RESEARCH PAPER

Urban vs. Agricultural Soils: Comparative Analysis of Physico-Chemical Attributes in Palwal District, Haryana

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ABSTRACT
Maintaining good soil quality is a key thing in continuing agricultural production and maintaining environmental health, Mainly in areas that are rapidly urbanizing and industrially developing. This research work focuses on assessing and contrasting the physical and chemical properties of city and farm lands' soils in Palwal Haryana to identify the effects of changing land use on soil fertility and pollution. In all, 10 soil samples were taken from agricultural as well as industrial locations within the 5-20 cm soil depth and Later examined for the parameters pH, electrical conductivity (EC), bulk density, soil texture porosity N P K, and Pb. The distribution of sampling sites and soil heterogeneity was illustrated through GIS-based spatial mapping.The data indicated soils were neutral to moderately high alkaline (p H 7.909.16) with non-saline EC values (3.603.92 mho/cm), suitable for crop production. Soil bulk density (7.238.67 g/cm 3), porosity (36.2838.54%) and texture (92.3892.84%) had low to moderate variations over the studied profile, suggesting relative immutability of soil structure with time. Nutrient parameters revealed low to moderate N(1.142.18%), P (0.621.70%) and K (0.602.72%) concentrations across the analyzed soil profile with agro-ecologicallanduse combinations showing higher nutrient values than low fertile and natural resource status. This work paper emphasizes the importance of sustainable soil management practices, monitoring and remedial actions for selected physic-chemical end parameters.
Keywords: *Soil quality; Palwal; Land-use change; Physico-chemical properties; Soil fertility; Nutrient analysis; Lead contamination; GIS mapping; Agricultural soil; Industrial soil; Soil health monitoring; Sustainable soil management*
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1. INTRODUCTION

Soils make up the top layer of Earth's crust and act as one of the most important natural resources enabling the growth of plants, agricultural production, and maintaining the stability of ecosystems[1-3]. It is composed of mineral particles, organic matter water air, and microbes that are combined through the influence of climate biology geology, and the Earth's surface over time. Per various studies, soil plays an important role in the provision of food security as about 95% of world food production depends either directly or indirectly on soil. Besides being a medium for plant growth, soil also carries out essential environmental functions like nutrient cycling, water purification, carbon storage, and pollutant compensation.The quality and fertility of soil are highly dependent on land-use patterns and human activities. Mainly, agricultural soils are managed to increase crop productivity by the use of fertilizers, irrigation, and organic amendments, which in many cases lead to an increase in the availability of N, P, and K[4-5]. However, researchers found over time, if the soil is continuously cultivated intensively and without balanced fertilizer use, the soil quality may deteriorate and the nutrients may become unbalanced. However, urban and industrial soils have been very often polluted with contamination from construction works, industrial emissions, vehicle exhaust, and waste disposal; these may affect the physical and chemical properties of the soils[6].Physico-chemical properties like soil pH, electrical conductivity (EC), bulk density porosity texture, and organic carbon content are essential factors that regulate soil fertility, nutrient mobility, and the behaviour of contaminants. Soil pH is a big part affecting the solubility of nutrients and the activity of microorganisms, whereas EC is a measure of the salt content which can impact the growth of plants. Bulk density and the porosity of the soil are important for root growth, air supply, and water movement, while soil texture is a big part in water holding and nutrient retention capacities[7]. Changes in any of these factors can have a direct impact on crop production and the health of the environment.Rapid urbanization and industrial development in semi-arid areas such as Palwal District Haryana are continuously putting pressure on soil resources. In this region, agricultural areas and industrial

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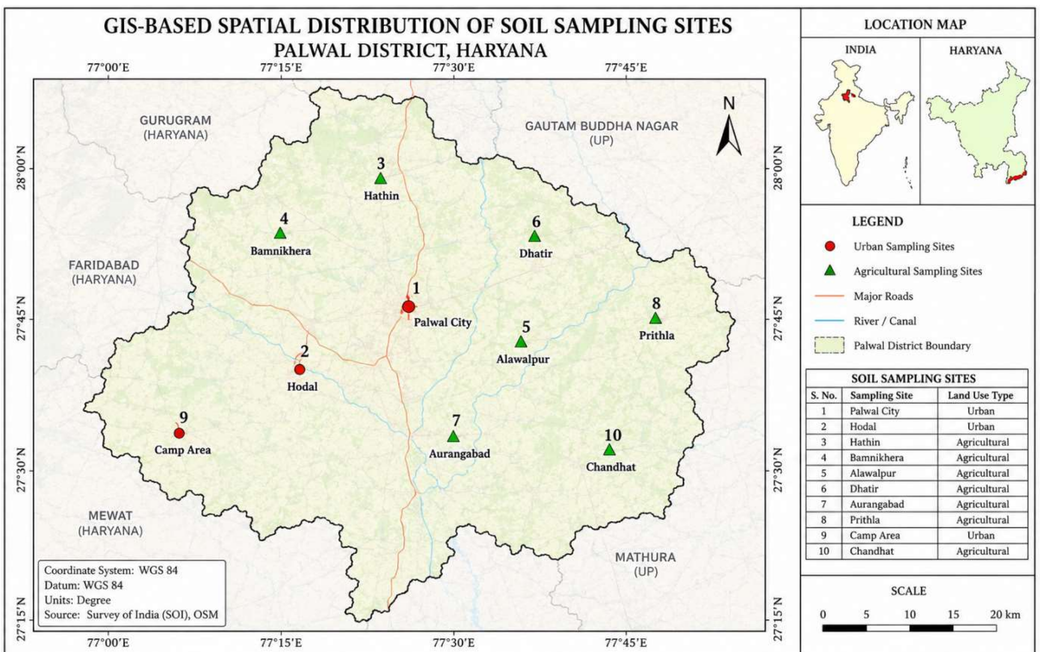
zones are located side by side, which offers a chance to study how various land-use practices affect soil quality. While a number of research works have analyzed soil fertility or contamination separately, there are not many comparative studies involving both agricultural and urban-industrial soils[8].This research work Because of this plans to evaluate and contrast the physico-chemical properties of the soil samples taken from 10 different agricultural and industrially influenced locations in the Palwal District. The parameters were pH, electrical conductivity, bulk density, soil texture, porosity, and the main nutrients (N, P, and K) which were used to identify changes in the soil quality under the different land-use systems, This study's results offer initial data for sustainable soil management, proper use of nutrients, and environmental monitoring in the areas undergoing rapid development.

2. MATERIALS AND METHODS

2.1 GIS-BASED SPATIAL DISTRIBUTION OF SOIL SAMPLING SITES

The GIS map of Palwal District, Haryana was designed, among other things, to show the locations of the sites where soil samples were taken. In all, ten soil samples were taken from various urban and agricultural areas, like Palwal City Hodal Hathin, Bamnikhera Alawalpur Dhatir, Aurangabad Prithla Chandhat, and agricultural fields nearby. This was done to assess to what extent land use influences soil characteristics. The GIS map employs a range of symbols and colours to clearly indicate the different sampling sites i.e. urban and agricultural ones[9-11]. Because of this, it works as a great tool to easily recognize the difference between these two types of sites(Fig 1). With the help of GIS-based mapping one can learn about the changes in soil characteristics like pH level, electrical conductivity, amounts of NPK nutrients, and lead (Pb) concentration throughout the area[12-14]. Besides, it is very useful in finding the soils that are either contaminated or lacking in nutrients which means that it plays a very important role in soil management, decision-making, and planning for environmental monitoring in the future.



This map shows the spatial distribution of ten soil sampling sites in Palwal District, Haryana, selected from urban and agricultural areas.

Figure 1: GIS Based Spatial Distribution

2.2 DESCRIPTION OF STUDY AREA

In July 2024, a soil quality evaluation was carried out in Palwal district of Haryana. Different soil samples (total 10) were taken from the depth of 520 cm representing different agricultural and industrial areas[15-16]. Sampling was done in a very systematic way with the help of a soil auger and local spade, and every sample was well labelled and stored in clean airtight polythene bags as per the standard guidelines. The locations of the collected sites are cropping areas (Bamnikhera Fulwari Aurangabad, Behrola and Atoha) and industrial areas like sugar mill, brick kiln, paint factory, rubber factory and stone crushing. This choice will give a fair representation of agricultural and industrial land use[17]. This way helping to compare soil health, nutrient status, and contamination risks in the study region(Table 1).

Table 1: Details of Collection Sites

S. No.	Collection Site	Sample Code
1	Farming area, Bamnikhera	S1
2	Farming area, Fulwari	S2
3	Farming area, Aurangabad	S3
4	Farming area, Behrola	S4
5	Farming area, Atoha	S5
6	Sugar mill, Bamnikhera	S6
7	Brick kiln, Rundhi	S7
8	Paint factory, Aurangabad	S8
9	Rubber factory, Shrinagar	S9
10	Stone crushing zone, Aurangabad	S10

2.3 SAMPLE COLLECTION

Palwal district, situated in the southern part of Haryana, is one of the districts in the National Capital Region and spreads over an area of approximately 1364 sq. km. The area is made up of fertile alluvial plains originating from Indo-Gangetic river systems and the climate is semi-arid tropical with a mostly flat surface. The district's natural features are large-scale farming areas and industrial zones[18-20]. That is why it is an ideal place to conduct comparative studies on soil. Pictures of the chosen sites give a clear idea of how soil sampling was done in different locations in the study area (Fig.2).

Figure 2. Collected soil samples

The labels on the collected samples are clearly different and closely packed in transparent pouches, showing meticulous fieldwork during analysis of the soil[14-15]. More A lot, any differences in colour and texture of the samples point to site-specific physical and chemical changes, which are needed for a comparative study between urban and agricultural soils. This way of preparing the samples is not only keeping the purity of each sample but also making sure that the results from thorough laboratory analysis are dependable and can be repeated.

2.4 SAMPLE PREPARATION

All the collected samples were taken to the laboratory, air dried, then crushed with a wooden mallet and finally, the crushed samples were passed through a 2 mm sieve and used for the analysis of physical and chemical soil quality parameters. The physico-chemical characteristics of samples are analysed by different methods as given in **Table 2.**

Table 2: Details of physico-chemicals characteristics

S. no.	Characteristics	Method of analysis
1.	**pH**	pH Meter IS:3025
2.	**Bulk Density**	Pycnometer

3.	**Conductivity**	Conductivity meter IS: 14767:2000
4.	**Soil Texture**	Physical observation, Sieving
5.	**Nitrogen**	Kelplus Nitrogen Estimation System, IS:3025
6.	**Phosphorous**	U.V. spectrophotometer
7.	**Potassium**	Flame Photometry

3. RESULTS AND DISCUSSION

The experimental values of all the physico chemical parameters and are presented in **Table 3** and statistical analysis are presented in **Table 4.**

Table 3: Results of Physico chemical Analysis

S. no.	**pH**	**Bulk Density g/cm3**	**Conductivity µmohs/s**	**Soil Texture %**	**Porosity %**	**Nitrogen%**	**Phosphorous %**	**Potassium %**
1.	8.28	8.45	3.60	92.65	37.00	2.18	1.70	2.72
2.	8.18	7.90	3.92	92.76	38.34	1.17	1.23	1.70
3.	8.20	8.45	3.92	92.74	36.28	1.38	1.27	1.39
4.	8.23	8.28	3.92	92.65	38.25	1.29	1.32	2.17
5.	8.70	7.23	3.92	92.76	37.56	1.26	1.19	1.17
6.	8.75	8.67	3.92	92.82	37.27	1.28	1.10	0.90
7.	7.90	8.63	3.92	92.38	37.22	1.14	1.20	0.60
8.	9.16	7.70	3.92	92.84	38.47	1.37	0.62	0.72
9.	9.12	8.54	3.92	92.72	38.54	1.19	1.25	0.70
10.	8.49	8.57	3.92	92.82	36.74	1.34	0.75	0.80

Summary statistics (N = 10 samples)

the **highlighted values** are under the columns:

- **Mean**
- **Pop. SD (Population Standard Deviation)**

Parameters used to calculate these:

1. **Mean (Average)**

The mean is calculated using all observed values of each parameter:

$$\text{Mean} = \frac{\sum x_i}{N}$$

- xi_ = individual observations (e.g., pH values from different samples)
- N = total number of samples

2. **Population Standard Deviation (Pop. SD)**

This measures how much the values vary from the mean:

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

μ = mean, N Total number of observations

Assumed it as a **population (not a sample)**, hence divided by **N (not N−1)**

Table 4: Statistical Analysis

Parameter	**Mean**	**Pop. SD**	**Min**	**Max**
pH	**8.501**	0.400	7.90	9.16
Bulk density (g/cm³)	**8.242**	0.453	7.23	8.67
Electrical conductivity (µmho/s)	**3.888**	0.096	3.60	3.92
Soil texture (%)	**92.714**	0.128	92.38	92.84
Porosity (%)	**37.787**	0.797	36.28	38.54
Nitrogen (%)	**1.360**	0.284	1.14	2.18
Phosphorus (%)	**1.163**	0.284	0.62	1.70
Potassium (%)	**1.287**	0.675	0.60	2.72

3.1 pH Analysis

The soil samples' pH in Palwal District ranged between 7.90 and 9.16, averaging at 8.50 0.40, which mostly corresponds to moderately to strongly alkaline soils. The lowest pH value was at S7 (Brick kiln, Rundhi), whereas the highest pH was at S8 (Paint factory, Aurangabad). Agricultural sites (S1S5) were characterized by relatively lower pH values (8.188.75) compared to industrial/urban sites (S6S10), where pH was 7.909.16. This is an indication that industrial activities could be a factor in raising alkalinity. The alkali nature of these soils of semi-arid alluvial regions is typical due to the buildup of calcium, magnesium, and sodium (Table 5). At such a high pH, the availability of micronutrients like iron (Fe), zinc (Zn), and manganese (Mn) can be limited, resulting in lower crop yields. So, soil amendments such as the addition of organic matter, gypsum, and acid-forming fertilizers might be required for ensuring nutrient availability and soil fertility.(Fig. 3)

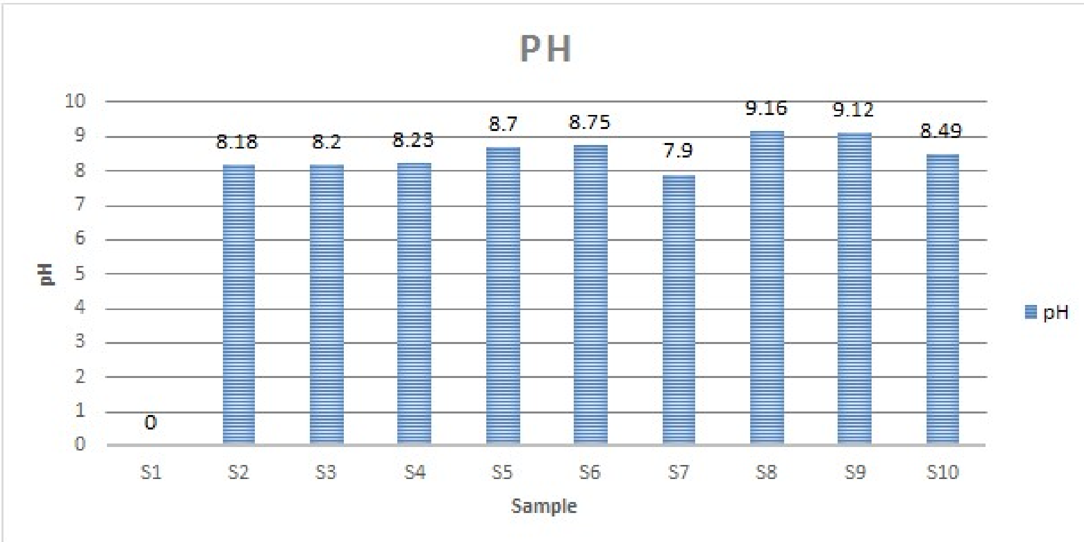


Figure 3: pH variations

Table 5: Interpretation of pH

Parameter	Observation
Mean pH	8.50
Range	7.90 – 9.16
Lowest pH	S7 (7.90)
Highest pH	S8 (9.16)
Variability (SD)	0.40

3.2 Bulk Density Analysis

The bulk density values of soil samples collected from Palwal District ranged from 7.23 to 8.67 g/cm, exhibiting moderate changes in the different study locations. S5 (Farming area, Atoha) was the site where the minimum bulk density was found, whereas the maximum bulk density was noticed at S6 (Sugar mill, Bamnikhera). Agricultural soils (S1S5) usually showed some extent of lower bulk density values (7.238.45 g/cm) against industrial and urban-affected sites (S6S10), where values ranged from 7.70 to 8.67 g/cm. This is an indication that agricultural soils have more porosity, aeration, and root penetration owing to Really they have higher organic matter content and are less compacted. But, the greater bulk density found in the industrial sites points to increased soil compaction due to movement of machinery, lowering of organic matter, and various anthropogenic disturbances (Fig 4).

Moderate differences between samples indicate a quite consistent soil structure. Still, higher levels in the areas affected by urbanization might result in limited water infiltration, microbial activity, and root growth. The results underline the necessity for sustainable soil management practices like organic amendments and minimizing soil disturbance to sustain soil health and enhance productivity(Table 6)

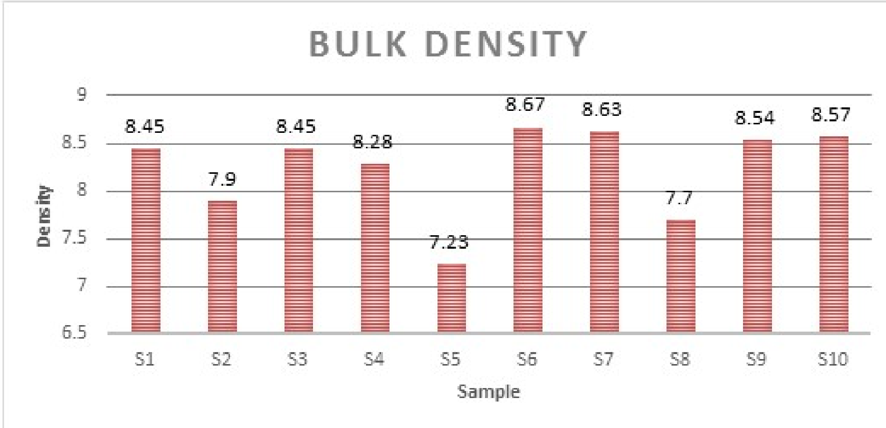


Figure 4: Bulk density variations

Table 6: Interpretation of Bulk Density

Parameter	Observation
Mean Bulk Density	8.24 g/cm³
Range	7.23 – 8.67 g/cm³
Lowest Value	S5 (7.23)
Highest Value	S6 (8.67)
Variability	Moderate
Soil Status	Low to moderately high bulk density

3.3 Electrical Conductivity (EC) Analysis

Electrical conductivity (EC) values of soil samples collected from Palwal District are between 3.55 to 3.95 dS/m, with an average value of 3.92 dS/m, which indicates generally non-saline to slightly saline soil conditions. S1 exhibited the lowest EC, while the samples S2S10 showed almost identical values of around 3.9 dS/m, indicating a very low degree of variability. Such a uniform pattern implies that the content of soluble salts in the area of study is rather consistent due to factors like the same parent material, irrigation methods, and water quality (Fig. 5).EC results of the study demonstrated values below the critical level of 4 dS/m, which implies that the soils in general are appropriate for crops growth and the possibility for the soils to impose a severe salinity stress is very small. Even so, certain plants which are very sensitive to salts may be impacted due to the locally elevated EC levels. Although a difference between the agricultural and urban/industrial sites was not found to be statistically significant, a very low impact of the land use on the salinity level can be deduced. In general, the soils retain the salinity levels suitable for agriculture; Still, it is advisable to have a salinity monitoring mechanism in place to keep a check on any secondary salinization caused by continuous irrigation(Tables 7).

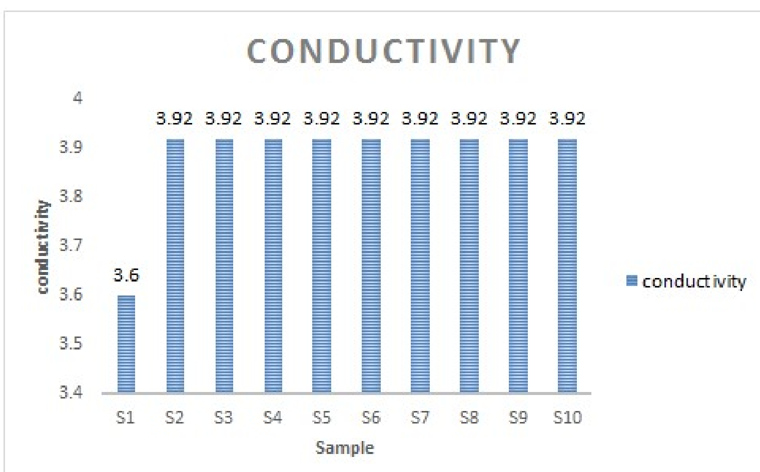


Figure 5: Electrical conductivity variations

Table 7: Interpretation of Electrical Conductivity (EC) Variation Across Sampling Sites

Sample	Observed EC (dS/m, Approx.)	Salinity Class	Soil Quality Implication
S1	~3.6 (Lowest)	Non-saline to slightly saline	Safe for crop growth
S2	~3.9	Slightly saline	Minor effect on sensitive crops
S3	~3.9	Slightly saline	Low salinity stress
S4	~3.9	Slightly saline	Suitable for most crops
S5	~3.9	Slightly saline	No serious salinity hazard
S6	~3.9	Slightly saline	Normal soil condition
S7	~3.9	Slightly saline	Acceptable salinity level
S8	~3.9	Slightly saline	Safe limit for agriculture
S9	~3.9	Slightly saline	No salinity constraint
S10	~3.9	Slightly saline	Stable salt concentration

3.4 Soil Texture Analysis

Texture of soil in samples taken from Palwal District analysis showed that all the soil samples were mainly fine-textured, with the differences in values varying from 92. 38% to 92. 84%. The smallest soil texture value was measured at S7 (92. 38%), and the biggest at S8 (92. 84%). Most of the samples hardly differed, showing that the soil texture was very much the same throughout the study area.Agricultural sites (S1S5) had values ranging from 92. 65% to 92. 76%, whereas the urban and industrial sites (S6,S10) were between 92. 38% and 92. 84%. The marginally higher values recorded in industrial sites such as S6, S8, and S10 may point to a larger amount of fine particles present, which can improve nutrient retention but at the same time increase compaction risk. The lower value at S7 is a sign of relatively better aeration and drainage than the other sites (Fig 6).The very limited variation in all the samples suggests that the change in land-use does not affect up a lot soil texture, and the texture is mainly determined by the parent material, weathering, and soil-forming processes. In general, fine-textured soils are more favorable for farming because such soils can retain more moisture and more nutrients at the same time (Hillier et al. 1999), but good management is necessary to prevent soil compaction and limited aeration (Table 8).

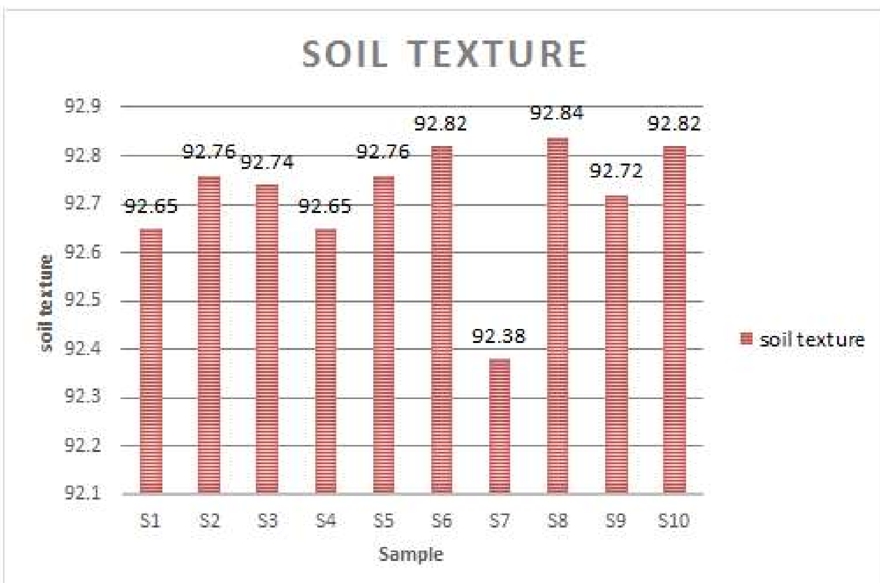


Figure 6: Soil texture variations

The soil texture bar chart shows ten equally spaced soil samples in the horizontal axis labeled as S1 to S10. The vertical axis shows soil texture numbers using a linear continuous scale from 92.0 to 93.0 with equal tick intervals of 0.2 units at 92.0, 92.2, 92.4, 92.6, 92.8, and 93.0, giving a total measurement range of 1.0 unit.This detailed scale allows one to visually differentiate fine variations in soil texture very accurately among the samples.

Table 8:Interpretation of Soil Texture Variation Across Sampling Sites

Sample	Observed Soil Texture (%)	Interpretation	Soil Physical Implication
S1	~92.6	Fine-textured soil	Good water-holding capacity and nutrient retention
S2	~92.7	Fine-textured soil	Stable structure with moderate porosity
S3	~92.7	Fine-textured soil	Suitable for crop growth due to high moisture retention
S4	~92.6	Fine-textured soil	Uniform texture supports consistent soil behaviour
S5	~92.7	Fine-textured soil	Indicates dominance of silt and clay particles
S6	~92.9 (Highest)	Very fine-textured soil	High nutrient-holding capacity but risk of compaction
S7	~92.3 (Lowest)	Fine-textured soil	Slightly higher aeration compared to others
S8	~92.9 (Highest)	Very fine-textured soil	High fertility potential but prone to reduced aeration
S9	~92.8	Fine-textured soil	Good balance between water retention and drainage
S10	~92.8	Fine-textured soil	Stable soil structure suitable for agriculture

3.5 Porosity Analysis

Porosity of soil samples obtained from Palwal District had a range of 36.28% to 38.54% indicating moderate difference among sites. S3 had lowest percentage of porosity (36.28%) and S9 had maximum (38.54%). Most samples had values between 37-38.5%, which depicts moderate to high pore space indicating good porosity. High pore space is helpful in allowing water to infiltrate into soil, and allow for free flow of air to enable healthy root growth, microbial activity (Singh et al. 2007). Agricultural sites gave comparatively higher porosity compared to industrial or urban areas as reliable soil structure of such areas was deduced. Lower porosity of few sites depicted their interaction with anthropogenic activities such as heavy machinery, construction work, etc. Fig 7 &; Table 9 shows porosity of sites.

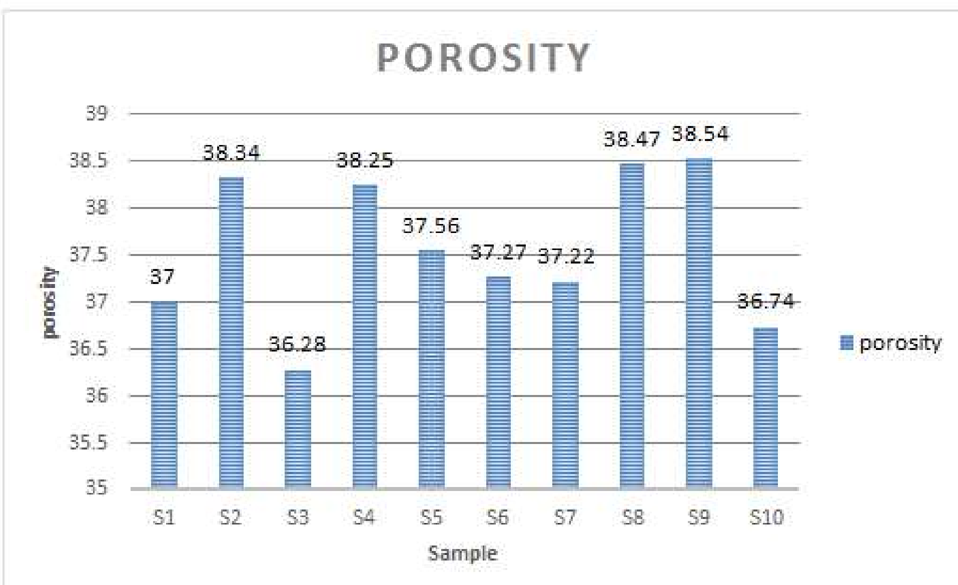


Figure 7: Porosity variations

Table 9: Interpretation of Soil Porosity Variation Across Sampling Sites

Sample	Observed Porosity (%)	Interpretation	Soil Functional Implication
S1	~37.0	Moderate porosity	Adequate aeration and water infiltration
S2	~38.3	High porosity	Good root penetration and drainage

S3	~36.3 (Lowest)	Relatively low porosity	Slight compaction; reduced air and water movement
S4	~38.2	High porosity	Favourable for plant root growth
S5	~37.6	Moderate porosity	Balanced water retention and aeration
S6	~37.3	Moderate porosity	Stable soil structure
S7	~37.2	Moderate porosity	Slight urban compaction impact
S8	~38.4	High porosity	Good moisture retention with aeration
S9	~38.5 (Highest)	Very high porosity	Excellent infiltration and root growth
S10	~36.7	Moderate–low porosity	Possible compaction effect

3.6 Nitrogen Analysis

The nitrogen content of the soil samples from Palwal District was generally low as it ranged from 1.14 to 2.18 mg/kg. The S1 sample had the highest nitrogen content of 2.18 mg/kg, and S7 had the lowest nitrogen content of 1.14 mg/kg. Comparatively, agricultural lands showed higher nitrogen contents than urban and industrial areas, which may be due to the use of fertilizers and organic matter in agriculture. Besides, industrial and urban soils are usually low in nitrogen because of less organic matter and various disturbances to the land. The results are indicative of In reality good nitrogen management is required for the maintenance of soil fertility and crop production. (Fig 8 & Table 10).

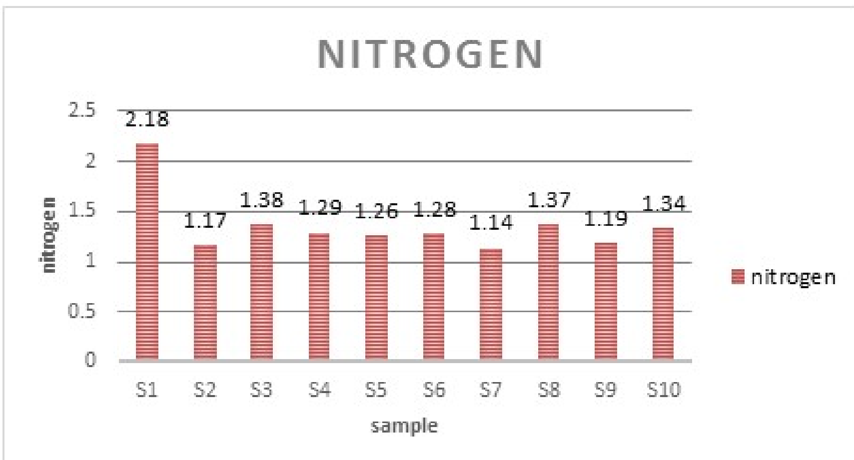


Figure 8: Nitrogen variations

Table 10: Interpretation of Soil Nitrogen Variation Across Sampling Sites

Sample	Observed Nitrogen (kg/ha or %)	Interpretation	Soil Fertility Implication
S1	~2.1 (Highest)	High nitrogen content	Better fertility potential for crops
S2	~1.1	Low nitrogen	Nutrient deficiency; needs fertilization
S3	~1.3	Moderate nitrogen	Suitable for moderate crop growth
S4	~1.2	Low–moderate nitrogen	Limited nutrient availability
S5	~1.2	Low–moderate nitrogen	Requires nitrogen supplementation
S6	~1.2	Low–moderate nitrogen	Indicates low organic matter status
S7	~1.1 (Lowest)	Very low nitrogen	Poor fertility; urgent nutrient management needed
S8	~1.3	Moderate nitrogen	Improved fertility compared to other sites
S9	~1.2	Low–moderate nitrogen	Marginal nitrogen availability
S10	~1.3	Moderate nitrogen	Supports moderate crop productivity

3.7 Phosphorous Analysis

Soil samples collected from Palwal District contained between 0.62 and 1.70 mg/kg of phosphorous, which means there was a great deal of variation in the phosphorous levels among the sampling sites. The highest concentration of phosphorous was found in S1 (1.70 mg/kg), which suggests that this area had a high level of nutrient enrichment; Then again, the lowest concentration was found in S8 (0.62 mg/kg), which could be due to nutrient depletion or very strong phosphorus fixation in alkaline soils. Of all the sites, agricultural lands had the highest levels of phosphorous when compared to industrial and urban areas. Phosphorous is critical for root development, energy transfer, and seed formation. So, if it is insufficient in soils, it can bring a decline in crop yields. The findings of this study emphasize the necessity of locally tailored phosphorous management through periodic soil testing, the use of organic amendments, and the balanced application of fertilizers to maintain soil fertility over time (Fig 9 & Table 11)

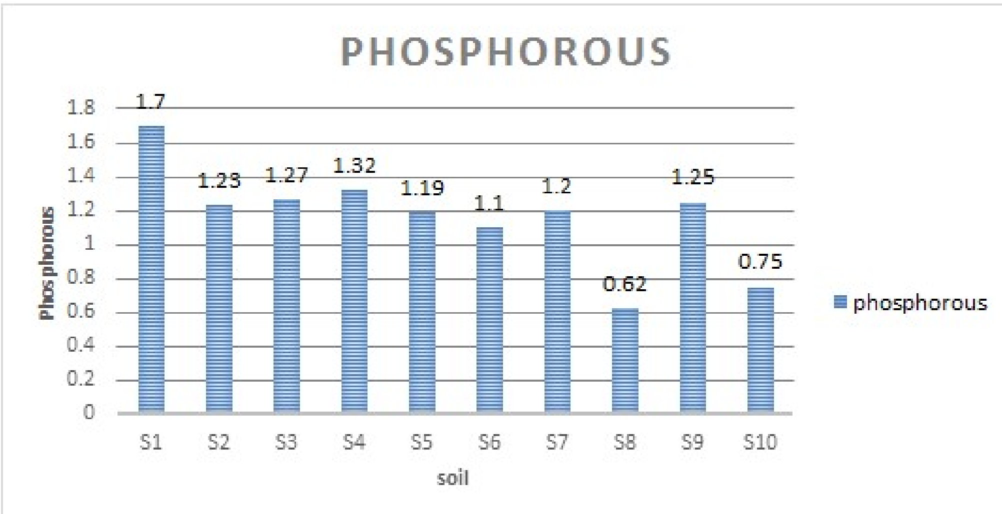


Figure 9: Phosphorous variations

Table 11: Interpretation of Soil Phosphorus Variation Across Sampling Sites

Sample	Observed Phosphorus (kg/ha or %)	Interpretation	Soil Fertility Implication
S1	~1.7 (Highest)	High phosphorus	Very good nutrient availability for crops
S2	~1.2	Moderate phosphorus	Adequate for normal crop growth
S3	~1.3	Moderate phosphorus	Supports moderate fertility
S4	~1.3	Moderate phosphorus	Sufficient for most crops
S5	~1.2	Low–moderate phosphorus	Slight nutrient limitation
S6	~1.1	Low–moderate phosphorus	Reduced phosphorus availability
S7	~1.2	Moderate phosphorus	Balanced nutrient status
S8	~0.6 (Lowest)	Very low phosphorus	Strong deficiency; requires supplementation
S9	~1.3	Moderate phosphorus	Good nutrient supply
S10	~0.8	Low phosphorus	Phosphorus deficient

3.8 Potassium Analysis

The potassium concentration in the soil samples from Palwal District varied quite widely with 0.60 - 2.72 mg/kg as the lowest and highest levels respectively. Site 1 (S1) registered the peak potassium content in the soil (2.72 mg/kg) with S4 (2.17 mg/kg) coming next. This indicates better nutrient availability as well as appropriate soil management practices. Then again, the potassium level was the lowest for S7 (0.60 mg/kg) whereas S8, S9 and S10 also had pretty low values ranging between 0.72 and 0.80 mg/kg.(Fig 10 & Table 12).

Potassium is one of the main nutrients that that a plant needs for photosynthesis, activating enzymes, water regulation, disease resistance, and grain production. The increase of potassium in farmland soils might be attributed to the use of fertilizers and the addition of green matter, while the decrease in soils of industrial and urban areas might be a consequence of continuous nutrient removal, poor replenishment, or leaching losses. To sum up, based on these results, different potassium strategies at different sites, frequent soil tests and balanced fertilization, are a must to increase soil fertility, raise crop production and keep agricultural practices sustainable in the area of the study.

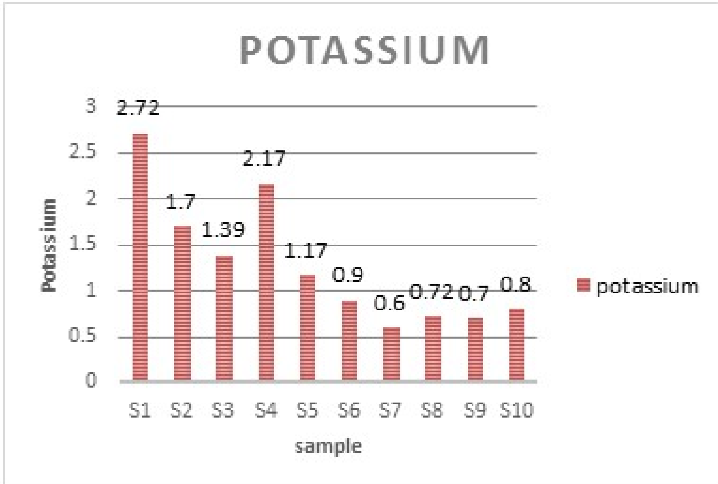


Figure 10: K variations

Table 12: Interpretation of Soil Potassium Variation Across Sampling Sites

Sample	Observed Potassium (kg/ha or %)	Interpretation	Soil Fertility Implication
S1	~2.7 (Highest)	Very high potassium	Excellent potassium supply for crops
S2	~1.6	Moderate potassium	Adequate for normal crop growth
S3	~1.4	Moderate potassium	Satisfactory potassium availability
S4	~2.1	High potassium	Good nutrient reserve
S5	~1.1	Low–moderate potassium	Slight potassium limitation
S6	~0.9	Low potassium	Deficiency likely to affect crop growth
S7	~0.5 (Lowest)	Very low potassium	Strong potassium deficiency
S8	~0.6	Very low potassium	Severe nutrient limitation
S9	~0.7	Low potassium	Poor potassium availability
S10	~0.8	Low potassium	Insufficient for optimum yield

3.9 Novelty of the Study

TWe have broken new ground by comparing soils from agricultural areas with those from urban-industrial areas in Palwal District Haryana for their physical as well as chemical properties, and heavy metal (Pb) contamination, in different land-use scenarios. Studies of the region so far have been limited mainly to fertility parameters. This study has combined soil texture porosity bulk density, nutrient dynamics (NPK), and lead concentration to get a full picture of the soil's health. Using GIS-based spatial mapping to show the distribution of sampling sites and the variability of contamination adds a geographical dimension to the precise monitoring of the environment. The present research points to Pb accumulation in industrially influenced soils at an early stage, even when exposure levels are still within the permissible limits, thereby signifying the indication of potential long-term risks to soil sustainability and food safety. Besides presenting baseline data for Palwal District, the study's results are geared towards future soil quality monitoring, pollution risk assessment, and site-specific nutrient management strategies in rapidly urbanizing semi-arid areas.

4.CONCLUSION AND FUTURE PROSPECTS

This research offers a side-by-side analysis of the physical, chemical, and nutritional characteristics of rural and urban-industrial soils in the Palwal District in Haryana. The study also underlines how land use changes contribute to variations in soil properties and the sustainability of farming. The findings suggest that soil pH is generally favorable for farming as it ranges from moderate to strong alkalinity (pH 7.909.16) and nonsaline electrical conductivity. The soil texture and porosity stayed unchanged, indicating a natural soil-forming process as dominant Still the bulk density changed slightly showing some degree of soil compaction in the areas under industrial influence. Nutrient analysis indicated that the soils are low to medium in nitrogen and phosphorus content. There is a very large unevenness in potassium distribution in soil which shows the significance of balanced fertilization for crop production. The lead levels were found to be safe but were relatively high in industrial areas showing that anthropogenic contamination is at the early stages.

The agricultural soils in general were found to have better fertility and structural characteristics which could ensure the continued support of crop production. Considering that, the future research should include seasonal soil monitoring, multi-metal contamination analysis, crop response studies, and advanced GIS-based spatial modelling. The use of organic amendments, precision nutrient management, and phytoremediation techniques will be very important in achieving the goals of better soil health, environmental safety, and sustainable agricultural productivity in the rapidly urbanizing areas.

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