MAPPING AND ASSESSMENT OF SOIL PROPERTIES FOR SUSTAINABLE AGRICULTURE WITH AN APPLICATION OF GIS IN DISTRICT CHINIOT, PUNJAB, PAKISTAN

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خلاصہ

پائیدار زراعت کے طریقوں کے لیے صحت مند مٹی کو برقرار رکھنا ضروری ہے۔ چنیوٹ ضلع سے مٹی کے 46 نمونوں پر ایک جامع مطالعہ کیا گیا، جس میں مختلف طبعی اور کیمیائی خصوصیات کا تجزیہ کیا گیا جیسے پی ایچ، برقی موصلیت، کل تحلیل شدہ نمکیات، چھلنی تجزیہ، اساس، کل سختی، کاربونیٹس، کلورائیڈ، کیلشیم اور میگنیشیم۔ جیو گرافک انفارمیشن سسٹم (GIS) کو استعمال کیا گیا جس میں الٹا فاصلہ وزن (IDW) تکنیک کا استعمال کیا گیا تھا۔ مٹی کے زیادہ تر نمونوں کی شناخت لومی ریتیلی اور ریتیلی لومی کے طور پر کی گئی۔ پورے علاقے میں بلند اساسیت دیکھی گئی، TDS کی قدریں 25 سے mg/L450، اور EC 10 سے 300 تک مختلف تھیں۔ چناب نگر، ہست کھیوا، اور کانانوالہ جیسے علاقوں میں سختی، کاربونیٹ، کلورائیڈ، کیلشیم اور میگنیشیم کی اعلی سطح کی نمائش ہوئی۔ ڈائمنڈ اور پائپر ڈایا گرام کا استعمال کرتے ہوئے ہائیڈرو کیمیکل چہرے کے موازنہ سے پتہ چلتا ہے کہ غالب مرکبات میگنیشیم بائکاربونیٹ کی قسمیں 58 فیصد ہیں، جہاں الکل نمکیات الکلائین زمینی دھات سے زیادہ ہیں 100 فیصد ہیں۔ مروجہ کیشن کی قسم میگنیشیم 100 فیصد تھی، اور آئن کی تقسیم نے 52 فیصد کے ساتھ کوئی غالب قسم نہیں دکھائی، سلفیٹ اور بائک کاربونیٹ کی 48 فیصد کی مساوی تقسیم کے ساتھ، اور سلفیٹ اور کلورائڈز میں سے کوئی بھی نہیں۔ یہ نتائج زرعی ماہرین کے لیے قابل قدر بصیرت فراہم کرتے ہیں، جو مٹی کی مخصوص اقسام کے لیے موزوں فصلوں کے انتخاب میں مدد فراہم کرتے ہیں۔

Abstract

Maintaining healthy soil is essential for sustainable agriculture practices. A comprehensive study was conducted on 46 soil samples from the Chiniot district, analyzing various physical and chemical properties such as pH, Electrical Conductivity, Total Dissolved Solids, Sieve Analysis, Alkalinity, Total Hardness, Carbonates, Chloride, Calcium, and Magnesium. Geographic Information System (GIS) employing the Inverse Distance Weighting (IDW) technique was utilized for mapping. The majority of the soil samples were identified as loamy sandy and sandy loamy. Elevated alkalinity was observed across the area, with TDS values ranging from 25 to 450 mg/L, and EC varying from 10 to 300µS. Regions such as Chenab Nagar, Hast Khiwa, and Kanvanwala exhibited higher levels of hardness, carbonates, chlorides, calcium, and magnesium. Hydro-chemical facies comparison using diamond and piper diagrams revealed that the predominant compounds were Magnesium bicarbonate types (58%), where alkalis exceeded alkaline earths (100%). The prevalent cation type was Magnesium (100%), and the anion distribution showed no dominant type (52%), with an equal distribution of sulfate and bicarbonate types (48%), and none of sulfate and chlorides. These findings provide valuable insights for agriculturists, aiding in the selection of crops suitable for specific soil types.

Keywords: Inverse Distance Weighted, Total Dissolved Solids, Electrical Conductivity.

Introduction

The soil constitutes a significant component of the environment, particularly for countries heavily reliant on agriculture. Soil degradation plays a role in diminishing fertility, impeding crop growth, and adversely affecting overall agricultural productivity (White and Broadley, 2003). The deterioration of soil quality is primarily attributed to overpopulation and urbanization, placing significant pressure on the agricultural sector to meet the needs of an expanding population. Preserving soil fertility is essential for enhancing crop yields and ensuring food security in the face of population growth in the country (Habte *et al*., 2018).

Crop cultivation is a substantial contributor to Pakistan's GDP, accounting for 24.1% of the country's economic output according to (Iqbal *et al*., 2015). The variety of crops and their productivity significantly relies on soil type and various other soil parameters. Regrettably, the scarcity of accessible soil data poses a barrier to stakeholders and farmers in decision-making. To preserve soil resources, it is crucial to assess various soil parameters and make the information available to agriculturists for optimizing crop production (Akhter and Sofi, 2022).

According to (Rahim *et al*., 2011) a study was conducted to examine the impact of calcium, magnesium, sodium, and potassium on agricultural plantations in various agro ecological zones of Punjab, Pakistan. Pakistan is segmented into nine major vegetation zones, and among them, 400 soil samples were tested. The soil samples underwent analysis for Ca^{2+}, Na^{+}, Mg^{2+}, and K^{+}, focusing on three ecological zones. Zone I encompassed certain districts of Sindh and others in Punjab, including Rahim Yar Khan, Bahawalpur, Bahawalnagar, and the Cholistan Desert. Zone II covered the Thal Desert, while Zone III included the Northern irrigated plains (Rahim *et al*., 2011).

In various agroecological zones of the Punjab Province, it was observed that in Rahim Yar Khan, Bahawalpur, Bahawalnagar, and the Cholistan desert area, the presence of Ca and Mg ions was absent. The findings indicated that the highest and comparable values of Ca + Mg were detected in the northern Punjab districts, including Faisalabad, Sahiwal, Gujranwala, and Gujarat, as well as the Potwar area zone. However, these values were significantly different from those of Ca and Mg in the Thal area (Rahim *et al*., 2011).

In the past the study was conducted to check the magnesium content in crops, according to (Ahmad *et al*., 2006) Magnesium serves as an essential component in the chlorophyll molecules within plant tissues.

A magnesium deficiency can lead to a shortage of chlorophyll, consequently causing stunted plant growth. Additionally, magnesium plays a crucial role in rejuvenating specific enzyme systems. Abundant in the Earth's crust, magnesium is present in various minerals. It becomes accessible for trees when these minerals undergo weathering or breakdown. The retention of magnesium occurs on the surface of clay and organic matter particles (Ahmad *et al*., 2006).

The presence of salinity in the Indus Basin in Pakistan is primarily attributed to the arid climate and weathering of marine parent material according to (Sims, 1986). The introduction of irrigation systems in the late 19th century led to an increase in groundwater tables, causing salt infiltration into the root zone. Recent salinization issues are exacerbated by the use of poor-quality groundwater from tube wells (Smets *et al*., 1997). Soil salinity, a consequence of soil formation processes, is influenced by factors such as inadequate drainage, seepage from unlined canals, poor water management, and the use of subpar groundwater for irrigation(Qureshi *et al*., 2008). According to (Nawaz *et al*., 2021) the Indus River contributes an annual salt inflow, but a substantial portion remains within the basin due to inefficient washing out. Heavy metal concentration, attributed to anthropogenic activities, poses environmental threats. Studies in Sargodha reveal significant metal concentrations in soil and vegetables, possibly from chemical use and sewage water. Elevated electrical conductivity in soil, especially from wastewater application, affects plant growth and soil acidity. Additionally, the presence of natural background radioactivity in the Chiniot district emphasizes the need for comprehensive environmental monitoring (Nawaz *et al*., 2021).

The current research takes place in Tehsil Lalian, District Chiniot, aiming to evaluate various physico-chemical soil parameters, including pH, TDS, EC, Ca, Mg, Total Hardness, Alkalinity, HCO_3, Cl^-, and soil texture. These assessments are crucial for gauging soil quality in the tehsil. Elevated levels of certain ions can potentially harm crops, leading to reduced yields.

Study Area

Lalian, located on the western bank of the Chenab River, is a tehsil in District Chiniot. The riverChenab, along with a well-established canal system, serves as the primary water source in the region, catering to irrigation and domestic needs. Geographically situated in the Punjab plains, the area also features some glimpses of the Kirana Hills. The scattered outcrops of the Kirana hills hold significant geomorphological importance. The region is approximately 100km away from the Salt Range (Khan *et al*., 1979).

The climate of district is hot in summer and experiences short and severe winter (Nawaz *et al*., 2021). Temperature variations are notable in District Chiniot, ranging from over 15°C during winters to 35-45°C in summers.This fluctuation is attributed to a cool season lasting approximately 2.7 months, characterized by an average daily temperature below 23ºC. The coldest month, January, sees an average low of around 16ºC and a high of 40ºC, occasionally dropping to approximately 15ºC (Nawaz *et al*., 2021). The altitude in the region spans from 180-190 meters above sea level. Soil samples were systematically collected from six Union Council towns within the Tehsil, namely Lalian, KanvenWala, Jhabana, Chenab Nagar, and Hast Khiwa, all situated on the west bank of the River Chenab (Fig. 1).

Methodology

Sample Collection and Analysis

This research emphasizes the importance of an authentic approach in soil sampling, preparation, preservation, and laboratory analysis to ensure accurate and meaningful results. The process involves using appropriate tools such as spades, trowels, plastic bags, buckets, and soil corers (Rahim *et al*., 2011). To enhance precision, GPS monitors are utilized to record the exact coordinates of sampling locations. It's crucial to clear the surface of debris before collecting soil samples, and specific guidelines are followed to avoid abnormal occurrences in the field. The samples, taken at a depth of approximately 15cm, are labeled with dates and numbers, and their GPS coordinates are recorded.

The samples are then prepared and promptly brought to the laboratory, maintaining a timeframe of one week. The organized labeling system ensures systematic recording and tracking of samples, with attention to site numbers and dates. Overall, the paragraph underscores the meticulous approach to soil analysis, from the initial sampling stage to laboratory preparation, emphasizing the significance of precision and adherence to protocols throughout the process.

Sample Procedure and Preparation

To initiate the solution-making process, begin by using a weighing machine. Place a petri dish on the machine, subtract the dish's weight by pressing tare, and then add 20 grams of soil sample onto the dish. Proceed with the filtration process using the prepared 20 grams of soil.

In the study, Sieve Analysis was conducted to evaluate the soil's particle size characteristics and texture. The apparatus employed for the Sieve Analysis Test included (i) sieves of various sizes (4 inches, 8mm, 10mm, 16mm, 30mm, 40mm, 50mm, 100mm, 200mm, and a Pan), (ii) a mechanical sieve shaker, (iii) a weighing scale, and (iv) a stopwatch. The sieving process involved arranging the sieves in descending order, placing the sieve set on the mechanical shaker, and shaking vigorously for a minimum of 2 minutes. Subsequently, the weight of aggregate retained on each sieve was measured and expressed as the percentage of passing. Finally, the percentages of clay, sand, and silt were calculated based on the results obtained.

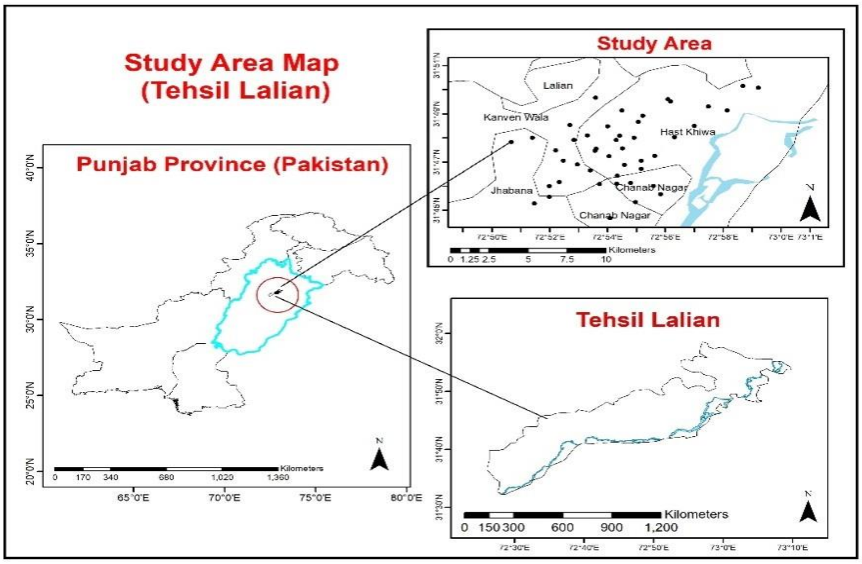

Fig. 1. Study area map shows sampling locations.

Fig. 2. (a) soil sample bags (b) soil weigh machine (c) sieving instrument (d) sieve showing soil grading (e) set of sieves for soil gradation.

The measurement of total dissolved solids (TDS) and electrical conductivity was conducted using a pH meter. A conductivity probe was employed to assess the capacity of dissolved salts and their resultant ions in an unfiltered sample to conduct an electrical current. Subsequently, the obtained conductivity values were converted to TDS, expressed in units of mg/L. To check TDS, follow the same procedure: activate the pH meter, press the dedicated TDS button, and await stable readings. For assessing the electrical conductivity of diverse soil samples, start by removing the probe cap from the pH meter and switching it on. Submerge the probe 1-2 cm into the solution, stir, and wait for the display to stabilize before recording the electrical conductivity (EC) reading.

The filtration process is anticipated to span approximately one day. Begin by taking 200 ml of distilled water in a beaker and adding a 20 gm soil sample to it. Stir the mixture thoroughly and allow it to sit for a day. Following this, commence the filtration process by setting up a tripod stand, placing the sample beaker, and preparing another labeled container with the same number as the sample to collect the filtered solution. Position a funnel in the tripod stand and insert three layers of folded filter paper. Filter each sample into its corresponding container, grouping solutions 1-10 in one set of containers, 11-20 in another, and so on. Pour the soil solution into the funnel and let it drain. Repeat this process for each sample until all solutions are filtered. Once the soil sample solutions are filtered, initiate the titration process to identify impurities. This method involves using 50 ml conical flasks, a 50 ml burette, a burette stand, a dropper, a funnel, and a pipette.

Results and Discussion

Given that it constitutes the predominant component of an ecosystem, soil faces potential threats from the consequences of industrial and intensive agricultural activities. The results of the physiochemical parameters are presented in Table 1.

Table 1. Studied physiochemical parameters.

Analysis	Minimum Value	Maximum Value	Average
pH	7.2	8.0	7.73
TDS(mg/L)	2	1024	340.761
EC(dS/m)	10	1400	472.609
Alkalinity(mg/L)	20	66.66	37.17
Total Hardness(mg/L)	73	780	303
Carbonates(mg/L)	0	166.66	77.78
Chlorides(mg/L)	61.11	372.22	158
Calcium(mg/L)	48	138.67	86.66
Magnesium(mg/L)	1.67	128.33	38.51

The soil texture map (Fig. 3) indicates that the soil identified in the study area predominantly falls into the categories of Sandy Loam and Loamy Sand, with occurrences of clay loam and sandy clay loam observed in the eastern and northern sections. Complete loam soil is identified in the northern regions of the study area (White and Broadley, 2003).

The distribution of Magnesium (Mg) and Zinc (Zn) in the soil is significantly impacted by soil pH, with organically complex forms of Fe-oxide binding prevailing at higher pH levels. The pH levels of the soil samples remained within the range of 7.2 to 8.0, averaging at 7.73. Elevated pH values were identified in the middle region and west bank of the River Chenab, while lower pH values were observed in the northern section (Fig. 3b) (Sims, 1986).

Electrical conductivity (EC) serves as a dependable indicator of the soil's available nutrient level. It is influenced by two key factors: the presence of solid particles associated with exchangeable cations and the contribution of the soil solution (White, 2005). The electrical conductivity (EC) values of the soil samples fluctuated within the range of 10 S/m to 1400 S/m, predominantly at lower concentrations (Fig. 4a). While soil EC is commonly utilized to assess salinity, it can also serve as an indirect composite measure of factors influencing soil quality in non-saline conditions (Chaudhari *et al*., 2014).

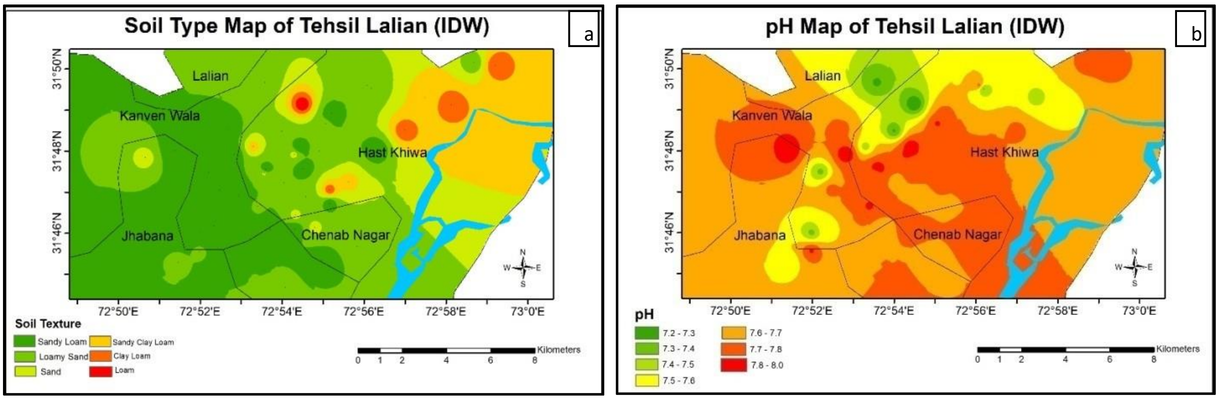

Fig. 3. IDW map for (a) soil type (b) soil pH.

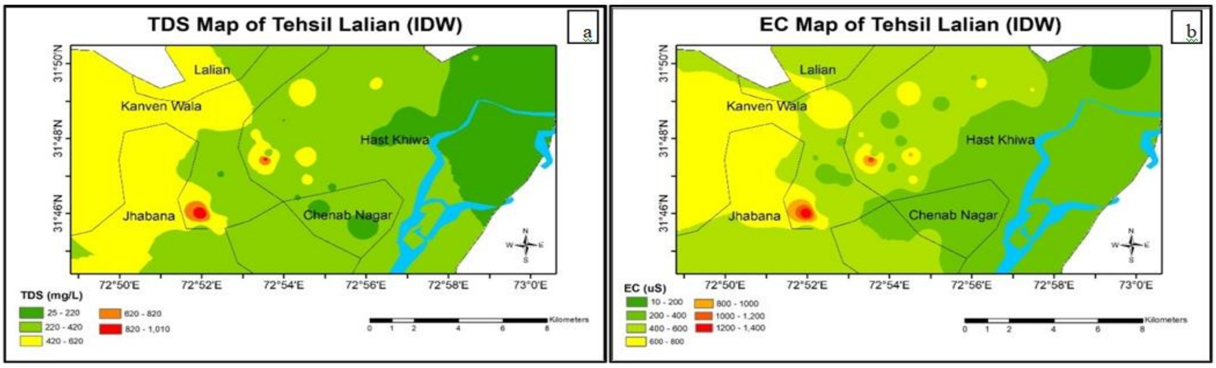

Fig. 4. IDW map for (a) soil TDS (b) soil EC.

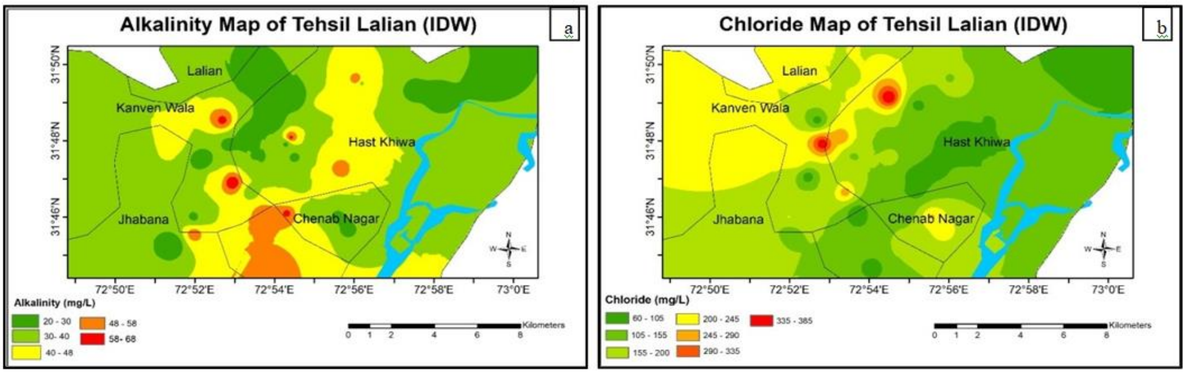

Fig. 5. IDW map for (a) soil alkalinity (b) soil chlorides.

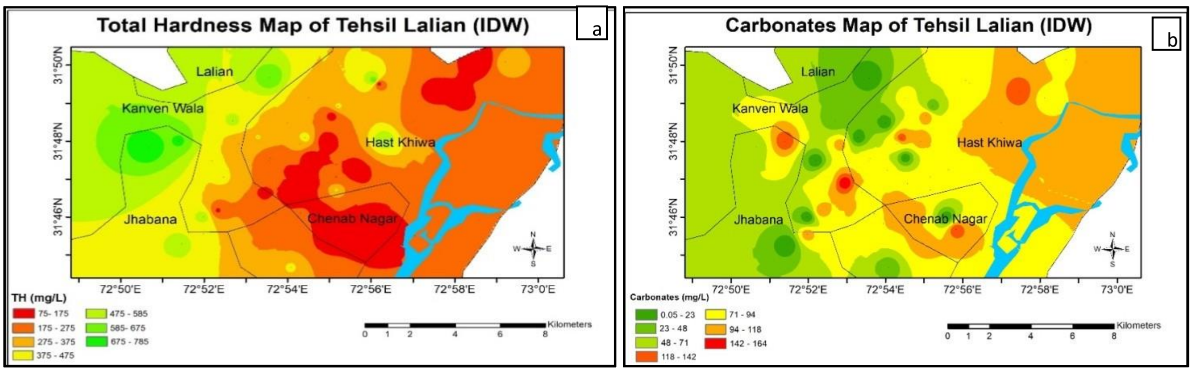

Fig. 6. IDW map for (a) soil total hardness (b) soil carbonates.

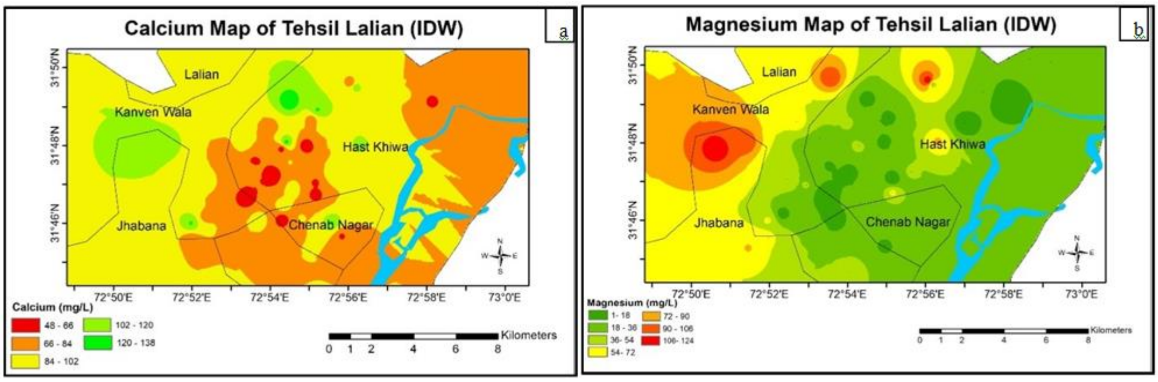

Fig. 7. IDW map for (a) soil calcium (b) soil magnesium.

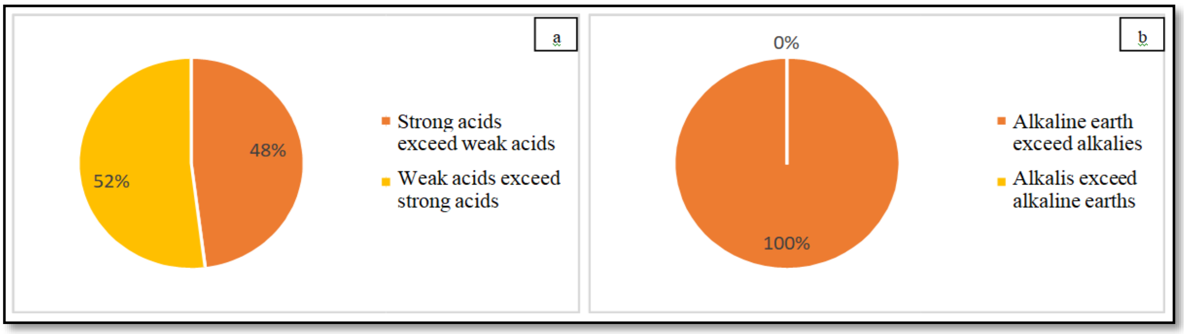

Fig. 8. Comparison of hydro-chemical facies of diamond according to (a) acids (b) alkaline earth metals.

Elevated levels of Total Dissolved Salts (TDS) can adversely affect crop yield and plant growth, with increased values observed at a specific location in the KanvenWala Union Council (Fig. 4a). TDS values consistently fall within the range of 23 mg/L to 1024 mg/L (Table 1). The alkalinity of the soil samples ranged from 20 mg/L to 66.6 mg/L, averaging 37.17 mg/L, with higher values generally concentrated in the central and southern regions (Fig. 5a). Chloride concentrations varied from 61.11 mg/L to 372.22 mg/L, with more significant amounts detected in the northern and western sections of the study area (Fig. 5b).

Total hardness values varied between 73 mg/L and 780 mg/L, with the highest concentrations observed in the Lalian and KanvenWala regions in the western part of the research area, while the lowest concentrations were noted in the Chenab Nagar and Hast Khiwa regions (Fig. 6a). Carbonate concentrations ranged from 0 mg/L to 166.66 mg/L, with higher levels detected in the northern segment of the study region and a gradual decline in the western half of the study area (Fig. 6b).

An essential element for plants is calcium. Deficiency in calcium is generally infrequent, while an abundance of calcium limits plant communities on calcareous soils (White and Broadley, 2003). Calcium concentrations ranged from 48 mg/L to 138.67 mg/L, with lower amounts observed in the eastern boundary of the research area and higher values in the northern and western regions (Fig. 7a). Magnesium, an essential mineral for plants, plays a vital role in chlorophyll production and is imperative for the regular structure of chloroplasts (Yan and Hou, 2018).Magnesium levels varied between 1.67 mg/L and 128.33 mg/L, exhibiting lower concentrations in the eastern half of the study area and higher concentrations in its western half (Fig. 7b).

Distribution of samples in Piper Diagram

In the diamond-type Piper diagram, the majority of samples are situated in the calcium chloride and magnesium bicarbonate region. Anion distribution revealed that most samples belong to the bicarbonate type and are non-dominant. Regarding cation type, a significant portion of the samples falls into the magnesium-type zone, as depicted in (Fig. 9a). The hydro-chemical facets are described by the triangle of the diamond, cation, and anion. According to the hydro-chemical diamond facies, 16% represent the calcium chloride type, 58% the magnesium bicarbonate type, and 13% the mixed type, while no samples of the Sodium Bicarbonate kind were found. The cation triangle indicated that all samples were of the magnesium type, with no discoveries of calcium, sodium, and potassium types or the dominant type. However, 22.22% of samples lacked a dominant type cation, and sodium and potassium type major cations were identified in 47.22% of samples, as depicted in (Fig. 9b). The anion triangle revealed that 48% of samples are of the bicarbonate type, 52% are of the non-dominating type, and very few are of the sulphate and chloride types.

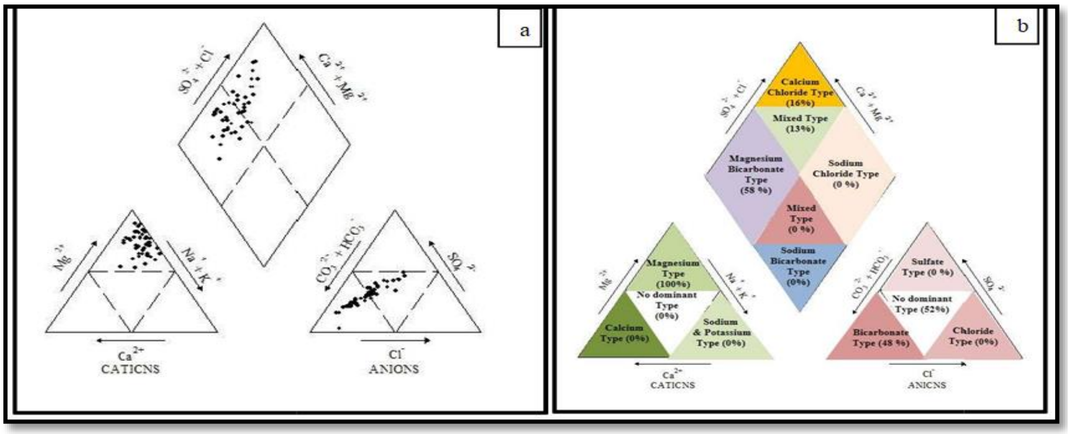

Fig. 9. (a) piper diagram (b) hydro-chemical facies according to diamond type classification.

Hydro-chemical facies according to alkaline earth metals and acids

The results mentioned in above Fig. 8 above indicate that in 48% of the samples, strong acids exhibit greater strength than weak acids, while in 52% of the samples, the opposite holds true. In all samples (100%), alkaline earths are more prevalent than alkalis, with no instances where alkalis outnumber alkaline earths. Analyzing the hydro-chemical facies in the Piper diagram, the highest percentage (58%) corresponds to compounds of the magnesium bicarbonate type, and in all instances (100%), alkalis outnumber alkaline earth. Cations are exclusively of the magnesium kind in 100% of the cases. Considering anions, the majority have no dominating type (52%), and there are equal proportions of bicarbonate and sulphate types (48%), while no samples exhibit chloride or sulphate dominance.

Normalized Differentiated Vegetation Index (NDVI)

The calculation of the Normalized Differential Vegetation Index (NDVI) was performed utilizing spatially acquired Landsat 8 images, particularly in the Red and Infrared bands. This process aimed to identify regions with vegetation, including forests and farms. NDVI values typically range between -1 and +1, where values close to +1 signify robust vegetation health. The NDVI computation was executed in the ArcMap environment using the Raster Calculator tool, applying the following formula:

$$NDVI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \ldots \ldots (1)$$

The NDVI index indicates that a significant portion of the study area is characterized by thriving vegetation and shrubs. Conversely, areas with the lowest vegetation levels are identified in the regions of Chenab Nagar UC, KanvenWala UC, and the surroundings of the River Chenab in Fig 10.

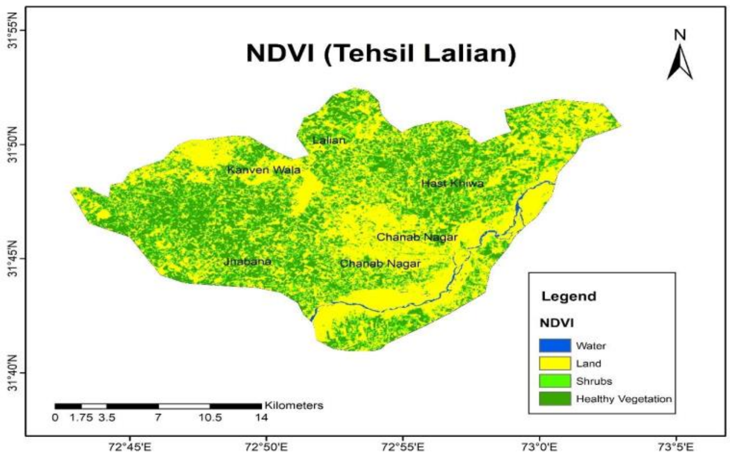

Fig. 10. NDVI map of Tehsil Lalian.

Normalized Difference Salinity Index (NDSI)

Utilizing spatially acquired Landsat images, particularly in the Green and Short-Wave Infrared (SWIR) bands, the calculation of the Normalized Differential Salinity Index (NDSI) was carried out. This index aimed to identify areas with salinity values in the study area. The salinity value is low throughout the area shown in Fig 11. In the ArcMap environment, the NDSI was computed using the Raster Calculator tool through the following formula:

$$NDSI = \frac{Band\ 3 - Band\ 6}{Band\ 3 + Band\ 6} \dots\dots (2)$$

The formation of soils from the weathering of rocks and various materials introduces soluble inorganic and organic compounds. Factors like rain, wind-transported materials, fertilizer application, poor irrigation water, and rising sea levels can contribute to soil salinization. Soil salinity, affecting over 800 million hectares globally, varies across climates and soil types. Traditional methods for salinity measurement have limitations, making continuous monitoring challenging. Satellite-based technologies, specifically Remote Sensing (Nawaz *et al*., 2021) and Geographical Information System (GIS), offer efficient and cost-effective solutions. RS tools, including multispectral and hyper spectral imagery, enhance the monitoring and mapping of soil salinity(Iqbal, 2011). This information is crucial for sustainable agriculture and resource management. The study emphasizes the importance of accurate mapping and monitoring for informed decision-making, particularly in regions prone to soil salinization, contributing to poverty alleviation and economic growth (Iqbal, 2011).

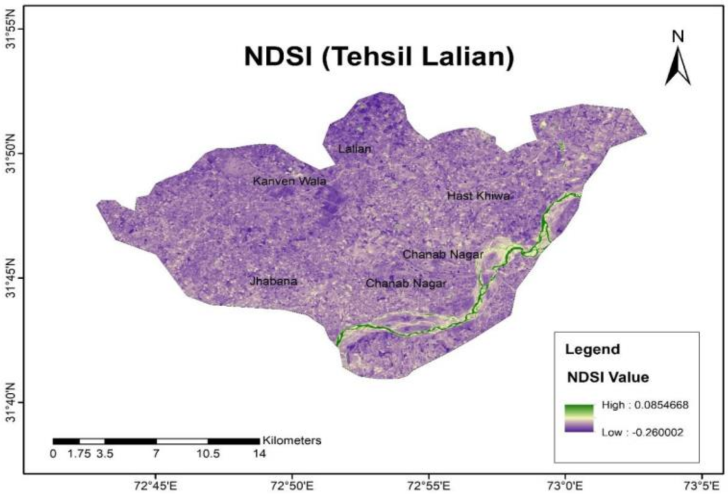

Fig. 11. NDSI map of Tehsil Lalian.

Conclusion

In conclusion, the soil in the surrounding communities is an indispensable resource for the residents, particularly the farmers. The extensive measurement of various physical and chemical factors in the region not only provides valuable information for current agricultural practices but also serves as a crucial foundation for future research endeavors. The utilization of GIS mapping enables the tracking of hazardous chemical concentrations, and the soil maps generated through this study will undoubtedly prove instrumental in mapping similar parameters in other areas within the district. This study holds significant potential to benefit local farmers by guiding them in optimizing crop combinations for maximum cost-benefit ratios and yield outputs. Moreover, the findings contribute to poverty reduction and have positive implications for the overall gross domestic product of the country. Overall, the comprehensive understanding of soil characteristics gained from this study reinforces its importance as a valuable and practical resource for the agricultural community and future research endeavors.

Acknowledgment

The authors express sincere gratitude to Ms. Madiha Iram, the Lab Incharge at the Water Lab, Nusrat Jahan College Rabwah, for her assistance and for generously providing lab facilities for sample testing. The authors also extend their heartfelt thanks to the Department of Earth Science, Abdus Salam School of Sciences, Nusrat Jahan College Rabwah, Chenab Nagar, Pakistan.

References

Ahmad, S., Ghafoor, A., Qadir, M. and Aziz, M. A. (2006). Amelioration of a calcareous saline-sodic soil by gypsum application and different crop rotations. *Int. J. Agric. Biol, 8*, 142-146.

Akhter, R. and Sofi, S. A. (2022). Precision agriculture using IoT data analytics and machine learning. *Journal of King Saud University-Computer and Information Sciences, 34*(8), 5602-5618.

Chaudhari, P. R., Ahire, D. V., Chkravarty, M. and Maity, S. (2014). Electrical conductivity as a tool for determining the physical properties of Indian soils. *Int. J. Sci. Res. Publ, 4*(4).

Habte Werede, M., Smith, J. U. and Boke Ambaye, S. (2018). Integrated soil fertility management for sustainable teff (Eragrostistef) production in Halaba, Southern Ethiopia. *Cogent food & agriculture, 4*(1), 1519008.

Iqbal, F. (2011). Detection of salt affected soil in rice-wheat area using satellite image. *Afr. J. Agric. Res, 6*(21), 4973-4982.

Iqbal, M. A., Iqbal, A., Afzal, S., Akbar, N., Abbas, R. N. and Khan, H. Z. (2015). In Pakistan, agricultural mechanization status and future prospects. *American-Eurasian Journal of Agricultural & Environmental Sciences, 15*(1), 122-128.

Khan, N., Mahmood, N. and Khaliq, M. (1979). Radioactive survey of Kirana hills using solid state nuclear track detectors. *Nuclear Tracks, 3*(4), 213-218.

Nawaz, S., Rebi, A., Khaliq-Ur-Rehman Arshad, G. Y., Arif, M., Naz, A., Khan, A. A. and Mahmood, A. (2021). Effect Of Waste Water On Chemical Properties Of Soil In Sargodha Region. *NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO*, 5173-5180.

Precision agriculture using IoT data analytics and machine learning. (2022). *Journal of King Saud University - Computer and Information Sciences*, Volume 34, Issue 38, Part B 5602-5618.

Qureshi, A. S., McCornick, P. G., Qadir, M. and Aslam, Z. (2008). Managing salinity and waterlogging in the Indus Basin of Pakistan. *Agricultural Water Management, 95*(1), 1-10.

Rahim, S. M. A., Hasnain, S. and Farkhanda, J. (2011). Effect of calcium, magnesium, sodium and potassium on farm plantations of various agroecological zones of Punjab, Pakistan. *Afr. J. Plant Sci, 5*(5), 450-459.

Sims, J. T. (1986). Soil pH effects on the distribution and plant availability of manganese, copper, and zinc. *Soil Science Society of America Journal, 50*(2), 367-373.

Smets, S., Kuper, M., Van Dam, J. and Feddes, R. (1997). Salinization and crop transpiration of irrigated fields in Pakistan's Punjab. *Agricultural Water Management, 35*(1-2), 43-60.

White, P. J. and Broadley, M. R. (2003). Calcium in plants. *Annals of botany, 92*(4), 487-511.

White, R. E. (2005). *Principles and practice of soil science: the soil as a natural resource*: John Wiley & Sons.

Yan, B. and Hou, Y. (2018). *Effect of soil magnesium on plants: a review.* Paper presented at the IOP Conference Series: Earth and Environmental Science.