Pak. j. sci. ind. res. Ser. B: bio. sci. 2022 **65B**(1) 37-44

An Assessment of Water and Soil Parameters Using Geospatial Techniques, A Case Study of Botanical Garden of University of the Punjab, Pakistan

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(received November 12, 2019; revised September 29, 2020; accepted October 8, 2020)

Abstract. This paper presents an in depth analysis of geospatial characteristics of water and soil parameters and its impact on herbs productivity. The study area considered for this research was Botanical Garden, University of the Punjab, Lahore Pakistan. Eleven soil samples and six water samples were collected from eleven sections and six sections of botanical garden respectively. Seven water parameters EC, Ca, Mg, Na, CO_3, HCO_3 and Cl were studied, while for soil EC, pH, organic matter, K and P were examined. Interpolation maps were formed to show the spatial pattern of the selected water parameters and graphical representation was done for soil parameters' analysis. Directional distributional ellipse (GIS statistical analysis) was performed to show the distribution of soil and water parameters and no abnormalities were found in the results which indicates that the soil and water is suitable for the productivity of plants and herbs found in the garden.

Keywords: interpolation, raster maps, statistical analysis, directional distributional ellipse.

Introduction

Botanical gardens are sole and absolute public green spaces. Botanical gardens are considered as the institutions (Botanical garden conservation international BGCI) containing comprehensive plant species for displaying, conservation, scientific research and educational purposes (Wyse Jackson and Sutherland, 2000). Web of almost 2200 global botanic gardens in 153 countries are assumed to be ecologically significant in conservation and mobilization of plant genetic resources for local as well as global development and expected to be a unique and particular identity of a society/community (Kuzevanov and Sizykh, 2006). Diverse plant species are grown with the aim of preservation and conservation in botanical gardens (Dosmann, 2006) wild populations of plants have been promoted by these gardens (Falk *et al*., 2006) and this can be considered for recreation, physiological restoration and also for academic educational activities this way unique and diverse flora can also be appreciated (Smith, 2019; Ballantyne *et al*., 2008). The role of botanical gardens for preservation of biodiversity and ecological innovations for human well-being is so diverse.Special gardens of spiritual value have been established by various nations for instance, the Japanese gardens, the english walled gardens, etc. The main aim of establishing such gardens was the demand from influential people (to some extent public) for collection of rare plant species from remote area for exotic, attractive and medicinal purposes.

Water and soil play to be pivotal factors for plant growth. Hydrogen, oxygen and carbon comes from water and air and the soil provides macro and micro nutrients (Miller *et al*., 1999). Fertility is the quality of soil to contain nutrients essential for growth of plants. The fertile soil always enjoys sufficient and significant elemental supply of nutrients which are needed by plant (Mgbenu and Egbueri, 2019). Significant quantity of debris of past plantation, uniform texture and the ability of soil to fulfil the requirements of water and air for plants, makes a soile i-e fertile soil. Fertile soils also have significant organic matter up to all levels/depths. Nutrient value of soil is also in the form of organic matter and minerals but cannot be utilized until they decay (National Research Council, 1993). Available nutrients may also be present as dissolved ions in soil water, which are most readily available form of plant nutrients. Out of sixteen elements present in soil, thirteen are originated from parent rock material, from which soil develops. These all are essential component of soil and plant growth.

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Study area. The botanical garden of University of the Punjab, Quaid-e-Azam campus is located at 31.4790 N̊, 74.2662 E̊ within the campus boundaries and it is controlled and maintained by the Department of Botany. It covers the area of about 247 km^2. This garden is regarded as the second largest beautiful garden in Lahore. Botanical garden is extending across 50 acres as it has preserved a broad diversity of living plants and trees belonging to different habitats. The garden has been majorly divided into 15 sections based on different categories of plants and trees and they all are labelled with their botanical names for their sustainability, conservation and most importantly for scientific research purposes.

Therefore, in the present exploration an effort has been made to study the concentration of water and soil physico-chemical parameters in the collected samples from botanical garden using geospatial analysis to monitor whether they are suitable for irrigation and plant growth or not.

Materials and Method

This section illustrates all the methodology opted for this study.

Sampling and analysis. Primary data collection was done by gathering 11 soil and 6 water samples by adopting random sampling technique from various sections of the botanical garden as shown in Fig. 3 (a & b) and Fig. 4. Soil samples were gathered out at 10 cm depth by using trowel and was carefully labelled in zip-lock bags. Similarly, water samples were also collected in plastic bottles and were labelled eligibly. Geographic coordinates of all sample points were collected through a GPS device (explorist 100) of Magellan Company which are illustrated in Table 1 and 2 below respectively. The gathered samples were then

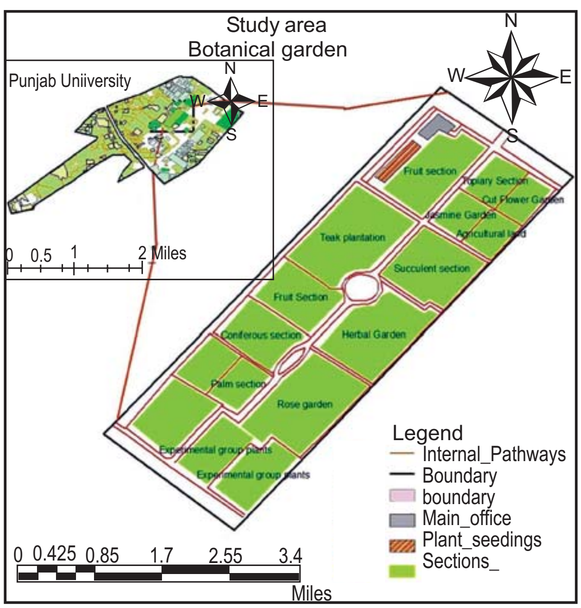

Fig. 1. Showing the study area. Source: Anwar, 2019

Fig. 2. Showing botanical garden of Punjab University.

Table 1. Geographic coordinates of soil sample sites

Location	Latitude	Longitude
Teak plantation	31° 30' 2.8692"	74° 18' 5.6124"
Coniferous section	31° 29' 55.5648'	74° 17' 55.5324"
Succulent section	31° 29' 57.3072"	74° 18' 1.2492"
Herbal garden	31° 29' 55.428'	74° 17' 59.4996"
Topiary section	31° 30' 2.8224"	74° 18' 5.58"
Palm section	31° 29' 53.6028'	74° 17' 54.744"
Rose garden	31° 29' 52.8576"	74° 17' 56.1264"
Fruit section	31° 30' 2.9016"	74° 18' 2.9952"
Cut flower garden	31° 30' 2.0484"	74° 18' 6.8868"
Agricultural land	31° 30' 0.5976"	74° 18' 5.094"
Jasmine garden	31° 30' 0.9324"	74° 18' 3.7008"

Table 2. Geographic coordinates of water sample sites

Location	Latitude	Longitude
Herbal garden	31° 29' 55.428"	74° 17' 59.4996"
Succulent section	31° 29' 57.3072"	74° 18' 1.2492"
Topiary section	31° 30' 2.8224"	74° 18' 5.58"
Fruit section	31° 29' 57.246"	74° 17' 56.9112"
Rose garden	31° 29' 52.7352"	74° 17' 57.1524"
Jasmine garden	31° 29' 59.3088"	74° 18' 2.0844"

Fig. 3. (a & b): Showing soil sample collection.

transported to the laboratory for physio-chemical characterizations. Water samples were tested for EC, Ca^+, Mg^+, Na^+, HCO^{3+}, and Cl-and were compared with FAO guidelines. Soil parameters were tested for EC, pH, OM, K and P and were adapted from "Technical Guide for Chemical Analysis of Soil and Water" revised by (Khan and Rafiq,1980). Phosphorus was evaluated by colorimetric technique and potassium by flame photometer (AFP 100).

Concept of IDW interpolation method. IDW (inverse distance weighted) is one of the universal mechanism for interpolation. It's one of the pivotal geospatial tool that helps to generate the values of unknown points from known points. The values to unknown points are calculated with a weighted average of the values available at the known points (Tuncay *et al*., 2016; Yasrebi *et al*., 2016). The sampling locations were stored as latitude / longitude data in degree, minute, seconds (DMS) unit. The data of all the sampling locations were converted into decimal degrees. All the converted data was entered into an excel file. This text file was used for analysis. For the interpretation of the data, The Spatial Analyst Tool of GIS software was used.

Fig. 4. Showing water samples collection.

Spatial statistics method. Directional distributional ellipsoid was employed to show the progression of water and soil sample points by calculating the standard distance separately in the x, y and z directions. That ellipsoid showed the water and soil sample points in an elongated polygon and hence pointing towards a particular direction.

Results and Discussion

The spatial distribution and the concentrations of various physico-chemical parameters of water samples collected from the different plots of the botanical garden are presented respectively in the form of Interpolated Distance Weighted Maps in the Fig. 5 (a, b, c & d).

Bicarbonate (HCO_3). Bicarbonate uptake in aquatic plants is a vital factor for distribution of species. The high concentration of bicarbonates (7.4-8meq/L) was found along the Succulent section, Teak plantation and the Topiary section of botanical garden this was mainly due to the presence of the tropical hardwood tree species and desert plants while low concentration was found along the rose garden, palm section and experimental

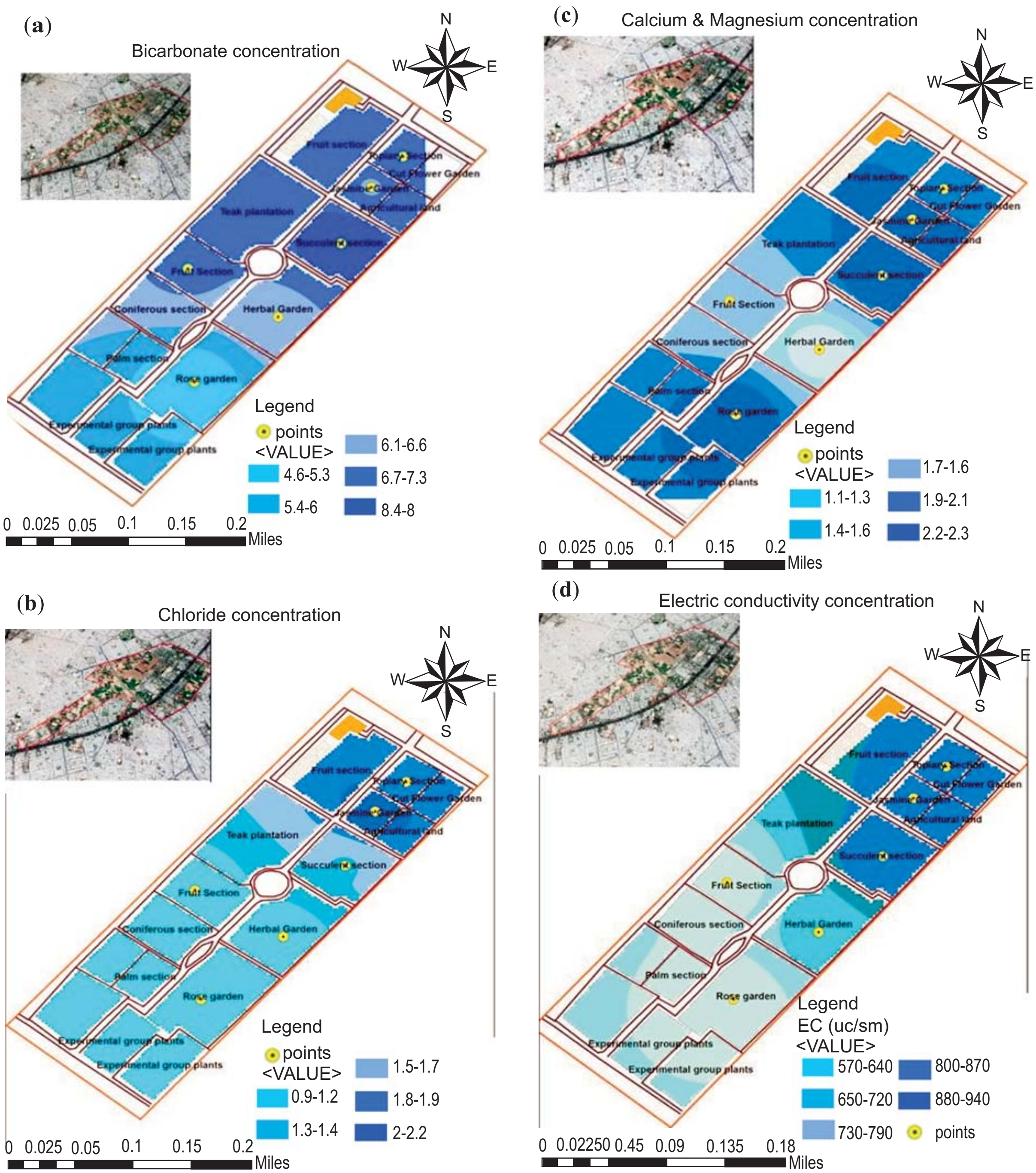

Fig. 5. Interpolated distance weighted map showing concentration of (**a**) bicarbonates (**b**) calcium and magnesium (**c**) chloride (**d**) electric conductivity.

section. The results revealed that HCO_3 concentration in water is suitable for the plant and crops production.

HCO_3 (meq/L)	Degree of restriction on use
<1.5	No restriction
1.5-7.5	Slight to moderate
>7.5	Severe

Calcium and magnesium. Hardness of water can be calculated through the level of calcium and magnesium. Excessive hardness is probably due to bulk of sewage and detergent into the lake from the nearby localities (Odiyo and Makunga, 2018). The average range of Ca and Mg concentration (2.2-2.3meq/L) were found to be in all the sections of botanical garden which revealed that water quality was favourable for plants growth (Tombuloglu *et al*.,2019; Sharma *et al*., 1996).

Parameter	Optimum range (meq/L)
Ca (EW=20)	2-5
Mg (EW=12)	0.4-2.1

Chloride. The results of water analysis revealed that normal range of chloride concentration was found along the Topiary section, cut flower garden, jasmine garden and fruit section ranging from (2-2.2meq/L) while remaining sections possessed low concentration as high concentrations of chloride can restrict the plant growth.

Chloride	Degree of Problem
>4	Nill
4-10	Increasing problem
>10	Severe problem

Electric conductivity (EC). EC is one of the most influential water quality parameter. Salinity(proportion of dissolved salts in water) is increased by dissolved ions and by conductivity, both of these characteristics are related (Fact sheet implemented by clean water Team by Katznelson in 2004). The increased EC concentration was found along the Succulent section, Topiary section, cut flower garden and Jasmine Garden ranging from (880-940 1500µs/cm), while low concentration was found along the coniferous section, palm section, rose garden and fruit section. EC in all collected water samples were found to be within the permissible limits of FAO (1500µs/cm). Below mentioned (Table 3) shows the laboratory analysis of physico-chemical parameters of water samples.

Table 3. Laboratory analysis of physico-chemical parameters

Location	Electrical conductivity (EC)	Calcium magnesium (meq/L)	Bicarbonate (meq/L)	Chloride (meq/L)
Herbal garden	750	1.1	6.4	1.0
Succulent section	940	2.3	8.0	1.4
Topiary section	890	1.9	7.0	1.8
Fruit section	580	1.6	6.8	1.0
Rose garden	570	2.3	4.6	0.9
Jasmine garden	890	2.3	6.6	2.2

Distribution of physico-chemical parameters of soil samples. The importance of soil fertility plays a significant role for plant nutrition and growth. Population growth is drastic causing huge stress on ecosystem and resources to grow more food and fibre significantly depend on soil for nutrients. It makes physical, chemical and biological properties and relationship between the soil plant-atmosphere continuum that controls nutrient availability, a critical phenomenon (Havlin *et al*., 2003). Bar graphs showing the concentrations of various physico-chemical parameters of soil samples collected from the different plots of the botanical garden are presented respectively in the in the Fig. 6 (a&b). Laboratory analysis of physico-chemical parameters of soil samples is shown in (Table 4). The analysis of the soil samples from the study area indicated that the concentration of electrical conductivity, phosphorus and pH are not lying within the guided limits. Soil pH was noted by using thymal blue indicator and from pH colour chart. The pH value of the soil ranges between 7.4 - 8, succulent section has the highest pH of 8 and highest EC 4.8 m/cm, showing that nutrient capacity and availability is greatly influenced by pH. The reason is that they are not indigenous plants and they need this amount of concentration. A usual trend of higher pH is found under grass vegetation. Sharma *et al*. (1996) suggested that either the soils are acidic or neutral or alkaline which is similar to the findings in this study. Palm section has the maximum concentration of potassium 159 mg/Kg and minimum of phosphorus (0.4 mg/Kg) along with agricultural land having same concentration of phosphorus but 12 mg/Kg of potassium.

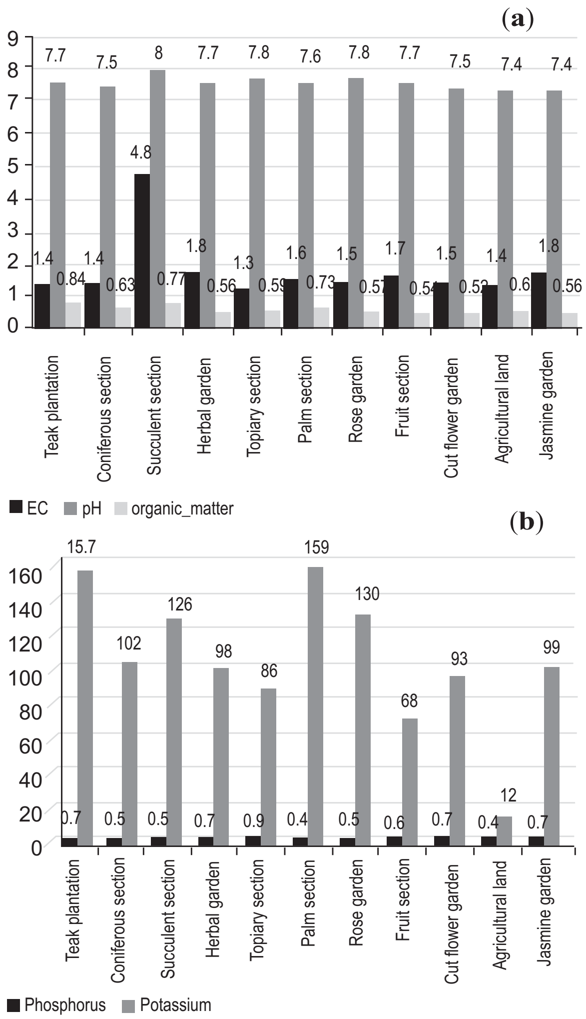

Fig. 6. Bar graph showing the concentration of (**a**) EC, pH and organic matter (**b**) Phosphorus and potassium content in soil.

Teak plantation has highest concentration of organic matter 0.84.

Productive capacity of soil and its potential is affected by multiple interdependent factors. These characteristics of soil are identified as soil quality or fertility. Most critical property is organic matter (OM) because various chemical, biological and physical properties in a productive soil are influenced by organic matter (Chan *et al*., 2008; Yang *et al*., 2008). Organic matter in soil is a necessary and significant component of soil. It is the source of 90 to 95% of nitrogen in unfertilized soils. Percentage of nitrogen in the soils under study varies from 0.02 to 1.5 (Fig. 5). It can be a major source of both available phosphorus and available sulphur when it is more than 2%. The soils from transported material

Table 4. Showing laboratory analysis of physico-chemical parameters of soil

Location	Electrical conductivity (EC)	pH meter	Organic	Phosphorus	Potassium	Depth
Teak plantation	1.4	7.7	0.84	0.7	157	10
Coniferous section	1.4	7.5	0.63	0.5	102	10
Succulent section	4.8	8.0	0.77	0.5	126	10
Herbal garden	1.8	7.7	0.56	0.7	98	10
Topiary section	1.3	7.8	0.59	0.9	86	10
Palm section	1.6	7.6	0.73	0.4	159	10
Rose garden	1.5	7.8	0.57	0.5	130	10
Fruit section	1.7	7.7	0.54	0.6	68	10
Cut flower garden	1.5	7.5	0.52	0.7	93	10
Agricultural land	1.4	7.4	0.62	0.4	12	10
Jasmine garden	1.8	7.4	0.56	0.7	99	10

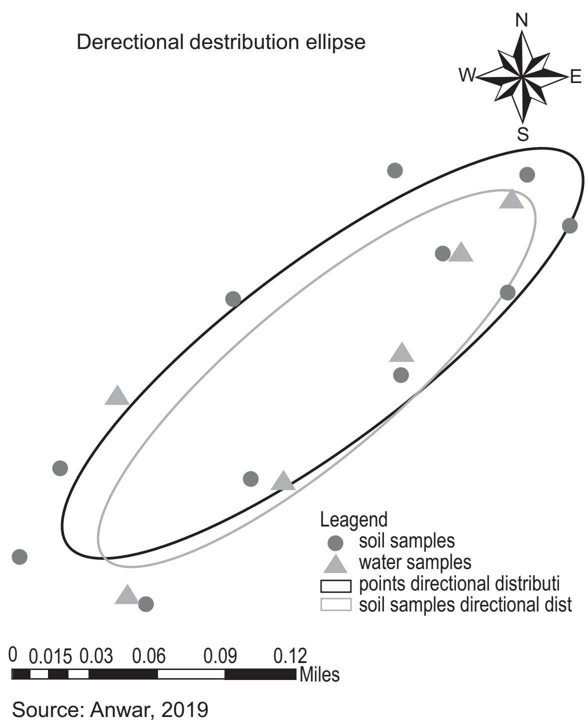

Fig. 7. Standard deviational ellipsoid for soil and water samples, Punjab University.

have fine, grained and uniform texture, containing particles of rougher order as compared to clay so that water can easily move by capillary action and can freely traverse by water and air, hence making the soils the most fertile (Hamilton, 2013).

Standard deviational ellipsoid for soil and water sample points. The direction of the ellipsoid is towards the north east as shown in Fig. 7. As the underlying spatial pattern of soil and water samples is concentrated in the centre with fewer features toward the periphery (a spatial normal distribution), a one standard deviation ellipse polygon will cover approximately 68% of the features, two standard deviations will contain approximately 95 percent of the features and three standard deviations will cover approximately 99 percent of the features in the cluster. Therefore, the results of the standard directional ellipsoid revealed one standard deviation of the selected parameters which shows that all the parameters were within the range hence suitable for herbs productivity.

Conclusion/suggestions/findings.

The main purpose of the study was to analyse the effects of different parameters of soil and water on the plant growth. The gathered results revealed wide variation in different physico-chemical parameters among various sections of the Botanical garden.After a comprehensive analysis and testing it has proved that all the parameters of soil and water are within the limits, we find no abnormalities except very little in few sections such as succulent has highest EC and pH, which is due to the type of plants that encourages (or suitable for) the growth of certain plants. Conclusively, overall the results showed that the water and soil are suitable for all the mentioned types of plants.

Conflict of Interest. The authors declare no conflict of interest.

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