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Delineation of soil fertility maps of Deolali Pravara village, Rahuri tehsil

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Abstract
The present investigation entitled "Delineation of Soil Fertility Maps of Deolali Pravara Village, Rahuri Tehsil" was carried out during 2024-2025 with the objective of determining the nutrient profile of local agricultural soils.
GPS-based grid sampling was employed to collect 130 representative soil samples at 0-15 cm depth, followed by laboratory analysis of physico-chemical properties. The soils were moderately alkaline (mean pH 8.27), low in available nitrogen (184-313 kg ha^{-1}), low to medium in available phosphorus (8.25-28.73 mg kg^{-1}), and medium to high in available potassium (281-612 kg ha^{-1}). Micronutrients (Zn, Fe, Mn, Cu) exhibited spatial variability, with deficiency of zinc being most widespread. Bulk density values averaged 1.37 Mg m^{-3}, reflecting good porosity in clay and silty clay soils. Fertility maps prepared using GIS highlighted zones of nutrient deficiency and surplus, enabling site-specific nutrient management recommendations. The study emphasizes the role of digital mapping in precision agriculture and sustainable resource management.

Keywords: Soil fertility, GPS, GIS, nutrient mapping, Deolali Pravara, precision agriculture

Introduction

Soil is one of the most vital natural resources, serving as the foundation for agricultural production and ecosystem sustainability. Its properties are strongly influenced by the underlying landforms, parent material, and management practices. In Maharashtra, soils are generally of low fertility and exhibit wide variability in their morphological, physical, chemical, and biological attributes (Challa *et al*., 1995) [4]. Plateau regions contain shallow, rocky soils with limited agricultural potential, whereas black cotton soils are rich in clay and iron but deficient in nitrogen and organic matter. The removal of vegetation from highly weathered lateritic soils in the Konkan and Sahyadri regions renders them infertile (Wikipedia, 2023) [28].

The increasing pressures of shrinking cultivable land, nutrient depletion, and soil degradation due to unbalanced fertilizer use have intensified the need for sustainable soil management (Kanwar, 2004) [11]. Declines in macronutrients such as phosphorus and potassium, coupled with imbalances in micronutrients like zinc and iron, have been widely reported (ResearchGate, 2025) [18]. Balanced nutrient management is therefore essential, requiring accurate assessment of soil fertility at regional and village levels.

Modern tools such as Geographic Information System (GIS) and Global Positioning System (GPS) are now widely used to assess spatial variability of soil fertility and generate digital maps (Patil *et al*., 2017) [16]. These maps support site-specific nutrient management (SSNM), enabling judicious use of costly fertilizers while maintaining long-term soil productivity. The present study was conducted in Deolali Pravara village, Rahuri Tehsil, with the objective of assessing soil fertility through GPS-based sampling and preparing fertility maps of macro- and micronutrients.

Soil is a finite and non-renewable natural resource that forms the basis of agricultural production, ecosystem stability, and human survival. Its fertility determines the capacity to supply essential nutrients to crops in sufficient quantities and in a balanced manner. In developing countries like India, agriculture still depends heavily on soil resources, yet these soils are under continuous pressure from population growth, shrinking cultivable land, intensive cropping, and imbalanced fertilizer use (Kanwar, 2004; Sehgal & Lal, 1988) [11, 21]. The degradation of soil organic matter, erosion, salinization, and nutrient mining have further aggravated fertility decline, thereby limiting crop productivity.

Globally, declining soil fertility is recognized as a major constraint to food security. The Food and Agriculture Organization (FAO) has emphasized the need for sustainable soil management, highlighting that one-third of the world's soils are already degraded due to unsustainable agricultural practices. Precision agriculture and site-specific nutrient management (SSNM) have emerged as promising solutions to address these challenges by integrating scientific knowledge with advanced geospatial technologies (Santhi *et al*., 2018) [19].

In India, soils exhibit wide variability in their morphological, physical, and chemical properties depending on landforms, parent material, and climate. Maharashtra represents a unique case, with black cotton vertisols rich in clay but deficient in nitrogen, phosphorus, and organic matter; shallow plateau soils with limited water-holding capacity; and lateritic soils of Konkan prone to nutrient depletion (Challa *et al*., 1995; Wikipedia, 2023) [4, 28]. Declining macronutrient levels, particularly nitrogen and phosphorus, along with widespread deficiencies of micronutrients such as zinc and iron, have been frequently reported in the region (Patil *et al*., 2017; Shinde *et al*., 2022) [16, 24]. Modern tools such as the Global Positioning System (GPS) and Geographic Information System (GIS) are increasingly applied for soil fertility assessment and mapping.

GPS ensures precise sampling locations, while GIS enables spatial interpolation of soil data to generate digital maps showing nutrient variability across landscapes. Such fertility maps not only provide a scientific basis for fertilizer recommendations but also help in reducing costs, improving nutrient-use efficiency, and ensuring environmental sustainability (Kumar & Palwe, 2017; Chaudhari *et al*., 2017) [12, 5]. Given this context, the present study was undertaken in Deolali Pravara village, Rahuri Tehsil, an agriculturally important region of Maharashtra, with the following objectives:

1. To assess the physico-chemical characteristics and nutrient status of soils through GPS-based sampling.
2. To delineate soil fertility maps of macro- and micronutrients using GIS techniques.
3. To suggest site-specific nutrient management strategies for sustainable agricultural productivity.

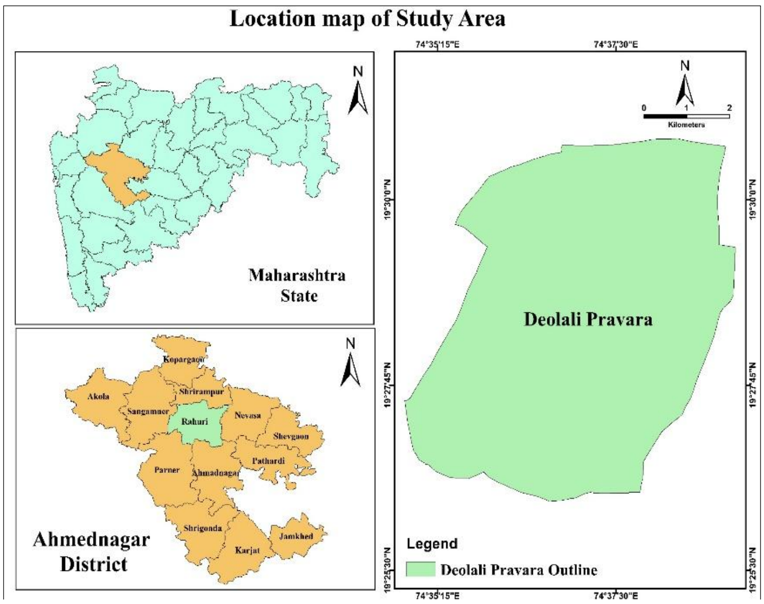
3. Materials and Methods

The study was conducted in Deolali Pravara village, Rahuri Tehsil, located at 19.4728° N latitude and 74.6210° E longitude, with an elevation of 515 meters above mean sea level. The village covers a geographical area of 4,234.82 hectares, of which 3,843.10 hectares are under cultivation.

A total of 130 surface soil samples (0-15 cm depth) were collected using a GPS-based grid sampling approach to ensure systematic spatial coverage. The samples were air-dried, sieved, and subjected to laboratory analysis. Physical properties (soil colour, texture, and bulk density) were determined using standard procedures. Chemical parameters including pH, electrical conductivity (EC), organic carbon (OC), and calcium carbonate ($CaCO_3$) were measured. Macronutrients (available N, P, K, S) and micronutrients (Zn, Fe, Mn, Cu) were analyzed following standard procedures. The data were statistically analyzed using mean, standard deviation, and coefficient of variation (CV). Nutrient status was classified into fertility ratings (very low, low, medium, high, and very high). Spatial variability maps were generated using GIS software.

4. Results and Discussion

Categor The research entitled "Delineation of Soil Fertility Maps of Deolali Pravara Village, Rahuri Tehsil" was carried out during 2024-2025 with the objective of determining the nutrient profile of the local agricultural soils. To achieve this, a well-structured sampling strategy was implemented to obtain representative soil samples from different parts of the village. These samples were subjected to laboratory analysis to quantify various chemical properties, encompassing both essential macronutrients and micronutrients that influence crop productivity. The collected data were further examined to assess spatial variability in soil fertility, enabling the preparation of detailed fertility maps. Such information is indispensable for developing site specific nutrient management plans, guiding sustainable agricultural practices, and enhancing long term soil health. This chapter presents and discusses the research findings in an organised manner, with each subsection focusing on individual soil parameters derived from the analysis is presented and discussed in this chapter.



4.1 Physical Properties of the Soils

4.1.1 Soil Colour and Texture

The soils of Deolali Pravara village exhibited considerable variation in both texture and colour, reflecting differences in parent material, organic matter content, drainage status, and degree of weathering. These properties play a crucial role in determining soil fertility, crop suitability, and management practices required for sustainable agriculture.

Clay soils were the most dominant, representing 46 out of 130 samples (35 percent). The dry colour of these soils varied from dark brown to reddish brown. The dark brown shades are generally attributed to higher organic matter accumulation, while the reddish brown hues can be associated with presence of iron oxides derived from basaltic parent material. Owing to their fine texture, clay soils possess high cation exchange capacity and nutrient retention ability. However, they are often poorly drained, with reduced aeration and slower infiltration, which may adversely affect crop growth under prolonged wet conditions.

Silty clay soils occupied 36 samples (28 percent) and showed colours ranging from brownish gray to dark gray. The grayish tones indicate imperfect drainage or seasonal waterlogging, while the darker shades suggest moderate organic matter accumulation in depressional areas where residues tend to collect. These soils are generally fertile, but they are susceptible to crusting and compaction when subjected to continuous intensive cultivation. To maintain their productivity, regular organic amendments and proper tillage practices are recommended.

Silty loam soils were also common, representing 30 samples (28 percent). Their colour ranged from light brownish gray to brown, which is indicative of relatively lower organic matter content in lighter shades and moderate fertility in the darker tones. Owing to their balanced physical properties, silty loams provide adequate water-holding capacity along with good aeration, making them well-suited for a wide variety of crops. These soils are considered favorable for diverse cropping systems and generally respond well to fertilization.

Clay loam soils accounted for 11 samples (9 percent) of the study area. They exhibited brown to dark brown colours, reflecting moderate to high organic matter accumulation. These soils represent a balance between water retention and drainage, making them suitable for both field and horticultural crops. However, if not managed properly, they may develop surface sealing, which can restrict seedling emergence and root growth.

Sandy loam soils were relatively less common, occurring in only four samples (3 percent). Their pale brown to yellowish brown colours suggest low organic matter content and the presence of hydrated iron oxides under well-drained conditions. These soils are easy to cultivate and support horticultural crops, but their low nutrient- and moisture-holding capacity makes them vulnerable to nutrient leaching and drought stress. As a result, frequent fertilizer applications and the addition of organic manures are essential to sustain crop yields.

Sandy clay loam soils were the least represented, with only three samples (2 percent). Their colour ranged from light brown to yellowish brown, indicating relatively low organic matter content and moderate mineral weathering. These soils have better aeration compared to pure clays, but their nutrient retention capacity is limited. For sustainable use, they require careful nutrient supplementation and proper moisture management.

Overall, the soils of Deolali Pravara are dominated by fine-textured classes, with clay and silty clay together accounting for 63 percent of the total samples. Such soils generally have high nutrient-holding potential but may face problems related to workability, drainage, and aeration. The observed variation in soil colour, from dark brown to pale yellowish brown, can be linked to differences in organic matter status, mineral composition, and drainage regimes. Darker soils are typically associated with higher fertility and organic matter, whereas lighter soils are indicative of low humus content and reduced fertility potential.

Table 4.1: The soil textural classes along with their typical soil colour of Deolali Pravara village

Soil Textural Class	Typical Soil Colour (Dry)
Clay 46 (35%)	Dark brown to reddish brown
Silty Clay 36 (28%)	Brownish gray to dark gray
Sandy Clay Loam 3 (2%)	Light brown to yellowish brown
Clay Loam 11 (9%)	Brown to dark brown
Silty Loam 30 (28%)	Light brownish gray to brown
Sandy Loam 4 (3%)	Pale brown to yellowish brown

4.2.2 Bulk Density (BD)

Bulk density ranged from 1.31 to 1.47 Mg m^{-3}, averaging 1.37 ± 0.002 Mg m^{-3} with a standard deviation of 0.02 Mg m^{-3} and CV of 2.064%, indicating low variability. The relatively low BD is likely due to higher clay content, which increases porosity. Continuous use of organic amendments can further reduce BD, as reported by Thakur (2011) [26].

Table 4.2: The soil textural classes along with their typical soil colour of Deolali Pravara village

Particulars	Bulk Density Mg m^{-3}
Mean	1.370384615
Range	1.31 -1.47
Standard deviation	0.028295337
Standard error	0.002482
Sample variance	0.000800626
Coefficient of variance	2.064773427

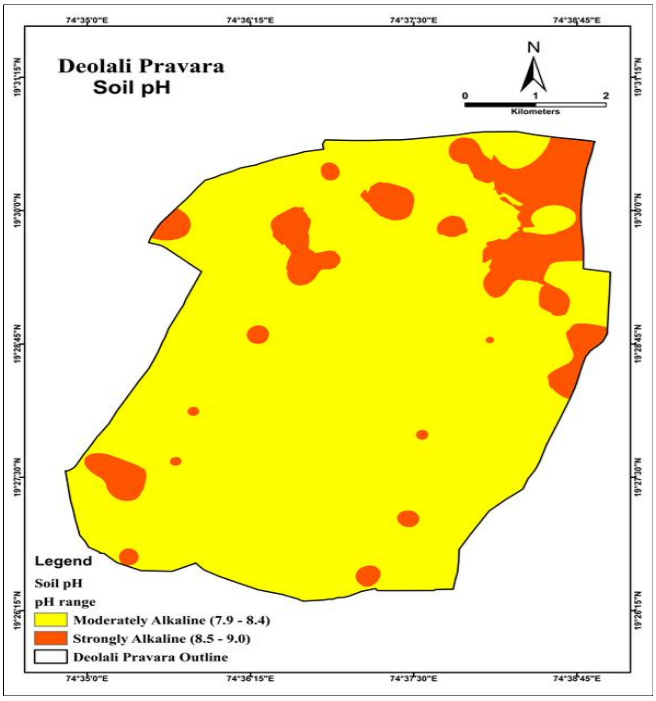
4.2 Chemical Characteristics of Deolali Pravara Village

The nutrient status of soils in Deolali Pravara Village was evaluated by collecting and analyzing 130 representative grid soil samples from systematically selected locations. The sampling design was planned to cover different land uses, topographic positions, and cultivation practices, ensuring that the results reflect the overall variability of the village soils. Each sample underwent laboratory testing to determine its chemical composition, including essential macronutrients (nitrogen, phosphorus, potassium, and sulphur) and micronutrients (zinc, iron, manganese, and copper), along with chemical properties *viz.* pH, electrical conductivity, organic carbon, and calcium carbonate.

To interpret the results effectively, the nutrient concentrations were classified using a sixtier rating system ranging from very low to very high. This classification provides a clear picture of the fertility gradient within the village, highlighting areas with nutrient deficiencies that require immediate management, as well as zones with nutrient surpluses that may benefit from balanced input strategies. Understanding these spatial variations was critical for the development of sitespecific nutrient management plans, which help optimise fertiliser use, minimise environmental risks, and promote sustainable crop production. The subsequent subsections present a detailed discussion of each chemical parameter, supported by statistical analysis and spatial distribution patterns derived from the collected data.

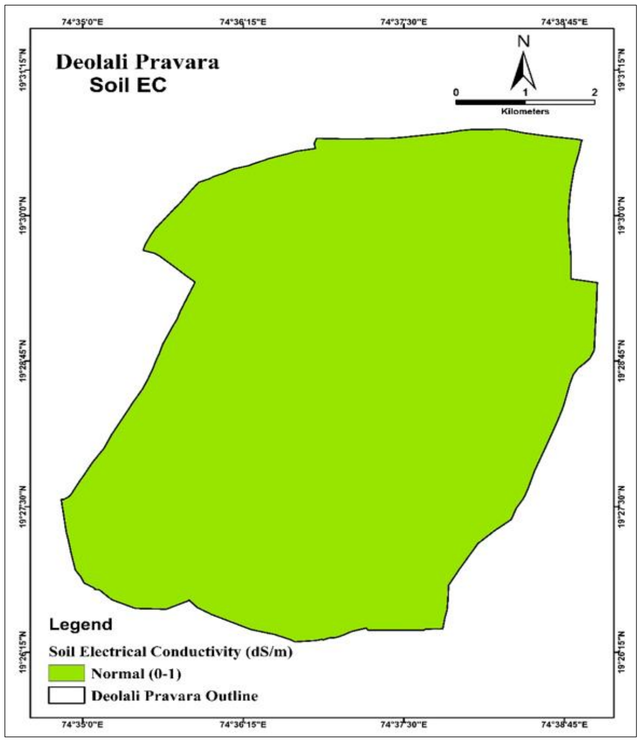
4.2.1 Soil Reaction

The pH statistics are presented in Table 4.1. The average pH for the soils of Deolali Pravara village was 8.27 ± 0.013, ranging from 8.02 to 8.72. The standard deviation was 0.15, with a coefficient of variation (CV) of 1.82%, indicating slight variability in pH levels within the sampling area. Most samples fell under the moderately alkaline category (92.30%), while a smaller proportion (7.69%) was classified as strongly alkaline. The maximum pH was found in sample 103 (N 19.50166 E 74.6225) and the minimum in sample 23 (N 19.465 E 74.64083). The moderately alkaline nature was likely due to the influence of basic parent materials, particularly deep to medium black soils, combined with the prolonged effects of irrigation. Comparable alkalinity patterns have been documented by Pavan (2016) [17].



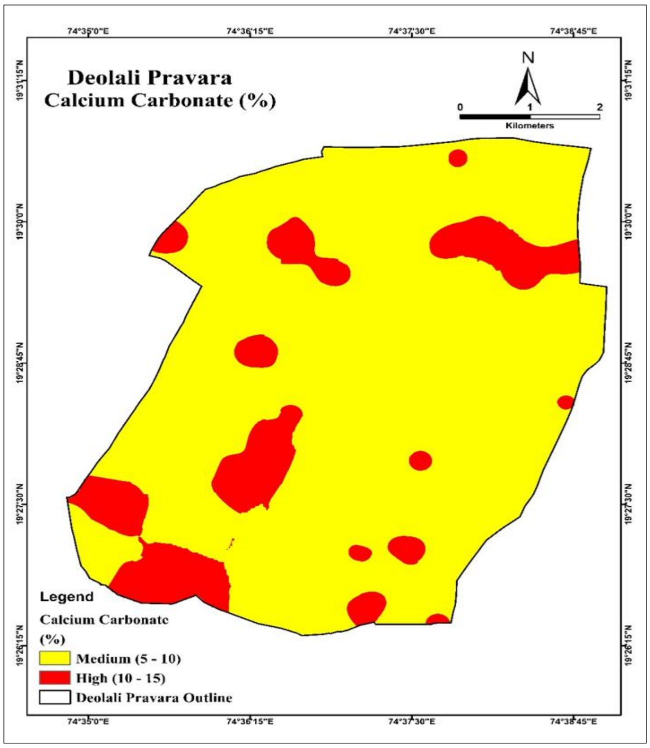
4.2.2 Electrical Conductivity

The electrical conduvtivity results, summarised in Table 4.1, indicate a mean value of 0.43 ± 0.0018 dS m^{-1}, with a standard deviation of 0.144 dS m^{-1} and CV of 33.47%, suggesting high variability. EC values ranged from 0.18 to 0.92 dS m^{-1}, with all samples falling within the normal range (100%). The highest electrical conductivity was recorded in sample 90 (N 19.4938 E 74.62278), and the lowest in sample 49 (N 19.485 E 74.64861). The relatively low electrical conductivity values could be linked to soils derived from basaltic parent material rich in basic cations but low in neutral salts such as chlorides and sulfates. Similar findings were noted by Babaruwan (2017) [2] and Indragir (2015) [10].



4.2.3 Organic Carbon

The organic carbon (Table 4.1) ranged from 0.26 to 0.58%, with a mean of 0.41 ± 0.005%, standard deviation of 0.06%, and CV of 15.49%, reflecting moderate variability. Most samples low were medium in organic carbon (75%), followed by low (55%). Sample 45 (N 19.4797222 E 74.63472) had the highest organic carbon, whereas sample 12 (N 19.4513888 E 74.61833) recorded the lowest. The generally low to moderate organic carbon status may result from rapid decomposition under high temperatures. Conversely, higher organic carbon levels in orchard areas could be due to organic matter accumulation from litter deposition. Similar results were reported by Pavan *et al.* (2016) [17] and Savata *et al.* (2014) [20].



4.2.4 Calcium Carbonate

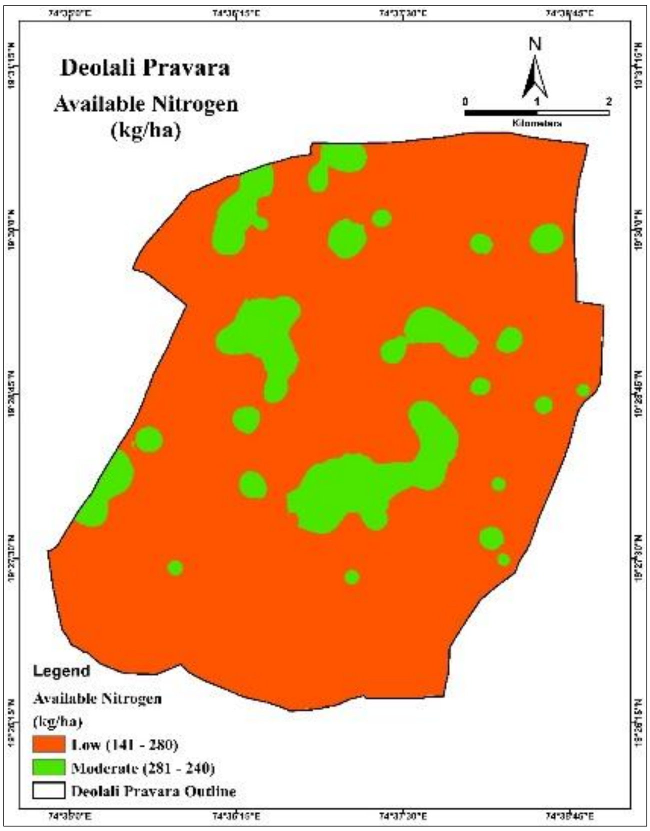
The calcium carbonate (Table 4.3) averaged 8.89 ± 0.135%, ranging from 5.25% to 14.25%, with a standard deviation of 1.54% and CV of 17.37%. Most soils were medium in cacium carbonate (85.38%), while 14.61% were high. The maximum calcium carbonate content was found in sample 93 (N 19.49805 E 74.60917), and minimum in sample 78 (N 19.46888 E 74.60139). The prevalence of calcareous soils in arid to semi arid vertisols could be attributed to carbonate precipitation under low rainfall and high evaporation. These findings align with Savata *et al*. (2014) [20] and Surabhi *et al*. (2017) [25].

Table 4.3: Chemical properties of Deolali Pravara village soil samples

Particulars	Chemical Properties			
	pH (1:2.5)	**EC (dS m^{1})**	**Organic carbon (%)**	**CaCO3 (%)**
Mean	8.27	0.432	0.41	8.89
Standered error	0.0132	0.0018	0.005	0.135
Standered Deviation	0.150	0.144	0.06	1.54
Sample variance	0.022	0.0210	0.020	2.38
Minimum	8.02	0.18	0.26	5.25
Maximum	8.72	0.92	0.58	14.25
CV (%)	1.820	33.47	15.49	17.37
Categories	Moderate Alkaline 120 (92.30%)	Normal 130 (100%)	Low 55 (42%)	Medium 111 (85.38%)
	Strong alkaline 10 (7.63%)		Medium 75 (58%)	High 19 (14.61%)

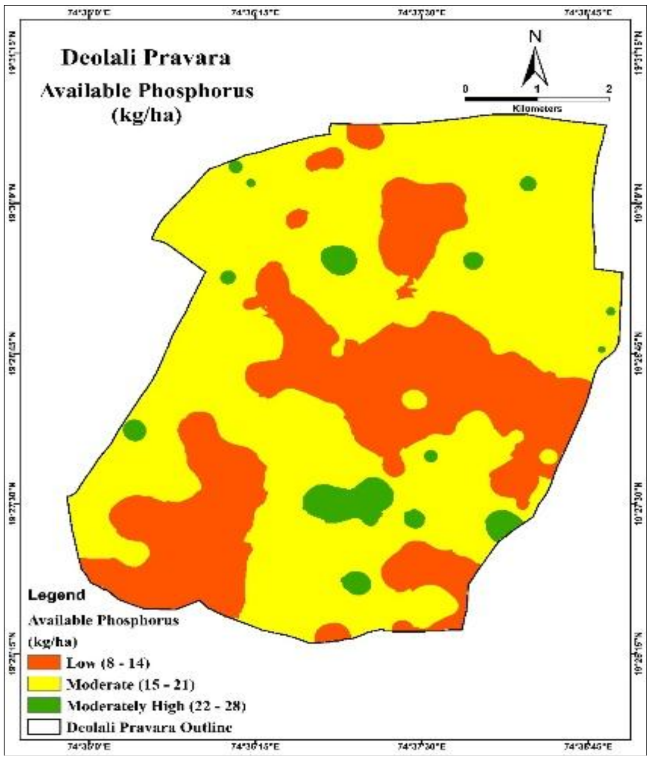
4.1.5 Soil available Nitrogen

As shown in Table 4.2, the available nitrogen content of soils in Deolali Pravara village had a mean of 252.9 ± 2.79 kg ha^{-1}, with values ranging from 184 to 313 kg ha^{-1}. The standard deviation was 31.89 kg ha^{-1}, and the CV was 12.61%, indicating moderate variability. Most samples (69.23%) fell under the moderate category, while 30.76% were low in nitrogen. The highest nitrogen level occurred in sample 75 (N 19.46361 E 74.58583), and the lowest in sample 99 (N 19.5091 E 74.63083). The generally low nitrogen availability might be attributed to elevated temperatures and high pH conditions, which accelerate organic matter decomposition and volatilization losses. The identical patterns have been observed by Babaruwan (2017) [2] and Indragir (2015) [10] in other semiarid regions.



4.1.6 Soil available Phosphorus

The soils exhibited an average available phosphorus level of 15.65 ± 0.37 kg ha^{-1}, with a standard deviation of 4.25 kg ha^{-1} and a range of 8.25 to 28.73 kg ha^{-1} (Table 4.2). The Olsen phosphorus test revealed moderate variability (CV 27.17%). Most samples were moderate in available phosphorus (60%), followed by low (31.53%) and moderately high (7.69%). The highest soil available phosphorus was recorded in sample 14 (N 14.45583 E 74.63583), and the lowest in sample 66 (N 19.44833 E 74.58444). The low phosphorus availability was likely linked to alkaline pH and high calcium carbonate, which promote fixation of phosphorus as insoluble calcium phosphates. In contrast, higher phosphorus in certain plots might result from longterm fertilizer use. Comparable findings was reported by Madhusudan (2017) [13-14] and Indragir (2015) [10].

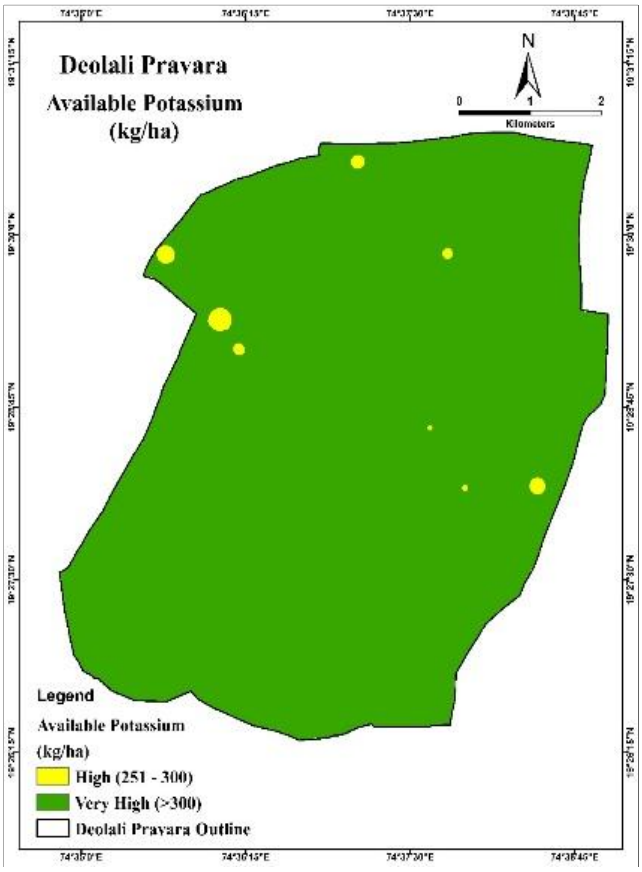


4.1.7 Available Potassium (K)

The mean available potassium content was 472.55 ± 9.12 kg ha⁻¹, with a range of 265-672 kg ha⁻¹ and a standard deviation of 104.05 kg ha⁻¹ (Table 4.2). Variability was moderate (CV 22.02%). Most samples (93.07%) fell into the very high category, and the rest (6.92%) were high. The maximum potassium value was in sample 75 (N 19.46361 E 74.58583), and the minimum in sample 101 (N 19.50861 E 74.61833). The high potassium status could be due to explained by the release of potassium from Krich minerals like feldspars and micas in basaltic parent material, coupled with fertilizer and manure applications. Similar observations were made by Pavan (2016) [17], Babaruwan (2017) [2], and Palwe & Yelwe (2018) [15].

4.1.8 Soil available Sulphur

The available Sulphur was ranged from 8.27 to 25.13 mg kg⁻¹, averaging 14.97 ± 0.33 mg kg⁻¹, with a standard deviation of 3.84 mg kg⁻¹ and CV of 25.69% (Table 4.2). Most soils (92.30%) were medium in S, with 4.61% low and 3.07% high. The highest sulphur content was found in sample 30 (N 19.46861 E 74.61917), while the lowest was in sample 4 (N 19.44416 E 74.62611). The sulphur deficiency might to continuous cropping without sulphur supplementation and moderate organic matter levels. In contrast, higher sulphur availability in some samples linked to sulphate accumulation in surface soils. Comparable trends documented by Hadole *et al*. (2020) [9] and Ushasri *et al*. (2019) [27].



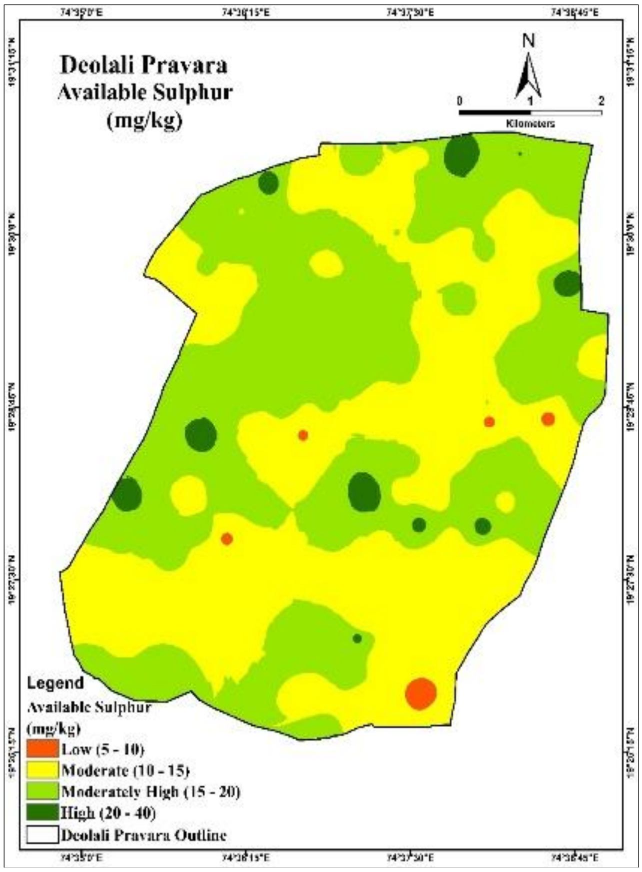
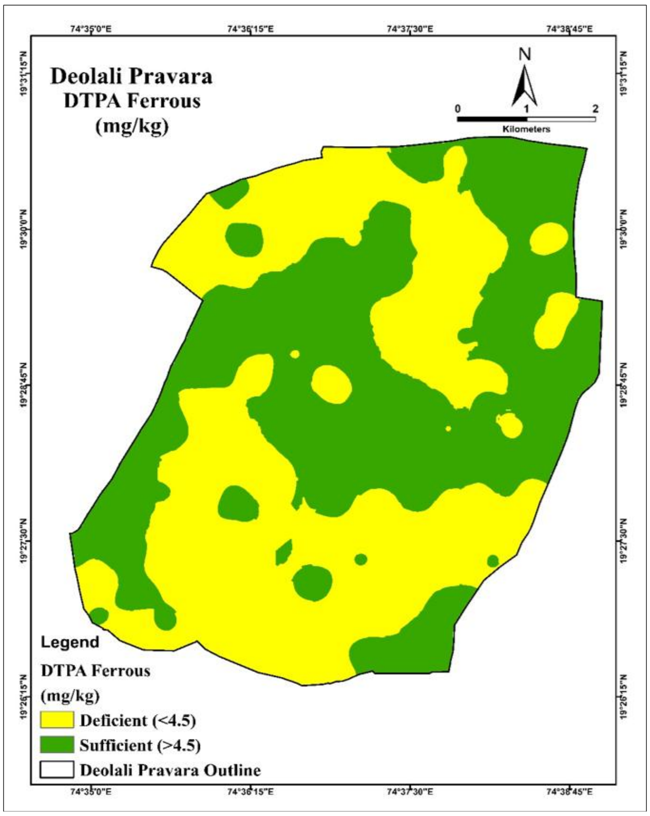


Table 4.4: Status of available Nitrogen, Phosphorus, Potassium, and Sulphur in soils of Deolali Pravara village

Particulars	Available Macronutrients			
	Nitrogen	Phosphorus	potassium	Sulphur
	(Kg ha)			(mg kg¹)
Mean	253.27	15.65	472.55	14.97
Standered error	2.84	0.37	9.12	0.33
Standered Deviation	32.42	4.25	104.05	3.84
Sample variance	1051.41	18.11	10827.8	14.80
Minimum	184	8.25	265	8.27
Maximum	313	28.73	672	25.13
CV (%)	12.80	27.17	22.02	25.69
Categories	Low 40 (30.76%)	Low 41 (31.53%)	High 9 (6.92%)	Low 6 (4.61%)
	Moderate 90 (69.23%)	Moderate 78 (60%)	Very high 121 (93.07%)	Medium 120 (92.30%)
		Moderately High 10 (7.69%)		High 4 (3.07%)

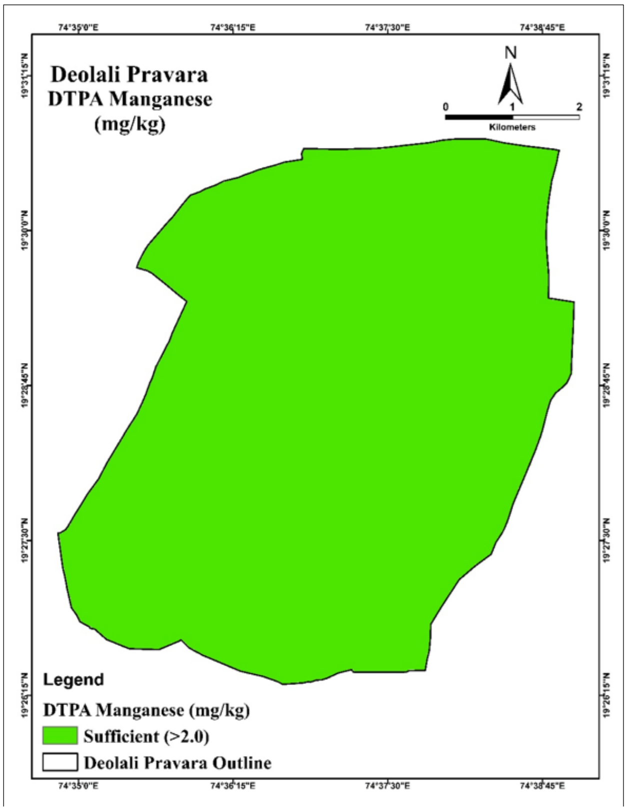
4.2.9 DTPA Extractable Iron

The mean DTPA extractable iron content was 2.92 ± 0.057 mg kg⁻¹, ranging between 3.67 and 5.56 mg kg⁻¹, with a standard deviation of 0.64 mg kg⁻¹ and CV of 22.11% (Table 4.3). All samples (99.33%) were deficient in Fe. The maximum Fe content was recorded in sample 69 (N 19.45666 E 74.58833) and the minimum in sample 25 (N 19.46427 E 74.63028). The widespread deficiency may be due to high $CaCO_3$ and P levels, along with low organic matter, which reduce Fe solubility. Similar deficiencies were reported by Savata (2014) [20].



4.2.10 DTPAExtractable Manganese (Mn)

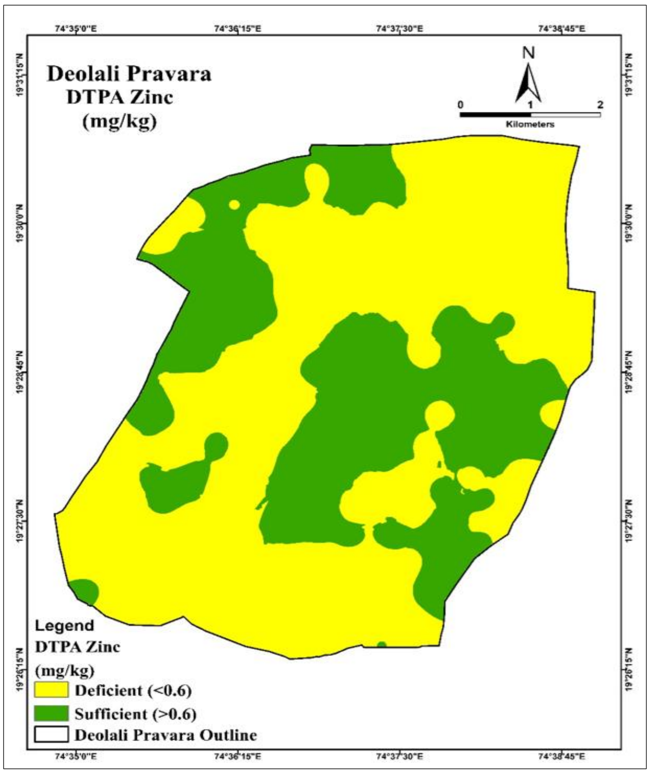
Manganese levels averaged 12.73 ± 0.050 mg kg^{-1}, with a narrow range (11.35-13.91 mg kg^{-1}) and low variability (CV 4.50%). All samples were sufficient in Mn (Table 4.5). The highest Mn content was in sample 6 (N 19.44416 E 74.61306) and the lowest in sample 91 (N 19.49861 E 74.6175). Adequate Mn levels are likely due to the ferromagnesian composition of basaltic soils and favorable soil moisture conditions. Comparable sufficiency levels were found by Madhusudan (2017) [13-14] and Savata (2014) [20].



4.2.11 DTPAExtractable Zinc (Zn)

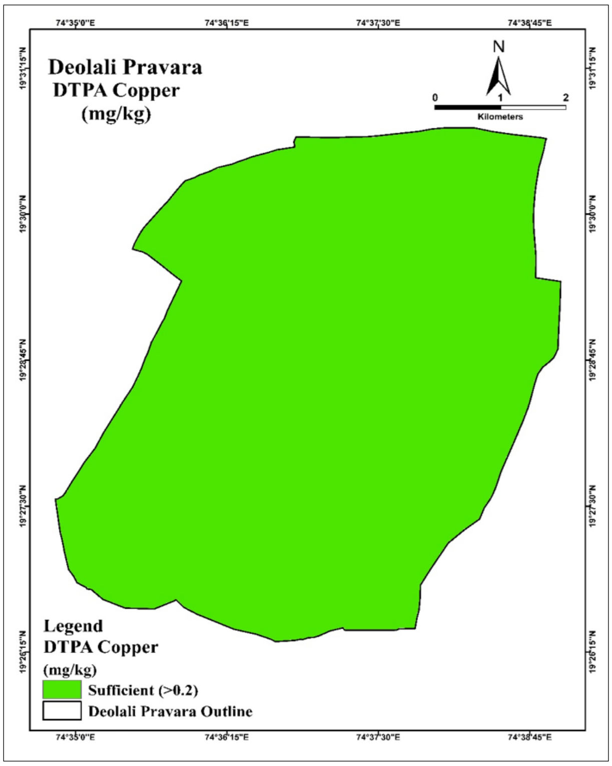
The average Zn content was 0.59 ± 0.02 mg kg^{-1}, ranging from 0.26 to 1.64 mg kg^{-1}, with a standard deviation of 0.20 mg kg^{-1} and CV of 41.72% (Table 4.3). Zinc deficiency was observed in 62.30% of samples, while 37.69% were sufficient. The highest Zn was in sample 117 (N 19.505 E

74.60167), and the lowest in sample 49 (N 19.485 E 74.64861). Alkaline pH likely reduces Zn solubility, leading to widespread deficiency. Similar results have been reported by Babaruwan (2017) [2] and Indragir (2015) [10].



4.2.12 DTPA Extractable Copper (Cu)

Copper levels ranged from 1.02 to 3.89 mg kg⁻¹, with a mean of 2.49 ± 0.05 mg kg⁻¹, standard deviation of 0.64 mg kg⁻¹, and low variability (CV 4.73%) (Table 4.3). All samples were sufficient in Cu. The highest Cu content was recorded in sample 54 (N 19.48361 E 74.61778), and the lowest in sample 95 (N 19.50277 E 74.63833). Adequate organic matter and favorable moisture conditions likely support Cu availability. Comparable findings were reported by Indragir (2015) [10] and Madhusudan (2017) [13-14].



4.2.13 Boron (B)

Boron content ranged from 0.21 to 0.68 mg kg⁻¹, with a mean of 0.483 ± 0.005 mg kg⁻¹, standard deviation of 0.067 mg kg⁻¹, and CV of 4.73% (Table 4.3). The highest B value was in sample 60 (N 19.45972 E 74.60139), and the lowest in sample 23 (N 19.465 E 74.64083).

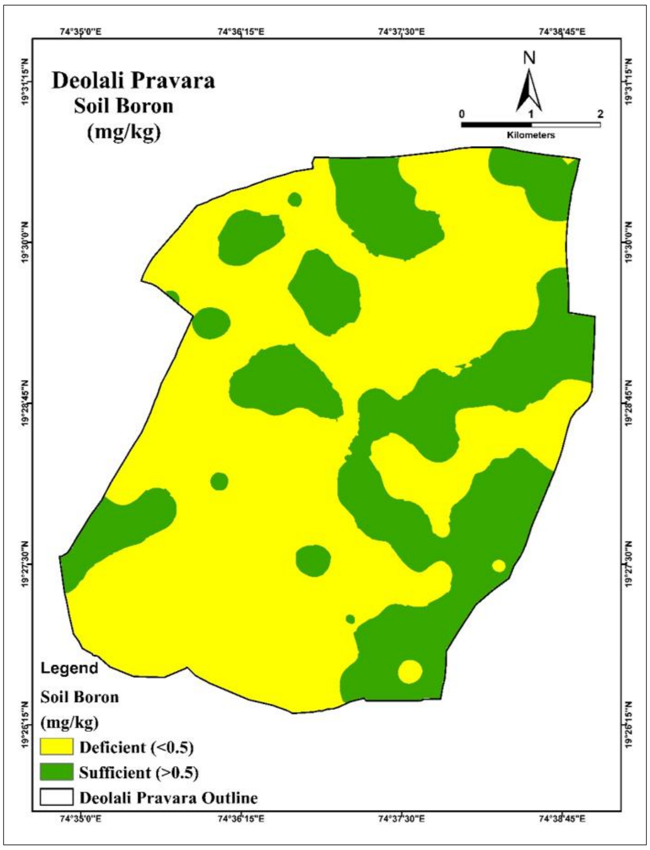


Table 4.5: Status of DTPA extractable micronutrients in soils of Deolali Pravara village

Particulars	DTPA extractable micronutrients (mg kg^{1})				Hot water soluble
	Fe	**Mn**	**Zn**	**Cu**	**B**
Mean	4.50	12.73	0.598	2.493	0.483
Range	3.67 -5.56	11.35-13.91	0.26-1.64	1.02-3.89	0.21-0.68
Standard Error	0.057	0.050	0.0216	0.0564	0.0059
Standard Deviation	0.647	0.573	0.246	0.643	0.067
Sample Variance	0.419	0.328	0.0607	0.4145	0.0046
Coefficient of Variance (%)	22.113	4.50	41.724	25.818	4.735
Categories	Deficient 66 (51%)	Deficient 0 (0%)	Deficient 81 (62.30%)	Deficient 0 (0%)	Deficient 79 (60.76%)
	Sufficient 64(49%)	Sufficient 130 (100%)	Sufficient 49 (37.69%)	Sufficient 130 (100%)	Sufficient 51 (39.23%)

4.3 Correlation of soil chemical properties with available nutients of Deolali Pravara village

The correlation analysis of soil reaction (pH), electrical conductivity (EC), organic carbon (OC), and calcium carbonate ($CaCO_3$) with macronutrients (N, P, K, S) and micronutrients (Fe, Mn, Zn, Cu, B) provides valuable insights into nutrient availability and soil fertility dynamics.

4.3.1 Effect of Soil pH on Nutrient Availability

Soil pH had a marked influence on nutrient availability. A negative correlation with nitrogen (-0.08) confirmed that alkalinity reduces nitrogen mineralization and promotes ammonia volatilization, lowering plant-available nitrogen. The weak positive correlation with phosphorus (0.16) indicates some enhancement, though much of the phosphorus in calcareous soils becomes unavailable due to precipitation as calcium phosphates. A strong negative correlation with potassium (-0.45) suggests that alkaline conditions limit potassium release from soil minerals.

Micronutrients were strongly influenced by pH. Negative correlations with Fe (-0.31), Zn (-0.39), Cu (-0.24), and B (-0.36) demonstrate reduced solubility of these elements in alkaline soils. A strong positive correlation with Mn (0.95) was observed, possibly reflecting local soil mineralogy and redox conditions that promote Mn solubility.

4.3.2 Electrical Conductivity and Nutrient Solubility

Electrical conductivity, reflecting soluble salts in the soil, was negatively related to N (-0.26), showing that saline conditions hinder nitrogen uptake. A moderate positive relationship with P (0.22) and weak associations with K (-0.06) andS (0.23) were recorded.

Micronutrients showed strong positive relationships with salinity.Zn (0.99), Cu (0.94), B (0.99), and Fe (0.25) increased with EC, indicating that soluble salts favor micronutrient availability through ionic competition. Conversely, Mn (-0.32) decreased with EC, suggesting antagonistic ionic effects under saline conditions.

4.3.3 Role of Organic Carbon in Nutrient Dynamics

Organic carbon plays a central role in nutrient cycling. A negative correlation with N (-0.25) indicated that in these soils, nitrogen mineralization efficiency may be limited despite organic matter presence. A positive relationship with P (0.22) suggests that organic matter improves phosphorus availability by complexing with calcium and reducing fixation. Correlations with K (-0.07) and S (0.23) were weak.

Strong positive correlations with Zn (0.99), Cu (0.94), B (0.99), and Fe (0.27) highlight the importance of organic matter in chelation and maintaining micronutrient solubility. A weak negative correlation with Mn (-0.29) suggests that organic matter may immobilize Mn in some conditions.

4.3.4 Calcium Carbonate and Its Interaction with Nutrients

Calcium carbonate influenced nutrient availability significantly. It showednegative correlations with N (-0.20) and K (-0.23), reflecting nitrogen volatilization and potassium fixation in calcareous soils. A positive correlation with phosphorus (0.31) was observed, although much of this phosphorus may remain in unavailable Ca-P complexes. Sulphur (0.27) showed a slight enhancement in calcareous soils.

For micronutrients, $CaCO_3$ exhibited a negative correlation with Fe (-0.21), confirming iron deficiency as a major limitation in calcareous soils. Positive correlations with Mn (0.37), Zn (0.35), Cu (0.45), and B (0.37) were recorded, suggesting that carbonate buffering may influence micronutrient dynamics, although excessive $CaCO_3$ often reduces their plant availability.

4.3.5 Scientific Implications

1. Soil alkalinity and carbonate content (pH and $CaCO_3$) limit the availability of most micronutrients (Zn, Cu, B) and reduce nitrogen and potassium availability.
2. Organic carbon strongly governs micronutrient availability, underlining the importance of maintaining soil organic matter through residue incorporation, manuring, and green manures.
3. Salinity (EC) enhances micronutrient solubility but reduces nitrogen availability, which has implications for fertilizer management in calcareous-saline soils.
4. Overall, integrated nutrient management that balances organic matter addition, appropriate fertilization, and reclamation practices is required to maintain nutrient availability and soil health in such soils.

These results emphasize the necessity of site-specific nutrient management in alkaline and calcareous soils. Incorporation of organic matter, balanced application of NPK, and targeted micronutrient supplementation (particularly Fe, Zn, Cu, and B) are essential strategies to sustain soil fertility and crop productivity.

Table 4.6: Correlation of soil chemical properties with available nutrients of deolali pravara village

Soil properties	N	P	K	S	Fe	Mn	Zn	Cu	B	Bulk density
pH	-0.08	0.16	-0.45	0.19	-0.31	0.95	-0.39	-0.24	-0.36	0.74
EC	-0.26	0.22	-0.06	0.23	0.25	-0.32	0.99	0.94	0.99	0.31
OC	-0.25	0.22	-0.07	0.23	0.27	-0.29	0.99	0.94	0.99	0.34
$CaCO_3$	-0.20	0.31	-0.23	0.27	-0.21	0.37	0.35	0.45	0.37	0.61

4.4 Alternate Land Use Pattern Based on Soil Properties

The evaluation of soil fertility status in Deolali Pravara village revealed considerable variation in nutrient availability, which directly influences the cropping potential of the region. Based on the observed soil constraints, alternate land use patterns are suggested to improve soil health, enhance crop productivity, and ensure long-term sustainability. Soils with low nitrogen, phosphorus, and organic carbon exhibited poor fertility and limited crop growth potential. The deficiency of nitrogen restricts vegetative growth and chlorophyll development, while low phosphorus limits root establishment and energy transfer within plants. In addition, insufficient organic carbon reduces the soil's capacity to retain nutrients and moisture. To address these constraints, legume-based cropping systems such as soybean, pigeon pea, and green gram can be promoted. These crops enhance biological nitrogen fixation through symbiotic associations with Rhizobium bacteria, thereby improving soil nitrogen status over time. The incorporation of green manuring crops such as dhaincha and sunhemp is another effective strategy to enrich the soil with organic matter and available nutrients. Furthermore, the integration of agroforestry systems, particularly the plantation of tree species such as Gliricidia and Subabul along with seasonal crops, can contribute significantly to restoring soil fertility and improving the productivity of marginal baran lands.

In certain areas, soils were characterized by high potassium but low to medium nitrogen and sulphur content, indicating an imbalance in nutrient availability. Such conditions limit balanced crop nutrition, often resulting in reduced yields despite adequate potassium reserves. To exploit the natural abundance of potassium, crops with high potassium requirements such as banana, sugarcane, and potato can be grown successfully. However, the deficiency of nitrogen and sulphur needs to be addressed through balanced fertilization strategies, which may include the application of urea, ammonium sulphate, and gypsum. Crop rotation involving oilseeds such as sunflower and mustard, along with pulses, is recommended for better nutrient cycling and utilization. This approach not only ensures efficient use of potassium but also contributes to improving the nitrogen and sulphur balance in the soil, thereby sustaining crop productivity.

Another significant soil constraint in the region was the presence of medium to high calcium carbonate, leading to calcareous soil conditions. These soils are often associated with poor phosphorus availability due to the precipitation of phosphorus as insoluble calcium phosphates, along with micronutrient deficiencies, particularly zinc and iron. Such constraints make crop production more challenging. To overcome these limitations, tolerant crops such as sorghum, pearl millet, chickpea, and cotton are recommended, as they can perform relatively well under calcareous conditions. In addition, targeted micronutrient management practices, including the application of zinc sulphate and iron chelates, are essential to correct nutrient deficiencies and enhance crop performance. Another promising strategy is the establishment of fruit orchards with species such as pomegranate, ber, and custard apple, which are known to thrive under calcareous conditions. These perennial systems not only provide higher economic returns but also contribute to the long-term sustainability of farming in these problem soils.

Overall, the suggested alternate land use patterns provide a framework for aligning cropping systems with inherent soil properties. By adopting legume-based systems, balanced fertilization, agroforestry, and tolerant crop species, the productivity and sustainability of soils in Deolali Pravara can be significantly enhanced while simultaneously addressing nutrient imbalances and soil health constraints.

Sample number	Latitude	Longitude	pH (1:2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
1	19.4403355	74.6138	8.2	0.38	0.42	7.75	238	12.48	566	17.27	3.76	12.68	0.51	2.02	0.48	1.36	Clay
2	19.4408756	74.62266	8.19	0.26	0.55	8.1	250	13.3	340	14.98	4.88	13.15	0.61	2.02	0.53	1.48	Silty Clay
3	19.44083333	74.62806	8.38	0.52	0.31	10.25	214	11.67	528	12.16	4.76	12.81	0.52	1.54	0.59	1.52	Silty Clay
4	19.44416667	74.62611	8.36	0.33	0.47	9.55	238	19.58	315	8.27	4.67	12.71	0.49	2.86	0.47	1.47	Silty Loam
5	19.44305556	74.61917	8.52	0.59	0.42	12.5	230	14.69	433	11.28	4.73	13.78	0.41	3.66	0.57	1.38	Silty Loam
6	19.44416667	74.61306	8.2	0.22	0.43	9.5	227	16.57	449	12.15	4.41	13.91	0.47	3.6	0.29	1.5	Clay
7	19.44861111	74.62972	8.13	0.21	0.57	8.5	233	10.33	495	10.32	4.86	12.65	0.9	3.57	0.55	1.5	Clay
8	19.44888889	74.62167	8.17	0.28	0.3	8.45	239	8.34	585	12.24	4.21	12.91	0.31	3	0.58	1.45	Silty Clay
9	19.44722222	74.61722	8.08	0.32	0.48	7.5	248	24.85	656	17.16	4.36	13.71	0.46	2.16	0.45	1.3	Clay
10	19.45305556	74.61889	8.26	0.35	0.31	8.75	229	15.85	566	11.25	4.49	12.87	0.49	3.07	0.41	1.44	Silty Loam
11	19.45194444	74.62417	8.49	0.56	0.39	11.75	215	11.82	612	11.25	4.15	12.98	0.31	3.11	0.53	1.44	Sandy Clay Loam
12	19.45138889	74.61833	8.39	0.3	0.26	11.25	246	18.92	578	21.22	3.87	13.13	0.45	3.33	0.51	1.46	Silty Loam
13	19.45277778	74.61306	8.03	0.26	0.28	7.5	189	19.85	418	18.42	4.67	13.42	0.51	3.36	0.43	1.45	Silty Clay
14	19.45583333	74.63583	8.32	0.43	0.43	7.2	256	28.73	483	11.98	4.52	12.94	0.63	2.98	0.63	1.46	Silty Loam
15	19.45694444	74.62972	8.38	0.4	0.44	9.1	223	19.43	479	10.17	4.32	13.15	0.76	2.94	0.46	1.39	Silty Clay
16	19.45583333	74.62417	8.12	0.37	0.52	7.7	239	22.33	499	12.18	4.32	12.81	0.73	2.58	0.37	1.35	Clay
17	19.45583333	74.61861	8.11	0.28	0.47	9.2	292	21.43	498	12.19	4.54	12.81	0.67	2.13	0.43	1.38	Clay

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients				Bulk density		Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})				(Mg m^{-3})		
18	19.45861111	74.61389	8.21	0.63	0.38	8.25	262	23.17	505	11.15	4.26	12.13	0.81	2.33	0.54	1.35	Silty Clay
19	19.46055556	74.61944	8.09	0.64	0.48	8.45	218	25.53	583	10.67	4.15	12.25	0.5	2.54	0.47	1.33	Silty Clay
20	19.45944444	74.62722	8.21	0.32	0.38	9.25	219	17.87	649	11.4	4.14	11.95	0.49	3.35	0.58	1.55	Silty Loam
21	19.46111111	74.63583	8.17	0.36	0.41	7.5	295	9.13	585	10.38	4.12	12.75	0.65	3.81	0.61	1.52	Clay Loam
22	19.45805556	74.6375	8.32	0.2	0.43	8.5	283	13.11	345	11.22	4.43	13.21	0.39	3.12	0.48	1.38	Clay
23	19.465	74.64083	8.02	0.37	0.38	5.75	211	14.43	388	19.66	4.19	12.61	0.37	2.24	0.68	1.51	Silty Loam
24	19.46472222	74.63417	8.28	0.28	0.51	7.25	225	14.97	465	21.75	4.32	12.67	0.54	2.48	0.54	1.47	Silty Loam
25	19.46277778	74.63028	8.05	0.44	0.48	9.5	230	17.87	383	12.66	4.09	11.65	0.65	2.56	0.49	1.4	Clay
26	19.465	74.62611	8.43	0.56	0.39	10.75	258	22.25	467	21.45	5.15	12.15	0.41	2.63	0.52	1.5	Silty Loam
27	19.46305556	74.62139	8.29	0.28	0.41	9	297	11.35	318	14.22	4.14	12.95	0.47	2.71	0.52	1.45	Silty Clay
28	19.46361111	74.61528	8.07	0.33	0.35	7.5	299	17.25	389	17.28	4.69	12.31	0.72	3.48	0.45	1.52	Silty Clay
29	19.46833333	74.61472	8.13	0.47	0.53	8.25	289	14.65	337	15.45	4.87	12.07	1.43	2.29	0.46	1.33	Clay
30	19.46861111	74.61917	8.33	0.39	0.42	7.5	293	10.45	383	25.13	4.82	12.54	0.69	2.13	0.59	1.4	Clay
31	19.46916667	74.62417	8.17	0.32	0.48	7.25	298	8.48	346	12.18	5.17	12.16	1.31	2.18	0.49	1.44	Clay
32	19.46888889	74.62806	8.2	0.38	0.46	7.75	299	13.3	465	10.38	4.66	13.07	0.4	2.15	0.43	1.5	Clay
33	19.46944444	74.63194	8.22	0.52	0.38	8.5	278	17.94	293	19.02	5.21	12.61	0.79	3.29	0.41	1.38	Clay Loam

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
34	19.46777778	74.63694	8.09	0.26	0.35	7.25	289	14.44	340	13.29	5.25	12.11	0.81	2.82	0.66	1.38	Clay
35	19.46972222	74.64111	8.3	0.6	0.43	8.25	278	8.77	271	16.75	5.18	12.45	0.89	2.92	0.57	1.4	Clay
36	19.47333333	74.64472	8.59	0.58	0.38	10.25	229	12.32	589	10.32	5.13	12.67	0.47	2.18	0.4	1.35	Silty Clay
37	19.47333333	74.63833	8.29	0.47	0.36	9.5	219	13.66	384	17.48	4.28	12.66	0.73	1.24	0.49	1.33	Clay Loam
38	19.47111111	74.63528	8.4	0.38	0.4	9.5	229	8.99	506	18.59	4.78	12.13	0.7	1.52	0.49	1.39	Clay
39	19.47333333	74.63	8.15	0.27	0.35	7.25	296	8.28	475	11.67	4.49	13.28	0.43	3.69	0.56	1.35	Clay Loam
40	19.4725	74.62417	8.03	0.34	0.43	8.5	238	15.89	626	18.17	4.92	13.15	0.9	3.51	0.45	1.41	Silty Clay
41	19.47777778	74.6425	8.19	0.43	0.48	7.5	289	14.29	388	9.19	5.17	12.15	1.01	2.29	0.49	1.44	Sandy Clay Loam
42	19.4775	74.635	8.29	0.68	0.51	8.25	230	12.28	409	9.22	4.67	13.91	1.06	2.56	0.36	1.46	Silty Loam
43	19.47666667	74.6275	8.29	0.58	0.46	7.5	295	10.98	295	11.55	4.57	12.81	0.81	2.02	0.57	1.45	Silty Clay
44	19.47944444	74.62167	8.39	0.6	0.46	7.25	245	9.97	654	10.28	4.87	11.93	0.86	2.39	0.53	1.46	Silty Loam
45	19.48166667	74.62833	8.15	0.41	0.52	7.5	230	10.97	528	10.58	4.36	12.43	0.49	2.74	0.51	1.39	Silty Clay
46	19.47972222	74.63472	8.41	0.3	0.58	7.25	293	14.38	514	15.08	3.98	13.11	0.69	2.46	0.61	1.35	Clay
47	19.48194444	74.64056	8.36	0.68	0.43	9.5	226	16.42	474	19.02	4.56	12.81	0.47	2.68	0.6	1.38	Clay
48	19.47972222	74.6475	8.59	0.68	0.49	9.75	283	21.14	666	19.97	5.17	12.78	0.51	3.51	0.39	1.35	Silty Clay
49	19.485	74.64861	8.19	0.18	0.39	7.25	219	21.14	553	11.16	5.11	12.16	0.26	3.59	0.63	1.33	Silty Clay
50	19.48611111	74.64278	8.52	0.65	0.35	8.5	243	17.19	489	18.05	4.17	12.36	0.39	1.86	0.53	1.55	Silty Loam

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		

							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
51	19.48611111	74.63861	8.21	0.42	0.31	6.75	299	17.12	471	19.45	5.18	12.35	0.66	1.92	0.59	1.46	Silty Clay
52	19.48583333	74.63194	8.2	0.42	0.41	7.25	289	16.63	368	10.78	4.67	11.86	0.81	2.78	0.49	1.44	Silty Loam
53	19.48444444	74.62361	8.29	0.66	0.38	7.75	290	15.11	409	19.13	4.18	12.03	0.61	2.18	0.36	1.46	Silty Loam
54	19.48361111	74.61778	8.28	0.29	0.52	8.25	237	15.46	490	18.16	5.26	12.41	0.73	1.02	0.41	1.45	Clay Loam
55	19.47944444	74.61444	8.17	0.3	0.43	8.5	227	14.21	452	15.19	3.83	12.91	0.75	2.3	0.56	1.55	Silty Clay
56	19.47583333	74.61139	8.21	0.55	0.41	9.25	239	10.43	491	9.67	5.14	11.89	0.44	1.59	0.31	1.24	Clay
57	19.47166667	74.60944	8.28	0.32	0.56	10.25	235	17.85	561	10.4	4.71	12.16	0.36	2.89	0.33	1.64	Sandy Loam
58	19.46777778	74.60583	8.29	0.52	0.36	12.5	296	15.77	528	17.8	3.81	12.36	0.41	3.59	0.39	1.48	Silty clay
59	19.46333333	74.60167	8.24	0.38	0.31	12.75	252	12.25	485	9.29	5.18	11.87	0.48	2.92	0.45	1.45	Silty clay
60	19.45972222	74.60139	8.1	0.4	0.31	10	263	13.89	667	10.32	4.32	12.87	0.6	1.88	0.21	1.46	Silty clay
61	19.45722222	74.59639	8.21	0.29	0.29	9.5	286	11.38	437	11.34	3.84	13.87	0.37	1.58	0.35	1.44	Clay Loam
62	19.45583333	74.5925	8.3	0.37	0.56	8.75	240	12.12	323	10.21	3.98	12.91	0.4	1.75	0.39	1.45	Silty Clay
63	19.45138889	74.58889	8.17	0.37	0.46	9.75	228	15.47	647	10.12	4.88	12.68	0.41	1.89	0.48	1.49	Clay
64	19.44777778	74.59278	8.28	0.47	0.35	11.25	224	10.22	478	18.66	4.56	12.14	0.38	1.81	0.49	1.46	Silty Clay
65	19.44611111	74.58861	8.45	0.46	0.37	12.5	229	13.45	574	19.56	3.96	12.92	0.35	1.89	0.4	1.38	Clay
66	19.44833333	74.58444	8.11	0.36	0.45	7.75	202	8.25	553	17.75	4.55	13.31	0.79	2.88	0.38	1.41	Silty Clay
67	19.45277778	74.58444	8.2	0.62	0.44	8.75	236	18.27	515	13.76	3.18	13.28	0.36	2.15	0.41	1.56	Sandy Loam
68	19.45638889	74.58139	8.14	0.62	0.42	9.75	254	15.9	552	11.67	2.56	13.11	0.55	3.11	0.54	1.46	Clay
69	19.45666667	74.58833	8.56	0.56	0.43	12	232	9.75	586	11.47	4.68	12.75	0.46	2.97	0.41	1.47	Silty Clay

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	$CaCO_3$ (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
70	19.46083333	74.58528	8.54	0.48	0.39	12.5	224	19.65	628	12.38	3.88	12.07	0.27	2.51	0.54	1.45	Clay
71	19.46083333	74.58528	8.23	0.59	0.37	8.25	255	18.23	460	18.23	3.88	12	0.31	2.66	0.41	1.46	Clay Loam
72	19.46083333	74.59472	8.42	0.36	0.4	8.5	246	17.45	628	16.38	4.56	13.14	0.69	1.88	0.4	1.47	Sandy Loam
73	19.46444444	74.59861	8.13	0.28	0.38	8.25	240	9.13	564	17.37	5.56	11.37	0.75	2.17	0.4	1.5	Clay
74	19.46472222	74.59278	8.21	0.4	0.45	9.75	217	18.17	596	19.18	4.55	12.13	0.61	2.63	0.68	1.59	Silty Loam
75	19.46361111	74.58583	8.17	0.35	0.45	7.25	313	14.43	672	17.13	4.18	12.51	0.48	3.14	0.59	1.45	Silty Clay
76	19.46833333	74.58917	8.32	0.24	0.42	9.75	299	22.25	543	21.53	4.37	13.31	0.54	2.24	0.41	1.43	Silty Loam
77	19.46861111	74.59694	8.42	0.32	0.44	8.5	236	9.75	499	10.83	4.56	13.62	0.4	1.95	0.47	1.47	Silty Loam
78	19.46888889	74.60139	8.18	0.68	0.48	5.25	224	17.28	564	18.45	3.89	13.68	0.67	1.37	0.52	1.45	Clay
79	19.47611111	74.60528	8.15	0.28	0.4	7.25	297	10.52	522	12.63	4.89	13.68	0.52	2.29	0.36	1.46	Clay
80	19.47555556	74.59861	8.15	0.68	0.41	7.5	210	19.23	486	21.76	5.18	12.77	0.38	2.81	0.43	1.44	Clay
81	19.47333333	74.59361	8.32	0.56	0.39	8	292	19.32	595	18.87	3.95	13.21	0.75	1.99	0.43	1.5	Clay
82	19.48222222	74.59889	8.05	0.52	0.38	9.75	241	14.97	640	19.96	4.48	13.69	0.79	1.79	0.42	1.38	Clay Loam
83	19.48055556	74.60528	8.52	0.51	0.35	12.5	224	19.87	446	15.97	4.82	12.69	0.46	1.81	0.58	1.38	Clay
84	19.48333333	74.61	8.24	0.41	0.49	8.5	298	9.13	394	15.86	5.19	12.61	0.4	2.71	0.62	1.4	Clay
85	19.48611111	74.60333	8.11	0.47	0.39	7.75	300	13.71	289	17.11	3.92	12.26	0.61	2.17	0.43	1.35	Silty Clay
86	19.49194444	74.63917	8.51	0.68	0.35	11.5	245	14.43	433	10.52	3.95	12.98	0.47	1.13	0.37	1.33	Clay Loam
87	19.49194444	74.63139	8.38	0.35	0.38	9.25	270	22.25	513	16.57	4.89	13.18	0.42	2.67	0.4	1.39	Clay
88	19.49833333	74.63444	8.33	0.4	0.45	10.75	289	20.25	447	15.77	4.89	13.49	0.48	2.47	0.5	1.35	Clay Loam

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	$CaCO_3$ (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
89	19.50083333	74.62778	8.15	0.62	0.45	7.25	202	9.75	497	16.85	3.87	13.83	0.58	1.19	0.53	1.41	Silty Clay
90	19.49388889	74.62278	8.07	0.92	0.42	9.5	197	9.13	361	15.65	5.35	12.57	0.48	1.81	0.43	1.44	Sandy Clay Loam
91	19.49861111	74.6175	8.19	0.52	0.34	8.25	313	15.11	567	15.96	4.42	11.35	0.53	2.17	0.43	1.46	Silty Loam
92	19.4925	74.61444	8.43	0.69	0.38	11.25	224	26.25	472	16.41	5.12	11.95	0.51	2.81	0.68	1.45	Silty Clay
93	19.49805556	74.60917	8.56	0.78	0.4	14.25	189	12.25	430	15	3.92	12.88	0.37	3.1	0.37	1.46	Silty Loam
94	19.49805556	74.60917	8.56	0.78	0.41	14.25	189	12.25	430	15	4.08	12.88	0.37	3.1	0.37	1.46	Silty Loam
95	19.49861111	74.64306	8.32	0.3	0.39	9.25	299	20.25	468	10.68	5.39	13.14	0.54	3.61	0.49	1.39	Silty Clay
96	19.50277778	74.63833	8.4	0.25	0.38	8.5	250	21.23	462	10.36	5.17	13.45	0.44	3.89	0.31	1.35	Clay
97	19.50555556	74.64333	8.68	0.56	0.35	9.25	246	19.23	417	18.57	5.19	12.65	0.32	3.71	0.54	1.38	Clay
98	19.50972222	74.63889	8.27	0.43	0.39	8.75	265	18.36	499	20.02	4.52	11.54	0.54	2.48	0.55	1.35	Silty Clay
99	19.50638889	74.63389	8.43	0.35	0.49	9.5	230	19.32	373	19.58	4.37	12.68	0.27	2.78	0.49	1.33	Silty Clay
100	19.50916667	74.63083	8.48	0.67	0.43	10.25	184	15.66	395	22.67	4.48	13.13	0.29	2.88	0.39	1.55	Silty Loam
101	19.50527778	74.6275	8.21	0.48	0.36	9	218	19.76	366	18.67	4.42	13.4	0.49	2.12	0.49	1.52	Clay Loam
102	19.50861111	74.61833	8.06	0.36	0.55	7.25	312	12.12	265	17.93	5.32	13.25	0.93	2.71	0.57	1.38	Clay
103	19.50166667	74.6225	8.72	0.58	0.41	8.75	293	11.25	432	14.98	3.69	12.21	0.51	2.41	0.53	1.51	Silty Loam
104	19.50611111	74.61417	8.48	0.28	0.35	7.5	297	13.39	468	12.11	3.78	11.52	0.32	2.83	0.3	1.47	Silty Loam
105	19.50138889	74.61389	8.37	0.29	0.43	6.5	249	15.28	392	17.37	3.82	13.13	0.55	1.81	0.47	1.4	Clay
106	19.50138889	74.61389	8.17	0.38	0.45	7.5	223	15.72	298	14.57	5.29	13.54	0.42	1.89	0.47	1.5	Silty Loam

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
107	19.48916667	74.60639	8.28	0.46	0.35	8.5	293	10.43	405	19.67	4.67	12.71	1.28	2.28	0.49	1.52	Silty Clay
108	19.48972222	74.60083	8.23	0.32	0.38	8.25	233	22.25	269	10.47	5.15	13.87	1.31	2.24	0.57	1.33	Clay
109	19.49277778	74.595	8.25	0.32	0.39	8.75	246	14.21	611	12.67	4.18	12.74	1.15	2.34	0.51	1.4	Clay
110	19.49416667	74.60278	8.08	0.28	0.35	8.75	252	15.46	312	12.43	4.17	13.07	0.78	1.92	0.3	1.36	Clay
111	19.4975	74.59417	8.53	0.54	0.34	11.25	229	15.11	270	10.43	3.87	13.21	0.36	2.85	0.42	1.39	Clay Loam
112	19.49611111	74.59917	8.34	0.24	0.41	8.25	268	14.53	371	15.65	3.89	13.21	0.86	1.73	0.47	1.38	Silty Clay
113	19.49861111	74.60333	8.39	0.39	0.53	7.5	300	17.92	416	16.67	5.18	11.87	0.64	3.1	0.57	1.29	Sandy Clay Loam
114	19.50166667	74.59806	8.32	0.38	0.44	9.25	250	17.19	489	16.57	3.95	11.76	0.35	2.98	0.43	1.37	Silty Loam
115	19.50277778	74.60361	8.13	0.36	0.43	8.75	298	21.14	451	14.86	3.98	12.99	0.55	1.43	0.52	1.34	Silty Clay
116	19.50055556	74.6075	8.35	0.52	0.41	8.25	285	20.27	580	17.23	4.42	12.21	0.47	1.65	0.59	1.36	Silty Loam
117	19.505	74.60167	8.13	0.47	0.34	8.5	246	21.23	510	18.57	5.19	13.15	1.64	2.92	0.43	1.29	Silty Clay
118	19.50611111	74.60722	8.35	0.39	0.39	9.75	297	19.23	601	21.96	3.92	12.93	0.83	2.14	0.45	1.45	Silty Loam
119	19.505	74.06139	8.18	0.25	0.35	9.25	234	13.35	623	9.96	3.95	12.13	0.9	3.21	0.52	1.34	Clay
120	19.50611111	74.60722	8.35	0.39	0.48	9.75	297	19.23	601	21.96	3.89	12.93	0.83	2.14	0.45	1.28	Clay
121	19.505	74.06139	8.18	0.25	0.39	9.25	234	13.35	623	9.96	3.89	12.13	0.9	3.21	0.52	1.45	Clay
122	19.50555556	74.61833	8.39	0.65	0.45	7.5	228	19.32	618	12.65	5.21	12.97	0.91	1.9	0.61	1.29	Silty Clay
123	19.50527778	74.62361	8.32	0.58	0.36	8.75	212	15.56	404	10.63	4.17	13.13	0.86	1.21	0.66	1.33	Clay
124	19.50916667	74.62639	8.13	0.33	0.35	9.25	228	18.76	318	14.21	5.25	12.63	0.48	2.15	0.47	1.33	Clay Loam
125	19.49777778	74.62972	8.48	0.59	0.34	11.5	229	13.39	286	10.86	5.18	12.66	0.53	1.69	0.47	1.61	Sandy Loam
126	19.49416667	74.64472	8.55	0.61	0.41	11.25	228	15.25	445	22.66	3.67	12.91	0.51	2.65	0.53	1.36	Clay
127	19.48805556	74.63556	8.49	0.25	0.46	8.25	263	17.25	463	12.47	4.18	12.98	0.53	2.98	0.4	1.57	Silty Loam
128	19.48805556	74.62778	8.17	0.28	0.35	9.25	295	14.21	526	14.19	5.38	12.66	0.47	2.69	0.49	1.42	Silty Clay

Sample number	Latitude	Longitude	pH (1: 2.5)	EC (dS m^{-1})	OC (%)	CaCO3 (%)	Available Micronutrients				Available nutrients					Bulk density	Soil texture
							N	P	K	S	Fe	Mn	Zn	Cu	B		
							(kg ha^{-1})			(mg kg^{-1})	(mg kg^{-1})					(Mg m^{-3})	
129	19.47972222	74.60889	8.11	0.37	0.45	9.75	298	13.17	498	17.15	5.17	12.12	0.52	2.79	0.62	1.51	Silty Loam
130	19.48638889	74.61361	8.21	0.42	0.36	8.25	258	17.72	318	15.77	5.19	12.69	0.42	3.03	0.48	1.33	Clay

5. Conclusion

The soil fertility assessment of Deolali Pravara village revealed that the soils are predominantly clayey, moderately alkaline, and low in available nitrogen and phosphorus. Potassium levels were medium to high, while zinc deficiency emerged as a critical constraint. Fertility maps prepared using GPS and GIS clearly depicted nutrient variability, enabling targeted recommendations. Adopting site-specific nutrient management based on these maps will help optimize fertilizer use, reduce costs, increase productivity, and sustain soil health. The study underscores the importance of digital mapping in precision agriculture and advocates its wider application for sustainable farming in Maharashtra and beyond.

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