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GPS-based characterization and delineation of soils of Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon

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Abstract
The investigation entitled "GPS-Based Characterization and Delineation of Soils of Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon" was conducted during 2024–25 to assess soil properties, fertility status, and spatial variability using GPS and GIS techniques. A total of 150 surface soil samples were analysed, and soil fertility maps were prepared using ArcGIS 10.8. The soils were alkaline (pH 7.38–8.72) and non-saline (EC 0.10– 0.92 dS m^{-1}), with organic carbon ranging from 0.24 to 0.58% and calcium carbonate from to 14.25%. The soils predominantly exhibited low available nitrogen (97.33%), medium phosphorus (94%) and very high potassium (94.33%). Sulphur was sufficient in 98% of the samples, while iron and zinc deficiencies were observed in 41.33% and 77.33% of the samples, respectively. Manganese and copper were sufficient throughout the study area. The soils were predominantly gravelly clay and classified as Typic Haplustepts and Vertic Haplustepts under USDA Soil Taxonomy. The findings indicate the need for balanced nutrient management, particularly nitrogen application and correction of iron and zinc deficiencies, to improve soil fertility and sustain crop productivity.

Keywords: Soil fertility, GPS, GIS, USDA Soil Taxonomy, Spatial variability

1. Introduction

Soil is an essential natural resource that must be utilized judiciously in accordance with its inherent potential to meet the increasing demands of a growing population. Regular assessment of soil quality is essential to maintain soil health, productivity, and the efficient use of natural resources. Soil is a vital natural resource that supports the production of food, fibre, fuel, and other essential materials. As the primary medium for plant growth, it plays a crucial role in crop production, food security, and the long-term sustainability of agricultural systems.

GPS and GIS are important tools for assessing soil fertility and understanding the spatial variability of soil properties. These technologies help prepare thematic maps of nutrient distribution, identify homogeneous soil management units, and improve the accuracy of soil sampling. Georeferenced soil sampling also allows researchers to revisit the same locations and monitor changes in soil nutrient status over time (Sharma, 2004; Sood *et al.*, 2004) [1, 2]. The soils of Maharashtra are characterized by generally low fertility and considerable variation in their genetic, morphological, physical, chemical, and biological properties (Challa *et al.*, 1995) [3]. Raychaudhari and Chakravarty (1943) [4] categorized the soils of the state into several major groups, including lateritic soils, coastal saline soils, coastal alluvial soils, black soils of different depths, saline and alkaline soils, and red to grey soils developed from diverse parent materials.

Soil profile study involves the systematic examination of soil horizons from the surface to the underlying parent material. It provides valuable information about soil morphology, structure, texture, and physico-chemical properties. Understanding the variations among soil horizons helps in assessing nutrient availability, water-holding capacity, and root development. This information is useful for selecting suitable crops and planning effective fertilizer and irrigation management practices.

Detailed soil survey of Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon. has carried out with following objective:

1. To characterize and classify the soils of Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon.

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2. Materials and methods

2.1 Study area

PAH Government College of Agriculture, Halgaon was located in between 18.59o N latitude and 75.24o E longitude covered total area of 40 ha. The elevation is 560 m above mean sea level.

The total geographical area of PAH Government College of Agriculture, Halgaon, is 40 ha, of which 10 ha is under cultivation. Tree plantations and non-cultivated land occupy 26.5 ha, while built-up areas and water bodies cover 2.6 ha and 0.9 ha, respectively. The natural vegetation is

adapted to the hot, dry, semi-arid climate and mainly comprises scattered trees, thorny shrubs, grasses, and other drought-tolerant species. The study area of PAH Government College of Agriculture, Halgaon, experiences a hot, dry, semi-arid climate with high summer temperatures and low, irregular rainfall. Summer temperatures may exceed 40 °C, particularly during April and May. Most rainfall occurs during the southwest monsoon from June to September, while winters are generally mild and dry. Jamkhed taluka receives an average annual rainfall of approximately

583.3 mm, indicating the semi-arid and drought-prone nature of the region.

Soil sampling

Geo-referenced surface soil samples (0–20 cm depth) were collected from the cultivated area of Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon, using a grid-based sampling approach at 50 m × 50 m intervals. A total of 150 soil samples were collected from predetermined locations. The latitude, longitude, and altitude of each sampling site were recorded using GPS/DGPS and maintained for GIS-based spatial analysis. Soil samples were collected using a stainless-steel auger to minimize contamination from metallic materials.

Mapping of soil

The delineation of the area for different nutrient levels of soils and their extent of area was calculated and mapping was carried out by using Arc-GIS 10, version 10.1 software.

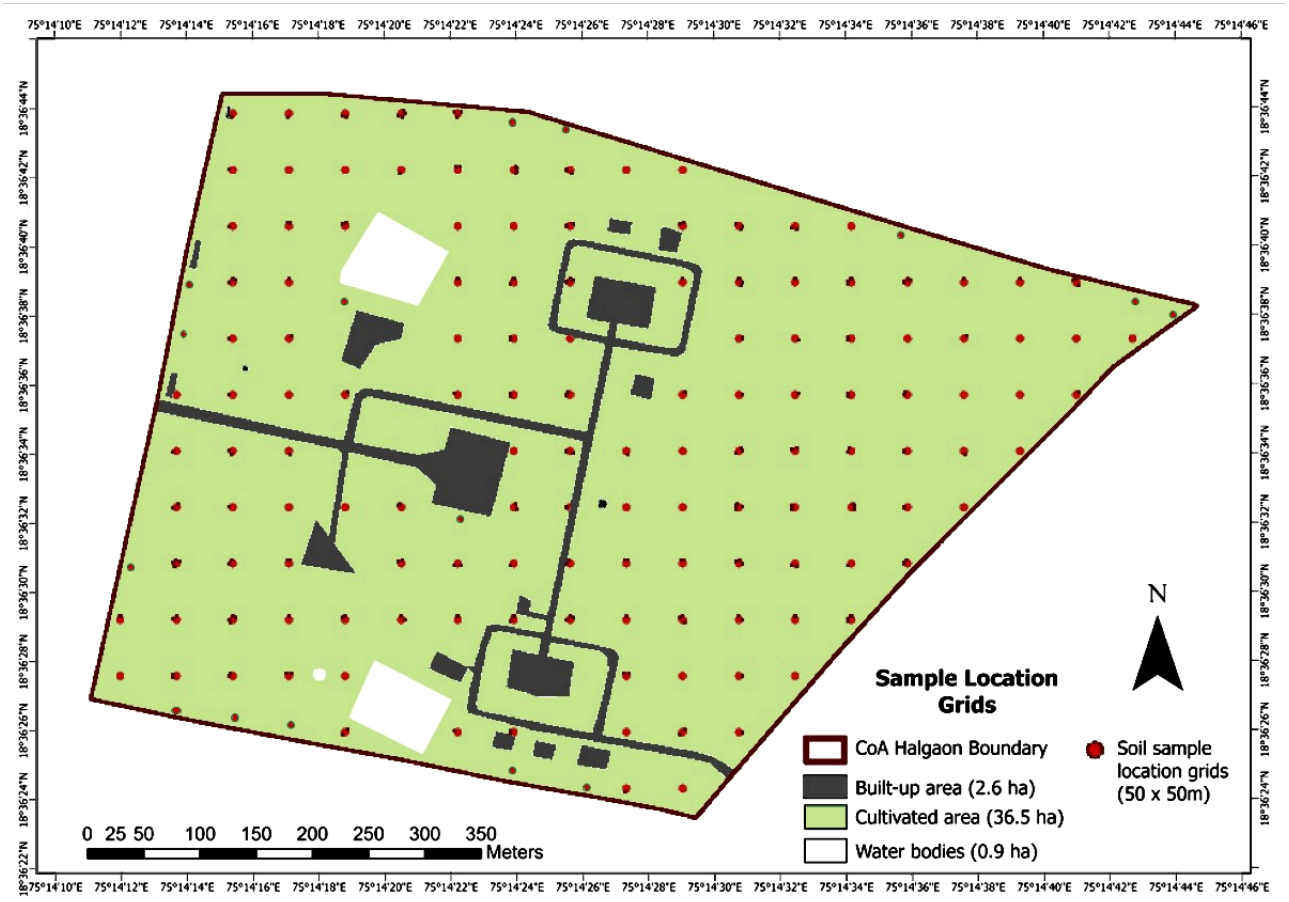


Figure 1. GPS-based grid soil sampling locations in PAH Government College of Agriculture, Halgaon

Result and discussion

3.1 Soil reaction (pH), EC, organic carbon and calcium carbonate

Soil pH ranged from 7.38 to 8.72 (mean 8.17), with 79.33% of soils moderately alkaline,

6.67% strongly alkaline and 14% slightly alkaline. Lower soil pH due to well-drained soil condition and light textured. Similar patterns of soil alkalinity were also reported by Pavan *et al.* (2017) [5] in the soils of Baragaon Nandur village, Rahuri taluka. Electrical conductivity ranged from 0.10 to 0.92 dS m^{-1} (mean 0.34 dS m^{-1}); 100% of samples were within the normal (non-saline) range. The observed variation in EC may be associated with differences in soil properties, drainage conditions, and the distribution of soluble salts. Similar findings were reported by Babaruwan (2017) [6] and Indragir (2015) [7]. Organic carbon content varied from 0.24 to 0.58% (mean 0.40%), with 50.67% of samples moderate, 49.33% low. Jadhav *et al.* (2024) [8] also reported low organic carbon status associated with erosion and coarse-textured soils in Nashik district. Calcium carbonate ranged from 3.0 to 14.25% (mean 7.86%), falling in the Low (6%), medium (87.33%), high (6.67%) categories. The predominance of moderately calcareous soils may be attributed to the semi-arid climatic conditions of the study area, where low precipitation and high evapotranspiration favour the accumulation and precipitation of calcium carbonate in the soil. Similar findings were reported by Patil *et al.* (2017) [9] at the Agriculture College Farm, Kadegaon, Sangli district, and by Surwase *et al.* (2024) [10] in Rahuri tehsil, Ahilyanagar district.

Available macronutrients (N, P, K and S)

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Available nitrogen ranged from 195 to 290 kg ha^{-1} (mean 247.5 kg ha^{-1}), with 97.33% of soils low and 2.67% medium, the low to medium status of available nitrogen in the study area may be attributed to the low organic carbon content of the soils, as soil organic matter is an important source of nitrogen. Furthermore, nitrogen losses through leaching, ammonia volatilization and denitrification, along with limited nitrogen mineralization under unfavourable soil moisture conditions, may have contributed to the observed nitrogen status. Similar findings were reported by Pranav *et al*. (2025) at the VNMKV farm, Parbhani, in north-western Maharashtra.

Table 1. Chemical properties of soils of PAH Government College of Halgaon (n = 150)

Particulars	Chemical Properties			
	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (%)	$CaCO_3$ (%)
Mean	8.17	0.34	0.40	7.86
Range	7.38-8.72	0.10-0.92	0.24-0.58	3.0-14.25
Standard deviation	0.24	0.14	0.07	1.72
Standard error	0.019	0.012	0.006	0.14
Coefficient of variance (%)	2.99	43.26	18.95	21.93
Categories	Slightly alkaline 14 % (21)	Normal 100% (150)	Low 49.33% (74)	Slightly calcareous 6% (9)
	Moderately alkaline 79.33% (119)		Medium 50.67% (76)	Moderately calcareous 87.33% (131)
	Strongly alkaline 6.67% (10)			Strongly calcareous 6.67% (10)

Available phosphorus ranged from 9.13 to 28.8 kg ha^{-1} (mean 16.32 kg ha^{-1}); 94% of samples were medium, 4% low, 2% high status reflecting alkaline conditions. The variation in available phosphorus may be attributed to differences in soil pH, $CaCO_3$, organic carbon, texture, and fertilizer management. Similar findings were reported by Bhoyar *et al.* (2023) [11] and Bandgar (2023) [12]. Available potassium was high to very high throughout, ranging from 265 to 672 kg ha^{-1} (mean 457.2 kg ha^{-1}) 94.33% very high, 6.67% high), the high to very high available potassium status may be attributed to potassium-bearing minerals, clay content and mineralogical composition of the parent material. Similar findings were reported by Shelke *et al.* (2022) [13] in the sugar factory command area of Rahuri Tehsil. Available sulphur ranged from 8.1 to 27.5 mg kg^{-1} (mean 16.6 mg kg^{-1}), with 98% of soils sufficient and 2% deficient. The predominance of sufficient available sulphur may be attributed to organic matter mineralization, sulphur retention and the application of sulphur-containing fertilizers. Similar findings were reported by Ghode (2016) [14] in Western Maharashtra and Hadole *et al.* (2019) in Jalgaon district.

Table 2. Available macronutrient status of soils of PAH Government College of Halgaon (n = 150)

Particulars	Available Macronutrients			
	N	P	K	S
		(kg ha^{-1})		(mg kg^{-1})
Mean	247.5	16.32	457.2	16.6
Range	195-290	9.13-28.8	265-672	8.1-27.5
Standard deviation	15.81	3.68	85.07	3.72
Standard error	1.29	0.30	6.94	0.3
Coefficient of variance (%)	6.38	22.55	18.60	22.33
Categories	Low	Low	High	Deficient
	97.33% (146)	4% (6)	6.67% (142)	2% (3)
	Medium 2.67%	Medium	Very High	Sufficient
	(4)	94% (141)	94.33% (8)	98% (97)
		High		
		2% (3)		

DTPA-extractable micronutrients

The DTPA-extractable iron content varied from 3.54 to 5.66 mg kg^{-1}, with a mean of 4.59 mg kg^{-1}. About 41.33% of the soil samples were iron-deficient, possibly due to reduced iron availability under alkaline conditions and low organic matter content. Available manganese and copper ranged from 10.3 to 21.0 mg kg^{-1} and 2.17 to 5.05 mg kg^{-1}, respectively, and were sufficient in all samples. Available zinc ranged from 0.31 to 0.95 mg kg^{-1}, averaging 0.52 mg kg^{-1}, with 77.33% of the samples classified as deficient. This deficiency may be associated with alkaline soil reaction and limited organic matter content, which can reduce zinc availability. Comparable Fe and Zn deficiency trends were reported by Hadole *et al*. (2019) in Jalgaon district and by Shelke *et al.* (2022) [13] in Rahuri tehsil.

Conclusion

The soils of PAH Government College of Agriculture, Halgaon exhibited variations in physical properties, including bulk density, colour and texture, and nutrient status. The soils were slightly to strongly alkaline and non-saline, with low to medium organic carbon and variable calcium carbonate content. Available nitrogen and phosphorus were low, potassium was high, and sulphur was sufficient. Among the

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DTPA-extractable micronutrients, iron and zinc were deficient, whereas manganese and copper were sufficient.

Table 3. DTPA-extractable micronutrient status of soils PAH Government College of Halgaon

Particulars	Available micronutrients (mg kg^{-1})			
	Fe	Mn	Zn	Cu
Mean	4.59	13.4	0.52	4.02
Range	3.54-5.66	10.3-21.0	0.31-0.95	2.17-5.05
Standard deviation	0.46	2.2	0.10	1.23
Standard error	0.03	0.17	0.008	0.10
Coefficient of variance (%)	10.19	16.36	19.65	30.80
Categories	Deficient 41.33% (62) Sufficient 58.67% (88)	Sufficient 100% (150)	Deficient 77.33% (116) Sufficient 22.67% (34)	Sufficient 100% (150)

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Disclaimer

The results and conclusions presented in this article are derived from the analysis of georeferenced soil samples collected from Punyashlok Ahilyadevi Holkar Government College of Agriculture, Halgaon, during 2024–25. The interpretations of soil physicochemical properties, nutrient availability, and spatial variability are specific to the sampling design, analytical procedures, and environmental conditions prevailing within the study area. The generated soil fertility maps and associated recommendations should therefore be interpreted within the geographical and temporal scope of the investigation. Their applicability to other locations may require site-specific validation through systematic soil sampling and laboratory analysis. The suggested nutrient management practices are intended to support informed agricultural decision- making and should be implemented in accordance with soil-test-based recommendations and locally applicable agronomic guidelines.

Conflict of interest

The authors declare that there are no conflicts of interest associated with this research article. The study was conducted independently, and no financial, personal, or institutional relationships are known to have influenced the research design, data analysis, interpretation of results, or preparation of the manuscript.

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