Environment and Ecology 40 (2A) : 482—490, April—June 2022
ISSN 0970-0420

Effect of Urban Managed Land Use on Seasonal Dynamics of Soil Properties

Bandna Kumari, Avinash Tiwari, Sangeeta Sharma

Received 10 October 2021, Accepted 10 February 202, Published on 26 April 2022

ABSTRACT

Urban managed system plays a vital role in maintaining urban green infrastructure and its sustainability. Soil provides sustainability to an ecosystem by supporting vegetation through integration of multiple processes including weathering, environmental input, leaching and biological cycling. Seasonal dynamics of soil nutrients under urban managed system provide information about the response of urban ecosystem to the environmental changes. An effective control of disturbed soil is essential for sustainable development and improving the quality of environment. The study was carried out by selecting two urban managed sites (site I - Sun Temple, site II - Jiwaji University Campus), located in Gwalior city of Madhya Pradesh, India. The physico-chemical parameters were analyzed in different seasons of the year and results revealed that the pH and EC in soil varied with different seasons. Nitrogen was highest during rainy while potassium and phosphorus during summer, calcium and sodium were found high during winter season. Soil N, P, Ca and Na were found greater at site I and potassium was found high at site II. Water soluble Na, Ca and K were also affected by environmental disturbances. The understanding the ecosystem sustainability with reference to nutrients becomes very important to further improve the urban environment.

Keywords Urban managed land use, Soil parameters, Seasonal changes.

INTRODUCTION

Maintaining healthy environment to improve the quality of people's life becomes very challenging in current world. Urban areas are more susceptible to anthropogenic activities, due to high standards of living, expansion of cities and industrialization (Galitskova and Murzayeva 2016). Managed land uses of urban forests are integral part of urban ecosystem which helps in regulation and recreation of healthy environment and provide many ecosystem services (Fan *et al*. 2014, Jim and Chen 2009). Urban forestry is helpful in controlling biotic and abiotic factors that influence the soil properties and act as an indicator of global changes (Yamashita *et al.* 2011, Olojugba and Fatubarin 2015, Pickett *et al.* 2011).

Bandna Kumari*, Avinash Tiwari, Sangeeta Sharma
School of Studies in Botany, Jiwaji University, Gwalior 474011, MP, India
Email: mebandna18@gmail.com
*Corresponding author

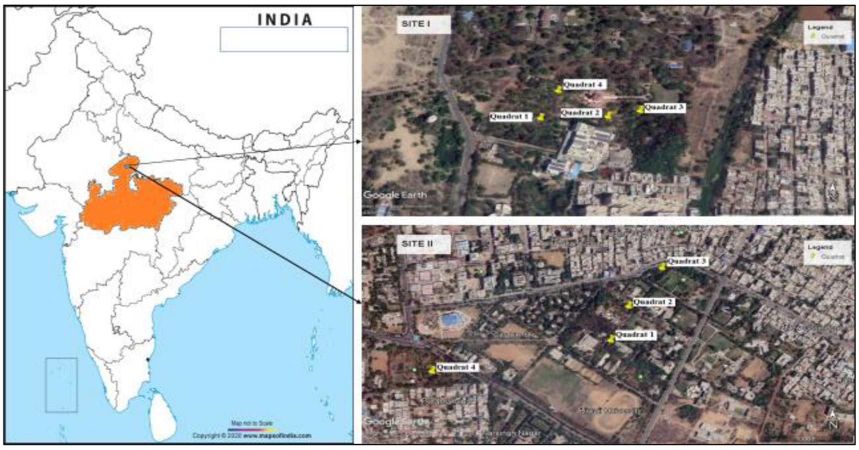

Fig. 1. Spatial distribution of selected plots in Gwalior urban forest (from Google Earth 2018).

Environmental disturbances and land cover changes along with chemical and physical gradients of environment affects the pedogenic processes under urban greenery (Zang *et al.* 2010, Olojugba and Fatubarin 2015, James *et al*. 2016), thus helpful in evaluating the interaction between people and environment (Pickett *et al.* 2011). Urban forest along with managed ecosystem generate significant ecosystem services such as carbon sequestration, removing air pollutant, reducing noise, regulating the microclimate, recreation and amenity, thus enhances the quality of life in urban area (Jim and Chen 2009). Nutrient cycling in an ecosystem also includes nutrient content in soil along with the biotic uptake and environmental input hence, play an important role in strengthening the plant growth and productivity (Deshmukh 2012, James *et al*. 2016, Pickett *et al*. 2011). Soil nutrients act as an indicator of ecosystem stability influenced by climatic condition, soil type and plant community. Nutrient dynamics on seasonal basis helpful in understanding the role of supply and interaction of these nutrients in different environment condition (Fan *et al.* 2014). Nutrient dynamics of soil has pedological as well as ecological importance (Olojugba and Fa-

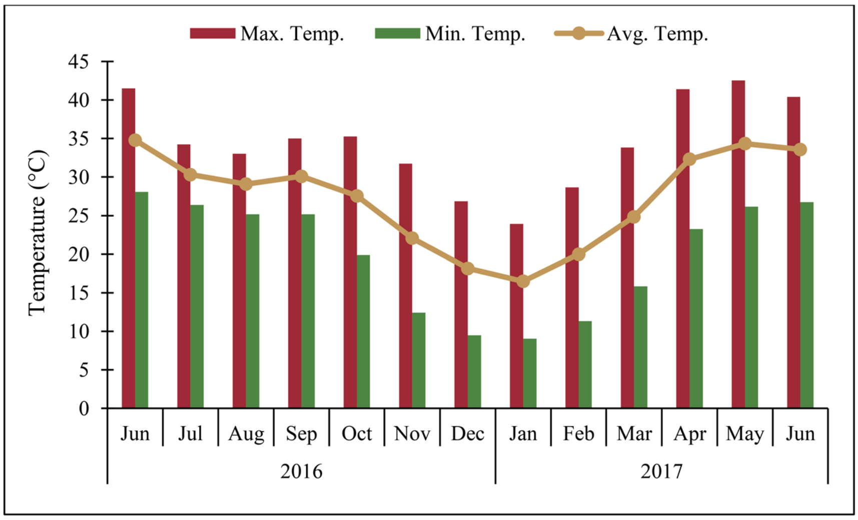

Fig. 2. Temperature observation during 2016-17.

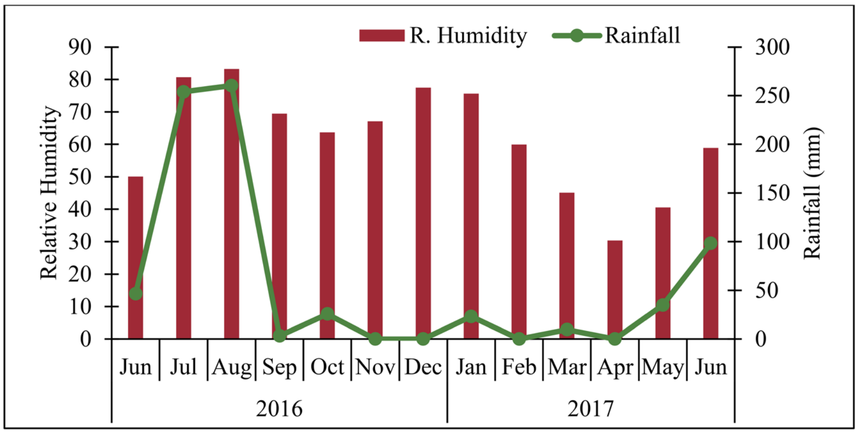

Fig. 3. Relative humidity and rainfall observation during 2016-17.

tubarin 2015, Fan *et al*. 2014). It not only affect the ion exchange in the soil but also affect the soil properties (Deshmukh 2012). Rapid urbanization has an impact on the physico-chemical properties of soil, hence, a scientific approach is essential for management of urban areas. The current study was aimed with the preliminary survey to assess the seasonal variation of soil nutrient status in urban managed system.

MATERIALS AND METHODS

Study area

The climate of Madhya Pradesh is characterized as semi-arid and extremely hot during May-June while extremely cold during end of December to January (Singh *et al.* 2014). The current study was focused on the two different sites Sun Temple (N 26014'10.72" and E 078013'07.49") designated as site I and Jiwaji University Campus (N 26012'11.10" and E 078011'44.88") as site II, located at Gwalior District of Madhya Pradesh during 2016-17 (Fig.1). The region have elevation of an average 197 meters above msl with three distinct seasons' viz., summer, rainy and winter. Temperature (maximum and minimum), rainfall and relative humidity were recorded during study period (Figs. 2,3).

Sampling techniques

Permanent quadrats of (20 m × 20 m) were established at each site and soil samples were collected with the help of soil corer at two different depths surface soil (0–10 cm) and subsurface soil (11-20 cm) during rainy, winter and summer season. The soil samples were stored in sealed polyethylene bags with proper marking, for further analysis.

Water soluble Ca, K and Na were also analyzed with deionize water saturation method and concentration was determined by the flame photometry.

RESULTS AND DISCUSSION

The soil texture of study area varies from sandy

Table 1. Physico- chemical parameters and their measurement methods.

Sl. No.	Parameters	Unit	Methods/References
1.	Physical		
	Soil texture		Brady and Weil 2002
	Bulk density	g/cm3	Wilde *et al.* 1985
	Soil moisture	%	Kadam and Shinde 2005
2.	Chemical		
	Soil pH		Jackson 1973
	Soil EC	Ds/m	Jackson 1973
	Available N	mg/kg	Kjeldahl (Subbiah and Asija 1956)
	Available P (as P_2O_5)	mg/kg	Olsen's (Olsen *et al.* 1954)
	Available K (as K_2O)	mg/kg	Hanway and Heidel (1952)
	Available Ca	mg/kg	Ammonium acetate (Jackson 1967)
	Available Na	mg/kg	Ammonium acetate (Jackson 1967)

Table 2. Seasonal and vertical changes in physico-chemical parameters.

Parameters	Depth (cm)	Site I Rainy	Site I Winter	Site I Summer	Site II Rainy	Site II Winter	Site II Summer
pH	0-10	8.93±0.02	8.70±0.05	8.02±0.02	7.68±0.07	7.41±0.05	7.11±0.04
	10-20	8.97±0.04	8.72±0.07	8.3±0.03	8.05±0.03	7.7±0.06	7.30±0.06
EC (dS/m)	0-10	0.25±0.04	0.20±0.06	0.15±0.02	0.19±0.11	0.16±0.09	0.12±0.08
	10-20	0.21±0.05	0.18±0.08	0.12±0.05	0.15±0.07	0.12±0.15	0.11±0.04
Bulk density (g/cm^3)	0-10	1.2±0.04	1.1±0.01	1.5±0.11	1.1±0.07	1.1±0.02	1.5±0.07
	10-20	1.3±0.01	1.2±0.03	1.8±0.09	1.2±0.07	1.1±0.03	1.7±0.05
Soil temp (°C)	0-10	29.4±0.21	20.1±0.79	34.7±0.43	29.1±0.59	21.6±0.31	34.9±0.51
	10-20	28.7±0.16	17.8±0.86	29.1±0.38	28.7±0.48	20.9±0.26	29.3±0.32
Soil moisture (%)	0-10	15.01±0.26	10.10±0.54	6.02±0.70	15.88±0.84	10.40±0.56	6.24±1.21
	10-20	14.61±1.14	9.70±0.53	4.63±0.60	15.04±0.59	9.80±0.73	4.45±0.57

loam (site I) to sandy clay loam (site II), Singh *et al.* (2014) showed the same results for Chambal region of Madhya Pradesh. Bulk density was highest during the summer and lowest during the winter at both the sites (Mora and Lazaro 2014). Status of bulk density at both the sites showed the increasing trend with increasing soil profile (Singh *et al.* 2016). The results of current study showed variation in soil moisture content during different seasons at both the sites and found that soil moisture during wet season was higher than that in the dry season. The moisture content was high at surface and decreased along with the soil depth (Tyagi *et al*. 2013) at both the sites. Soil moisture play important role in the study of soil respiration which directly or indirectly affects the physico-chemical parameters of soil (Wangluk *et al.* 2013). Soil moisture acts as an indicator of changing environment conditions and also a difficult parameter to assess, as it directly influenced by physical factors such as change in land use type, forest cover and topography (Tyagi *et al*. 2013). It also act as a factor to induce seasonal variation in soil respiration along with some hydrological factor (Tyagi *et al.* 2013, Wangluk *et al.* 2013).

Soil pH is an important parameter as it ensure the availability of plant nutrients and soil status (Deshmukh 2012). The pH of soil samples was alkaline and ranged from 7.1 to 8.9 (Singh *et al.* 2014). Soil pH was found highest during rainy season (Bhat *et al.* 2014 Yamashita *et al.* 2011) at both sites and site I showed higher pH value than that of site II. Soil pH reflects the important physical and chemical properties of the soil, as it directly related to accumulation of extractable ions (Singh *et al*. 2014). Soil pH showed increment with the increasing soil depth (Olojugba and Fatubarin 2015). Soil pH can be significantly correlated with the electrical conductivity (EC), soil moisture, N, P, Na and Ca. Soil EC ranged from the

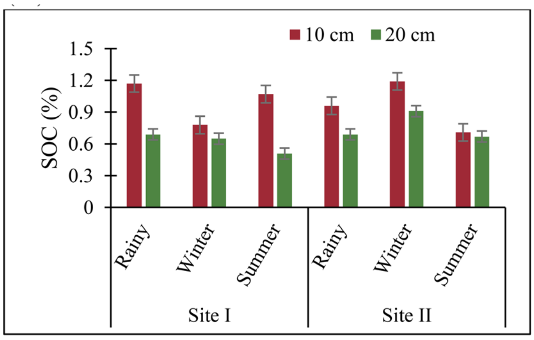

Fig. 4. Effect of seasonal variation on soil SOC (%).

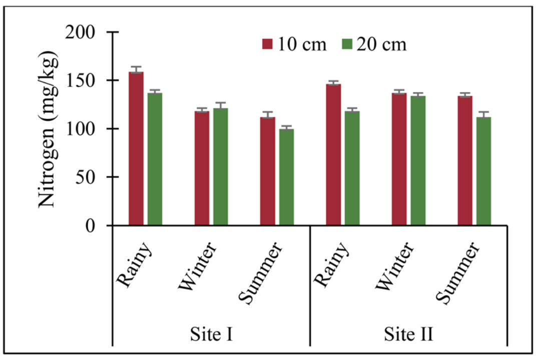

Fig. 5. Effect of seasonal variation on soil available nitrogen (mg/kg).

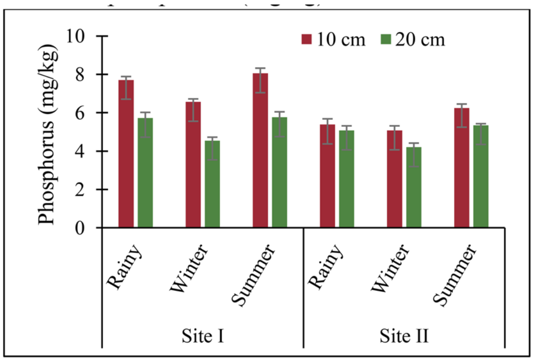

Fig. 6. Effect of seasonal variation on soil available phosphorus (mg/kg).

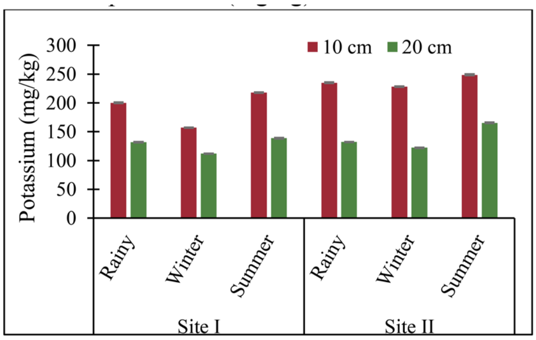

Fig. 7. Effect of seasonal variation on soil available potassium (mg/kg).

0.11-0.25 dS/m and was found highest during rainy season (Bhat *et al.* 2014, Sheikh et al. 2013) at both the sites and site I showed higher EC than site II. Soil EC showed decreasing trend with increased soil depth (Singh et al. 2016).

SOC concentration was ranged from 0.51-1.17 % at site I and at site II it ranged from 0.67-1.19 % (Fig. 4). The result showed that SOC was found highest at the upper surface than the sub-surface in the study area. At 10 cm of soil depth maximum SOC concentration was observed at site II (1.19%) during winter season and lowest was observed at site II (0.71 %) during summer season. While at 20 cm of soil depth site II (0.91 %) showed highest SOC content during winter season and lowest SOC content at site I (0.51 %) during summer season. SOC showed decreasing trend with increasing soil depth at both the sites (Fig. 4). The concentration of SOC differ significantly along with the soil depth although during different season it does not differ significantly. SOC showed a positive correlation with EC, soil moisture, N, Na and with Ca. Positive correlation coefficient between SOC and soil pH was found very low (Tables 1-3).

The value of the available N was ranged from 99.6-158.7 mg/kg at site I and at site II it ranged from 112-146 mg/kg (Fig. 5). Maximum values of available nitrogen was measured at surface horizon in comparison with sub-surface (Singh *et al.* 2016) except for site I during winter season. The availability of nitrogen was highest during the rainy season and lowest during the summer season (Zhang *et al.* 2010, Turner *et al.* 2015, Olojugba and Fatubarin 2015) at both the sites. The increase of nitrogen concentration during the wet season possibly due to enhancement

Table 3. Structural correlation coefficient of soil properties.

	pH	EC	Bulk density	Soil temp	Soil moisture	SOC	Available N	Available P	Available K	Available Na	Available Ca
Soil pH	1										
Soil EC	0.89	1.00									
Bulk density	-0.29	-0.55	1.00								
Soil temp	-0.25	-0.27	0.76	1.00							
Soil moisture	0.45	0.77	-0.77	-0.21	1.00						
SOC	0.04	0.22	-0.52	-0.28	0.44	1.00					
Available N	0.20	0.60	-0.63	-0.15	0.78	0.62	1.00				
Available P	0.50	0.25	0.65	0.61	-0.21	-0.30	-0.24	1.00			
Available K	-0.79	-0.65	0.55	0.76	-0.30	-0.05	-0.03	0.00	1.00		
Available Na	0.53	0.41	-0.61	-0.92	0.14	0.18	0.00	-0.27	-0.92	1.00	
Available Ca	0.24	0.56	-0.83	-0.61	0.65	0.63	0.87	-0.49	-0.36	0.44	1.00

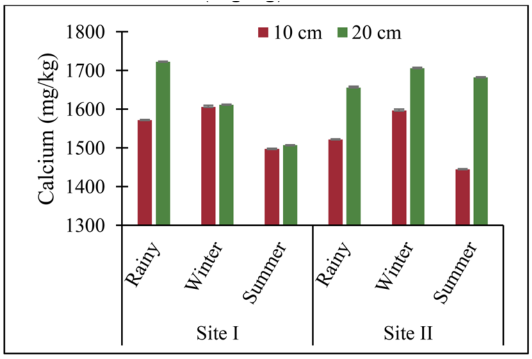

Fig. 8. Effect of seasonal variation on soil available calcium (mg/kg).

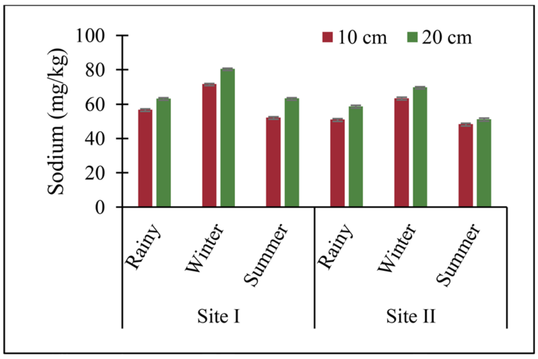

Fig. 9. Effect of seasonal variation on soil available sodium (mg/kg).

in nitrogen fixation by microbes along with increase mineralization rates (Olojugba and Fatubarin 2015). Although concentration of soil nitrogen does not differ significantly along with the soil depth and also during different seasons. Soil nitrogen can be positively correlated with the pH, EC, soil moisture, SOC and Ca.

Available phosphorus of the study sites ranged from 4.55 to 8.05 mg/kg at site I and 4.20 to 6.24 mg/kg at site II respectively (Fig. 6). Available phosphorus is one of the limiting nutrient for plant growth and was found highest during the summer and lowest during winter season (Bhat *et al.* 2014, Sheikh *et al*. 2013, Fan *et al.* 2014). High pH and calcium precipitation with phosphorus might be reducing the availability of phosphorus in the soil. Increased temperature and plant root activity promote enhancement in phosphorus during the summer season than the winter season (Zhao *et al.* 2009). Available P content was higher in surface horizons and decreased with depth (Singh *et al.* 2016). Phosphorus concentration differ significantly along with the soil depth on the other hand during different season its concentration does not differ significantly. The soil P can be positively correlated with the pH, EC, bulk density and soil temperature.

Available potassium ranged from 112.0 to 217.7 mg/kg at site I and 122.2 to 248.5 mg/kg at site II and was found highest in the summer season at both the sites (Fig.7). Soil potassium follow the same trend as followed by N and P hence, decreased with increased soil depth. This can be related to the higher values of organic form of these nutrients in surface layer (Babar *et al.* 2007). This study revealed that the concentration of soil potassium varied significantly along with the soil depth but not during different seasons. Available nutrients present in the soil affected by biological uptake (woody and herbaceous species) hence can also be related to nutrient storage in perennial biomass, atmospheric cycling and litter fall. Biological uptake is more important control over the distribution of potassium ions and it lack a positive correlation with both calcium and sodium (James *et al.* 2016).

The value of available calcium was ranged from 1497.4 to 1722.7 mg/kg at site I and 1445.0 to 1705.95 mg/kg at site II. Sodium was ranged from 52.25 to 80.5 mg/kg at site I and 51.02 to 69.83 mg/kg at site II. Calcium and sodium was found highest during winter season and lowest during summer season at both the sites (Figs. 8, 9). Available calcium was highest among all the nutrients present in the soil. Both Ca and Na increases along with the increasing soil depth. Sodium is not considered as an essential element as that of calcium, but its concentration in soil act as an indicator of salinity or alkalinity. In semi-arid conditions Ca showed more value than the other cations (K+ and Na+) (Deshmukh 2012). The concentration of soil available calcium varied significantly along with the soil depth but not during different seasons. The sodium was found to be higher at subsurface level than the surface level might be due to base rich environment (Deshmukh 2012). The results also revealed that concentration of available

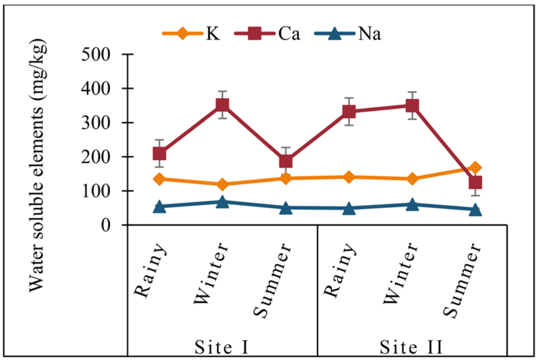

Fig. 10. Water soluble potassium, calcium and sodium at 10 cm soil depth.

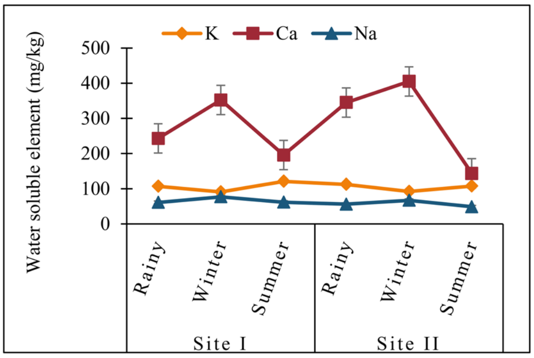

Fig. 11. Water soluble potassium, calcium and sodium at 20 cm soil depth.

sodium differ significantly during different season but does not differ significantly along with the soil depth. A positive correlation between calcium and sodium was observed and also with other soil parameters such as pH, EC, soil moisture and SOC (Table 3). Calcium can also be positively correlated with available nitrogen.

Soil carbon is an important factor which regulate the cations (K^+, Ca^+ and Na^+) and also partially accountable for their vertical distribution within different soils. Change in potassium or sodium content can be observed with depth in response to soil carbon concentration changes. The concentration of potassium does not increase with soil depth as the concentration of calcium and sodium increases with soil depth (James *et al.* 2016). Because vertical distributions of potassium follows a different trajectory hence, differ considerably from calcium and sodium and does not related to the soil carbon as closely as calcium related to it. This can be due to dominate control of processes other than leaching (biological uptake and its cycling) on potassium distribution within the soil (Jobbagy and Jackson 2001). High concentration of potassium was found in plant tissue thus supply can be limited in the soil. The release of potassium and sodium ions in the soil solution is the result of total ionic concentration and leaching rate (James *et al*. 2016).

Among water soluble elements potassium ranged from 91.1-137.2 mg/kg at site I, 92.44-168.8 mg/kg at site II, calcium ranged from 187.9-351.73 mg/kg at site I, 125.8-404.8 mg/kg at site II and sodium ranged from 50.67-77.13 mg/kg at site I and 46.0-67.0 mg/kg at site II (Figs. 10,11). Results revealed that concentration of water soluble calcium and sodium varied significantly during different season but not differ significantly along with the soil depth. On the other side water soluble potassium differ significantly along the soil depth but not during different seasons.

Soil showed more selectivity for potassium ions than sodium ions, but at low temperature the selectivity for sodium ions was increased (Blank *et al.* 2010). This can also be observed in current study, sodium concentration was found high during winter season. Increased concentration of water soluble sodium in soil was induced due to soil degradation and enhance clay dispersibility in that area (Nguetnkam and Dultz 2011). Additional nutrients can be applied to reduce the concentration of water soluble sodium in the soil (Nguetnkam and Dultz 2011). More stability was shown by sodium salt than other soil salt solution and makes the soil more toxic (Richards 1954). The distribution of cations in soil is affected by biological (plant) uptake and leaching. Plant utilize the nutrients from soil and recycled them to the soil again by litter fall decomposition (James *et al.* 2016). Pedogenic process of soil were affected by cations concentration and enhancement in soluble salts can produce harmful effect in soil. Soil with more available cations requires special attention (Richards 1954). Soil nutrients were influenced by seasonal variation which further affect the chemical properties of the soil. In the current study pH, EC, nitrogen and soil moisture were estimated high in rainy, the other factors like soil potassium and phosphorus were found increased in summer whereas calcium and sodium were found high during winter season. Nutrient pools of all extractable/available elements except K were greater at site I than the site II and were in the following order: Ca > K > N > Na > P at both study sites. Comparing the surface and sub-surface layer it appears that the surface layer display highest values for nutrients (except Ca, Na and pH which were found highest at sub-surface layer), soluble ions, electrical conductivity (Nguetnkam *et al.* 2011). Both the sites contain good amount of biodiversity and can be enhanced further by good management practices. Ecological benefits of soil conservation includes nutrient cycling, hydrological cycling, soil quality and climate change (Lal 2014).

CONCLUSION

Soil provides necessary support for vegetation and its conservation is important for sustenance of environment. The condition of soil provide us a chance to examine the ecosystem structure and its function under immense pressure of rapid growth in urbanization. The present study mainly aim to establish the positive role of soil in maintaining the nutrient cycles in urban managed land use system. Nutrient status and its availability in soil is dependent on the factors like environmental conditions, vegetation type and tree species. Management practices are most important to strengthen the soil quality which further helpful in improving biodiversity, water quality and renewability, enhancing soil rigidity to climate change and mitigating climate change. The study of physical and chemical characteristics of soil provides a considerable information about the quality of management type present in the urban area. Though the rate of change in soil quality varies from site to site, it is mainly influenced by the anthropogenic disturbance. Proper conservation measures should be taken to enhance the quality of life in urban ecosystem.

ACKNOWLEDGEMENT

The authors express gratitude to Jiwaji University Gwalior for providing financial support and School of Studies in Botany, Jiwaji University for necessary laboratory facilities to carry out the research work. The authors are also thankful to the management committee of Sun Temple for their support and cooperation during the research program. India Meteorological Department, Meteorological office, R. K. Thatipur, Gwalior (MP) is also acknowledge for providing needful data of study area.

REFERENCES

Babar S, Rathod PK, Narkhed AH, Rathod SD, Yewale AC (2007) Studies on forms of potassium and nutrients status of soil in central and eastern Vidarbha region of Maharashtra. *Asian J Biol Sc*i 2(2): 102-109.

Bhat BA, Sheikh MA, Tiwari A (2014) Impact of various edaphic factors on AMF spore population and diversity in Catha ranthus roseus at Gwalior. *Int J Pl Sci* 9 (1): 1-6.

Blank RR (2010) Effect of temperature on potassium and sodium exchange in a Sierra Nevada Riparian soil. *Soil Sci Soc Am* J 74: 105–106.

Brady NC, Weil RR (2002) The nature and properties of soils. 13th edn. Macmillan Publishing Co. New York, NY.

Deshmukh KK (2012) Studies on chemical characteristics and classification of soils from Sangamner area, Ahmednagar District, Maharashtra, India. *Rasayan J Chem* 5(1): 74-85.

Fan J, Wang JY, Hu XF, Chen FS (2014) Seasonal dynamics of soil nitrogen availability and phosphorus fractions under Urban forest remnants of different vegetation communities in Southern China. *Urban For Urban Greening* 13: 576–585.

Galitskova YM, Murzayeva AI (2016) Urban soil contamination. *Procedia Engg* 153: 162 – 166.

Hanway JJ, Heidal H (1952) Soil analysis methods as used in lowa state college soil testing laboratory, lowa state college agriculture. *Agric Bull* 57: 1-13.

Jackson ML (1967) Soil chemical analysis. Constable Company Limited, London.

Jackson ML (1973) Soil chemical analysis. Prentice Hall of India (P) Ltd, New Delhi.

James J, Littke K, Bonassi T, Harrison R (2016) Exchangeable cations in deep forest soils: Separating climate and chemical controls on spatial and vertical distribution and cycling. *Geoderma* 279: 109–121.

Jim CY, Chen WY (2009) Ecosystem services and valuation of urban forests in China. *Cities* 26: 187–194.

Kadam JR, Shinde PB (2005) Practical Manual on Soil Physics – A method manual. Department of Agricultural Chemistry and Soil Science, PGI Rahuri, pp 29.

Lal R (2014) Soil conservation and ecosystem services. *Int Soil Water Conserv Res* 2(3): 36-47.

Mora JL, Lazaro R (2014) Seasonal changes in bulk density under semiarid patchy vegetation: The soil beats. *Geoderma* 235: 30–38.

Nguetnkam JP, Dultz S (2011) Soil degradation in Central North Cameroon: Water-dispersible clay inrelation to surface charge in Oxisol A and B horizons. *Soil Tillage Res* 113: 38–47.

Olojugba MR, Fatubarin AR (2015) Effect of seasonal dynamics on the chemical properties of the soil of a Northern Guinea savanna ecosystem in Nigeria. *J Soil Sci Environ Manag* 6(5): 100-107.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. US Department of Agriculture Circular No. 939.

Pal DK, Srivastava P, Bhattacharyya T (2003) Clay illuviation in calcareous soils of the semi-arid part of the Indo-Gangetic Plains, India. *Geoderma* 115: 177– 192.

Pickett STA, Cadenasso ML, Grove JM, Boone CG, Groffman PM, Irwin E, Kaushal SS, Marshall V, McGrath BP, Nilon CH, Pouyat RV, Szlavecz K, Troy A, Warrenm P (2011) Urban ecological systems: Scientific foundations and a decade of progress. *J Environ Manag* 92: 331-362.

Richards LA (1954) Diagnosis and Improvement of Saline and Alkali Soils (United States Department of Agriculture: Washington).

Sheikh MA, Bhat BA, Tiwari A, Thakur A (2013) Impact of physico-chemical parameters of soil on AMF diversity during different seasons in Gwalior region. *Int J Agron Pl Prod* 4(12): 3284-3288.

Sheikh MA, Sharma S, Tiwari A (2017) Phyto-sociological characters and biodiversity of sacred grove a preliminary study. *Int Res J Environ Sc*i 6(1): 67-69.

Singh YP, Gupta N, Yadav S, Tomar RS, Yadubanshi NPS, Dubey SK (2016) Characterization of sodic soils and suggestions for management of Chambal command area of Madhya Pradesh. *J Ind Soc Soil Sci* 64 (2): 111-119.

Singh YP, Raghubanshi BPS, Tomar RS, Verma SK, Dubey SK (2014) Soil fertility status and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. *J Ind Soc Soil Sci* 62(4): 369-375.

Subbiah BV, Asija GL (1956) A rapid procedure for the determination of available nitrogen in soils. *Curr Sci* 25: 259-260.

Turner BL, Yavitt JB, Harms KE, Garcia MN, Wright SJ (2015) Seasonal changes in soil organic matter after a decade of nutrient addition in a lowland tropical forest. *Biogeochemistry* 123: 221-235.

Tyagi JV, Qazi N, Rai SP, Singh MP (2013) Analysis of soil moisture variation by forest cover structure in lower western Himalayas, India. *J For Res* 24(2): 317−324.

Wangluk S, Boonyawat S, Diloksumpun S, Tongdeenok P (2013) Role of soil temperature and moisture on soil respiration in a teak plantation and mixed deciduous forest in Thailand. *J Trop For Sci* 25(3): 339–349.

Wilde SA, Corey RB, Iyer JG, Voigt GK (1985) Soil and Plant Analysis for tree culture. Oxford and IBH Publishing Co, New Delhi.

Yamashita N, Ohta S, Sase H, Kievuttinon B, Luangjame J, Visaratana T, Garivait H (2011) Seasonal changes in multiscale spatial structure of soil pH and related parameters along a tropical dry evergreen forest slope. *Geoderma* 165: 31–39.

Zhang K, Xu X.-N., Wang Q (2010) Characteristics of N mineralization in urban soils of Hefei, East China. *Pedosphere* 20(2): 236–244.

Zhao Q, Zeng D.-H., Fan Z.-P., Yu Z.-Y., Hua Y.-L., Zhang J (2009) Seasonal variations in phosphorus fractions in semiarid sandy soils under different vegetation types. *For Ecol Manag* 258: 1376–1382.