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Research Article

Unveiling Soil Fertility Dynamics in Rawalpindi Region: Implications for Sustainable Agriculture and Fertilizer Strategies

Sarosh Alvi[1], Muhammad Akram Qazi[2], Muhammad Rashid[1]*, Sher Afzal[3], Raja Abad Raza[1], Muhammad Tahir Shah[4], Saftain Ullah Khan[5], Sajid Ali[6], Hafiz Imran Iqbal[7]

[1] *Soil and Water Testing Laboratory, Rawalpindi, Pakistan.*
[2] *Rapid Soil Fertility Research Institute, Lahore, Pakistan.*
[3] *Soil and Water Testing Laboratory, Jhelum, Pakistan.*
[4] *Soil and Water Testing Laboratory, Toba Teck Singh, Pakistan.*
[5] *Soil and Water Testing Laboratory, Attock, Pakistan.*
[6] *Soil and Water Testing Laboratory, Chiniot, Pakistan.*
[7] *Land Resources Research Institute, NARC, Islamabad, Pakistan.*

ABSTRACT

In Pakistan, the adoption of high-yielding crop varieties and intensive farming practices since the commencement of the green revolution has led to a degradation in soil quality and fertility. Particularly in rainfed areas, rapid mineralization of soil organic matter (SOM) has exacerbated widespread nutrient deficiencies. This study, conducted in Rawalpindi district, aimed to evaluate the extent of soil nutrient deficiencies to formulate precise fertilizer recommendations for management of soil health and fertility to obtain sustainable crop production. A comprehensive analysis of 4080 soil samples from various tehsils within Rawalpindi district was carried out. Results revealed that the majority of soils (79%) were classified as loam, with an overwhelming percentage (88%) exhibiting alkaline pH (7.5 to 8.5). Furthermore, 99% of soils had an electrical conductivity (EC) within the safe limit of <4.00 dS m^{-1}. However, more than 96% of soils displayed poor levels of SOM, and deficiency of available phosphorus was observed in 99% of the samples. Conversely, 63% of soils had adequate extractable potassium. These findings underscore that deficiency of SOM, available-P, and alkaline soil pH are the major contributing factors in Rawalpindi region to the poor soil fertility. Therefore, soil fertility management strategies must consider the findings of this study to obtain the maximum agronomic benefits. Furthermore, farmers are recommended to get their soil tested after every three years to revise the nutrient management programs.

Keywords: Cultivated land; Fertility status, Soil nutrients, spatial distribution, Rawalpindi

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Correspondence
Muhammad Rashid
abuxeneb@gmail.com

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INTRODUCTION

Soil is a complex system composed of diverse minerals, air, water, and SOM(Flores-Magdaleno *et al.*, 2011). The quality of soil is dependent on multiple factors including land use, fertility level, soil structure, and microbial biomass (Doran and Parkin, 1994). Adequate soil fertility ensures the long-term productivity of soils since soil fertility is depleting due to intensive cultivation and inadequate soil management (Sharma, 2022). It is noted that continuous cropping to maximize crop production has mined a substantial quantity of soil nutrients.

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Soil testing is the basic tool to diagnose the level of soil fertility for a proper soil fertility management strategy. Blind management without considering the actual status of soil fertility could deteriorate soil quality and crop productivity (Habtamu *et al.*, 2014). Low soil fertility in rainfed areas of Pakistan is the major constraint to achieving high soil productivity goals (Ullah *et al.*, 2022). We know that soil fertility is a dynamic soil property that fluctuates considerably throughout the growing season each year. Therefore, soil fertility management should be on the basis of a comprehensive soil fertility diagnostic system. The lack of awareness and knowledge already has created widespread deficiencies of N, P, K, S, Zn, Fe, B, etc. in Rawalpindi areas.

Under intense nutrient deficiencies visual symptoms are observed in major crops but in case of moderate deficiency symptoms are not visible and only a soil test can determine the extent and nature of nutrient deficiency (Singh and Mishra, 2012). The implications of nutrient deficiencies could be, (i) acute and widespread nutrient-deficiency, (ii) poor nutrient use efficiency, (iii) threatening foundation of high return and sustainable farming, and, (iv) rising the soil remedial rebuilding costs (Baig *et al.*, 2013).

Therefore, for maintaining soil health and sustainable agricultural production, replenishment of macro and micronutrients is must to obtain good crop yields. The available knowledge on soil resources and their agricultural potential in the Rawalpindi area is outdated since major changes in soil fertility status have occurred in the last few years. Recognizing this knowledge gap this study was planned to assess the fertility of soils, in terms of organic matter and the physicochemical properties that are in turn affected in the present agriculture system.

MATERIALS AND METHODS

The Rawalpindi district (Figure 1) lies within semi-arid to humid subtropical agro-ecological region of Pakistan. With an ample average annual rainfall of 1,249 mm, predominantly during the monsoon season, the area boasts a lush environment. Its climate is distinguished by scorching and humid summers, followed by chilly and arid winters (Rabia *et al.*, 2023).

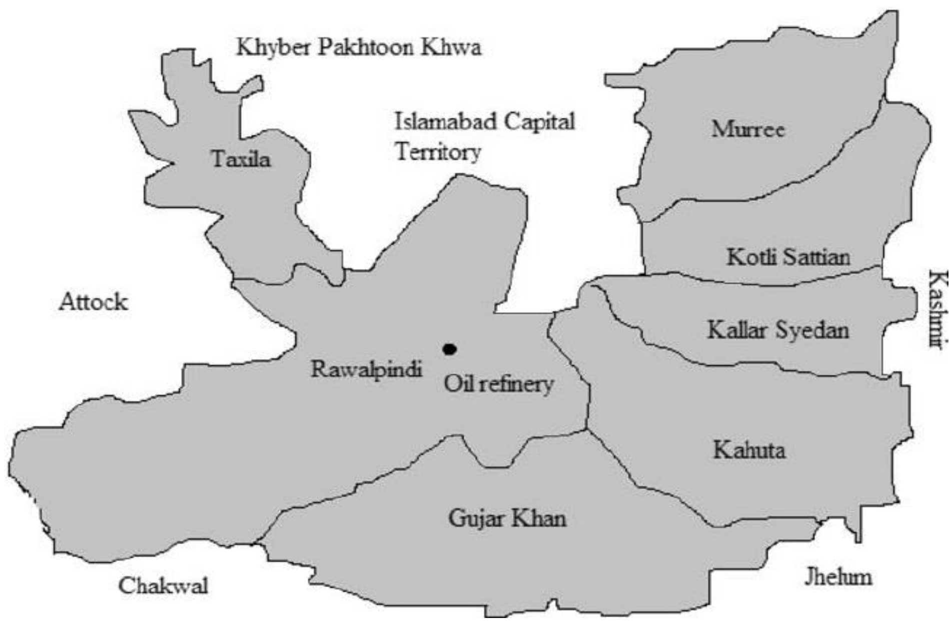

Figure 1. Map of district Rawalpindi.

Experimental setup

A comprehensive soil survey was conducted in the study area, resulting in the collection of a total of 4,080 soil samples from various tehsils within the Rawalpindi district: Tehsil Rawalpindi (2,586 samples), Tehsil Gujar Khan (115 samples), Tehsil Taxila (94 samples), Tehsil Kahuta (62 samples), Tehsil Murree (107 samples), and Tehsil Kallar Sydan (110 samples). These collected soil samples were transported to the Soil and Water Testing Laboratory in Rawalpindi for subsequent physicochemical evaluations. The stored soil samples were then subjected to analyses for soil texture, soil reaction (pH), electrical conductivity (EC), soil organic matter (SOM), available phosphorus (P_2O_5), and extractable potassium (K_2O) at the aforementioned laboratory. Soil pH was determined using a soil-to-water ratio of 1:1, while EC was measured at a ratio of 1:10 soil to water, as outlined by Sajida Perveen *et al.* (2010). SOM content was assessed via titration method (Larson and Pierce, 1991), P_2O_5 was extracted using 0.5 M $NaHCO_3$

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(Olsen and Sommers, 1982), and K_2O was extracted with 1 M CH_3COONH_4 (Helmke and Sparks, 1996). Samples prepared for P_2O_5 and K_2O were analyzed using a spectrometer and flame-photometry, respectively. Soil texture was determined according to the method described by Gee and Bauder (1986). Statistical analysis of the data was performed using the MS Excel package.

Soil Fertility Index (SFI)

SFI was determined by formula reported by (Parker *et al.*, 1951):

Soil Fertility Index (SFI) = $((N_i \times 1) + (N_m \times 2) + (N_h \times 3))/ N_t$ ………......…. (1)

Where:

N_t = Number of soil samples; N_i = Number of soil samples falling in the low category; N_m = Number of soil samples falling in the medium category; N_h = Number of soil samples in the high category. The criteria used for the classification of soil samples were adopted from Sajida Perveen *et al.* (2010) is given as under.

Table 1: Criteria used for soil classification

A- Soil texture

Saturation (%)	Textural Class
0-20 %	Sand
21-30 %	Sandy Loam
31-45 %	Loam
46-65 %	Clay Loam
66-100 %	Clay

B- Soil EC (dS m^{-1})

EC (dSm^{-1})	Remarks
< 4.0	Normal. No harm to most of the crops.
4.0- 8.0	Medium Salinity. Yield of sensitive crops may be affected.
> 8.0	High Salinity. Only tolerant crops can grow satisfactorily.

C- Soil pH

pH	Remarks
7.0-7.50	Normal. Soil contains no alkaline earth carbonates.
7.6-8.0	Slightly Alkaline.
8.2-8.5	Alkaline soil contains some alkaline earth carbonates are present.
> 8.5	Alkaline. Carbonates are dominant anions and ESP exceeds 15.

D- Soil salinity/sodicity

Status	E.C (d Sm^{-1})	Soil pH
Normal	< 4.0	< 8.5
Saline	> 4.0	< 8.5
Saline Sodic	> 4.0	8.5
Sodic	< 4.0	> 8.5

E- Soil organic matter (%)

Organic Matter	Remarks
> 0.86	Poor
0.86-1.29	Satisfactory
>1.29	Adequate

F- Soil available phosphorus (mg kg^{-1})

Available Phosphorus	Rating	Remarks

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> 7	Very Low to low	The optimum yield of all crops cannot be obtained without P applications.
7 - 14	Medium	All crops need Phosphorus
> 14	High	Phosphorus is recommended for soil fertility maintenance or to balance N: P ratio.

G- Soil available potash (mg kg^{-1})

Available Potash (K)	Rating	Remarks
> 80	Poor	The optimum yield of all crops cannot be obtained without K applications.
80-180	Satisfactory	Better yield can be obtained by K applications
>180	Adequate	No need of K application to all crops but K fertilizer is recommended to balance its mining.

Table 2: Soil Fertility Criteria

Status	O. matter (%)	A. Phosphorus (mg kg^{-1})	E. Potassium (mg kg^{-1})
Poor	<0.86	> 7	> 90
Satisfactory	0.86-1.25	7-14	90-180
Adequate	>1.25	> 14	>180

RESULTS AND DISCUSSION

Status of fertility in the study area

The analytical results of physicochemical analysis in the soil samples from the study area are presented in Figure 2, 3, 4, 5, 6, 7, and 8.

Soil Texture

Soil texture significantly influences various soil properties such as nutrient retention, water-holding capacity, permeability, and workability. The findings from this study, as depicted in Figure 2, highlight the distribution of soil textures across Rawalpindi District. Medium-textured soils were predominant, constituting 66% of the soil samples, while 22% exhibited heavy texture, and only 12% showed coarse texture characteristics. Notably, heavy texture soils were predominantly found in Tehsil Murree and Kahuta regions. The prevalence of loam texture suggests that the majority of soils in Rawalpindi District are likely derived from loess deposits.

The variability in soil texture can be attributed to topographical and land terrain features, as indicated by previous studies (Nizami *et al.*, 2004). Medium texture soils are dominant in Rawalpindi region indicating that these soils not only have good nutrient and water holding capacities but also possess good drainage, compared to heavy and coarse texture soils which are relatively less abundant in Rawalpindi (Rabia *et al.*, 2023).

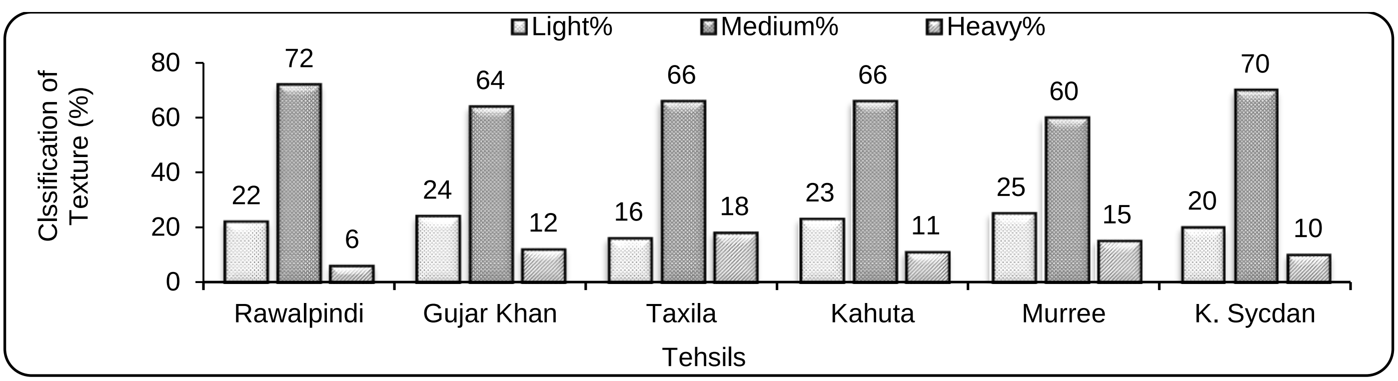

Figure 2: Classification of soil texture in different tehsils of Rawalpindi

Soil pH

Soil pH, which determines the acidity or alkalinity of the soil solution, plays a crucial role in describing the cation exchange capacity (CEC) of soil. CEC, in turn, regulates the transformation and recycling of nutrients within the soil. Consequently, the availability of nutrients in the soil system is significantly influenced by soil pH.

Research conducted in Rawalpindi District has revealed variations in soil pH ranging from neutral to moderately alkaline (7.5-8.5). The majority of soils (87%) were found to possess a moderate alkaline pH, with only 13% exhibiting a neutral pH (Fig. 3). Additionally, within the district, Murree and Kahuta Tehsils were observed to have soils with neutral to slightly acidic pH levels, while soils in all other Tehsils demonstrated alkaline pH. The prevalence of alkaline pH levels in the soil may be attributed to inherent calcareousness, potentially resulting from the precipitation of calcium and magnesium carbonates (Singh and Mishra, 2012). The deficiency of SOM as observed in this study is also one the major reasons for alkaline soil pH. Studies conducted by other scientists have suggested that the addition of organic materials is imperative for restoring soil fertility by mitigating alkalinity in such soils. Maintaining a neutral pH is crucial for optimal availability of plant nutrients, as most nutrients tend to precipitate at mineral complexes under alkaline conditions (Jamal *et al.*, 2018). The plant uptake of N, K, and S is generally less affected by soil pH. However, the uptake of P and most of micronutrients, on the other hand, is more affected by the soil pH. Most of the other nutrients (trace elements in particular) tend to be less available when the soil pH is above 7.5, whereas they are perfectly available when the pH is slightly acidic at 6.5 to 6.8. In addition, losses of N in the form of NH_3 are greatly favored by high soil pH (Mehdi *et al.*, 2021). Therefore, while selecting N fertilizers, ammoniated fertilizers should be avoided in Rawalpindi region as soil pH of this region is alkaline.

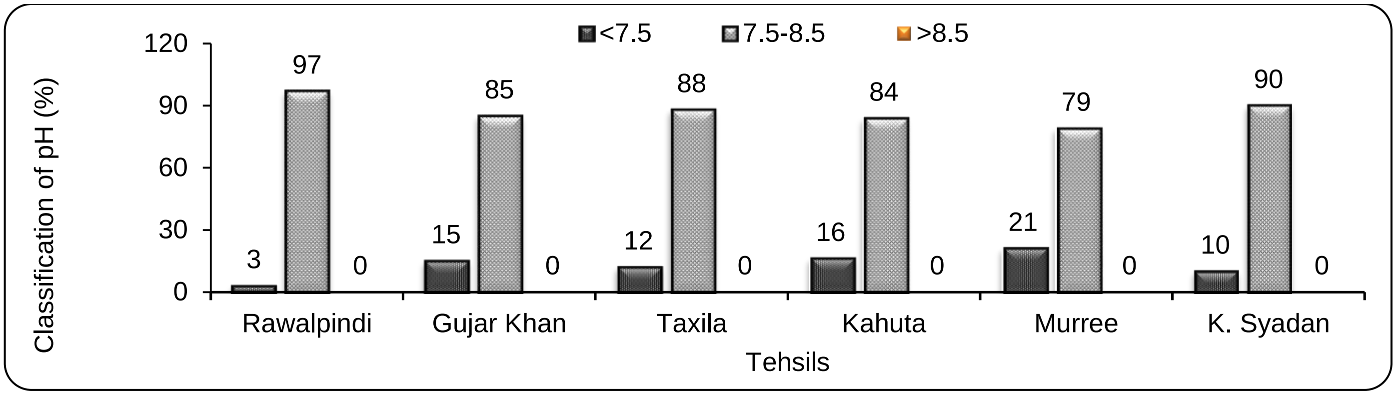

Figure 3: Classification of soil pH in different tehsils of Rawalpindi

Soil EC

The electrical conductivity (EC) of soil, a measure of soluble salts, is influenced by various factors including cropping pattern, land use, and fertilization practices (Rabia *et al.*, 2023). Excessive levels of dissolved salts in soil can impede nutrient uptake mechanisms through several means, including ion imbalance, antagonistic effects between nutrients, excessive osmotic potentials, or a combination of these factors (Rabia *et al.*, 2023). According to the findings illustrated in Figure 4, the current study area does not face salinity hazards as over 99% of soils exhibit an EC value of less than 4.0 dS m^{-1}. This suggests that, at present, the soil salinity levels are within acceptable limits for agricultural productivity and do not pose significant constraints on crop growth and nutrient uptake (Aamer *et al.*, 2015).

Soil Organic Matter (SOM)

Soil organic matter (SOM) constitutes an essential component of soil, contributing to various functions crucial for plant growth and soil health. SOM plays a pivotal role in supplying plant nutrients, enhancing soil structure, promoting water infiltration, and improving soil nutrient retention (Brady, 1984). The findings of our study, as depicted in Figure 5, underscore the prevalent deficiency of SOM in the soils under investigation, with nearly 95% exhibiting poor SOM levels. This depletion can be attributed to factors such as continuous cultivation practices and extreme temperature variations within the study area, which accelerate the mineralization of SOM (Gómez *et al.*, 2014). The diminishing levels of SOM have adverse repercussions on soil structure and drainage systems, consequently impairing nitrogen use efficiency (NUE) and crop yields (Tisdale *et al.*, 1985). The lack of adequate SOM compromises soil structure, leading to decreased water infiltration rates and exacerbating issues related to soil moisture retention, particularly in regions where water resources are already scarce (FAO, 2014). It has been reported earlier that mountainous regions of Pakistan like Rawalpindi; soil fertility is a concern due to land degradation and nutrient deficiencies. In arid and semi-arid regions, salinization of agricultural lands is a serious problem, affecting SOM and N. It was reported that that organic amendments and ecological crop rotations can increase SOM and stimulate microbial activity. Overall, there is a need for better soil and plant nutrient management practices in Pakistan to address soil fertility issues and improve agricultural productivity (Sajida Perveen *et al.*, 2010).

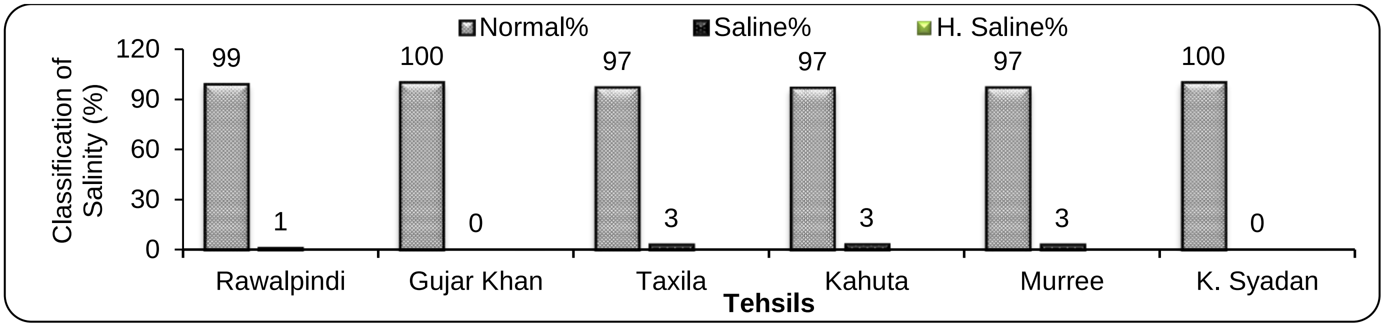

Figure 4: Classification of EC in different tehsils of Rawalpindi

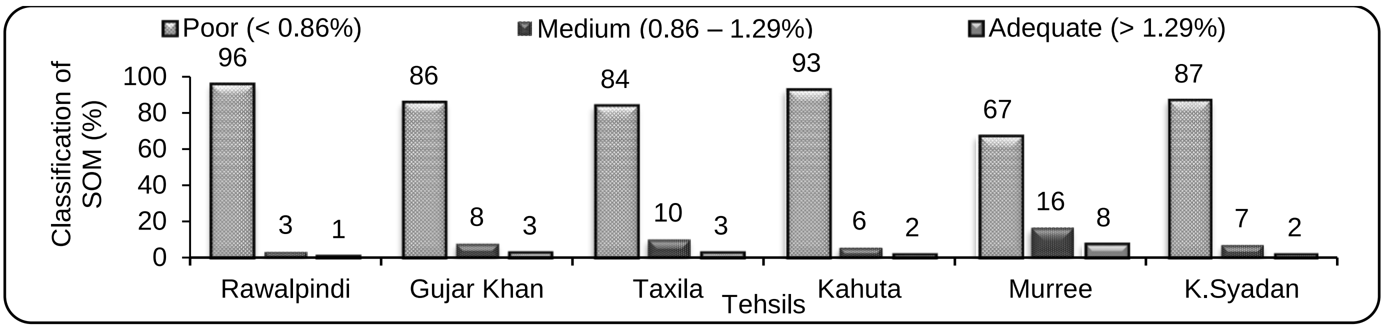

Figure 5: Classification of SOM in different tehsils of Rawalpindi

Available phosphorus

Soil phosphorous plays a prominent role in energy storage and transfer. Soil is the greatest sink that supply phosphorus to plants. In alkaline calcareous soils the solubility and availability of phosphorus is limited. Besides having an ample phosphorus level, the extreme deficiency of phosphorus is widely reported in rainfed areas of Pakistan. The results of this study confirmed 96% soils in Rawalpindi area are deficient in available phosphorus (Figure 6).

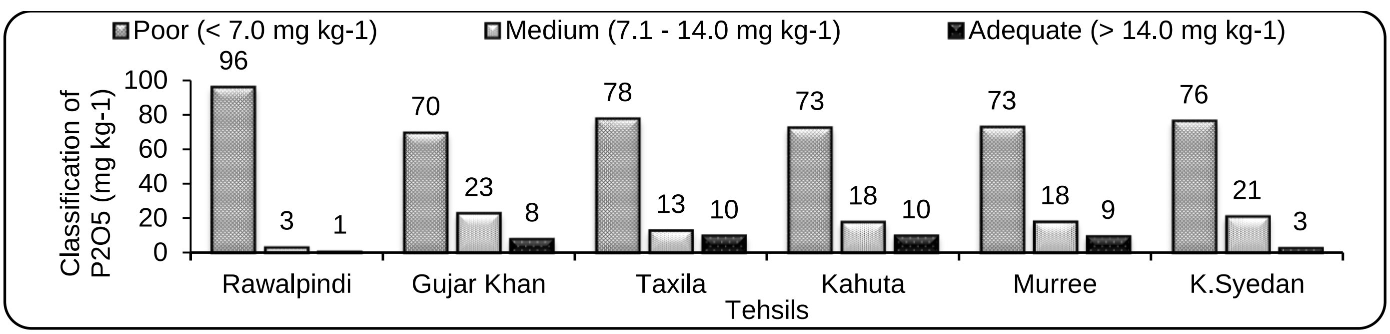

Figure 6: Classification of P_2O_5 in different tehsils of Rawalpindi

The deficiency could be due to fixation of phosphorus at the exchange complex since these soils have high calcareousness and high soil pH. These results also an indication that deficiency of phosphorus is expanding because earlier reports showed about 90% deficiency (NFDC, 2001; Ahmad and Rashid, 2003). As it was reported that Pakistani soils are deficit of P up to 90% and to optimize its level it is needed to apply P externally (Jamal *et al.*, 2018) as the pH and calcium content decrease the availability of P to crops and increase its fixation. Therefore, type of soil should be in consideration while selecting fertilizer application (Naseer and Muhammad, 2014). Structural stability is greatly influenced by organic matter, soil particle size distribution and extent of calcium carbonate in soils (Amanullah *et al.*, 2015). Soil P relates with P bioavailability, it is determinant of balance between sufficient soil P

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fertility and offsite P escape. For this soil testing is best management tool to know the need of P fertilization to make sure that soil has adequate supply of P for crop production. It is not true that Pakistani soils have less P, it has rich amount of P in spite of that 80–90% soils are P deficient because of its availability problem (Pakistan, 2015).

Extractable potassium

Potassium plays a crucial role in various physiological processes vital for plant growth. This study has unveiled remarkably surprising findings regarding potassium levels, showing that merely 5% of soil samples possess adequate potassium, while a staggering 52% are classified as deficient. Previously, it was widely assumed that Pakistani soils did not suffer from potassium deficiency. Hence, these results offer a fresh perspective to researchers and cultivators, guiding them towards more informed planning strategies. This underscores the potential necessity for potassium supplementation, especially considering that farmers in the study area refrain from utilizing potassium-based fertilizers. Besides several other issues (high pH, low N, P and organic matter), the problem of K availability and uptake by plants in calcareous soils has extensively been noticed and reported in the world mainly due to antagonistic relationship with other basic cations *i.e.,* Na^{+}, Ca^{2+} and Mg^{2+} present in such soils (Ertiftik and Zengin, 2015; Narayanasamy *et al.*, 2023). The majority of the K in plant tissue is absorbed by roots from the soil solution as a monovalent cation, and the rate of absorption is controlled by environmental and plant factors (Jan, 2022). Even though K is typically abundant in calcareous soils, a large amount of soil K is nevertheless unavailable to plants due to imbalances between available Ca^{2+}, Mg^{2+}, and K ions that may result in K deficit through competitive uptake interactions (Brady and Weil, 2017).

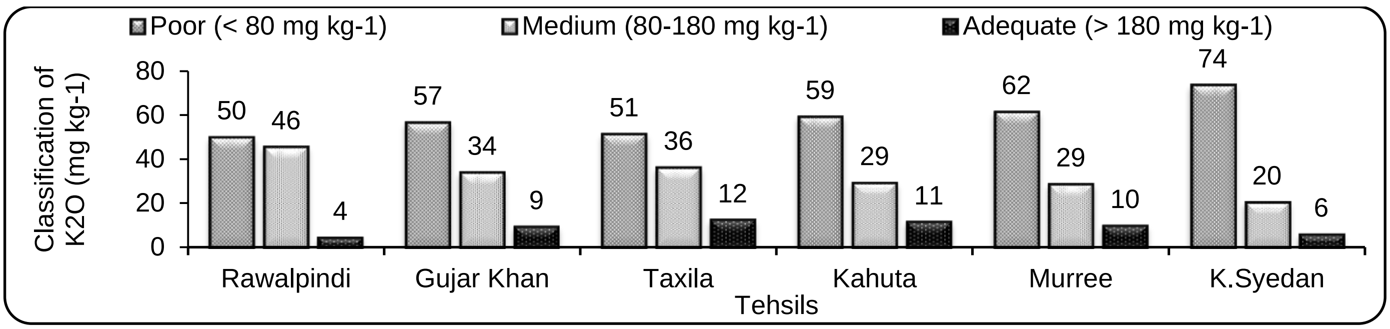

Figure 7: Classification of K_2O in different tehsils of Rawalpindi

Soil fertility indexation (SFI)

Soil fertility indexing serves as a vital tool for assessing the fertility status of a given area. As per the criteria established by Motsara (2002), a Soil Fertility Index (SFI) value greater than 2.5 is indicative of high fertility, while values falling between 1.5 and 2.5 suggest medium fertility, and values below 1.5 signify low fertility.

In the case of Rawalpindi (Figure 8), the fertility index values for organic matter and available phosphorus are notably low, standing at 1.06 and 1.12, respectively. However, the extractable potassium value (1.60) indicates a medium fertility status. These findings align with similar results reported by Kausar et al. (2016) for soils in Sargodah and Khalid *et al.* (2012) for the Chakwal area of Pothwar. Conversely, (Singh *et al.*, 2018) observed medium nutrient index values for soil organic matter (2.3) and available phosphorus (2.2), along with high potassium levels (3.0), in soils from the Varanasi district, Uttar Pradesh, India.

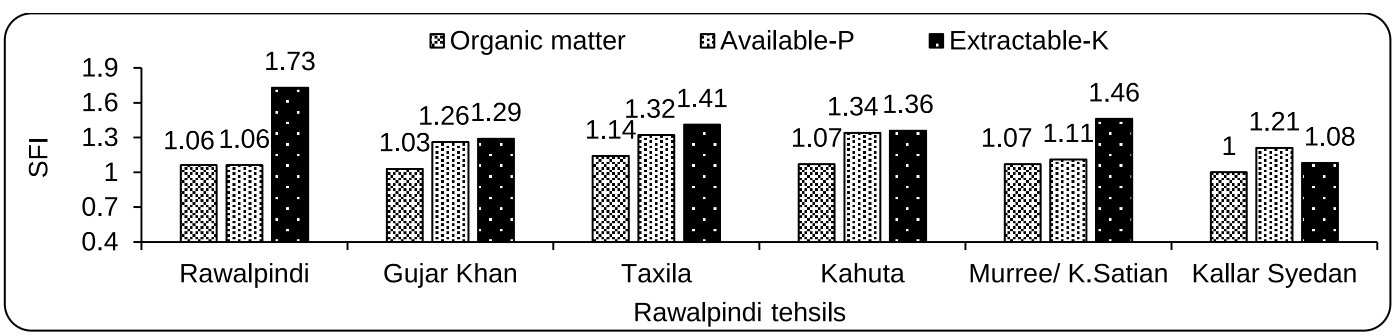

Figure 8: Classification of SFI in different tehsils of Rawalpindi

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CONCLUSION

The soil fertility indices across all tehsils of the Rawalpindi district highlight a pervasive issue: low soil fertility. This underscores the necessity of supplementing soils with appropriate fertilizers to ensure successful crop production. Several factors may contribute to this concerning trend, including alkaline soil pH, low organic matter levels, and calcareousness. Additionally, there are indications of salinity or sodicity, previously absent, further complicating matters. The decline in organic matter status is particularly alarming, prompting a reevaluation of our reliance solely on chemical fertilizers. The combination of high pH and low organic matter not only impedes phosphorus recovery but also exacerbates the deficiency of potassium—a clear indicator of essential element depletion. Intensive farming practices and the cultivation of high-yielding crop varieties are exacerbating soil fertility decline, exacerbated by the lack of appropriate management strategies. To address this issue, the use of organo-mineral fertilizers and the incorporation of crop residues are recommended to mitigate the deteriorating soil fertility in the Rawalpindi region. Without intervention, efforts to maximize agronomic benefits may yield minimal gains.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

REFERENCES

Aamer, M., F. Iqbal, M. Iqbal and Q. Javed. 2015. Physico-chemical properties and fertility status of District Rahim Yar Khan, Pakistan. Journal of Environment and Earth Science, 5: 11-16.

Ahmad, N. and M. Rashid. 2003. Fertilizers and their use in Pakistan. Planning and Development Division, NFDC, Islamabad, Pakistan.

Amanullah, I. Khan, A. Jan, M. T. Jan, S. K. Khalil, Z. Shah and M. Afzal. 2015. Compost and nitrogen management influence productivity of spring maize (*Zea mays* L.) under deep and conventional tillage systems in Semi-arid regions. Communications in Soil Science and Plant Analysis, 46: 1566-78.

Baig, M. B., S. A. Shahid and G. S. Straquadine. 2013. Making rainfed agriculture sustainable through environmental friendly technologies in Pakistan: A review. International Soil and Water Conservation Research, 1: 36-52.

Brady, N. 1984. The nature and properties of soils(14th ed.). Hoboken: Prentice Hall.

Brady, N. C. and R. Weil. 2017. The nature and properties of soils: Pearson New International edition. Pearson.

Doran, J. W. and T. B. Parkin. 1994. Defining and assessing soil quality. Defining soil quality for a sustainable environment, 35: 1-21.

Ertiftik, H. and M. Zengin. 2015. Effects of increasing rates of potassium and magnesium fertilizers on the nutrient contents of sunflower leaf. Selcuk Journal of Agriculture and Food Sciences, 29.

FAO. 2014. The Importance of Soil Organic Matter. Food and Agriculture Science: 417-22.

Flores-Magdaleno, H., O. R. Mancilla-Villa, E. Mejía-Saenz, M. d. C. Olmedo-Bolaños and A. Bautista-Olivas. 2011. Heavy metals in agricultural soils and irrigation wastewater of Mixquiahuala, Hidalgo, Mexico. African journal of agricultural research, 6: 5505-11.

Gee, G. W. and J. W. Bauder. 1986. Particle-size analysisMethods of soil analysis: Part 1 Physical and mineralogical methods, 5: 383-411.

Gómez, J. A., J. Infante-Amate, M. González de Molina, T. Vanwalleghem, E. V. Taguas and I. Lorite. 2014. Olive cultivation, its impact on soil erosion and its progression into yield impacts in Southern Spain in the past as a key to a future of increasing climate uncertainty. Agriculture, 4: 170-98.

Habtamu, A., G. Heluf, B. Bobe and A. Enyew. 2014. Fertility status of soils under different land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. Agriculture, Forestry and Fisheries, 3: 410-19.

Helmke, P. A. and D. L. Sparks. 1996. Lithium, sodium, potassium, rubidium, and cesium. Methods of soil analysis: Part 3 Chemical Methods 5: 551-74.

Jamal, A., I. Hussain, M. S. Sarir and M. Fawad. 2018. Phosphorous transformation as influenced by different levels of phosphorous alone and in combination with humic acid. World Scientific News: 173-79.

Jan, R. 2022. Fate of Potassium in Crop Production. The Journal of Community Mobilization and Sustainable Development, 17: 1065-74.

Khalid, R., T. Mahmood, R. Bibi, M. T. Siddique, S. Alvi and S. Y. Naz. 2012. Distribution and indexation of plant available nutrients of rainfed calcareous soils of Pakistan. Soil & Environment, 31.

Larson, W. E. and F. Pierce. 1991. Conservation and enhancement of soil quality. Director Rapid Soil Fertility Lahore. Nelson, S.W. and I.E. Sommers. 1982. The total carbon, organic carbon and organic matter. p 539-80. In: Methods of Soil Analysis Chemical and Microbial Properties. Agron. 9 Part 2, 2nd Ed. A.L. Page (ed.). USA.

https://doi.org/10.55627/agrivet.003.02.0724

Mehdi, S. M., R. Abad, S. Saleem, R. Khalid, S. T. Alvi and A. Munir. 2021. Soil Characteristics and Fertility Indexation in Gujar Khan Area of Rawalpindi. Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences, 64.

Motsara, M. 2002. Available nitrogen, phosphorus and potassium status of Indian soils as depicted by soil fertility maps. Fertilizer News, 47: 15-21.

Narayanasamy, R., C. Thiyagarajan, M. P. Pillai, M. Muthunalliappan, K. Subburamu and M. Subramanian. 2023. Nutrient release from biodegradable polymer-coated multi-nutrient fertilizer granules in calcareous soils. Arabian Journal of Geosciences, 16: 53.

Naseer, M. and D. Muhammad. 2014. Direct and residual effect of hazara rock phosphate (HRP) on wheat and succeeding maize in alkaline calcareous soils. Pakistan Journal of Botany, 46: 1755-61.

NFDC. 2001. Balanced fertilization through phosphate promotion. Project terminal report NFDC, Islamabad, Pakistan: 205-301.

Nizami, M., M. Shafiq, A. Rashid and M. Aslam. 2004. The soils and their agricultural development potential in Pothwar. NARC, Islamabad.

Olsen, S. and E. Sommers. 1982. Phosphorus soluble in sodium bicarbonate. Methods of soil analysis, part, 2: 404-30.

Pakistan, G. o. 2015. Ecnomice survey of Pakistan 2014-15, Ministry of food, Agriculture and livestock (Fedral Bureau of Statistics), Islamabad: 23-44.

Parker, F., W. Nelson and E. Winters. 1951. The broad interpretation and application of soil test information. Agronomy Journal, 48: 105-12.

Rabia, K., S. J. and O. Rehman. 2023. Biomass Conversion and Biorefinery, 13: 9549–64.

Sajida Perveen, S. P., Z. M. Zubaria Malik and W. N. Wajahat Nazif. 2010. Fertility status of vegetable growing areas of Peshawer, Pakistan. Pakistan Journal of Botany, 42: 1871-80.

Sharma, S. B. 2022. Trend setting impacts of organic matter on soil physico-chemical properties in traditional vis-a-vis chemical-based amendment practices. PLOS Sustainability and Transformation, 1: e0000007.

Singh, R. and S. Mishra. 2012. Available macro nutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (UP) in relation to soil characteristics. Indian Journal of Scientific Research, 3: 97-100.

Singh, S. P., S. Singh, A. Kumar and R. Kumar. 2018. Soil fertility evaluation for macronutrients using parkers nutrient index approach in some soils of varanasi district of eastern Utter Pradesh, India. International Journal of Pure and Applied Bioscience, 6: 542-48.

Tisdale, S. L., W. L. Nelson and J. D. Beaton. 1985. Soil fertility and fertilizers. Collier Macmillan Publishers.

Ullah, A., S. E. Saqib and H. Kächele. 2022. Determinants of farmers' awareness and adoption of extension recommended wheat varieties in the rainfed areas of Pakistan. Sustainability, 14: 3194.

https://doi.org/10.55627/agrivet.003.02.0724