

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

Analysis of Soil Physico-Chemical Properties in Various Sites at Yamuna Biodiversity Park, Delhi, India

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ABSTRACT: The present study comprises the analysis of soil samples across the park. The samples were analyzed for their temperature, moisture content, pH, salinity, electrical conductivity (EC), organic matter, nitrate, and phosphate contents. Results showed a direct proportional relationship between soil salinity and EC. Soil organic matter has also correlation with soil pH in which plots with high soil pH have less organic content. Contour of land affected soil characteristics in which sites with relatively low-land areas received high salinity, EC and phosphate content. But the most important finding was the role of vegetation. Plots which high plant cover performed to have soil with relatively neutral pH, high nitrate and phosphate content, but low salinity and EC values. Comparison to earlier condition showed that soil pH, salinity and EC were decreasing during five year period. Soil organic matter, nitrate and phosphate content have also been increasing significantly.

KEYWORDS: soil analysis, soil property, soil nutrient, soil reclamation, soil salinity, soil sampling

I. INTRODUCTION

Desertification does not only undermine efforts for sustainable development, but it is introducing new threats to human health, ecosystems and national economies of several countries. It was postulated that 6% (more than 800 million ha) of the world lands are affected by salinity [1]. Saline and/or sodic soil is also well-known to limit crop production and environmental quality. Excessive amounts of salts have adverse effects on physical and chemical properties of soil, microbiological processes and on plant growth [2].

In India, salinisation is one of the most serious problems confronting ecosystems in semi-arid and arid regions. Large area of land remains barren and uncultivable because of bad soil affected by salinity [3]. Plant growth in these highly saline-sodic soil is directly affected by high levels of salts mostly sodium chloride. One of the major causes of soil salinisation is evaporation of salty ground water due to shallow water tables [4].

Yamuna Biodiversity Park (YBP) which lies on the river basin area of Yamuna flood plain in the semi-arid region of Delhi has also problem in soil salinity. When the park first developed in 2002, the soil was found to be highly saline. The land was covered by a crust of salt deposition on its surface. This sodic characteristic of the soil that revealed to have pH of up to 9.8 makes it extremely difficult for the wild plant species to survive [5]. The problem of this saline-sodic soil has forced many scientists to work hard on bringing down the pH of the soil without using any chemicals.

YBP has applied phytodesalination techniques to reclaim its sodic soil. Many types of plants have been introduced to the park to reduce the soil pH and salinity and to enrich its nutrient content, so other sensitive plants can also share the habitats. The more improvement of soil quality, the more number of plant species can grow and survive in the park. Presently, after almost eight years operation, the plant communities in YBP have increased remarkably due to suitable condition of soil profile and nutrients required for plant growth.

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The aim of the study is to analyze different characteristics of soil in various types of mini forests which are designed and compiled in a biodiversity park. The soil properties include a number of physico-chemical parameters i.e. temperature, moisture, pH, salinity and electrical conductivity as well as mineral and nutrient contents including soil organic matter, nitrate and phosphate contents. To achieve the above, following objectives have been laid down, particularly: (i) soil sampling in various habitats, (ii) soil property analysis, and (iii) comparison of present condition of soil profile with the earlier condition described in any available secondary data.

II. STUDY AREA

Study was conducted in Yamuna Biodiversity Park, which is located in the region of Delhi, extended from 28°25'N to 28°53'N and 76°50'E to 77°22'E. The park itself is located at 28°44'N and 77°12'E on northern part of Delhi, specifically in Jharoda Majra Burari, near Jagatpur village, Wazirabad on western side of River Yamuna. Therefore, this park was originally a floodplain area and often experienced flooding in every monsoon season at about 3-4 decades ago [6]. YBP is located in an elevation of 682 ft above sea level and spread over an area of 437 acres. The park features two major areas i.e. the Visitor Area and the Nature Reserve Area, and provides almost 30 different biotic communities.

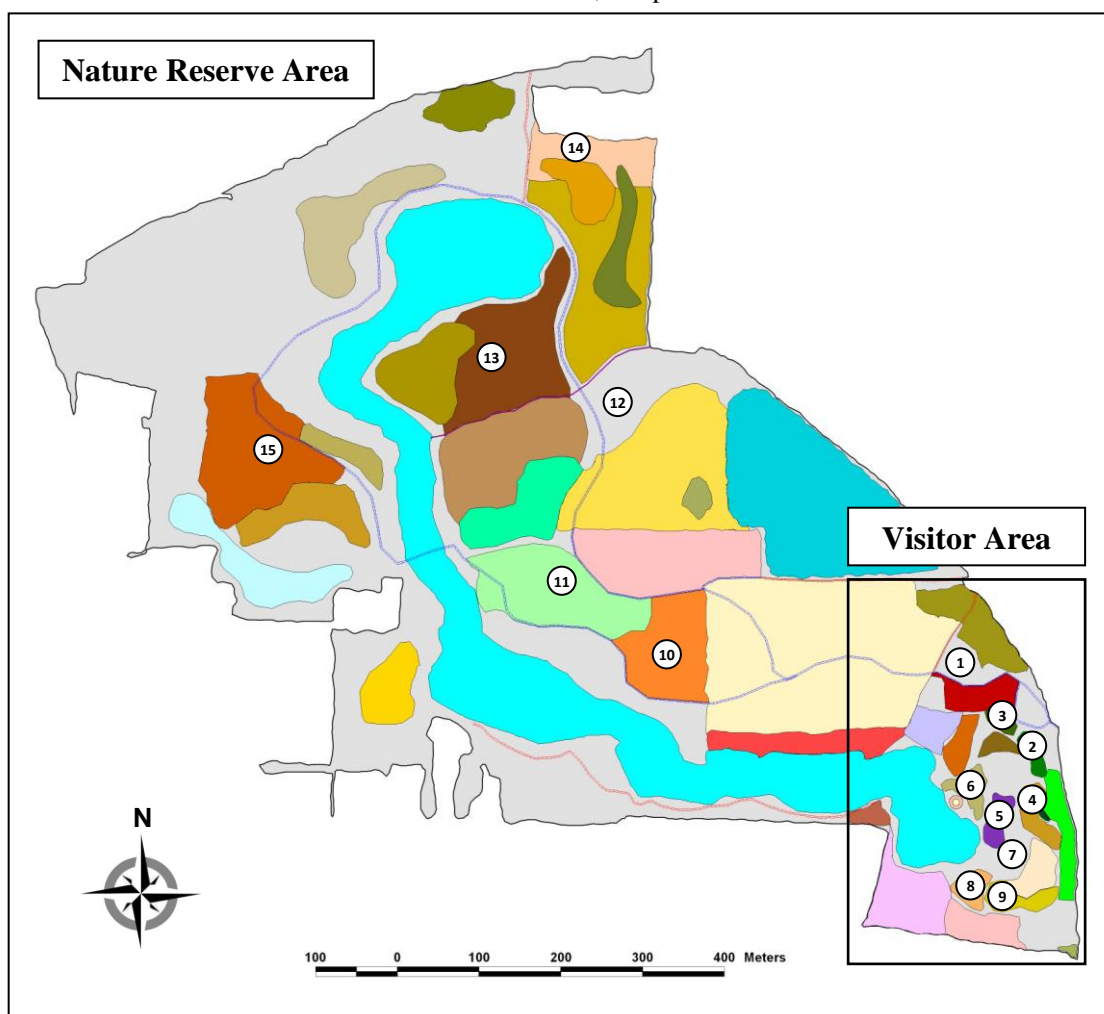


Fig. 1. Map of Yamuna Biodiversity Park showing location of 15 sampling sites.

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Tabel 1. Geographical locations of the plots.

No.	Names of Plant Community	Geographical Location		Area Location
1.	Mixed deciduous forest	N 28° 43' 55.8"	E 77° 13' 07.9"	in Visitor Area
2.	Subtropical mixed evergreen forest	N 28° 43' 53.9"	E 77° 13' 09.3"	
3.	Subtropical mixed semi-evergreen forest	N 28° 43' 54.6"	E 77° 13' 08.4"	
4.	Tropical thorn forest	N 28° 43' 51.4"	E 77° 13' 09.6"	
5.	Tropical moist deciduous forest with teak	N 28° 43' 51.3"	E 77° 13' 08.3"	
6.	Tropical dry deciduous forest with sal	N 28° 43' 52.2"	E 77° 13' 07.1"	
7.	Rangeland	N 28° 43' 49.0"	E 77° 13' 09.1"	
8.	Tropical mixed dry deciduous forest with bamboo	N 28° 43' 48.0"	E 77° 13' 06.9"	
9.	Tropical dry deciduous forest with teak	N 28° 43' 47.5"	E 77° 13' 08.2"	
10.	Hardwickia community	N 28° 43' 58.2"	E 77° 12' 55.6"	in Nature Reserve Area
11.	Grassland	N 28° 44' 00.7"	E 77° 12' 50.3"	
12.	Teak community	N 28° 44' 05.9"	E 77° 12' 52.9"	
13.	Tropical dry deciduous forest (Malwa forest)	N 28° 44' 06.1"	E 77° 12' 49.2"	
14.	Sal community	N 28° 44' 16.7"	E 77° 12' 53.2"	
15.	Mixed dry deciduous forest (Kuno forest)	N 28° 44' 04.7"	E 77° 12' 40.7"	

Of all forests and communities provided in the park, fifteen sites were selected as sampling locations among the designated habitats in which nine plots were located in the Visitor Area and the remaining six were in the Nature Reserve Area. All sites in both areas are protected and managed by joint-collaboration project between Delhi Development Authority (DDA) and the Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi [6]. Most of the plots in Visitor Area were mounds ranging from 480 to 1764 m². The map and the geographical locations of these 15 sampling sites are described in Figure 1 and Table 1 respectively.

III. MATERIALS AND METHODS

There are mainly two basic methods used in this study: soil sampling and soil physico-chemistry analysis. Stratified random sampling method was used to select locations of soil sampling points [7]. A number of quadrates sized 10×10 m² have been constructed as permanent plots in different habitat types, and geographical location of each sampling points were recorded using Global Positioning System (Garmin GPS 60™). Soil samples were collected from the sampling plots by using 4-ft long, 1½" bore diameter soil auger, stored in a number of zipper-sealed plastic pouches, labeled and taken to laboratory for further analyses.

Soil temperature was directly measured using wood-covered soil thermometer developed by SITA Thermometers Industries at the same time with that of soil collection. Soil samples were air-dried at room temperature (30°C) for some time, then grinded and screened before starting the analyses. Soil pH, salinity and electrical conductivity were measured by direct reading of digital pocket instruments from Eutech (i.e. pH Testr, Salt Testr and EC Testr low+ respectively) after dissolving and filtering the soil in some amount of distilled water. Soil moisture content was determined using gravimetric method (oven-drying method), while soil organic matter was estimated by Walkley-Black method [8]. Estimation of nitrate and phosphate content in soil used combination of chemical preparation method, filtration and direct reading of Portable Nitrate Photometer HI 93728 and Portable Phosphate Photometer HI 93713 respectively developed by HANNA instruments.

IV. RESULTS AND DISCUSSION

Analysis of Soil Physico-Chemical Properties

Soil Temperature

Soil temperature exhibits almost similar state between all forests in YBP. There were no significant differences between each other. Most of the temperatures range between 15 to 25°C. This range depends mostly on the climate of the city of Delhi, which is located above the Tropic Cancer, and the season when measurement takes place. However, the study

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found that three plant communities, i.e. Plot No. 10, 11 and 13 (Hardwickia community, Grassland and Tropical dry deciduous forest respectively) have higher soil temperature among others (Table 2). It might be due to those communities have smaller number of big trees. Big trees by their wide canopies might help on covering soil surfaces and protecting them from hot radiation of sunlight at daytime.

Table 2. Distribution of soil physico-chemical properties in different sampling plots in YBP in 2011.

Plot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature, °C	17.7	20.1	17.8	16.6	15.4	20.2	17.1	17.7	18.3	25.3	24.9	21.6	25.0	21.4	21.2
Moisture content, %	16.5	10.1	11.6	11.6	11.5	9.8	16.9	8.7	9.1	26.0	26.7	25.0	29.7	19.2	29.3
pH	7.41	7.80	7.13	7.24	7.32	7.70	7.36	7.18	7.27	6.82	7.01	7.06	7.90	7.20	7.22
Salinity, ppt	0.10	0.10	0.10	0.30	0.10	0.00	0.10	0.00	0.00	1.10	1.20	0.40	0.60	0.20	0.10
EC, µS/cm	259	163	164	703	207	112	170	130	96	1571	1679	1046	1437	481	353
Organic matter, %	0.30	1.33	2.81	0.37	1.41	1.92	1.70	0.67	0.07	1.33	2.30	1.85	2.07	3.18	3.78
NO ₃ -N, mg/100 g	8.9	16.0	11.5	4.8	10.0	7.8	8.2	13.0	10.1	3.7	10.5	10.3	9.0	4.1	11.5
PO ₄ -P, mg/100 g	15.2	8.0	19.0	4.8	7.2	6.4	18.6	5.0	5.6	3.6	7.6	7.2	7.8	5.6	8.4

Soil Moisture Content

Soil moisture content hardly depends on water content in the soils. High soil moisture content indicates that the soils have two main characteristics: (i) more water washing either from precipitation or from water flooding of neighboring water bodies, and (ii) less water evaporation from soils due to high cover of lands by relatively dense vegetation. Table 2 showed that forests in Visitor Zone (Plot No. 1 to 9) have less soil moisture content than forests in Plot No. 10 to 15 (all in Nature Reserve Zone).

The amount of water in the soil was mostly influenced by the quantity of precipitation occurred in that area. Therefore, soil moisture content would be higher in monsoon season. The difference in selecting sampling time sometimes created an error on soil study and made the data incomparable. This was also happened in this study. Soil samples of Plot No. 1 to 9 were collected one week before collecting samples of Plot No. 10 to 15. In between these two sampling time, there was a relatively huge rain occurred in this area. Therefore, soil in former plot has lower moisture content than the latter. Ideally measurement of soil moisture content is highly advisable to include all conditions in every season. But due to time constraint, this cannot be done completely in this work.

Soil pH

Acidity, or pH, salinity and conductivity of the soil highly affect plant growth. Meanwhile some plants also have their pH preferences for their growth. Soil that has pH lower or higher than these requirements will not serve as good habitats for some specific plants. In the other hand, plants can also slowly alter soil conditions to meet their preferences. Soil pH, salinity and conductivity can change by the time during plants grow in that particular area. The process needs time, maybe years or so, to meet suitable conditions that plants require. This is an example of reclamation or remediation process of the soil, which is often called as phytoremediation.

In general, most of the sites in YBP have recovered their soil pH from saline to neutral, except for Plots No. 2, 6 and 13 that still have pH above 7.5, while all the remainings have relatively neutral pH ranged from 6.5 to 7.5 (Table 2). Plot No. 11 has relatively neutral soil pH (7.01), because the site was relatively dense by small plants and grasses, whereas Plot No. 2 and 13 which have less vegetation cover in their soils are found to have high soil pH (7.8-7.9). The decline in soil pH during this period of time was due to the act of plants and soil microbes that help on degrade plant litter and convert it into humic acid (or later into humus) and, hence, slowly decline the soil pH.

Soil Salinity

Soil salinity was measured in ppt unit. It indicated the amount of salts contained in the soil. High amount of salts can be identified by clear white deposition present in the soil surface. Grassland showed high content of salinity followed by Hardwickia community. This is due to these two sites are low-land area and sometimes experienced flooding from

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water bodies or from precipitation run-off fallen from neighboring high-land areas or mounds. All forests in Visitor Area have low salinity. Soil salinity in Plots No. 6, 8 and 9 was even untraceable to ppt unit.

Salinity of the soil was also influenced the diversity and richness of plant communities and vice versa. Table 2 showed that Plots No. 10 and 11 have high salinity profiles (1.10 and 1.20 ppt respectively), and in reality both of them have low vegetation richness and diversity.

Soil Electrical Conductivity

The parameters of soil salinity and electrical conductivity (EC) were found to be closely related each other, because both parameters refer to the amount of ions present in the soils. The 2011 data presented similar profiles between these two parameters. Both have peak values on Plots No. 11 and 10, and showed relatively low EC values on all plots located in Visitor Area as compared to plots in Nature Reserve Area, except for the Kuno (Table 2). It may be due to sites and mounds in Visitor Area are mostly man-made sites and have experienced higher degree of tillage and soil hoarding, hence more-saline surface soil and less-saline deep soil were mixed well.

Comparison between EC values with vegetation profiles resulted in similar relation with soil salinity, in which the EC was found to have inversely proportional relation with the vegetation profiles. The reason of this similarity was that both parameters were influenced by the amount of free ions contained in the soil, mostly Na^+ and Cl^- ions. Therefore, they have, somehow, direct proportional relation between each other.

Soil Organic Matter

Soil pH, somehow, relates to soil organic matter (SOM), but inversely proportional. It means that lesser soil pH, more SOM. SOM represents amount of nutrients present in soil required for plant growth, either macro- or micronutrients. In simply way, SOM identifies the humus content in the soil as a result from decomposition of crop and microbial residues. Humus is acid in nature, because of its humic acid content. Therefore, large amount of humus or organic matter may generate more acidity in soil (or less pH value). From Table 2, it was found that Plots No. 3, 11, 14 and 15, which have lesser (neutral) pH values, were having higher SOM content as compared to other plots (e.g. Plots No. 2, 6 and 13) which have relatively high pH values, but lesser in organic matter content.

Nitrate-Nitrogen Content

One of most important nutrients required for plant growth is nitrogen. Nitrogen presents in soils can be measured as total nitrogen (N), nitrate (NO_3), nitrate-nitrogen ($\text{NO}_3\text{-N}$), ammonium (NH_4) or ammonium-nitrogen ($\text{NH}_4\text{-N}$). Nitrogen is important because it is the major constituent of all proteins, chlorophyll and nucleic acids. The deficiency of nitrogen will cause stunted growth and yellowish leaves.

The amount of nitrate-N represents the nitrogen content in soil. Table 2 described that Plot No. 2 (Subtropical mixed evergreen forest) and No. 8 (Tropical moist deciduous forest with bamboo) performed as the two highest nitrate-N content, while Plot No. 10 (Hardwickia community) was the least one. Here the relation between nitrate-N content and vegetation profiles was found. Having high nitrate-N content in their soil, Plots No. 2 and 8 have high plant diversity and density. Conversely, lowest nitrate-N content in soil at Plot No. 10 resulted in low vegetation.

Phosphate-Phosphorus Content

As general, phosphate-P content in YBP's soil was almost same to all sites, except for some plots in Visitor Area which showed extreme profiles. Plots No. 3, 7 and 1 in Visitor Area performed as the 1st, 2nd and 3rd highest phosphate-P content among others respectively. The phosphate-P content of these 3 plots was quite distinct to others which have phosphate-P content below 9 mg/100 g soil, while these three have values above 15 mg/100 g soil (Table 2).

High amount of phosphate-P in these plots may be due to these sites earlier was used as agricultural farming by villagers before the park was developed, especially Plot No. 1 and 3. Plot No. 7 (Rangeland) is low-land area and it has high amount of phosphate from run-off of fertilizer from its neighboring high-land area or mounds that have been washed away during precipitation. Soil in Rangeland has high phosphate-P content also because of its high plant diversity. Conversely, soil in Hardwickia community has low phosphate-P content due to its low plant diversity.

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Comparison of Soil Property Analysis between 2006 and 2011

Soil Temperature

Soil temperature can alter plant growth, especially at seedling stage. But in this study plant community was not found to affect much to soil temperature profiles. Though trees' canopy could cover and cool the soil surface, soil temperature was mostly affected by climate and seasonal variation in the forests through the year. As described in Figure 2 (a), soil temperature data collected in 2006 were higher than in 2011. This was due to the 2006 soil sampling was carried out in hot summer (Saha, 2006), while 2011 soil data were sampled in late winter or early spring.

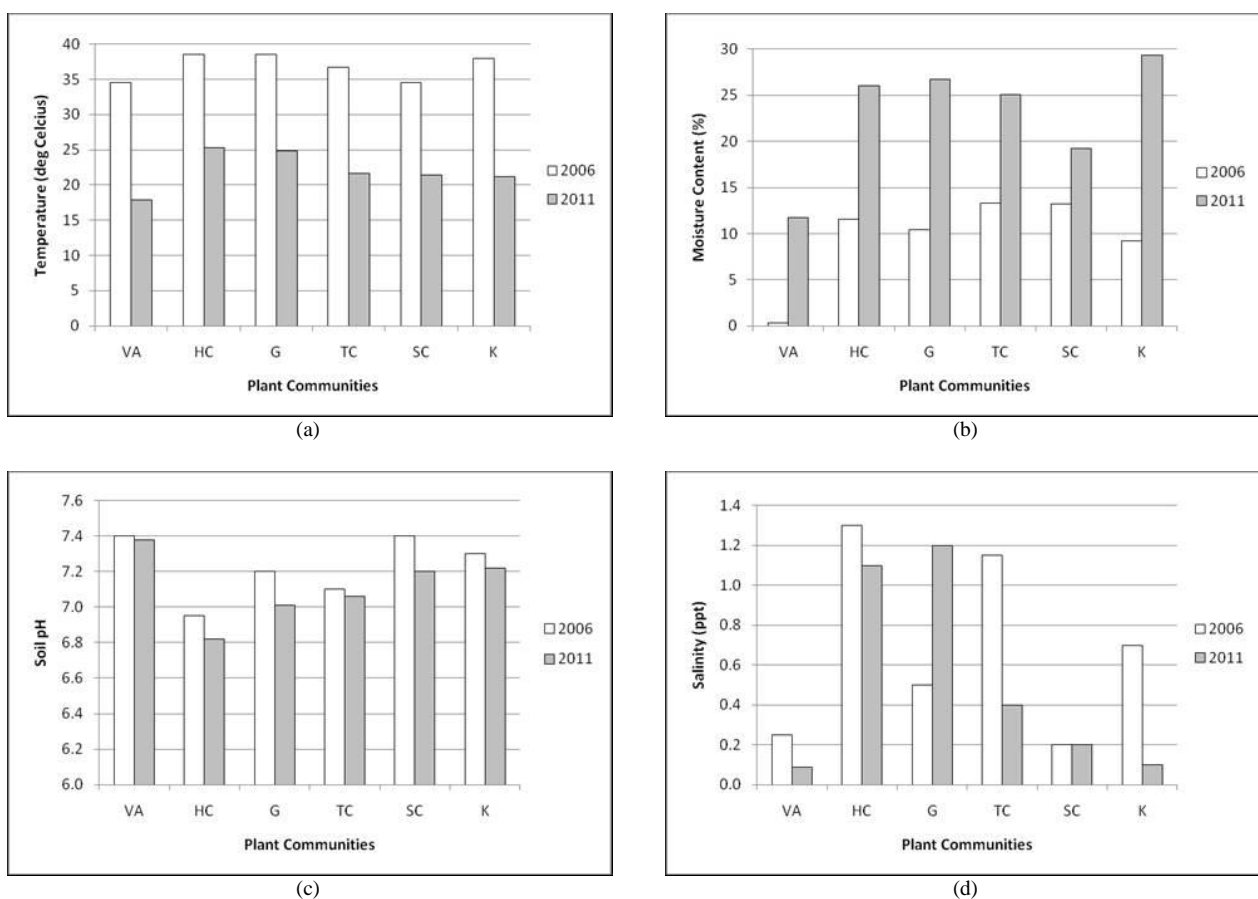


Fig. 2. Comparison of soil properties between 2006 and 2011 (a) soil temperature (b) soil moisture (c) soil pH (d) soil salinity.

Soil Moisture Content

Similar to soil temperature, soil moisture was also affected mostly by weather and seasonal conditions. Even though evaporation of soil moisture can be prevented by plants' cover, effect of air temperature and duration of sunlight during particular season influenced more. Soil collection conducted in midsummer of 2006 presented less soil moisture content than soils collected in late winter and early spring of 2011, as shown in Figure 2 (b). Effect of plants' cover to soil moisture was clearly figured in Table 2 where forests located in the Nature Reserve Zone, which have high soil cover, have higher soil moisture content as compared to forests in the Visitor Zone.

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Soil pH

The soil in Yamuna Biodiversity Park at early stage of its development has high pH, salinity and conductivity values that was not preferable for most of plants. In 2002 soil pH has reached 9.8 makes it difficult for the plants to survive (Saha, 2006). As time goes by, some specific plants were introduced, especially the one that having salt tolerant characteristics. More and more plants were then planted as well as the native species of Yamuna river basin were also reintroduced. Introducing number of plants species helps the soil to recover and to decrease its pH gaining in more suitable conditions to all plant species. Hence plant diversity of the area was increasing through the year. Till the year of 2006, more enhancement of soil pH can be revealed. Many areas or habitats then reached more neutral pH values around 7.0 to 7.2. The decrease in soil pH in YBP is still continuing till now, as described in Figure 2 (c).

The highest decline in soil pH was found in Sal Community (SC), while the lowest decline was in Visitor Area (VA). It is notably clear since SC has large number of plant density as well as high species richness.

Soil Salinity

Salinity of the soil was created by continual desertification along the Yamuna river basin. The basin area, or also called as Khadar area, often experienced flooding every monsoon season at about 3-4 decades ago. But when summer came, the area was faced to high intensity of solar evaporation. The basin was then dried up for few months lasting some salt depositions to remain on the land surfaces. This desertification continued regularly every year resulting on an accumulation of salt depositions that created the soils to have high salinity, pH and conductivity. The presence of salts was sometimes clearly identified from the white crusts found on the land surface that, in some stretch area of YBP, can be seen by naked eyes especially in area nearby or outline the water bodies. However, testing of soil in laboratory was the best way to prove it.

Figure 2 (d) showed that among six habitats studied, Teak Community (TC) and Kuno forest (K) have high decline in soil salinity. This correlates the facts that these two plant communities have high plant diversity and species richness.

Soil Electrical Conductivity

The important concern of soil parameter in YBP was the pH, salinity and electrical conductivity. Soil characteristics have changed significantly in YBP by times and years of its development. As general, most of the sites in YBP showed decrease in soil pH, salinity and conductivity from 2006 to 2011, as described in Figure 2 (c), 2 (d) and 3 (a).

An unpredictable phenomenon was found in Grassland community (G). Grassland showed an anomaly by performing an increase in two parameters: salinity and electrical conductivity. It may be caused by selection of different sampling plot within the site between 2006 and 2011. Another reason was that Grassland, which is a relatively low-land area, often experienced flooding or run-off due to precipitation from the high-lands or mounds on its peripheral communities that later, deposited some amount of salts on its soil surface. The accumulation of deposited salts in the Grassland soil, hence, resulted in an increase in soil salinity and electrical conductivity.

Soil Organic Matter

Observing soil parameter profiles in Figure 2 (d), 3 (a) and 3 (b) found a figure that Kuno forest (K), which has very distinct change in soil salinity and EC (in declining pattern) from 2006 and 2011, also experienced extreme change in soil organic matter (SOM) but in increasing pattern. The change in soil salinity, EC and SOM profiles within this five year period was relatively significant to the changes found in other plant communities. In other word, high decrease in soil salinity and EC in Kuno forest affect significant change in plant diversity, hence enhance more SOM there.

Nitrate-Nitrogen Content

Hardwickia Community (HC) was found to have experience in a long nitrogen deficiency through the year, as shown in Figure 3 (c). It has the smallest nitrate content of all sites since 2006 and was still being the smallest in 2011. The increase of nitrate (which refers to the increase of nitrogen) content in this site was very slow and needs more efforts from human intervention to help the plants gaining more nitrogen sources.

A different phenomena occurred in Kuno site (K). Even though Kuno has experienced in nitrogen deficiency in 2006, all plants there were succeed to increase nitrogen content in the soil, and bring Kuno to have the highest nitrate content

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in 2011. The success was probably due to maximum number of sapling were planted in Kuno which resulted in high increase in plant diversity and density.

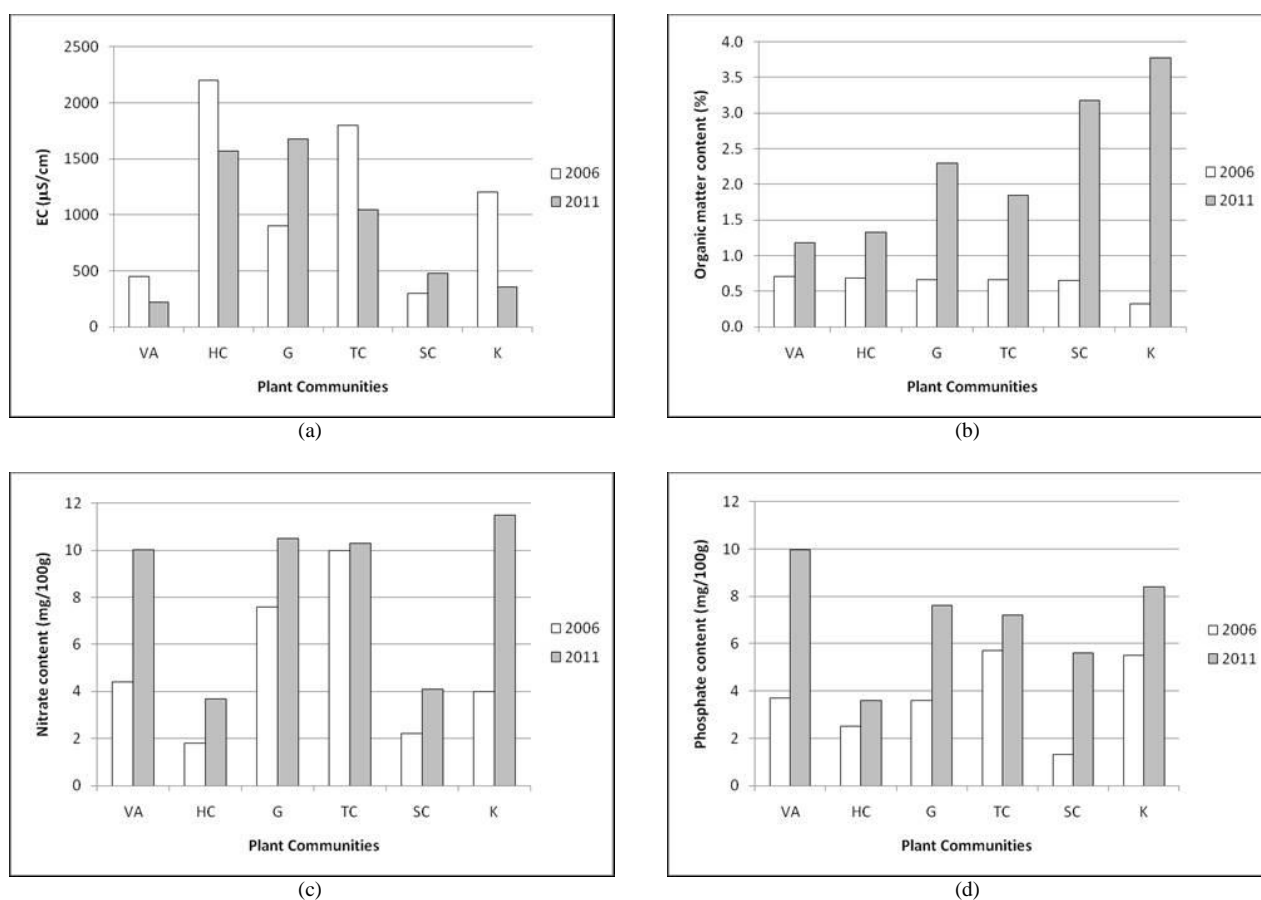


Fig. 3. Comparison of soil properties between 2006 and 2011 (a) soil EC (b) soil organic matter (c) nitrate content (d) phosphate content.

Phosphate-Phosphorus Content

Phosphorus is also the major nutrient required for plants. In laboratory analysis, phosphorus is calculated as the percentage of available phosphate ions (PO_4^{3-}) or phosphate-phosphorus (PO_4 -P). The content of phosphate-phosphorus in YBP's soil has increased from 2006 to 2011 at all sites, as presented in Figure 3 (d). High increase was found in Grassland (G) and Sal Community (SC). This is due to high plant density was found in these two sites and affected the soil chemical properties of the soil, particularly the available phosphorus. The increase was also higher in the Visitor Area (VA). Agricultural farming activities in the site before the park was developed have also affected the soil to have more N and P content. Overall, the increase in nitrogen and phosphorus content in the soil has affected to the increase in plant density as well as diversity, and vice versa. These N and P parameters were important in the study of soil, particularly in the purpose of soil reclamation and restoration, because the increase in these two parameters, together with potassium or K parameter, indicates the enhancement of soil nutrients and soil fertility [9,10].

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V. CONCLUSION

The study has extracted many correlations between various chemical properties presented in soil. Results showed a direct proportional relationship between soil salinity and conductivity, in which both parameters figured relatively low values on plots located in Visitor Area as compared to plots in Nature Reserve Area due to different treatment in tillage and soil hoarding. Soil OM has also correlation with soil pH, in which plots with high soil pH have less organic content as compared to plots with less (neutral) pH.

Contour of land, somehow, affected soil characteristics. For example, Grassland, which is a relatively low-land area, performed increases in soil salinity and EC due to run-off from high-land areas on its peripheral communities that deposited high amount of salts on its soil surface. Rangeland in Visitor Area is also low-land area and it has high phosphate content from fertilizer run-off from its neighboring mounds that has been washed away during precipitation. But the most important finding was the role of vegetation in maintaining enhancement of soil profiles. Plots which high plant density and diversity showed to have soil with relatively neutral pH, high nitrate and phosphate content. Conversely, less plant cover made the soil to have high salinity and EC values.

The data was then compared to earlier secondary study taken in 2006. The results showed many improvements in soil chemical properties during 2006 to 2011. Soil pH, salinity and EC were continuously decreasing during this five year period. Highly saline soil that mostly found in the early development of the park was improving to be more suitable for plant growth. Soil nutrients including organic matter, nitrate and phosphate content have also been significantly increasing to certain values as recorded by this study. This proved that the park has succeeded to reclaim its degraded saline-sodic soil and to restore soil nutrients to be more preferable for growing many plant species.

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