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GPS-GIS Based Assessment of Soil Micronutrients of Agriculture College Farm, Pune, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Present soil survey in College of Agriculture, Pune (Maharashtra) India was carried out during 2024 by using Global Positioning System (GPS) and Geographical Information System (GIS). was undertaken with 160 geo-referenced soil samples collected by randomized method. Out of 160 soil samples, 127 samples from Agronomy Farm and 33 samples were collected from Modi Baugh and

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Pathology Farm by using standard soil sampling procedure and were analysed for chemical properties at College of Agriculture, Pune with an objective to study assess the soil nutrient status, delineate soil fertility maps of College of Agriculture farm, Pune. The pH and EC of soils of Agronomy Farm was found in between 7.63 to 8.96 (mean 8.11) and 0.20 to 0.78 dS m^{-1} with mean 0.41 dS m^{-1} respectively. The organic carbon and calcium carbonate content of the Agronomy Farm was ranged from 0.10 to 0.73 per cent with mean 0.39 per cent and 10.25 to 27.5 per cent with mean 18.53 per cent respectively. The DTPA extractable micronutrients viz., iron, manganese, zinc and copper in soils ranged from 3.02 to 10.26 mg kg^{-1} (mean 4.71 mg kg^{-1}), 3.61 to 11.47 mg kg^{-1}(mean 7.06 mg kg^{-1}), 0.66 to 3.58 mg kg^{-1} (mean 1.92 mg kg^{-1}), 1.65 to 3.98 mg kg^{-1} (mean 3.00 mg kg^{-1}) respectively.

The soils of Modi Baugh and Pathology Farm showed pH and EC between from 7.52 to 8.45 with mean 7.85, and 0.21 to 0.64 dS m^{-1} with mean 0.45 dS m^{-1} respectively. The organic carbon content and calcium carbonate ranged from 0.17 to 0.62 per cent with mean 0.32 and 8.5 to 25.5 per cent with mean 14.1 per cent respectively. The DTPA extractable micronutrients viz, iron, manganese, zinc and copper present in soil ranged from 2.08 to 6.94 mg kg^{-1} (mean 4.51 mg kg^{-1}), 3.25 to 10.28 mg kg^{-1} (mean 8.10 mg kg^{-1}), 0.55 to 3.98 mg kg^{-1} (mean 2.15 mg kg^{-1}), 2.25 to 3.91 mg kg^{-1} (mean 2.98 mg kg^{-1}) respectively.

Based on the GPS locations of samples and soil test results, soil fertility maps of College of Agriculture Farm, Pune were prepared by using Arc-GIS 10.8.2 for soil pH, EC, OC, $CaCO_3$ and DTPA extractable micronutrients i.e Fe, Mn, Zn, Cu.

Keywords: GIS; GPS; micronutrients; soil fertility maps.

1. INTRODUCTION

Soil is a dynamic, biologically active medium essential for agriculture, supporting organisms like microbes and earthworms that influence nutrient cycling and plant growth. Efficient soil management is crucial for food production and socioeconomic development, particularly in developing nations facing food security challenges. While comprehensive soil testing on every farm is impractical, advances in technology, such as portable sensors, remote sensing, and machine learning, allow for cost-effective, large-scale data collection. Systematic sampling combined with statistical methods helps extrapolate soil health across regions, supporting sustainable agricultural practices and precision farming, which increase productivity and resilience against climate change (Xieet al*.,* 2020; Shavivet al*.,* 2008).

Crop availability is significantly impacted by the parent material, organic matter, calcium carbonate, soil response, texture, and mineralogical composition. According to Nayyar et al*.,* 1999, calcareous soils with high pH and little organic matter are more likely to have micronutrient shortages. The term “micronutrient” refers to certain vital nutrients that are needed in extremely small amounts for the development of microbes and plants. Assessing micronutrients in agricultural soils is crucial because deficiencies in elements like iron, manganese, zinc, and copper can significantly reduce crop yield and quality, impacting overall food production and human health. These elements are vital for fundamental plant processes, including photosynthesis, enzyme function, and chlorophyll production. Assessment methods, such as soil testing and analyzing correlation between nutrient levels and yield, determine current soil status, guide the application of micronutrient fertilizers, and support sustainable agriculture by ensuring balanced plant nutrition and preventing nutrient depletion.

Global Positioning System (GPS) and Geographic Information Systems (GIS) are also essential tools for determining the soil’s spatial variability. Spatial data can be collected, stored, retrieved, transformed, and shown using a powerful set of tools known as GIS (Das et al*.,* 2004). GPS- assisted soil sample collection is crucial for creating thematic soil fertility maps. Anywhere in the world, a GPS device can accurately determine the latitude and longitude of the location, it provide soil nutrient status of various site for the future supervision, it is extremely important in agriculture (Mishra et al*.,* 2014). The use of modern technologies like GPS (Global Positioning System) and GIS (Geographic Information System) has revolutionized soil fertility mapping, enabling precise assessment of soil conditions, including micronutrient status. GPS, originally developed by the U.S. military, provides accurate geographical coordinates to determine the exact location on Earth's surface. This allows for high-precision soil sampling in specific areas. GIS, on the other hand, is a powerful computer system that captures, queries, and displays geographic data. By integrating GPS-based soil sampling with GIS, soil fertility maps can be generated that show detailed information about the micronutrient status across large areas. These maps can be updated easily, allowing for ongoing monitoring and adjustments to soil management practices based on real-time data. The ability to assess micronutrient status at a granular level enhances the precision of agricultural practices, ensuring that crops receive the right nutrients at the right time, thereby improving yields and sustainability.

This approach aligns with the objective of improving soil management through detailed and dynamic soil fertility maps, making it easier to track changes in micronutrient availability and tailor agricultural practices to meet specific crop needs.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

The campus of Agriculture College Farm, Pune is located in between latitude N 180 32’17.268’’ and longitude E 73050’37.2084’’and it covers total area of 42 ha. The elevation is 557.7 m above mean sea level. The College of Agriculture, Pune is situated at the Ganeshkhind Road, Shivaji Nagar, Pune. The Research Farm is under culturable command area since 1907 and present study was, therefore, undertaken to prepare detailed soil survey of College of Agriculture Farm, Pune. The base map of Agriculture College Farm, Pune was depicted in Fig. 1. The Agriculture College Farm in Pune, located in a subtropical climate zone, experiences an average annual rainfall of 675 mm, with the South-West monsoon accounting for 75% of this between June and September, and the North-East monsoon contributing 25% from October to November. Temperatures range from a maximum of 40.2°C to a minimum of 19.1°C, with morning humidity varying between 46% and 76%, and evening humidity ranging from 15% to 41%. The region enjoys up to 10.9 hours of bright sunshine per day, peaking in the 18th meteorological week. The soils of the farm, derived from basaltic Deccan Trap rocks, are medium black, well-drained, and typically reach depths of up to 90 cm. These soils are rich in minerals such as feldspar, augite, and titaniferous magnetite, with some vesicular cavities filled with zeolite and quartz. The farm cultivates a variety of crops, including wheat, gram, sugarcane, chickpea, maize, sorghum, and soybean, while the natural vegetation consists mainly of dry deciduous trees like *Azadiracta indica, Mangifera indica, Prosopis juliflora, Syzigium cumini, Bambusa spp.*etc. The soils are likely of Vertisol class, characterized by high clay content, making them suitable for agriculture while requiring effective soil management.

2.2 Soil Sample Preparation and Laboratory Analysis

The randomization technique in study involved selecting soil sampling sites across the College of Agriculture Farm at 100-meter intervals, ensuring that each location had an equal chance of being chosen. The latitude and longitude of these sites were accurately recorded using Differential GPS. Geo-referred surface (0 - 22.5 cm) soil samples were 160 soil samples were collected, out of 160, 127 samples collected from Agronomy Farm and 27 samples from Modi Baugh and only 6 samples were collected from Pathology Farm as per farm size. Using non-metallic instruments to avoid contamination. After collection, the samples were dried, sieved, and stored for laboratory analysis, where chemical properties such as pH, EC, organic carbon, and micronutrients were evaluated. While this randomization method ensures broad spatial coverage, variations in elevation across the field can influence soil properties due to differences in factors like drainage, temperature, and organic content. After collecting the soil samples, they were brought to the laboratory. The soil drying method using shade drying, After drying, the soil is pounded with a wooden pestle and mortar, followed by sieving through 2 mm and 0.5 mm mesh sizes to standardize the sample for analysis, ensuring that fine particles are isolated and coarse materials like gravel are excluded. All the precautions were followed as per the procedure described by Jackson (1973) and standard procedure outlined by Page et al., (1982) was used to estimate chemical properties of soil. Soil samples were analyzed for pH, EC, organic carbon, calcium carbonate and DTPA extractable micronutrients viz, iron, manganese, zinc and copper. The geospatial analysis of the study area was carried out using ArcGIS 10.8.2.

2.3 Statistical Analysis

The soil samples analysis data was used to calculate the statistical data as given below-

- Range:- Range is defined as the minimum and the maximum value of the data.
- Minimum:- Minimum value of the data from all the observation.
- Maximum:- Maximum value of the data from all the observation.
- Mean:- Summing all the values or score and dividing it by total number of respondents or observations.

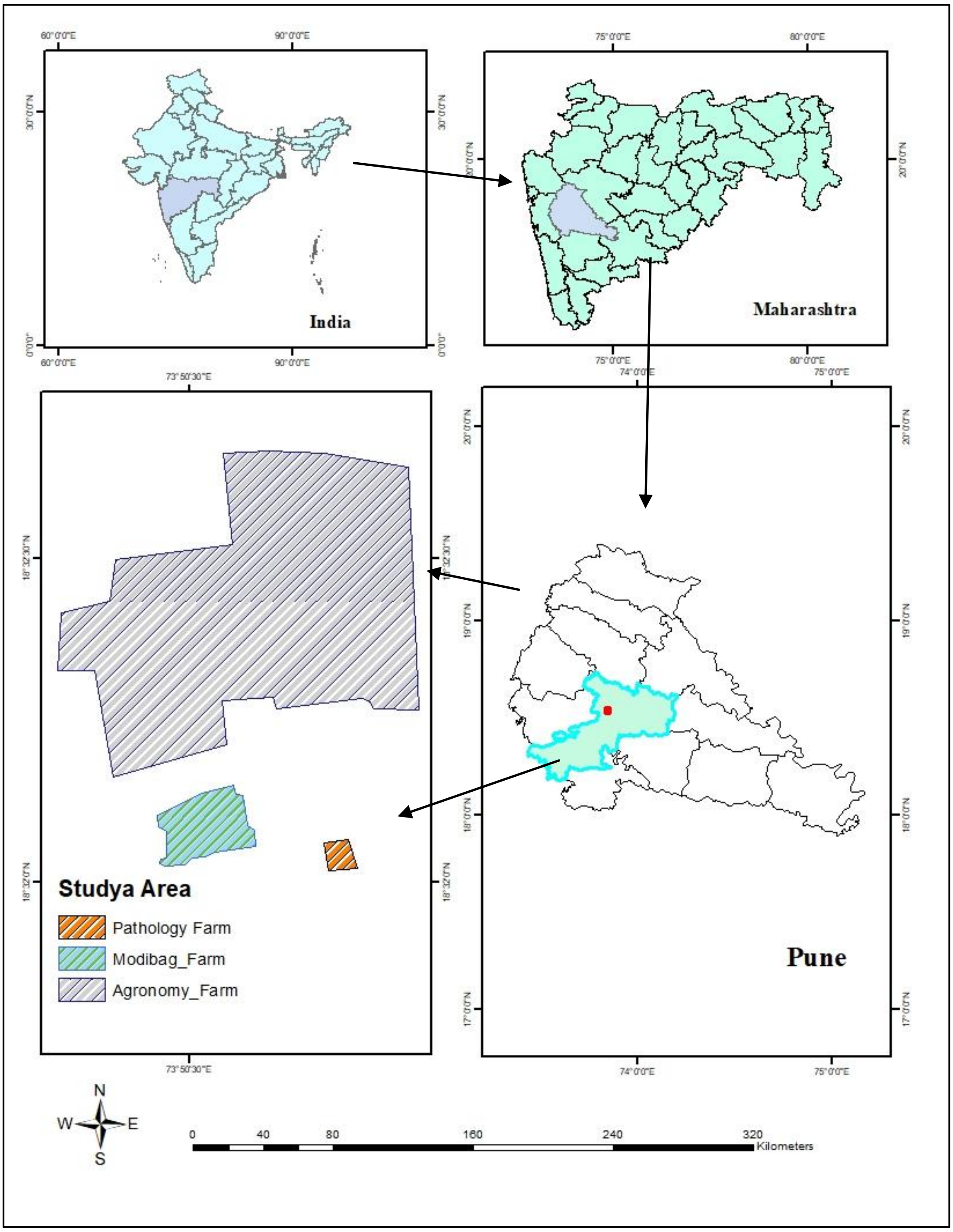

Fig. 1. Study area of College of Agriculture Farm, Pune

3. RESULTS AND DISCUSSION

3.1 Soil Reaction

Soil pH data are presented in Table 1. A total of 127 soil samples from the Agronomy Farm were analyzed, revealing a pH range of 7.63 - 8.96, with a mean of 8.11. Among these, 9.44 per cent of samples were slightly alkaline, 87.42 per cent moderately alkaline and 3.14 per cent strongly alkaline. The spatial variability across the farm is illustrated in Fig. 2.

27 samples from Modi Baugh Farm and 6 from Pathology Farm were analyzed, with pH values ranging from 7.52 - 8.45 and an average of 7.85 pH evaluations are presented in Table 2. According to the results of the analysed soils, 75.75 per cent of samples were slightly alkaline, and 24.25 per cent were moderately alkaline. Fig. 3 depicts the geographic distribution of pH for these farms.

The data of samples interpreted that most of the soils of Agriculture College Farm, Pune are moderately alkaline in range, it might be due to the influence of parent material, rainfall and topography and medium deep blacks soils brought under irrigation since long back have shifted to alkaline condition. Similar results were recorded by Nalawade and Palwe (2014) in soils collected from the ARS, SavaleVihir Farm, MPKV, Rahuri. The relative high pH in these soils might be due to origin of soil from basaltic parent material, which is inherently rich in basic cations (Patil et al*.,* 2019).

3.2 Electrical Conductivity (EC)

The soil Electrical Conductivity (EC) data are presented in Table 1. A total of 127 samples from the Agronomy Farm showed EC values ranging from 0.20 to 0.78 dS m^{-1}, with an average of 0.41 dS m^{-1}. These values fall within the normal range, suitable for healthy plant growth. The highest EC recorded was 0.78 dS m^{-1}, and the lowest was 0.20 dS m^{-1}. Spatial variability across the farm is depicted in Fig. 4, showing most soils with EC within the normal range.

For the Modi Baugh and Pathology Farms, 33 soil samples exhibited EC ranging from 0.21 to 0.64 dS m^{-1}, with a mean of 0.45 dS m^{-1} (Table 2). All samples from these farms also fell within the normal EC range, indicating favourable conditions for plant development. Fig. 5 illustrates spatial variability across these farms.

The normal EC values are likely due to careful irrigation management and the non-saline nature of the soils, as indicated by low soluble salt content. Excessive leaching of salts to lower soil horizons and removal of bases through percolation and drainage help maintain normal EC levels (Satish et al., 2018). Similar findings were reported by Golhar and Chaudhari (2013) in Jalgaon district and by (Salma et al*.,* 2019), who noted that low EC prevents salt accumulation at greater depths.

3.3 Organic Carbon

Organic carbon content in Agronomy Farm soils ranged from 0.10 % to 0.73 %, with a mean of 0.39 % (Table 1). Among 127 samples, 13.39 per cent were very low, 39.37 per cent low, 38.58 per cent moderate and 8.66 per cent moderately high in organic carbon. Higher and lower values were 0.73 % and 0.10 %, respectively. Fig. 6 highlights spatial variability, showing predominantly low organic carbon in the western zone.

There were 27 samples taken from the Modi Baugh Farms and the 6 samples taken from the Pathology Farm. The organic carbon ranged from 0.17 % to 0.62 %, averaging 0.32 % (Table 2). Out of these, 18.18 per cent very low, 57.58 per cent low, and 24.24 per cent moderate organic carbon content. Fig. 7 demonstrates spatial variability, with most soils showing low organic carbon.

Low organic carbon may be due to minimal FYM and crop residue application, rapid decomposition under high temperatures, and low vegetation cover. These findings align with reports by (Naiknaware et al., 2020) and Gosavi and Chaudhari (2016) from similar agro-climatic zones in Maharashtra.

3.4 Calcium Carbonate

Calcium carbonate content in Agronomy Farm soils ranged from 10.25 per cent to 27.5 per cent, with a mean of 18.53 per cent (Table 1). Among samples, 36.22 per cent fell into the moderate category, while 63.78 per cent exhibited very high $CaCO_3$ levels. Fig. 8 depicts the spatial distribution, showing higher $CaCO_3$ in the western zone.

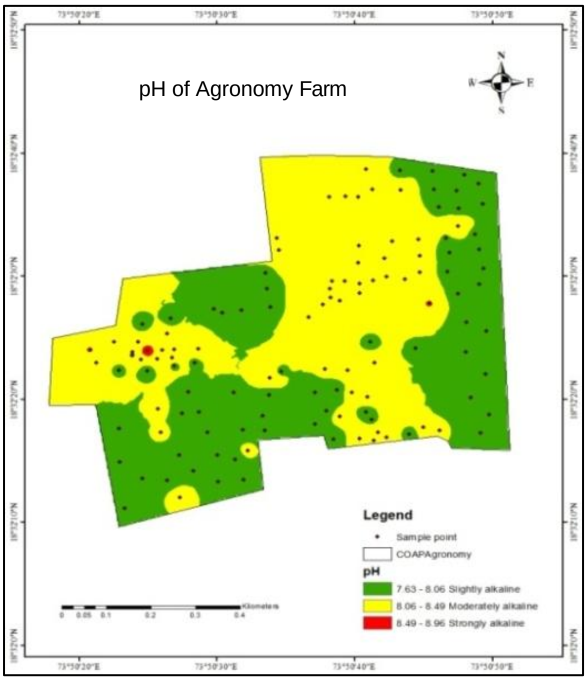

Fig. 2. pH of Agronomy Farm

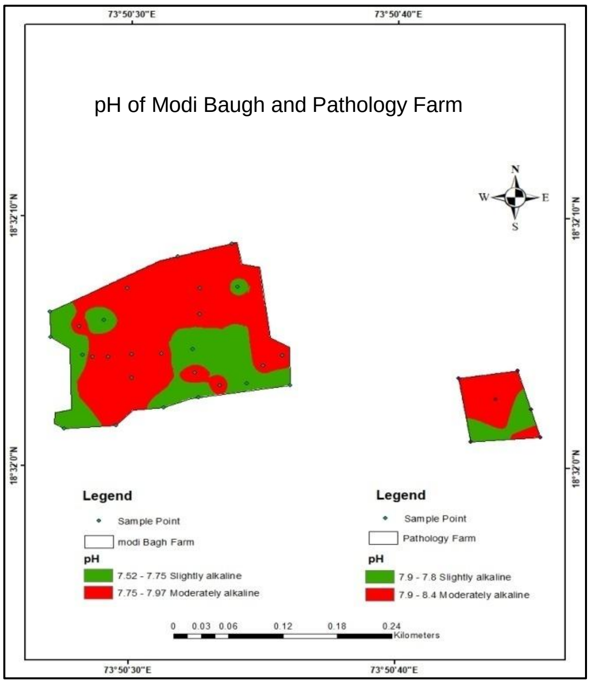

Fig. 3. pH of Modi Baugh and Pathology Farm

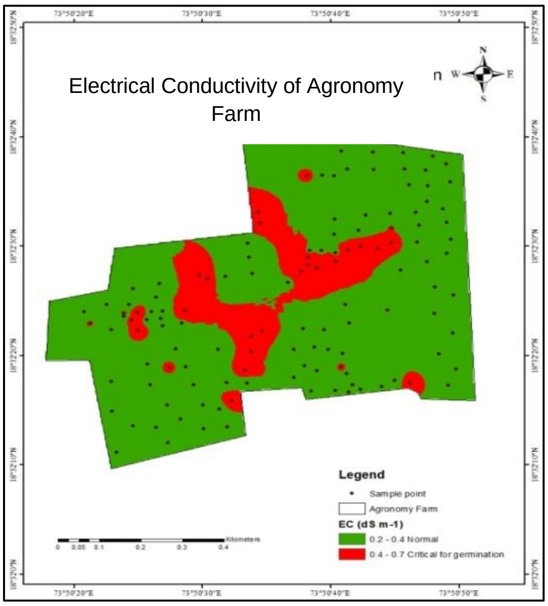

Fig. 4. EC of Agronomy Farm

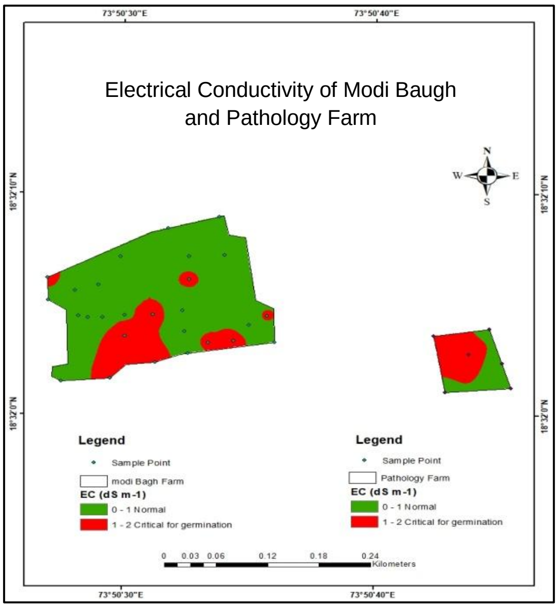

Fig. 5. EC of Modi Baugh and Pathology Farm

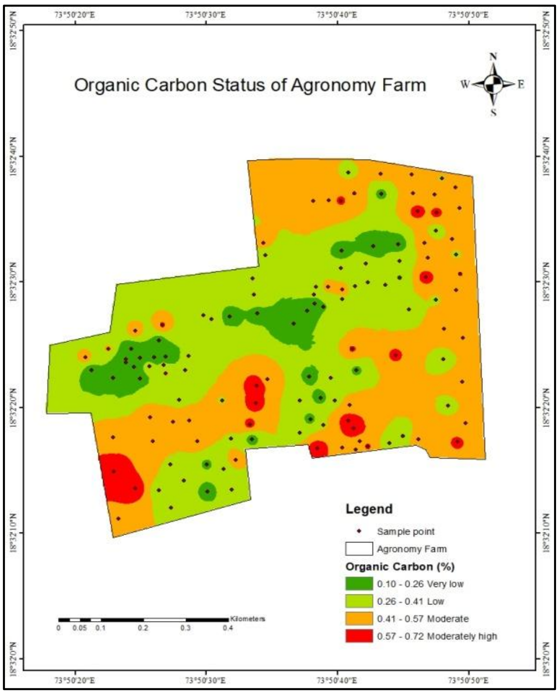

Fig. 6. Organic carbon status of Agronomy Farm

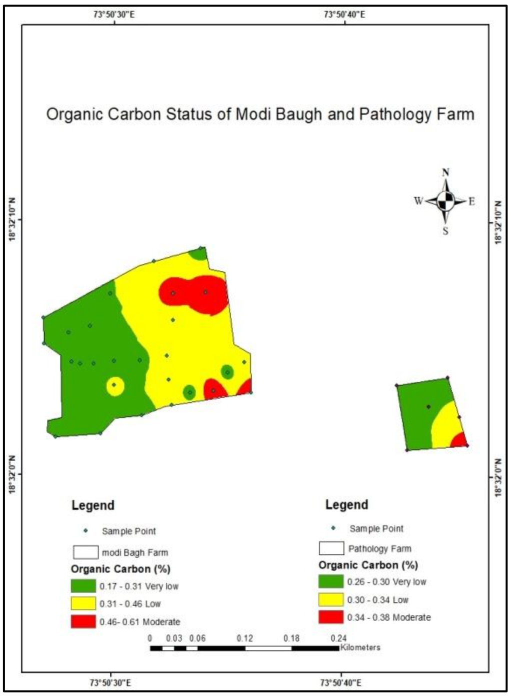

Fig. 7. Organic carbon status of Modi Baugh and Pathology Farm

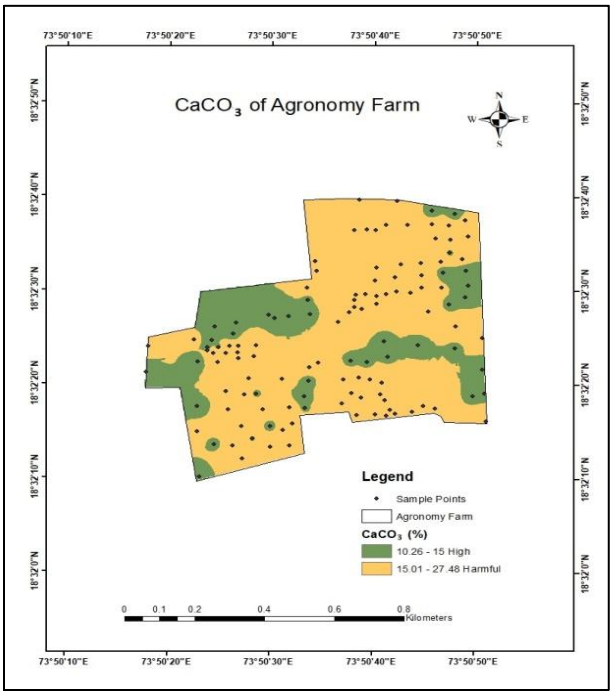

Fig. 8. Calcium Carbonate status of Agronomy Farm

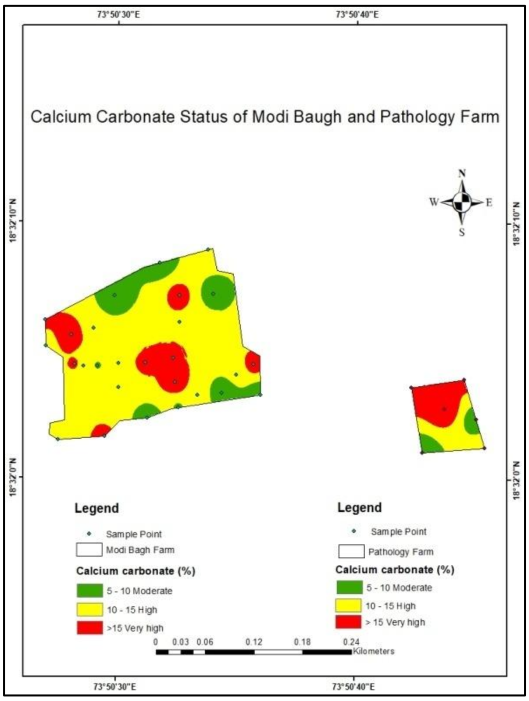

Fig. 9. Calcium Carbonate status of Modi Baugh and Pathology Farm

Table 1. Chemical properties of soils from Agronomy Farm

Particulars	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (%)	$CaCO_3$ (%)
Range	7.63 - 8.96	0.20 - 0.78	0.10 - 0.73	10.25 - 27.5
Mean	8.11	0.41	0.39	18.53
Categories	Slightly alkaline 12 (9.44%)	Normal 127 (100%)	Very Low 17 (13.39%)	Moderate 46 (36.22%)
	Moderately alkaline 111 (87.42%)		Low 50 (39.37%)	Very high 81 (63.78%)
	Strongly alkaline 4 (3.14%)		Moderate 49 (38.58%)	
			Moderately High 11 (8.66%)	

Table 2. Chemical properties of soils from Modi Baugh and Pathology Farm

Particulars	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (%)	$CaCO_3$ (%)
Range	7.52 - 8.45	0.21 - 0.64	0.17 - 0.62	8.5 - 25.5
Mean	7.85	0.45	0.32	14.1
Categories	Slightly alkaline 25 (75.75%)	Normal 33 (100%)	Very Low 6 (18.18%)	Moderate 6 (18.18%)
	Moderately alkaline 8 (24.25%)		Low 19 (57.58%)	High 19 (57.58%)
			Moderate 8 (24.24%)	Very high 8 (24.24%)

From Modi Baugh and Pathology Farms, $CaCO_3$ ranged from 8.5 per cent to 25.5 per cent, with an average of 14.10 per cent (Table 2). Among these, 57.58 per cent showed high, 24.24 per cent very high, and 18.18 per cent moderate $CaCO_3$ content. Fig. 9 illustrates spatial variability, with most areas classified as high.

These patterns align with findings by (Patil et al., 2017) and (Magare et al*.*, 2023). The semi-arid climate, characterized by low rainfall and high evaporation, promotes $CaCO_3$ precipitation. The soils' basaltic origin further contributes to these levels (Verma et al., 2012).

3.5 Available Macronutrient Status of Soil

A total of 160 soil samples were collected from the College of Agriculture Farm, Pune, to evaluate the status of essential micronutrients - iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu). These samples were taken from two key areas: 127 samples from the Agronomy Farm and 33 samples from the Pathology and Modi Baugh Farms.

The available iron content in the Agronomy Farm varied from 3.02 to 10.26 mg kg^{-1}, with an average of 4.71 mg kg^{-1}. Among these, 59.05 per cent of the samples were categorized as low in iron, while 40.95 per cent showed moderate levels. Spatial variability (Fig. 10) revealed that most of the farm was under the low iron category, particularly in the central and western zones, with the eastern region showing moderate levels. In the Pathology and Modi Baugh Farms showed a range of 2.08 to 6.94 mg kg^{-1}, with average of 4.51 mg kg^{-1}. Of these samples, 51.52 per cent exhibited moderate iron content, 42.42 per cent were low, and 6.06 per cent were categorized as very low. As seen in Fig. 11, the moderate iron levels were mainly concentrated in the northern zone. The lower availability of iron in these soils is attributed to high soil pH and the presence of calcium carbonate, which leads to iron precipitation. These findings are consistent with earlier reports by (Nagawade et al*.,* 2014).

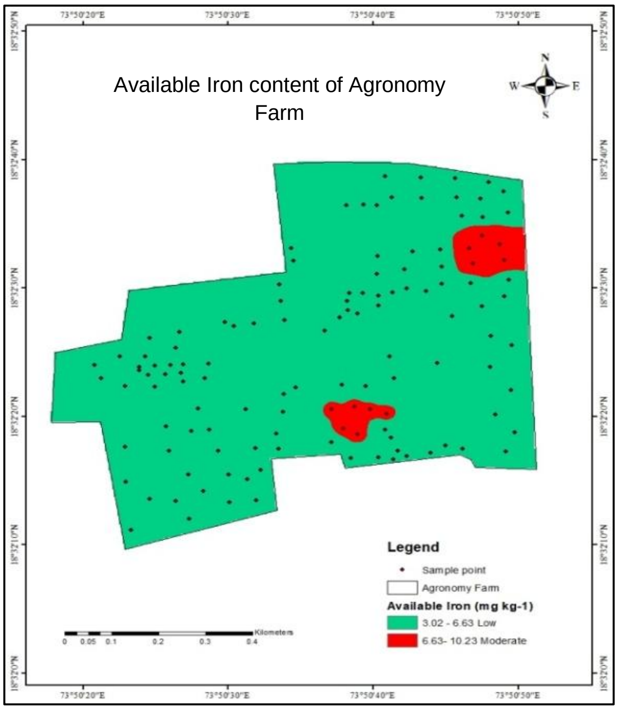

Fig. 10. Available Iron content of Agronomy Farm

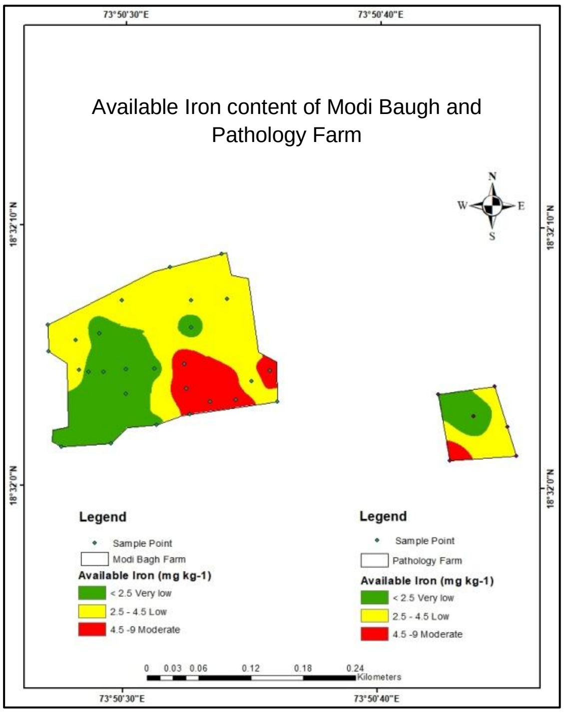

Fig. 11. Available Iron content of Modi Baugh and Pathology Farm

The available manganese content in the Agronomy Farm ranged from 3.61 to 11.47 mg kg^{-1}, with a mean of 7.06 mg kg^{-1}. A majority of the samples 66.14 per cent were in the moderately high category, 33.07 per cent were high, and only 0.78 per cent were moderate. Fig. 12 indicates generally sufficient manganese levels across the farm. In the Pathology and Modi Baugh Farms, manganese levels ranged from 3.25 to 10.28 mg kg^{-1}, with an average of 8.10 mg kg^{-1}. Here, 54.55 per cent of the samples were high, 36.36 per cent moderately high, and 9.09 per cent moderate (Fig. 13). The adequacy of manganese is likely due to higher organic matter content and optimal soil pH, as reported by (Vijaykumar et al*.,* 2011) and Gosavi and Chaudhari (2016).

Zinc content in the Agronomy Farm ranged from 0.66 to 3.58 mg kg^{-1}, with a mean of 1.92 mg kg^{-1}. Very high zinc levels were observed in 36.22 per cent of the samples, while 28.35 per cent were moderately high, 22.05 per cent moderate and 13.38 per cent high. Spatial mapping (Fig. 14) showed the northern part of the farm with the highest zinc availability. In the Pathology and Modi Baugh Farms, zinc ranged from 0.55 to 3.98 mg kg^{-1}, with a mean of 2.15 mg kg^{-1}. A large portion of the samples showed very high 39.39 per cent and moderate 33.34 per cent zinc content (Fig. 15). High organic carbon and optimal pH contributed to sufficient zinc availability, consistent with (Patil et al*.,* 2016).

Copper content was found to be uniformly very high across all farms. In the Agronomy Farm, ranged from 1.65 to 3.98 mg kg^{-1} (mean 3.00 mg kg^{-1}), while in the other farms it ranged from 2.25 to 3.91 mg kg^{-1} (mean 2.98 mg kg^{-1}). Spatial maps (Figs. 16 and 17) showed high copper availability may be due to adequate organic matter, favourable pH, and soil moisture, as supported by Mahashabde and Patel (2012) and (Vaddepally et al*.,* 2016).

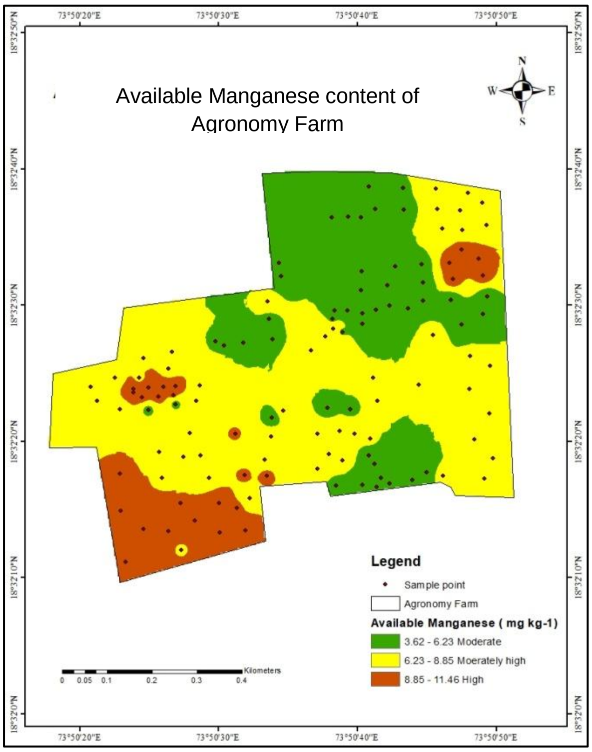

Fig. 12. Available Manganese content of Agronomy Farm

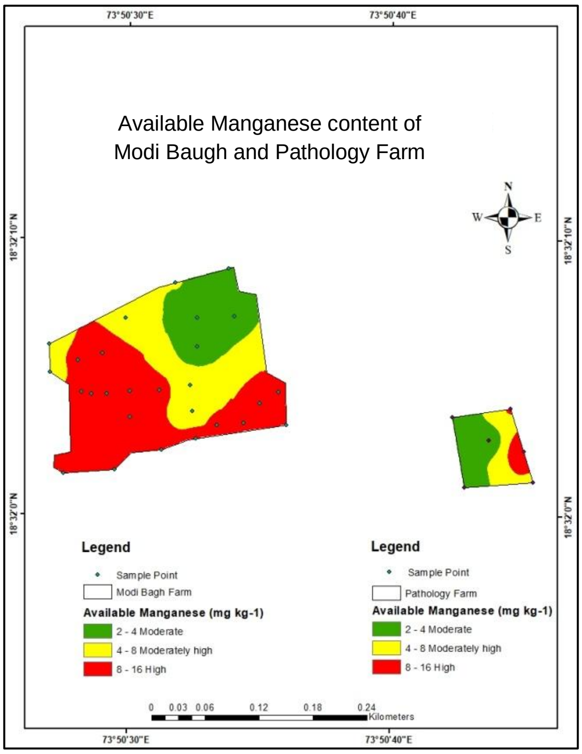

Fig. 13. Available Manganese content of Modi Baugh and Pathology Farm

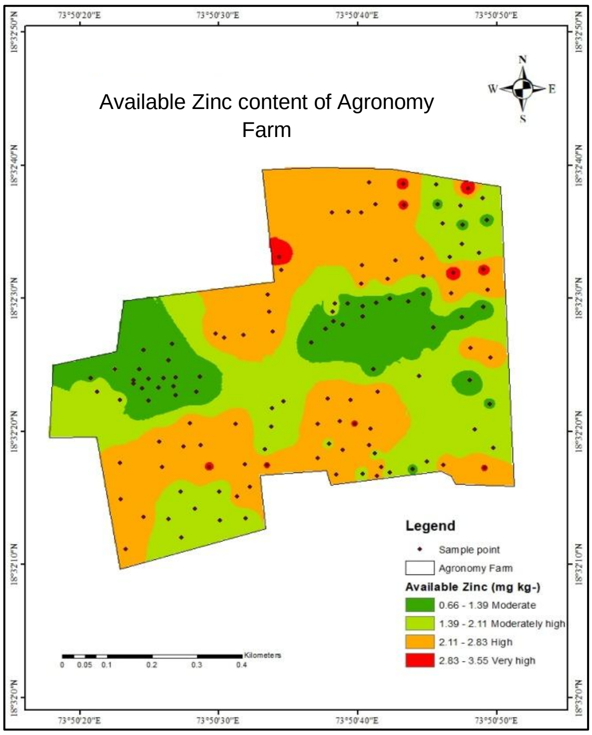

Fig. 14. Available Zinc content of Agronomy Farm

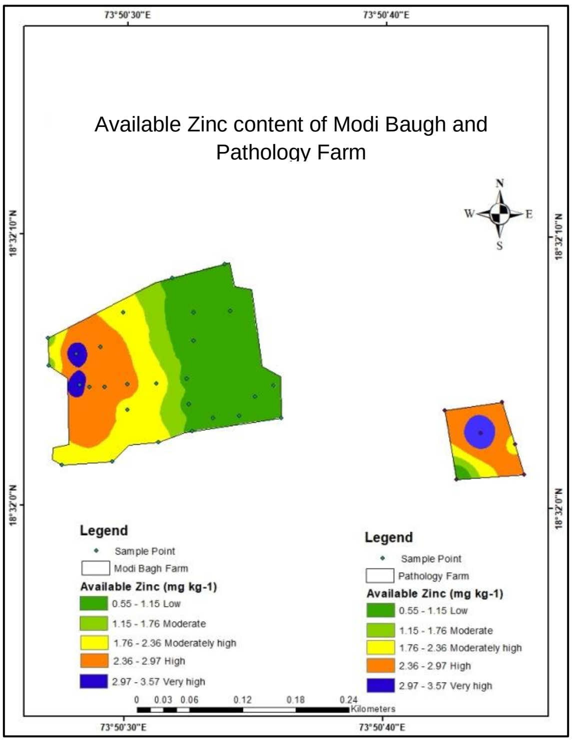

Fig. 15. Available Zinc content of Modi Baugh and Pathology Farm

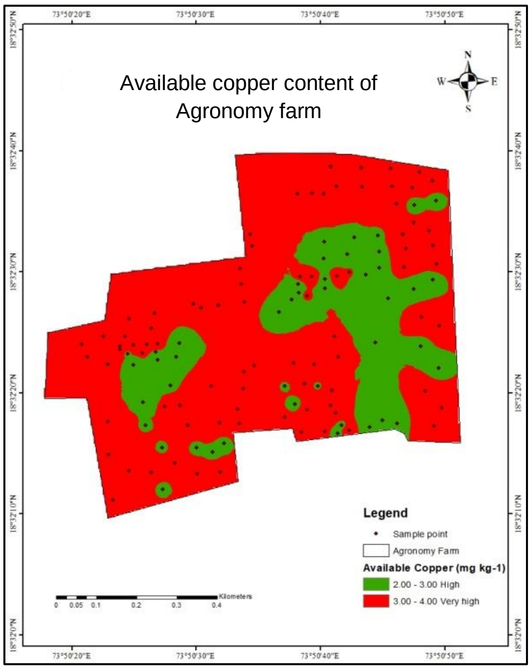

Fig. 16. Available Copper content of Agronomy Farm

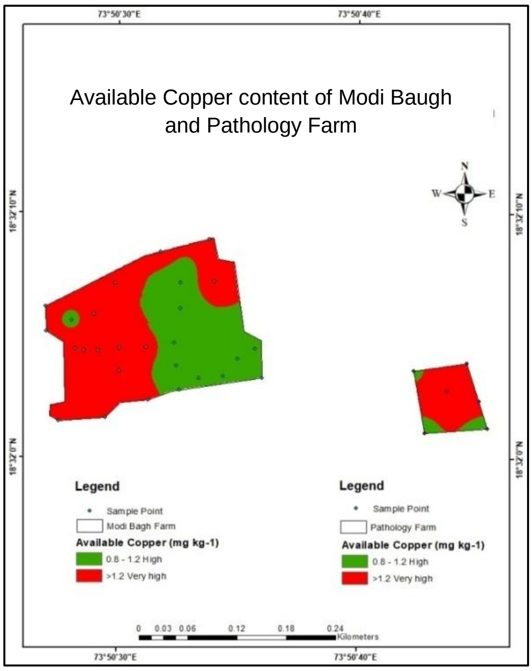

Fig. 17. Available copper content of Modi Baugh and Pathology Farm

Table 3. Status of available micronutrients (Fe, Mn, Zn, Cu) in soils of Agronomy Farm

Particulars	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Range	3.02 - 10.26	3.61 - 11.47	0.66 - 3.58	1.65 - 3.98
Mean	4.71	7.06	1.92	3.00
Categories	Low 75 (59.05%)	Moderate 1 (0.78%)	Moderate 28 (22.05%)	Very High 127 (100%)
	Moderate 52 (40.95%)	Moderately high 84 (66.14%)	Moderately high 36 (28.35%)	
		High 42 (33.07%)	High 17 (13.38%)	
			Very High 46 (36.22%)	

Table 4. Status of micronutrients (Fe, Mn, Zn, Cu) in soils of Modi Baugh and Pathology Farm

Particulars	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Range	2.08 - 6.94	3.25 - 10.28	0.55 - 3.98	2.25 - 3.91
Mean	4.51	8.10	2.15	2.98
Categories	Very low 2 (6.06%)	Moderate 3 (9.09%)	Low 2 (6.06%)	Very High 33 (100%)
	Low 14	Moderately high 12	Moderate 11	

Particulars	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
	(42.42%)	(36.36%)	(33.34%)	
	Moderate 17 (51.52%)	High 18 (54.55%)	Moderately high 2 (6.06%)	
			High 5 (15.15%)	
			Very High 13 (39.39%)	

4. CONCLUSION

It is concluded that the soils of the Agronomy Farm were found to be slightly alkaline to strongly alkaline in reaction, with normal electrical conductivity, and organic carbon content ranging from very low to moderately high. Calcium carbonate levels were moderate to very high, while DTPA-extractable iron was low to moderate. Manganese content was moderate to high, zinc ranged from moderate to very high, and copper was categorized as very high. Similarly, soil samples from Modi Baugh and the Pathology Farm were slightly to moderately alkaline in reaction, with normal electrical conductivity and organic carbon content ranging from very low to moderate. Calcium carbonate levels were also moderate to very high, DTPA-extractable iron was very low to moderate, manganese content was moderate to high, zinc varied from low to very high, and copper remained in the very high category.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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