SOM) through two different methods i.e. (a) Loss on Ignition (LOI) (Storer, 1984) and (b) Revised Walkley-Black rapid titration method (Trivedi & Goel, 1986). The SOC stock was computed by multiplying the SOC values (g/kg) with bulk density (g/cm$^3$) and depth (cm) and was expressed in ton/ha (Joao Carlos *et al*., 2001). The flow chart of methodology has been shown in Fig. 2.

## Results and Discussion

In the present study, Sentinel 2A satellite imagery of different years (2016) was classified for the land use land cover analysis. The classified image obtained after preprocessing and supervised classification which are showing the land use and land cover of the Salcete taluka.

### Land Use and Land Cover map analysis

The LULC map depicts five major LULC classes which include Wetlands, Rivers, Mangroves, Settlements, Other Vegetations and Agriculture which is further classified into Paddy fields, Barren Land & Current fallow land (Fig. 3). The total geographical area of Salcete taluka is 292.94 sq.km, out of which Rivers covers 5.48sq.km (1.87%); Wetlands 5.87 (2.00%), Mangroves 3.53sq.km (1.21%); Settlements 24.85sq.km (8.48%); Other Vegetations 96.37sq.km (32.90%) and Agriculture covers 156.83sq.km (53.44%). In agricultural area, Paddy fields occupies 19.04sq.km (6.50%), Barren Land 48.25sq.km (16.47%) and Current Fallow land occupies 89.54sq.km (30.57%) of the total area of Salcete taluka (Table 1). The Land Use and Land Cover map reveals that present agriculture practices constitute 53.44% area (Table 1), whereas the other vegetation area shares 32.9% of the geographical area of the taluka. Wetlands Mangroves, Rivers and Settlement all together comprise 13.56%.

### Spatial distribution patterns of SOC stock:

The soils collected from 63 sites of taluka consisting paddy fields, current fallow lands, barren lands, wetlands and mangroves which were used for laboratory testing of SOC using WB and LOI method. Results are used for spatial interpolation using IDW interpolator to generate the spatial distribution of SOC over the study region (Fig 4). The analysis reveals that the SOC ranges from 5 t/ha to 60 t/ha. It is clearly evident that are three classes of SOC stock i.e. Class I (green to lemon yellow): 5t/ha to 30t/ha, Class II: 30t/ha to 45t/ha (yellow to ochre) and Class III (orange to dark red): 45t/ha to 60t/ha with represents agricultural land, wetlands and mangroves respectively.

Class I: A very high concentration of SOC stock which ranges from 45t/ha to 60t/ha was found in mangroves areas such Curtorim, Rachol and Macazana as mangrove soils register high concentrations of carbon (Donato *et al.*, 2011) because of high rate of sedimentation and production of biomass that promote the accumulation of organic compounds in soil and generate large quantities of organic matter (Choudhury *et al.*, 2013).

Class II: Wetland areas such as Carmona, Davorlim, Bhindemol, Sirlim, Loutolim, Sarzora and Sao Jose de areal revealed high concentration of SOC stock ranging from 30t/ha to 45t/ha as wetlands accumulate high amounts of carbon in their soils because of anaerobic conditions produced by the presence of water which enhances the carbon storage in wetland soils (Meyers, *et al.*, 2016).

*Class III*: Agricultural land which includes paddy fields, current fallow land and barren land revealed comparatively low concentration of SOC stock ranging from 5t/ha to 30t/ha due to management practices such as fallowing, repeat cultivation, stubble burning or removal, and overgrazing which reduces SOC by reducing inputs to the soil.

## Conclusion

From the present study, it has been revealed that the total carbon stock of entire Salcete taluka which includes Paddy fields, Barren land, Current fallow land, Mangroves and Wetlands is 5,47,626.15 tonnes. The methodology followed in the present study gives better representation of the spatial distribution of the SOC stock on the different land use systems of Salcete taluka of Goa. According to the present analysis, mangroves and wetlands are the potential reservoir of carbon which needs to be taken into consideration with regards to their conservation along with the upcoming developments. Present day minimum tillage methods in agriculture may contribute in enrichment of carbon reservoir of the region as paddy, barren land and current fallow land contributes 6%, 19% and 34% of the total carbon stock of the taluka. The present study can be road map for the enrichment of the carbon pools.

**Acknowledgement**

The present work is funded by University Grants Commission under Major Research Project. The authors are thankful to Department of Geography & Research Center and Principal, Parvatibai Chowgule College of Arts and Science (Autonomous), Margao-Goa for the infrastructural and financial facilities extended.

**References**

1. **Baker, D. F.** (2007). Reassessing carbon sinks. *Science*, **316(5832):** 1708-1709.

2. **Batjes, N. H.** (1996). Total carbon and nitrogen in the soils of the world. *European journal of soil science*, **47(2):** 151-163.

3. **Choudhury, B. U., Mohapatra, K. P., Das, A., Das, P. T., Nongkhlaw, L., Fiyaz, R. A. and Munda, G. C.** (2013). Spatial variability in distribution of organic carbon stocks in the soils of North East India. *Current Science*, 604-614.

4. **Davidson, E. A., Trumbore, S. E., and Amundson, R.** (2000). Biogeochemistry: soil warming and organic carbon content. *Nature*, **408(6814):** 789-790.

5. **Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M., and Kanninen, M.** (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature geoscience*, **4(5):** 293-297.

6. **Glance, G. A.** (2000). Statistics Section. *Directorate of Education, Government of Goa*.

7. **Gupta, R. K. and Rao, D. L. N.** (1994). Potential of wastelands for sequestering carbon by reforestation. *Current science*, 378-380.

8. **Janzen, H. H.** (2005). Soil carbon: a measure of ecosystem response in a changing world? *Canadian Journal of Soil Science*, **85(Special Issue)**, 467-480.

9. **Kirschbaum, M. U.** (2004). Soil respiration under prolonged soil warming: are rate reductions caused by acclimation or substrate loss?. *Global Change Biology*, **10(11):** 1870-1877.

10. **Lal, R.** (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, **304(5677):** 1623-1627.

11. **de M, S., Carlos, J., Cerri, C. C., Dick, W. A., Lal, R., Solismar Filho, P. V. and Feigl, B. E.** (2001). Organic matter dynamics and carbon sequestration rates for a tillage chronosequence in a Brazilian Oxisol. *Soil Science Society of America Journal*, **65(5):** 1486-1499.

12. **Meyers, L. M., Nahlik, A. M., and DeKeyser, E. S.** (2016). Relationship between the natural abundance of soil nitrogen isotopes and condition in North Dakota wetlands. *Ecological Indicators*, **60:** 394-401.

13. **Negi, S. S., and Gupta, M. K.** (2010). Soil organic carbon store under different land use systems in Giri catchment of Himachal Pradesh. *Indian Forester*, **136(9):** 1147.

14. **Post, W. M., and Mann, L. K.** (1990). Changes in soil organic carbon and nitrogen as a result of cultivation. *Soils and the greenhouse effect*, 401-406.

15. **Schlesinger, W. H., and Andrews, J. A.** (2000). Soil respiration and the global carbon cycle. *Biogeochemistry*, **48(1):** 7-20.

16. **Scott, N. A., White, J. D., Townsend, J. A., Whitehead, D., Leathwick, J. R., Hall, G. M. and Whaley, P. T.** (2000). Carbon and nitrogen distribution and accumulation in a New Zealand scrubland ecosystem. *Canadian Journal of Forest Research*, **30(8):** 1246-1255.

17. **Sedjo, R., & Sohngen, B.** (2012). Carbon sequestration in forests and soils. *Annu. Rev. Resour. Econ.*, **4(1):** 127-144.

18. **Shachi, S., Venkatramanan, V. and Sah, V. K.** (2009). Carbon sequestration activities in the forest: strategies and challenges. *Indian Journal of Forestry*, **32(4):** 533-536.

19. **Six, J. and Jastrow, J. D.** (2002). Organic matter turnover. *Encyclopedia of soil science*, 936-942.

20. **Storer, D. A.** (1984). A simple high sample volume ashing procedure for determination of soil organic matter.*Communications in Soil Science & Plant Analysis*, **15(7):** 759-772.

21. **Trivedy, R. K. and Goel, P. K.** (1984). *Chemical and biological methods for water pollution studies*. Environmental publications.