*Article*

# Assessment of soil characteristics in different land-use systems in Gandhinagar, Gujarat

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**Abstract**
Soil is a source of food and habitation for all terrestrial organisms and provides innumerable ecosystem services. However, it is a finite resource as it is not renewable on a human time scale. Land-use change drastically alters soil characteristics and increased soil carbon emissions. In this study, an effort has been made to assess soil characteristics in different land-use classes of Gandhinagar district, Gujarat. Land-use land cover classification was done using digital interpretation method and 9 classes were mapped. Stratified random sampling approach was adopted to obtain composite samples from 4 sites in 6 out of 9 land-use land cover classes from increasing depths of 0-10, 10-20 and 20-30 cm. Soil quality was assessed by testing pH, electrical conductivity, organic carbon, available phosphorous, potassium, and total nitrogen. It was found that vegetation class contained most fertile soil. The agriculture closely followed vegetation while urban showed least amount of soil organic carbon and other nutrients. Vegetation showed highest carbon and potassium levels while nitrogen and phosphorous were equally high in vegetation and agriculture class. Tree cover and the nature of land-use were crucial factors affecting soil health.

**Keywords** agriculture; land-use; soil ecosystem; nutrients; land-use classes.

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## 1 Introduction

Soil is one of the fundamental resources forming the basis of life. It is the source of food and habitation for all terrestrial organisms and is the medium for all biogeochemical processes (Newbold et al., 2015). Soil essentially fulfils all the basic human needs from food to fiber to shelter (Vashum et al., 2016). Thus, parameters of the soil can be utilized as ecological indicators to assess degradation (Dominati et al., 2010). Copious services are provided by the soil through degradation and transformation of complex substances, water filtration, and habitat provision, carbon storage and acting as archive of geology, history and culture (McBratney et al., 2014). According to Costanza et al. (1997), soil ecosystem services contribute nearly less than 1% of global gross domestic product (GDP). Though, the proportion seems small, its subtraction will result in significant loss in global GDP. Thus, it forms an important component of ecological economics and need to be included in ecosystem service frameworks.

However, land is a finite resource. Climate change along with anthropogenic activities have intensified and pacified the natural degradation process of soil by deforestation and land use change for various other purposes (Ballestores and Qiu, 2012; Zhang and Liu, 2012). The kind of change determines the change in soil quality. Soil soaks water and provides to the plants slowing the rush of water. However, tree felling exposes soil to full force of rain and snow. Bare soil is more vulnerable to heat stress and soil erosion due to absence of plants and plant litter to hold soil in place, infiltrate water and reduce clogging (Hillel, 1991). Eroded soil thus lacks the necessary nutrients and enzymes to support the microbial and higher flora and fauna. This results in a decline in the rate of biogeochemical reactions bulk density, porosity, and soil fertility and infiltration rate. Consequently, an adverse effect is also seen on allied services.

In a similar manner for the restoration of landscapes or conversion of barren lands to forest, vegetation or pastures. Land-use change impact regional climate and a wide range of ecosystem services like biodiversity, soil degradation (Lambin et al., 2003). Anthropogenic land-use change is driven by several patrons and institutions acting in accordance with the emerging global trends in trade and industry (Lambin et al., 2001). About 500 million hectare (Mha) in the tropics (Lamb, 2005), and globally 33% of earth’s land surface is affected by some type of soil degradation (Koch et al., 2013; Lal, 2015). 2015 was declared as year of soils by UN General Assembly while FAO conducted an international symposium on soils in 2017 (FAO, 2017), while IPCC published a special report on soils (IPCC, 2000). This evolved the concept of soil security (McBratney et al., 2014).

This work tries to evaluate soil properties in different land-use systems of Gandhinagar, Gujarat by analyzing major properties of pH, electrical conductivity, organic carbon, total nitrogen, phosphorous and potassium. Gandhinagar district was mapped and 9 land-use land cover classes’ were generated with varying tree cover from vegetation, scrub, agriculture, rural, urban, to barren, river-canal and water body. 7 classes out of 9, except river-canal and water body, were selected for the analysis of soil properties. A review of published literature in Gujaratshows studies exploring soil properties which include “Climate change Impacts: vegetation and plant responses in Gujarat” (Rathore, 2014) and another study assessing influence of soil properties on vegetation in western Gujarat (Panchal and Pandey, 2002). There are two works in Gandhinagar district, nutrient analysis in soils of different talukas of Gandhinagar (Karlikar and Solanki, 2014) while another one was a study on soil organic carbon stocks of Gandhinagar, Gujarat (Purswani and Pathak, 2017).

## 2 Study Area and Methodology

### 2.1 Study site

Gandhinagar city was the second planned city built in India after Chandigarh in 1975. According to a book written by the town planner of Gandhinagar city, no tree was cut while it’s designing and it was designed to be most ecofriendly and sustainable city (Fig. 1). Gandhinagar city, the capital of Gujarat state lies in Gandhinagar district, an administrative division of Gujarat. As per the 2011 census conducted by government of India, Gandhinagar district had a population of 1,334,455 in 2011 of which 35.02% were urban (Directorate of Census Operations, 2011). The district is subdivided in four talukas namely Gandhinagar, Kalol INA (on the west), Dehgam (on the east) and Mansa (in the North)– consisting of 216 villages.

As it lies in tropical semi-arid zone, the weather is very dry experiencing annual average rainfall of less than 100 cm. Sandy loamy soils of grey to buff to brown color are predominant in the district. According to a UNDP study, the soils are generally deep with good permeability and drainage capacity. The soils near Kalol taluka are comparatively more saline. Greyish in color, the soils are deep, alkaline, calcareous sandy loam in texture with low permeability and drainage.

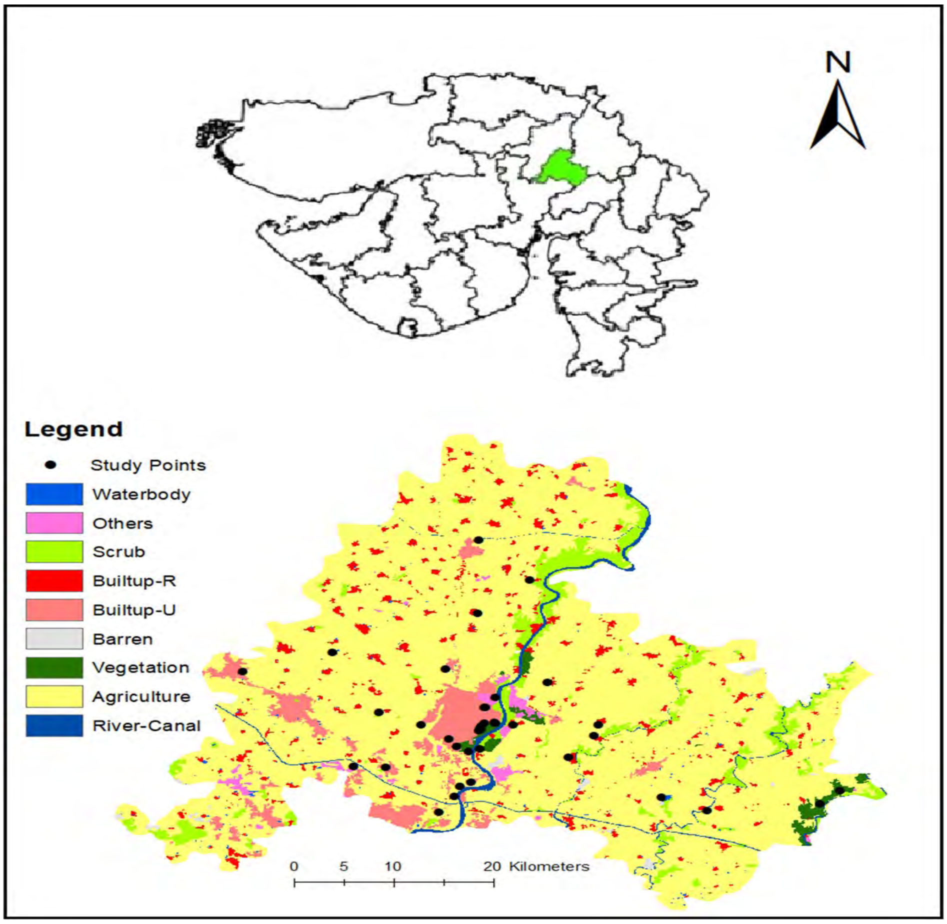



**Fig. 1** Study area location map and sampling points

## 2.2 Sampling

For sampling, firstly, Gandhinagar district was mapped to generate 9 land use land cover classes with the help of Landsat OLI image of 2016. The 9 land use classes were vegetation, agriculture, scrub, rural, urban, others, water body, river/canal, and barren. Others was a heterogeneous class consisting areas nearby industries, brick kilns, thermal power plant, boundaries of national defense force campuses like air force and educational institutes.

Considering the average no. of trees and the distance from roads, it was assumed the tree cover in the classes decline in the order vegetation>scrub>rural=agriculture>urban>others>barren. 3-5 spots at a minimum distance of 100 m from each other were sampled in each of the land use classes. 3 spots in each of the barren and scrub areas, 4 spots in vegetation and others classes and 5 sites in agriculture, rural and urban classes were selected to collect samples as agriculture, rural and urban classes occupied larger area. A quadrate of 0.1 ha containing 4 small quadrats of 1 sq. m. at each corner and the center was placed at every designated spot. Composite samples were obtained from all the small quadrats of each plot at growing depth of 10 cm each (0-10 cm, 10-20 cm, 20-30 cm). Samples were carried to laboratory in air sealed bags for further analysis and air dried. Then they were weighed and were sieved to clear plant residues. Clods were crumpled with hand or mortar and pestle to break them into smaller particles. Fine soil particles adhered to the gravel or stones were removed and weighed to obtain percentage in soil composition. Sieving of all samples was followed by chemical analysis.

**2.3 Soil analysis**

2.3.1 pH and electrical conductivity

Soil pH affects influence all the biochemical reactions from dissolution, microbial degradation to nutrient mobilization. Mild acidic to neutral soils (pH 5.5-7.5) provide optimum conditions for microbial reactions and nourishment to the plants. Soil electrical conductivity (EC) gives an estimate of salinity of the soil which influences other soil properties like soil texture, organic matter, cation exchange capacity, drainage conditions, etc. thus is an important soil quality indicator. EC gives a measure of free cations and anions and therefore is correlated to the nutrient concentration of soil. In soils with less salt concentrations, EC measurement gives a cost effective way for estimation of available nitrogen (N). Osmosis the process by which plants uptake water and nutrients from soil depends entirely on the salt concentration in the soil. Activities like cropping, irrigation, use of fertilizers and pesticides and land management influence the concentration of salts in the soil. Therefore, it becomes important to understand the influence of land-use land cover pattern on soil.

pH and electrical conductivity were determined as basic parameters for all the samples in 1:2.5 1M KCl solution potentiometrically.

2.3.2 Elemental analysis

Soil was analyzed for carbon and nitrogen elements using C, N, H and S elemental analyzer which operated on the principle of complete oxidation of compounds and measure the respective forms as percentage of the total. Soil was analyzed for phosphorous by Olsen's method. Potassium was estimated by Flame photometric method (Toth and Prince, 1949).

## 3 Results

Land use classes showed significant variation in soil characteristics. Soil nutrients declined in direct proportion to tree cover. pH of the soils ranged from 6.5 (mild acidic) to 8.3 (alkaline).. Lower electrical conductivity was observed. This may be probably due to low organic matter in soils. Soils were majorly 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 each soil property with land use class are discussed separately in detail below:

**Table 1** Mean soil properties (± SD) in different land use systems and in different depth class

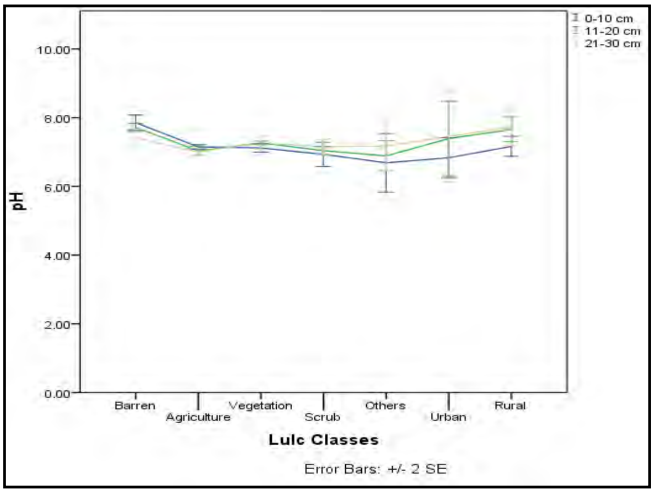
| **Parameters/Land-use class** | | **Barren** | **Agriculture** | **Vegetation** | **Scrub** | **Others** | **Urban** | **Rural** |
|---|---|---|---|---|---|---|---|---|
| Total C (%)* | 0-10 | 0.49 ± 0.14 | 1.29 ± 0.14 | 3.00 ± 0.39 | 2.32 ± 0.27 | 0.98 ± 0.33 | 1.02 ± 0.05 | 1.25 ± 0.34 |
| | 10-20 | 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 |
| Total Nitrogen (%) | 0-10 | 0.08 ±0.01 | 0.14 ±0.04 | 0.14 ±0.03 | 0.11 ±0.01 | 0.11 ±0.05 | 0.15 ±0.01 | 0.11 ±0.02 |
| | 10-20 | 0.07 ±0.00 | 0.12 ±0.01 | 0.12 ±0.04 | 0.09 ±0.01 | 0.09 ±0.04 | 0.12 ±0.03 | 0.10 ±0.01 |
| | 20-30 | 0.05 ±0.00 | 0.09 ±0.01 | 0.10 ±0.04 | 0.07 ±0.02 | 0.07 ±0.02 | 0.11 ±0.01 | 0.08 ±0.01 |
| P (µg/gm) | 0-10 | 27.07 ±5.40 | 182.00 ±49.77 | 97.33 ±1.15 | 81.67 ±6.66 | 62.67 ±5.86 | 124.33 ±60.01 | 67.33 ±19.50 |
| | 10-20 | 28.47 ±3.00 | 114.51 ±6.91 | 175.67 ±141.46 | 88.97 ±11.34 | 197.00 ±123.28 | 103.33 ±30.92 | 73.00 ±5.57 |
| | 20-30 | 23.07 ±1.84 | 96.41 ±8.01 | 325.00 ±226.32 | 82.67 ±4.62 | 197.00 ±123.28 | 73.00 ±20.22 | 154.00 ±70.79 |
| Extractable | 0-10 | 3.72 ±0.73 | 12.52 ±0.37 | 6.00 ±0.00 | 5.70 ±0.26 | 8.67 ±4.73 | 4.33 ±0.58 | 5.00 ±1.00 |

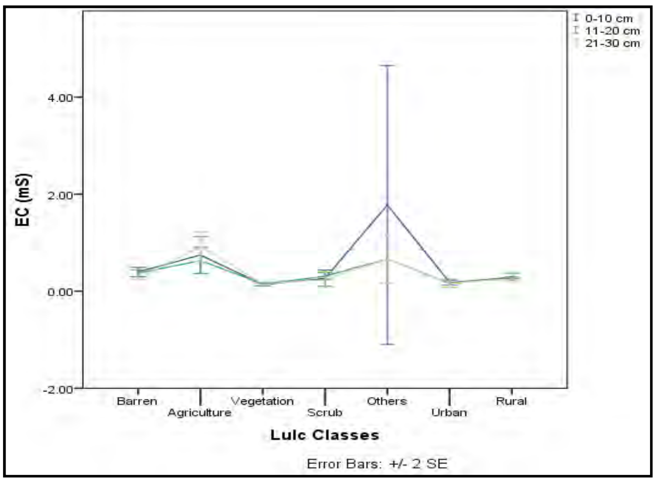
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K (µg/gm) | 10-20 | 3.30 ±0.61 | 11.19 ±0.37 | 6.00 ±0.00 | 6.00 ±1.00 | 5.57 ±0.59 | 5.00 ±0.00 | 5.37 ±0.36 |
| | 20-30 | 2.20 ±1.19 | 9.05 ±1.11 | 5.67 ±0.58 | 6.03 ±0.31 | 5.57 ±0.59 | 4.67 ±0.58 | 6.47 ±0.49 |

* - pH, EC and C have been reported earlier in (Purswani and Pathak, 2017).

The average pH range in all land-use classes ranged from 7.0-8.0. The pH of soils in rural, urban and barren classes was nearly alkaline (Table 1). The highest variation in pH range was observed in ‘others’ and urban class. The mean pH of soils in urban areas was a little higher than soils in scrublands but equivalent to soils in vegetation class (Fig. 2a). The deepest layer (21-30 cm) of rural areas showed highest pH while 10-20 cm depth showed slightly smaller pH (Table 1).

The areas under ‘others’ class also showed maximum variance in electrical conductivity (Fig. 2b). And the conductivity of soils in ‘others’ class was highest in the upper layers (0-10, 10-20 cm). Agricultural soils showed highest value in 21-30 cm depth. Soils in Scrub and rural classes then trailed with conductivity values flanked by 0.3 and 0.5. Barren soils showed least conductivity values. The electrical conductivity in agricultural soils, soils near industrial areas and thermal power plants were in between ‘scrub and rural classes’ on upper side and ‘others’ and barren classes on lower side.




Error Bars: +\- 2 SE

Key: B- Barren, A – Agriculture, V – Vegetation, S – Scrub, O – Others, U – Urban, R-rural

**Fig. 2** Mean pH and Mean Electrical conductivity in all depths among land use classes

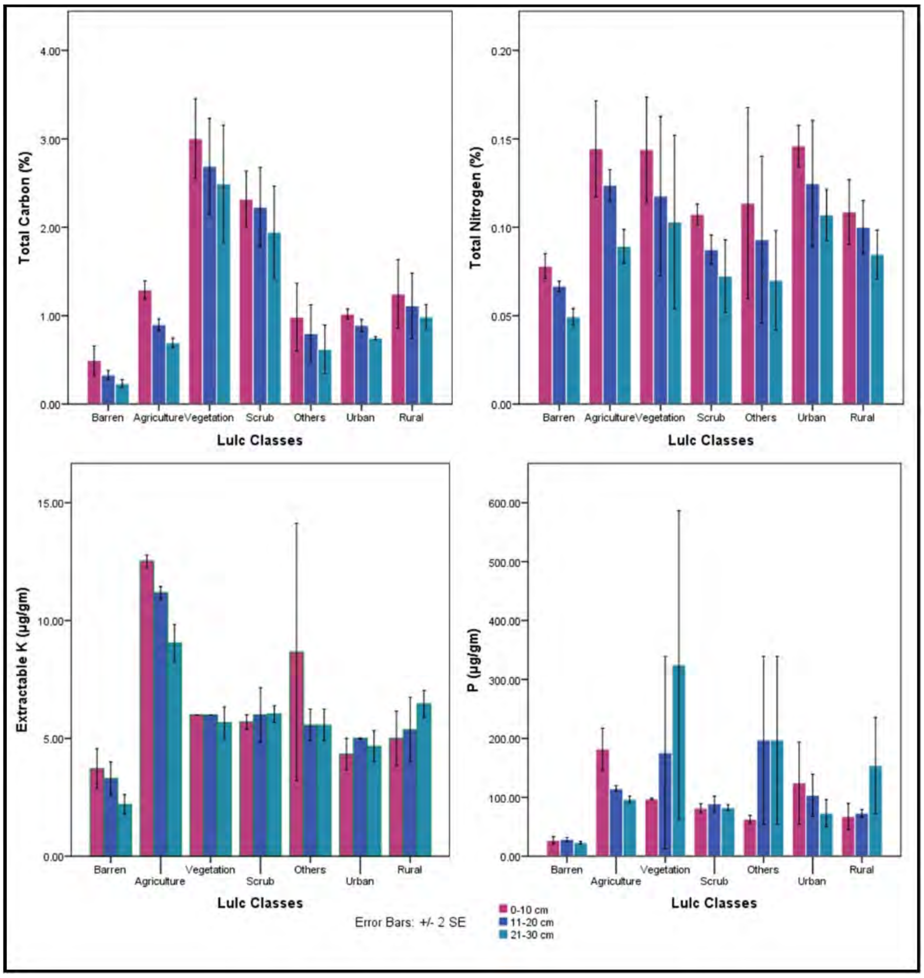



**Fig. 3** Trend in a) Total Nitrogen, b) Total Carbon, c) extractable potassium and d) phosphorous (P) in three different depths among land use classes.

Nitrogen content was seen to be highest in agriculture, urban and vegetation classes (Fig. 3a). Sites labelled as rural, others, scrub and barren showed little lesser than the above classes with rural being highest and barren being lowest. The classes others and vegetation showed large variation in nitrogen content among sites in all three depths.

Carbon content was found to be maximum in vegetation and scrub classes (Fig. 3b). Areas under agriculture, rural, urban and barren classes followed consequently. Vegetation showed highest variation within classes among locations tailed by scrub and others.

Soils in vegetation class showed highest phosphorous content followed by agriculture in 0-10 cm depth and others in 10-20 and 20-30 cm depths (Fig. 3c) while barren soils showed the least phosphorous content. This was contrary to the assumption of sites from ‘others’ class being depleted of nutrients. Agriculture class closely followed vegetation.

Potassium ($K^+$) showed very high values in others in 10-20 cm depth with large variation among sites (Fig. 3d). Highest potassium levels were found in agricultural areas followed by areas under ‘others’ class. Vegetation, scrub and rural classes showed higher levels of potassium than urban and barren classes.

ANOVA was applied on soil properties to test the variation between and within groups (classes). The soil nutrients varied significantly at $\alpha$=0.95 (Table 2).

**Table 2** Analysis of variance of soil properties among different land use classes.

| **Parameters/Land-use class** | | **F value** | **Sig.** |
|---|---|---|---|
| pH | 0-10 | 3.93 | **0.010** |
| | 10-20 | 2.63 | **0.050** |
| | 20-30 | 1.07 | 0.412 |
| EC (mS) | 0-10 | 1.37 | 0.278 |
| | 10-20 | 2.36 | 0.071 |
| | 20-30 | 4.96 | **0.003** |
| Total C (%) | 0-10 | 39.71 | **0.000** |
| | 10-20 | 36.47 | **0.000** |
| | 20-30 | 31.35 | **0.000** |
| Total Nitrogen (%) | 0-10 | 2.65 | **0.048** |
| | 10-20 | 3.30 | **0.021** |
| | 20-30 | 3.23 | **0.023** |
| P (μg/gm) | 0-10 | 9.65 | **0.000** |
| | 10-20 | 2.66 | **0.048** |
| | 20-30 | 4.15 | **0.008** |
| Extractable K (μg/gm) | 0-10 | 20.04 | **0.000** |
| | 10-20 | 93.40 | **0.000** |
| | 20-30 | 33.39 | **0.000** |

## 4 Discussion

A plethora of literature on the effects of land-use patterns on soil characteristics is available on the internet (Edmondson et al., 2014; Lal, 2003; Qiu et al., 2016; Rittl et al., 2017). Many Indian works have also shown or tried to understand the effects of changes in land-use and land management on soil characteristics (Choudhury et al., 2013; Grace et al., 2012).

There was a significant variance in soil nutrients among all land-use classes. We predicted the probable reason as the significant variation within ‘others’ class. According to the knowledge of the field, we attributed this to the proximity of sites in ‘others’ class to different types of industries and institutions. Though, all the sites showed soil health decline with decrease in tree cover.

The concentrations of organic carbon, nitrogen and phosphorus in the present study, did not differ significantly among the three sites at 0 - 10 cm depth. Each of the individual soil variables showed a high degree of correlation with tree species richness. However, tree density was clearly negatively correlated to variables like phosphorus and nitrogen and positively correlated with carbon.

All the ordinal directions viz., north, east, west, and south were sampled. More associated factors need to be studied to understand the factors underlying variance within classes. Carbon, nitrogen and phosphorous were dominant in vegetation class.

Nitrogen was also seen to be high in agriculture class which may be due to the application of nitrogen fertilizers in the field. Phosphorous was high in agriculture class followed by others in 10-20 cm depth and then in vegetation and scrub classes. This would also be attributed to the application of phosphate fertilizers in agricultural fields. Therefore, the others class showed high amount of ‘phosphorous’ in upper layers of soil. While the phosphorous content near fertilizer industry was high, it was low near thermal power plant. This is similar to results reported by other studies (Bhattacharyya et al., 2000; Falkengren-Grerup et al., 2006; Leaflets et al., 2013; Mehta et al., 2013; Post and Kwon, 2000; Ramachandran and Radhapriya, 2016).

Potassium was highest in vegetation class and in top layer as trees hold the soil particles together and increase the organic matter by constant litter fall and litter decomposition. The high amount of organic matter makes available free charged particles in clay making available higher potassium content.

Many studies including a work in western India by Kumar et al., 2010 showed that the conversion of forest into agricultural land negatively affects soil organic carbon stocks. The direction and magnitude of this impact depends on the type of land use (Kumar et al., 2010; Lal, 2015, 2003). Their findings show that the overall soil carbon stocks down to a depth of 30cm do not decline when forest is converted to pasture. However, the direction and the magnitude of soil organic carbon changes can differ for each soil layer. Soil carbon stock significantly increased in the top soil (0–10cm) and only slightly decreased at a depth of 20–30 cm after conversion from forest to pasture. This decrease was only significant for the soil layers 0–10 cm and 20–30cm (Purswani and Pathak, 2017). Therefore, the establishment of agricultural areas is linked to substantial changes in soil organic matter that resulted in an increase (pasture) or decrease in SOC stocks. This type of information will be useful for assessing the impact of land use change on total carbon fluxes (Kumar et al., 2010; Rittl et al., 2017).

Approximately, all the nutrients inversely varied with depth. There was no regular trend seen in pH and conductivity with respect to LULC classes or increase in depth. The constant litter decomposition in the upper layers of the soil is the suspected cause for this observation. However, some areas were more eroded and hence, the lower layers of soil showed higher amounts of phosphates in others and rural classes.

## 5 Conclusions

Being in a semi-arid zone, the soils are alkaline and saline with low organic content. The direct correlation of soil quality and soil nutrients with tree cover was observed which was obvious. Larger sample size from the heterogeneous classes viz., ‘urban’ and ‘others’ could reduce the variance in nutrient concentrations. More cations and nutrients should be included to reveal a complete soil profile. To understand the mechanisms affecting soil properties, their relation with plants need to be studied. This study tried to assess the major six soil characteristics among land use classes. The classes urban’, ‘scrub’ and ‘barren’ showed lower soil quality than vegetation and agricultural areas. ‘Others’ class being a heterogeneous class could not be conclusively judged for its higher nutrient content. More effective land management practices need to be adopted to conserve soil in anthropogenic land-use systems.

## References

Ballestores Jr. F, Qiu ZY. 2012. An integrated parcel-based land use change model using cellular automata and decision tree. Proceedings of the International Academy of Ecology and Environmental Sciences, 2(2): 53-69

Bhattacharyya T, Pal DK, Mandal C, Velayutham, M. 2000. Organic carbon stock in Indian soils and their geographical distribution. Current Science, 79: 655-660

Choudhury BU, Munda GC, Mohapatra KP, et al. 2013. Spatial variability in distribution of organic carbon stocks in the soils of North East India. Current Science, 104: 604-614

Directorate of Census Operations. 2011. District Census Handboook Gandhinagar. 36-42, Central Ground Water Board (West Zone), Ahmedabad, India

Dominati E, Patterson M, Mackay A. 2010. A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecological Economics, 69: 1858-1868

Edmondson JL, Davies ZG, McCormack SA, Gaston KJ, Leake JR. 2014. Land-cover effects on soil organic carbon stocks in a European city. Science of Total Environment, 472: 444-453

Falkengren-Grerup U, Brink DJ ten, Brunet J. 2006. Land use effects on soil N, P, C and pH persist over 40–80 years of forest growth on agricultural soils. Forest Ecology and Management, 225(1-3): 74-81

FAO 2017. Proceedings of the Global Symposium on Soil Organic Carbon 2017. Food and Agriculture Organization of the United Nations. Rome, Italy

Grace PR, Antle J, Aggarwal PK, Ogle S, Paustian K, Basso B, 2012. Soil carbon sequestration and associated economic costs for farming systems of the Indo-Gangetic Plain: A meta-analysis. Agriculture, Ecosystems and Environment, 146: 137-146

IPCC. 2000. Land use, land-use change, and forestry. https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf/background

Karlikar BH, Solanki HA. 2014. Estimation of nutrients ( N , P , K , Zn ) in soils of Gandhinagar District with referrence to selected Weeds. Global Journal of Research Analysis, 3: 5-6

Karlikar BH, Solanki HA.2013. Estimation of micronutrients and physico-chemical analysis of soils of Gandhinagar District, Gujarat , India. Life science leaflets, 4297: 49-54

Koch A, Mcbratney A. 2013. Soil security: solving the global soil crisis. Global Policy, 4(4): 434-441

Kumar JIN, Kumar RN, Bhoi RK, Sajish PR. 2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Tropical Ecology, 51: 273-279

Lal R. 2015. Restoring soil quality to mitigate soil degradation. Sustainability, 7: 5875–5895

Lal R. 2003. Global potential of soil carbon sequestration to mitigate the greenhouse effect. Critical Revisions in Plant Science, 22(2): 151-184

Lamb D. 2005. Restoration of Degraded Tropical Forest Landscapes. Science, 310: 1628-1632

Lambin EF, Geist HJ, Lepers E. 2003. Dynamics of Land-use & Land-Cover Change in Tropical Regions. Ann of Rev. Environ. Resources, 28: 205-241

Lambin EF, Turner BL, Geist HJ, et al. 2001. The causes of land-use and land-cover change : moving beyond the myths. Global Environmental Change, 11: 261-269

Karlikar BH, Solanki HA. 2013. Estimation of micronutrients and physico-chemical analysis of soils of gandhinagar district, GUJARAT, INDIA. Life Science Leaflets, 4297: 49-54

McBratney A, Field DJ, Koch A. 2014. The dimensions of soil security. Geoderma, 213: 203-213

Mehta N, Dinakaran J, Patel S, Laskar AH, Yadava MG, Ramesh R, Krishnayya NSR. 2013. Changes in litter decomposition and soil organic carbon in a reforested tropical deciduous cover (India). Ecologial Resources, 28: 239-248

Newbold T, Hudson LN, Hill SLL, et al. 2015. Global effects of land use on local terrestrial biodiversity. Nature, 520(7545): 45-50

Panchal NS, Pandey AN. 2002. Study on Soil Properties and Their Influence on Vegetation in Western Region of Gujarat State in India . India

Post WMM, Kwon KCC. 2000. Soil carbon sequestration and land-use change: processes and potential. Global Change Biology, 6: 317-327

Purswani E, Pathak B. 2017. Soil carbon stocks in different land-use classes of Gandhinagar, Gujarat. International Journal of Advance Engineering and Research, 4(11): 937-942

Qiu L, Zhu J, Wang K, Hu W. 2016. Land use changes induced county-scale carbon consequences in southeast China 1979-2020, evidence from Fuyang, Zhejiang province. Sustainability, 8(1): 38

Ramachandran A, Radhapriya P, 2016. Critical Analysis of Forest Degradation in the Southern Eastern Ghats of India : Comparison of Satellite Imagery and Soil Quality Index. Plos One, 1(1): e0147541

Rathore A. Soil Quality and Soil Organic Carbon under Different Agro-Climatic Zones of Gujarat. In: Climate Change Impacts Vegetation on Plant Responses in Gujarat. 119-143, India

Rittl TF, Oliveira D, Cerri CEP. 2017. Soil carbon stock changes under different land uses in the Amazon. Geoderma, 10: 138-143

Vashum KT, Kasomwoshi T, Jayakumar S. 2016. Soil organic carbon sequestration potential of primary and secondary forests in Northeast India. Proceedings of the International Academy of Ecology and Environmental Sciences, 6(3): 67-74

Zhang WJ, Liu CH. 2012. Some thoughts on global climate change: will it get warmer and warmer? Environmental Skeptics and Critics, 1(1): 1-7