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Soil carbon stocks in different land-use classes of Gandhinagar, Gujarat

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Abstract:- *Land-use change exacerbates soil degradation by alterations in soil physical, chemical and biological properties. In this study, we evaluated the total soil carbon in different land-use classes in Gandhinagar district. Stratified random sampling approach was adopted to collect soil samples at three different depths of 10 cm each up to 30 cm from top. On the basis of analysis of variance between classes and within classes, it was observed that pH and electrical conductivity did not show significant variation within each class and between different classes. Carbon stocks varied with areas under vegetation class showing maximum amount while barren showing minimum carbon stocks. With depth, carbon stocks showed a decrease in all classes with least standard deviation in barren and maximum deviation in vegetation. Soil carbon stocks decrease with increased disturbance and decline in number of trees.*

Keywords: *Soil carbon, Land-use change, land-use classes, soil properties*

INTRODUCTION

Land-use change by natural causes or anthropogenic activities like deforestation for conversion to agriculture, intensive cropping, and urbanization causes degradation of soil by impact on physical, chemical and biological properties[1–3]. The magnitude and pace of soil decay varies according to the nature and intensity of change. A reverse change like agriculture or pastures to forest or restoration of degraded lands enhance soil quality and fertility[4]. Naturally, degradation is a slow process but human interference has both directly and indirectly exacerbated the process causing soil infertility and desertification as global problems[1].
Anthropogenic land-use change is a result of multiple stakeholders and institutions playing their roles in response to the economic development[5]. Forest clearing and tree felling aggravate soil erosion by direct exposure to wind and rainfall and decrease litterfall and humidity[6,7]. These changes deplete soil nutrients and organic matter negatively, increase soil salinity and affect the soil flora and soil enzymes and thereby decrease the rate of biogeochemical reactions[8]. Such changes also result in reduction in bulk density, porosity, soil fertility and infiltration rate are also observed. Consequently, associated services like biodiversity, carbon storage, agricultural productivity and provision of water are also adversely affected.

Soil is the third largest pool of carbonstoring approximately 2500 Pg up to 1 m depth[9]. Soil organic carbon pool comprising of soil microbial carbon, labile fraction, humus, various fractions of degradation and soil flora stores about 1500 Pg of C while soil inorganic carbon which is mainly formed by soil elemental carbon and carbonate minerals form about 950 Pg[10,11]. Various characteristics and functions of soil are dependent on soil organic matter and soil carbon[12]. The pedologic, atmospheric and biotic pools of carbon interact with each other and are the key players of global carbon cycle[13]. Presently, with the cumulative effect of climate change and land-use changes under increased population pressure, soil carbon is continuously being lost to the atmosphere. Intensive cultivation in dryland regions has resulted in decline of its meager SOC pool (~ less than 1g kg^{-1} in most areas) at a faster rate and even more under climate change-related desertification processes[13,14].

There have been few studies in Gujarat state on soil analysis which include a study by Rathore, (2014)in her thesis "Climate change Impacts: vegetation and plant responses in Gujarat". Karlikar and Solanki reported nutrient analysis in soils of different talukas of Gandhinagar[16]. Panchal and Pandey studied soil properties and their influence on vegetation in western Gujarat[17].In this study, an attempt has been made to use soil nutrients especially soil carbon as ecological indicators by assessing their quantities in different land-use systems. We classified Gandhinagar district in 9 different patterns or classes' viz., agriculture, vegetation, scrub, rural, urban, barren, river-canal and water body. Out of 9, except barren, river-canal and water body, rest 6 were selected for the analysis of soil properties.

Materials and Methods

Study Area

The study area is Gandhinagar district of Gujarat state of India. Gandhinagar District is an administrative division of Gujarat, whose headquarters are at Gandhinagar, the state capital since 1964. It has a population of 1,334,455 of which 35.02% were urban (2001 census). The four tehsils are - Gandhinagar, Kalol INA, Dahegam and Mansa - and 216 villages. Total area of the district is 2137.62 sq. km. It is situated between latitude 22°56' and 23°36' and longitude

72°23' to 73°05'. Major portion of the district falls under Sabarmati basin. The entire district is a part of North Gujarat Alluvial plain with neither hill features nor any prominent natural water bodies.

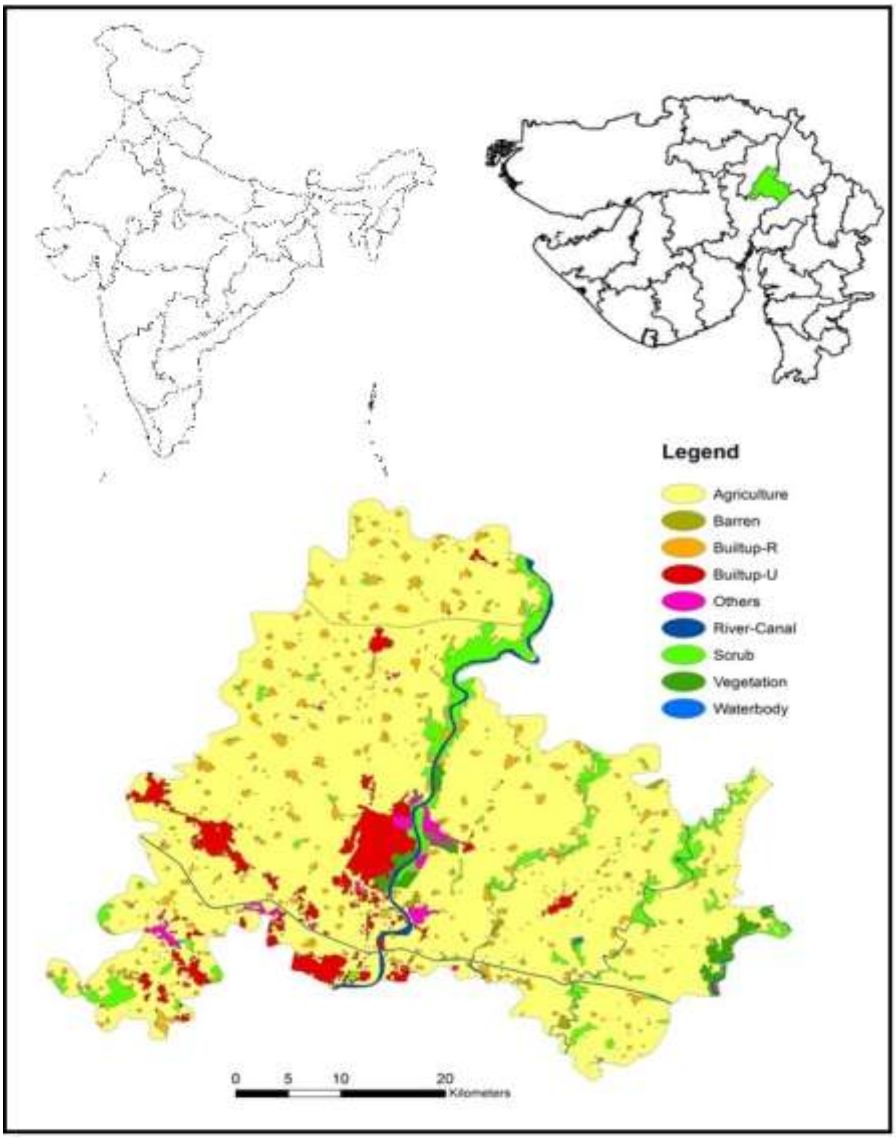

Figure 1: Study area location and land use land cover

The district experiences semi-arid type of climate and seasonal change of weather. The annual average rainfall is 823 mm. The soils in the district are generally sandy loam type with grey to brown color. As per the studies carried out during UNDP project, they are generally deep and have moderate to good permeability and drainability. In the western part of the district, the soils are alkali type and saline. They are typically deep, grey, calcareous sandy loam of very low permeability.

Sampling design

We prepared land use land use land cover map of Gandhinagar using Landsat (L) image. Landsat (L) image(paths 148 and 149/row 44) was obtained for year 2016 (L8 OLI-TIRS) from NASA-Earthexplorer. LULC map of 2016 was prepared with on screen digitization using visual interpretation of satellite images.The study area was categorized in Nine LULC categories which included Built-up urban, built-up rural, agriculture, vegetation, scrub, barren, water body, river-canal and others (industries, commercial complexes, etc.) by modifying level II of Anderson et al. (1976) LULC classification system (Table 1; Fig. 1). Six land use classes were selected to sample soil viz., agriculture, rural, vegetation, urban, scrub and others. 3-5 sites were taken for all the land use classes depending upon the areal extent covered by each class. 3 sites were taken for barren and scrub classes, 4 sites were selected for areas under vegetation and others and 5 sites were selected for agriculture, rural and urban classes.

Table 1: Area (sq. km) in all land use classes of Gandhinagar district in 2016

Land use class	Area (sq. km)
Agriculture (A)	1730.411
Barren (B)	7.7902
Builtup-R (BR)	86.8346
Builtup-U (BU)	111.1212
Others (O)	21.1142
River-canal (R)	37.5224
Scrub (S)	118.5535
Vegetation (V)	24.5048
Waterbody (W)	5.11
Total	2142.962

A quadrat of 0.1 ha was laid at each selected site. A composite sample was collected from 5 different corners of each plot at increasing depth of 10 cm each (0-10 cm, 10-20 cm, 20-30 cm). Soil samples were brought to laboratory for further analysis.

Soil and data analysis

Samples brought to the lab are weighed. Plant residues were removed from the air-dried samples and the samples were further sieved to remove particles larger than 2 mm. Clods were crushed with mortar and pestle to break them into smaller particles. Gravel or rock fragments larger than 2 mm were cleared of adhered fine soil particles and their content is reported as fraction of whole sample. All the samples were kept in airtight bags kept in cool, dark place.

Soil was analyzed for texture, pH, conductivity and carbon stocks. Texture, pH, and electrical conductivity were determined to assure the similarity in basic properties of soil to analyze the variations in soil carbon stocks and the find out the probable causes for the same.

Soil pH is the most key variable in soils as almost all the chemical reactions from dissolution of salts to degradation by microbes are influenced by pH. The most important reaction for farmers and plant biologists is the plant nutrient uptake. The optimum pH range for healthy growth and nutrient uptake by most plants is between 5.5 and 7.5.

Soil electrical conductivity (EC) measures salinity of the soil, playing key role in indicating soil health. Salts in the soil affect the process of osmosis and thereby, affect soil-water balance which is important for proper plant nutrient uptake and biochemical reactions occurring in soil. A deficient or excess amount of salts hinders plant growth. Soils in water containing excess salts occur naturally in arid and semiarid climates. Salt levels can increase as a result of cropping, irrigation, and land management. Although EC does not provide a direct measurement of specific ions or salt compounds, it has been correlated to concentrations of nitrates, potassium, sodium, chloride, sulfate, and ammonia. For certain non-saline soils, determining EC can be a convenient and economical way to estimate the amount of nitrogen (N) available for plant growth.

All the samples were tested potentiometrically for pH, EC in 1:2.5 1M KCl solution using pH meter and conductivity meter.

Soil was analyzed for carbon using elemental analyzer. The elemental analyzer works on complete combustion method. All the compounds are oxidized to their elemental gaseous forms and results are obtained directly in percent element forms. Hence, total soil (inorganic carbon as well as organic carbon) carbon referred to further as soil carbon, was determined in this study.

Results

Soil properties varied greatly among land use classes. Depletion of soil carbon was observed in areas with fewer trees and barren areas. Soils were largely neutral to alkaline with pH ranging from 6.5 to 8.3. Electrical conductivity was generally low due to lesser clay content in soils. Soil texture was largely sandy loam to sandy clay loam. Therefore, the moisture content of the soils is also very low. All the properties except pH decreased with increase in depth and decline in tree cover. Variations in soil carbon stocks with land use class are discussed separately in detail below.

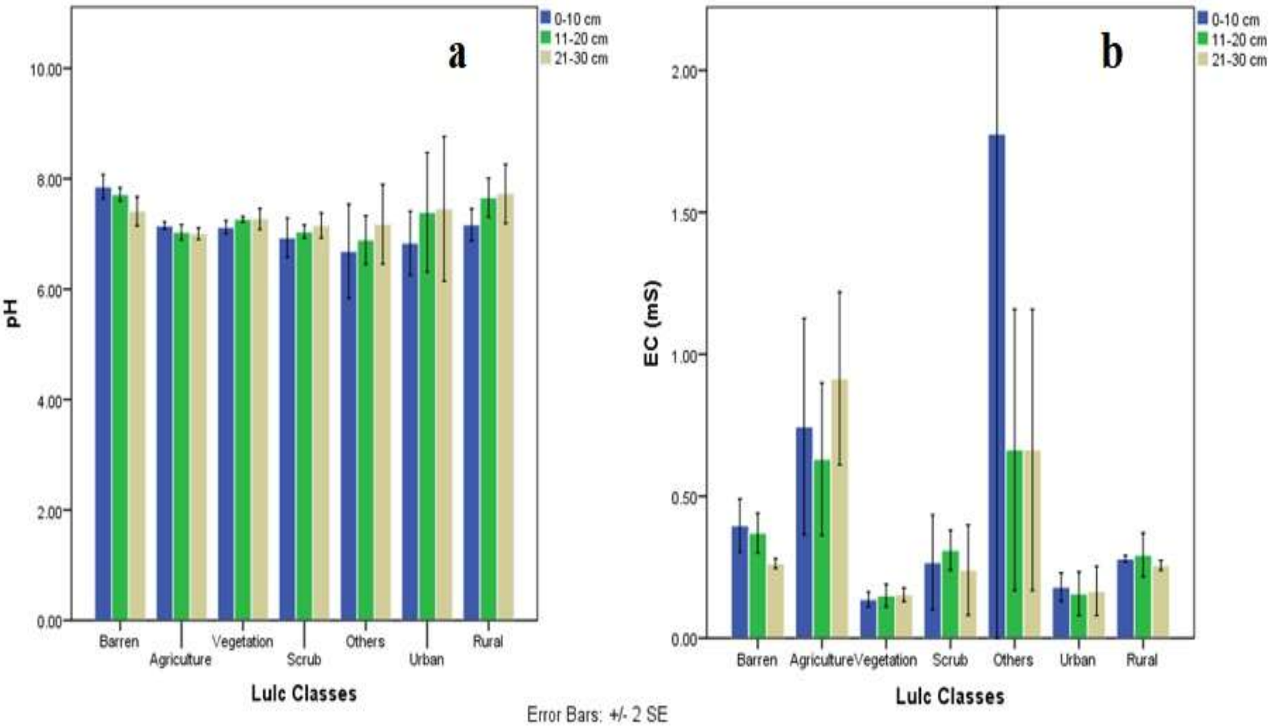

Figure 2: **a.** Soil pH and **b.** Electrical Conductivity in different land use classes and soil depths.

Table 2: Descriptive analysis of carbon, pH and electrical conductivity in all land-use classes

Parameters/ Land-use class		**Barren**	**Agriculture**	**Vegetation**	**Scrub**	**Others**	**Urban**	**Rural**
Total C (%)	0-10	0.49 ± 0.14	1.29 ± 0.14	3.00 ± 0.39	2.32 ± 0.27	0.98 ± 0.33	1.02 ± 0.05	1.25 ± 0.34
	10-20	0.33± 0.04	0.90 ± 0.09	2.69 ± 0.47	2.23 ± 0.39	0.80 ± 0.28	0.89 ± 0.06	1.11 ± 0.32
	20-30	0.23 ± 0.04	0.69 ± 0.08	2.49 ± 0.58	1.94 ± 0.45	0.62 ± 0.24	0.75 ± 0.01	0.98 ± 0.12
pH	0-10	7.86 ± 0.19	7.15 ± 0.09	7.12 ± 0.10	6.93 ± 0.30	6.60 ± 0.74	6.83 ± 0.50	7.17 ± 0.25
	10-20	7.72 ± 0.10	7.03 ± 0.19	7.23 ± 0.04	7.04 ± 0.10	6.89 ± 0.38	7.39 ± 0.94	7.66 ± 0.31
	20-30	7.41 ± 0.23	7.00 ± 0.15	7.27 ± 0.16	7.15 ± 0.19	7.18 ± 0.62	7.45 ± 1.11	7.73 ± 0.47
EC (mS)	0-10	0.40 ± 0.08	0.74 ± 0.54	0.14 ± 0.02	0.27 ± 0.14	1.77 ± 2.49	0.18 ± 0.04	0.28 ± 0.01
	10-20	0.37 ± 0.06	0.63 ± 0.38	0.15 ± 0.03	0.31 ± 0.06	0.66 ± 0.43	0.16 ± 0.07	0.29 ± 0.07
	20-30	0.26 ± 0.01	0.91 ± 0.43	0.15 ± 0.02	0.24 ± 0.14	0.66 ± 0.43	0.17 ± 0.07	0.26 ± 0.01

Electrical conductivity showed highest variation among areas under 'others' class. Even the value of conductivity was highest in 'others' class. This pattern was followed by agricultural areas which showed highest value in 21-30 cm depth. Scrub and rural then followed with conductivity values between 0.3 and 0.5. Barren areas were near agricultural fields, industrial areas, and thermal power plants. They showed larger conductivity values than agriculture and others class.

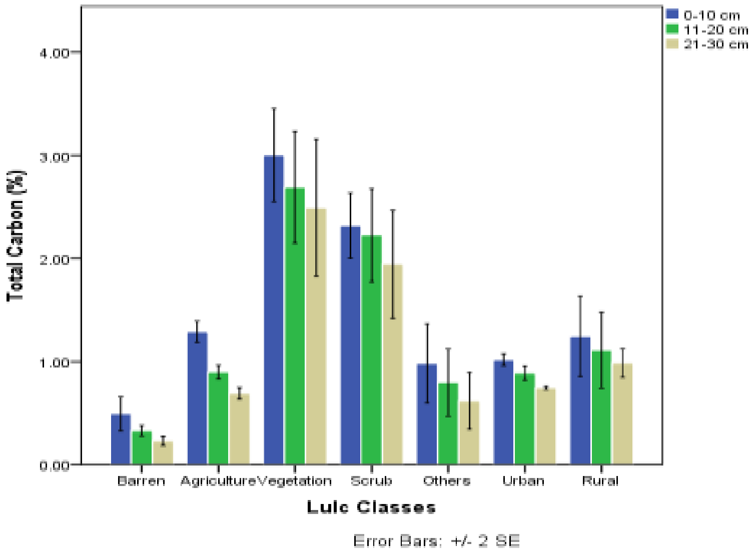

Figure 3: Total soil carbon in different land use land cover classes of Gandhinagar

Total carbon showed highest values in vegetation and scrub classes. Agriculture, rural, urban and barren followed subsequently. The variation among sites was highest in vegetation, followed by scrub and others.

Analysis of variance of soil propertiesin different land use class

Analysis of variance in each property within classes and between classes was performed. The carbon stocks showed significant difference at 95% significance between classes as well as within classes. However, the different was very less within the groups and quite large between the groups (Table 2).

Table 3: Analysis of variance for soil carbon stocks

Soil Depth		Sum of Squares	df	Sig.
0-10	Between	13.773	6	.000
	Within Classes	1.098	19	
	Total	14.872	25	
10-20	Between Classes	13.612	6	.000
	Within Classes	1.182	19	
	Total	14.794	25	
20-30	Between Classes	12.481	6	.000
	Within Classes	1.261	19	
	Total	13.742	25	

Discussion

Soil carbon stocks showed huge variation among land use classes. No regular trend is seen in the properties. This was probably reasoned to the variation within classes, particularly in 'others' class. The others class showed maximum deviation from expectation as the sites were located near different industries. Nevertheless, all the sites showed lower soil nutrients with less number of trees.

The different sites selected covered different directions viz., north, east, west, and south. More number of sites needs to be sampled to conclusively tell the reasons of variance within classes. Vegetation class showed maximum soil carbon stocks while barren class showed the least. But the deviations with depth were opposite, being minimum in barren class and maximum in vegetation class.This may be attributed to the large amount of leaf fall and dead organic matter of plants decomposing and contributing to soil organic matter.

Agriculture class showed little lesser carbon stocks in vegetation class and low deviations. This may be due to a mediated amount of fertilizers added to the crop plants. Also, as all the samples were collected just before the harvesting season, the carbon could have been probably utilized by the crop plants for their own growth. Due to no carbon inputs by dead plant material and increased carbon output by microbial consumption, leaching and erosion, soils under agriculture show less organic carbon stocks[18].

Soil carbon stocks in all the classes showed decline with increase in depth. This is attributed to the higher organic content in upper layers of soil due to fresh litter decomposition.

Conclusion

A decline in soil carbon stocksis seen which is a trend as also seen by the earlier studies. Areas under 'others' class and urban class were quite heterogeneous in nature due to different amount and nature of plantations carried out in such areas and hence, samples from more sites could better representthese classes. Additional properties like macro-nutrients and micro-nutrientssulfur and soil cations would reveal more details in the soil health. This study depicted the variation in six soil properties among land use classes and tried to study their causes. Apart from the industrial effects of deposition, soil carbon was largely less in urban, scrub and barren areas. This may be due to the barren areas being cleared of vegetation for construction and urbanization purposes since long time and hence, less litter decomposition in those areas. Plantations should be seriously carried out in urban areas by reserving certain parts of the city only for plantations. A more detailed analysis of the urban areas can be performed by analyzing the urban areas in different classes like gardens, lawns, road-side plantations, plantation areas and evaluating soil carbon stocks separately in each of them.

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