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Evaluation of physico-chemical properties and their correlation with nutrients of soil of Sayala block VNMKV, Parbhani

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Abstract
Soil is a vital natural resource that underpins agricultural productivity, environmental health, and long-term sustainability. Accurate assessment of soil properties is essential for effective land management and informed agricultural decision-making. The present study was conducted to evaluate the soil fertility status of Sayala Block, VNMKV Parbhani, using scientific methodologies integrated with geospatial techniques. A total of 80 surface soil samples were systematically collected and analyzed to assess key physico-chemical properties and nutrient availability. The findings revealed that the soils in the study area are dense in nature with clayey to clayey loam texture. Soil pH ranged from neutral to moderately alkaline (7.07-8.10), while electrical conductivity (0.14 to 0.23 dSm^{-1}) values indicated non-saline conditions. Organic carbon content varied from very low to moderate (3.10 to 4.20 g/kg), and calcium carbonate content was observed in medium to high concentrations (48.6-145.00 g/kg). Macronutrient analysis showed that available nitrogen was low (101.51-177.64 kg/ha), phosphorus was in the medium range (8.98-22.11 kg/ha), and potassium content was high (666.28-1041.48 kg/ha). Sulphur levels ranged from 5.46 to 17.91 mg/kg, indicating moderate availability. Micronutrients such as iron (3.82-5.12 mg/kg), manganese (9.15-15.67 mg/kg), copper (0.99-2.65 mg/kg), and boron (0.33-0.83 mg/kg) were found to be sufficient, whereas zinc (0.28-0.94 mg/kg) was deficient in several samples, suggesting a need for supplementation. Correlation analysis showed that increasing soil pH was negatively associated with potassium (r=-0.315), sulphur (r=-0.251), copper (r=-0.285), and boron (r=-0.340) availability. Higher calcium carbonate reduces phosphorus availability (r=-0.292) potassium (r=-0.227) and sulphur (r=-0.297). Electrical conductivity was negatively correlated with copper (r=-0.335), and organic carbon was positively correlated with phosphorus (r=0.274), copper (r=0.257), and manganese (r=0.276).

Keywords: Soil fertility, correlation, sustainability, electrical conductivity

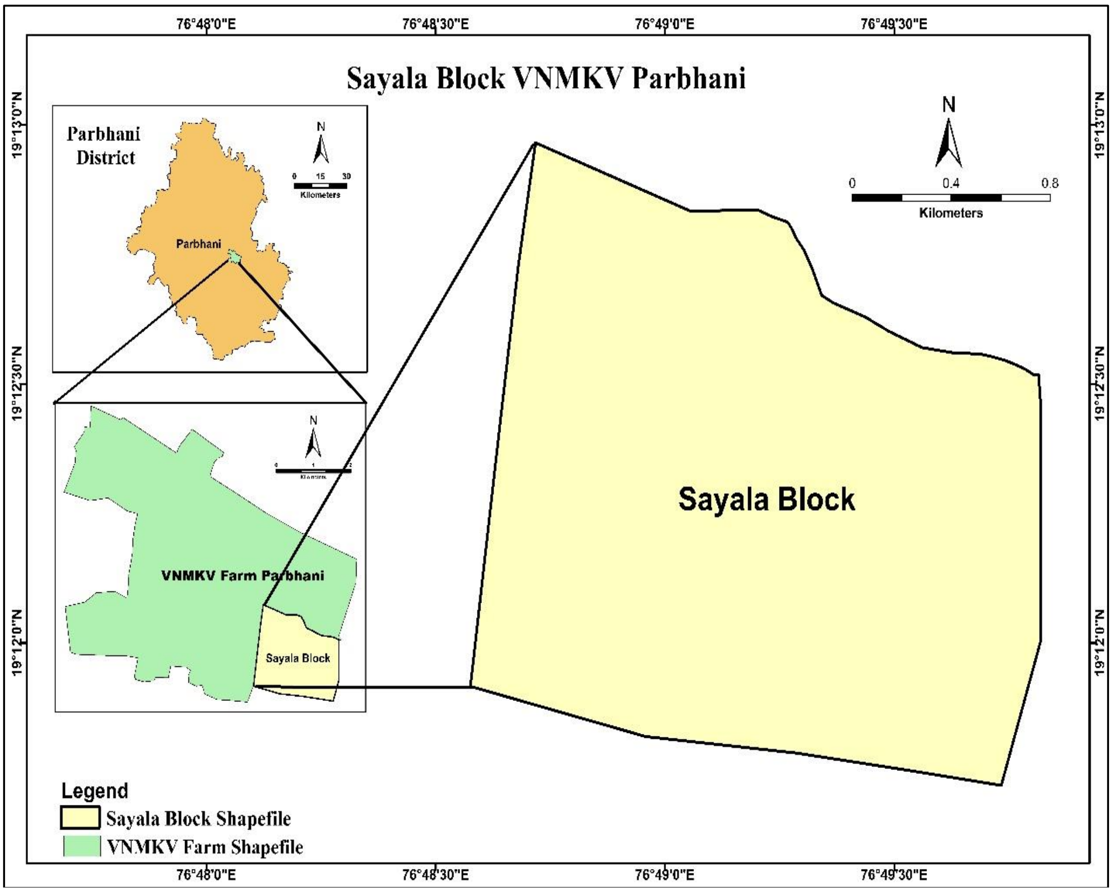
1. Introduction

Soil is an essential natural resource that constitutes the Earth's thin, living surface layer. It consists of a dynamic combination of minerals, organic matter, water, air, and a vast array of organisms ranging from microscopic microbes to larger fauna. Soil formation is a slow and ongoing process resulting from the weathering of rocks and the breakdown of organic material over thousands of years. This leads to the development of diverse soil types, influenced by factors such as parent rock material, climate, terrain, biological activity, and time. Functioning as more than just a medium for plant growth, soil plays multiple critical roles. It regulates water availability, recycles nutrients, filters contaminants, and provides a habitat for a wide range of organisms, thereby making it indispensable to life on Earth. In agriculture, soil supports crops by anchoring roots and supplying essential nutrients and water. Beyond farming, it contributes to environmental sustainability by filtering water to maintain groundwater quality and by storing carbon in its organic matter an increasingly vital role in mitigating climate change. Additionally, healthy soils support biodiversity by housing a multitude of organisms that are key to nutrient cycling and the breakdown of organic residues. Understanding the physico-chemical properties of soil is fundamental for assessing its fertility and guiding effective nutrient management strategies.

Parameters such as soil texture, pH, electrical conductivity (EC), organic carbon content, and calcium carbonate concentration significantly influence the availability, mobility, and retention of essential nutrients. These properties interact closely with both macro-and micronutrients, affecting their solubility and uptake by plants. Evaluating these properties provides critical insights into the soil's capacity to supply nutrients under varying environmental and management conditions. For instance, soil pH influences the chemical forms of nutrients and their bioavailability, while organic carbon content is closely linked to soil structure, microbial activity, and the retention of nutrients like nitrogen and phosphorus. Similarly, electrical conductivity reflects the presence of soluble salts, which can either facilitate or hinder nutrient uptake depending on concentration levels. Correlating physico-chemical characteristics with nutrient concentrations allows for the identification of limiting factors and nutrient imbalances in the soil. Such analysis not only supports precision agriculture practices but also promotes sustainable use of fertilizers by ensuring nutrients are applied based on actual soil needs. Therefore, a comprehensive evaluation of soil physico-chemical properties and their relationship with nutrient status is crucial for enhancing crop productivity, maintaining soil health, and ensuring long-term agricultural sustainability.

2. Study Area

Sayala block situated between 19^{0}11’42.87’’ N to 19^{0}13’2.39’’ N Latitude and 76^{0}48’34.61’’ E to 76^{0}49’54.02’’ E Longitude. The Sayala Block of VNMKV Parbhani is part of the Deccan Traps, comprising massive and vesicular basalt formed during the Cretaceous to Eocene period. The area lies at an elevation of 410-420 m above mean sea level, Sayala falls under the Scarcity Agro-Climatic Zone VI of Maharashtra and has a semi-arid tropical climate (Köppen: Aw). Summers are extremely hot (March-May), followed by moderate rainfall during June to September. Winters (November-February) are cool and dry. October marks the transition with decreasing temperatures and minimal rainfall.



3. Material and Methods

3.1 Collection of Soil Samples

Soil samples were collected from 80 locations systematically distributed across the study area using a predefined grid-based approach. At each sampling point, approximately 500-1000 grams of soil were collected by excavating pits up to a depth of 0-30 cm. The collected samples were initially air-dried at ambient room temperature in the laboratory. After drying, the soils were gently crushed using a wooden mortar and passed through a 2 mm sieve to remove coarse fragments. The processed samples were then properly labeled and stored in clean polythene bags for subsequent laboratory analysis. For the determination of specific parameters such as organic carbon, a portion of the sieved soil was further ground finely and passed through an 80-mesh sieve to ensure uniformity and accuracy in analysis.

3.2 Chemical Analysis of Soil

Soil pH and electrical conductivity (EC) were measured using a 1:2.5 soil-to-water suspension. The pH was determined electrometrically with a digital pH meter, while EC was assessed using the standard conductivity method. Calcium carbonate content was estimated by the rapid titration technique described by Richard (1954). Organic carbon was analyzed using the Modified Walkley and Black's back titration method as outlined by Jackson (1973). The available nitrogen content was determined using the modified Kjeldahl method, while available phosphorus was estimated by the Olsen method. For available potassium, extraction was done using 1 N ammonium acetate solution at pH 7.0. Available sulphur was measured by the turbidimetric method following Jackson (1973). Micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were extracted using DTPA (0.005 M) and analyzed through atomic absorption spectrophotometry, following the protocol by Lindsay and Norvell (1978) [7]. Water-soluble boron was determined by the hot water extraction method using Azomethine-H reagent as described by Berger and Troug (1939) [1].

4. Result and Discussion

4.1 Chemical properties of soil

Soil pH is a critical parameter that influences nutrient availability, microbial activity, and overall soil fertility. It affects the solubility of minerals and determines the chemical form in which nutrients are available to plants. The pH levels of study area are ranging between 7.07 to 8.10, showing the neutral to moderately alkaline nature. Such pH range supports good microbial activity and enhances the availability of macronutrients, similar findings were by Mali and Raut (2001) [9]. Electrical Conductivity (EC) indicates the soil's salinity level, affecting nutrient availability and crop growth. The EC values ranged between 0.10 to 0.39 dSm^{-1}, indicates the minimal salinity, which are typically more favourable for plant development. The low EC values in some soils is due to good drainage conditions (Chandrashekhar *et.al* 2014) [3]. Organic carbon is a key indicator of soil fertility, enhancing nutrient availability, water retention, and microbial activity. The OC in study area are varies from 1.60 to 6.30 g/kg, the low OC is due to rapid decomposition of organic matter in hyperthermic temperature conditions. The Calcium content in area is as low as 48.6 g/kg to high as 145.00 g/kg, majority of samples lay between the 60.00 to 110.00 g/kg indicating high levels of $CaCO_3$ in soils significantly influence soil pH, often increasing alkalinity, which may affect nutrient availability and plant growth (Bolland 1998) [2].

Table 1: Soil Chemical Status of Sayala Block VNMKV, Parbhani

Particulars	pH	EC (dSm^{-1})	OC (g/kg)	$CaCO_3$ (g/kg)
Mean	7.67	0.16	3.30	94.10
Range	7.07-8.10	0.10-0.39	1.60-6.30	48.60-145.00

4.2 Macronutrients Status of Soil

Soil nutrients play a vital role in supporting healthy plant growth and crop productivity. Nitrogen (N) is essential for vegetative growth and chlorophyll formation, while Phosphorus (P) promotes root development and energy transfer. Potassium (K) enhances disease resistance, water regulation, and overall plant vigor. Sulphur (S) is important for protein synthesis and enzyme function. Micronutrients like iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and boron (B) are required in small quantities but are crucial for physiological and biochemical processes in plants. The nitrogen content in Soil varied from the range 101.51 to 177.64 kg/ha, the available nitrogen content in the soil was found to be low, primarily due to the poor organic carbon content. The phosphorous levels in the soils of Sayala Block shows wide range of 8.98 kg/ha to 22.11 kg/ha, waikar *et aL* (2004) [15] recorded that the available phosphorous ranging from 10.00 to 19.10 kg/ha in their soil samples south central part of Maharashtra. The Potassium content in soils varied to the range of 666.28 kg/ha to 1041.48 kg/ha, the elevated levels of K_2O in the soils due to the presence of potassium rich mineral found in vertisols and their associated soils, as noted by Gajbe *et aL* (1976) [5]. Sulphur in soil ranged between 5.46-17.91 g/kg, surface layer show higher level of Sulphur than deeper soil due to the high organic matter in surface soil as noted by Thangasamy *et.al* (2005) [14].

Table 2: Status of available macronutrients in soil of Sayala block

Particular	Available macronutrient			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (g/kg)
Mean	130.22	15.94	842.36	12.10
Range	177.64-101.51	8.98-22.11	666.28-1041.48	5.46-17.91
Critical limit	280	14	150	10
Sufficient	0	59	80	15
Deficient	80	21	0	65

4.3 Micronutrient status of soil

The iron content in the soils of Sayala is between 3.82 mg/kg to 5.12 mg/kg, indicates the high level of iron in soil, similar findings were reported by the by the Patel *et aL.* (2015) [10], who observed the high levels of available iron in the soils of central India due to iron rich parent material. Mangenese ranged from 9.15-15.67 mg/kg, indicates the high level of mangenese in soil, similar findings were reported by the by the Patel *et aL.* (2015) [10], who observed the high levels of available iron in the soils of central India due to Mangenese rich parent material. Zinc content in the soils ranges from 0.28 mg/kg to 0.94 mg/kg, indicating a moderate level of availability of this vital micronutrient. According to Dhamak *et aL.* (2014) [4], the available zinc content ranged from deficient to sufficient when compared with the critical level of 0.6 mg/kg. Copper (Cu) content in the soils ranges from 0.99 mg/kg to 2.65 mg/kg, suggesting a moderate to high availability of this essential micronutrient, Similar findings were reported by Sharma *et aL.* (2003) [13], who observed copper levels ranging from 0.5 to 3.9 mg/kg in the soils of Nagpur district, Rajasthan. The boron levels in the soils vary from 0.33 to 0.83 mg/kg, Soils in Maharashtra, particularly in Vertisol and Inceptisol regions, often show variable boron availability due to differences in soil texture, pH, and organic matter content. (Patil *et aL.* (2010) [11].

Table 3: Soil available micronutrients status of Sayala Block, VNMKV Parbhani.

Particular	Available micronutrient				
	Cu (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	B (mg/kg)
Mean	1.73	0.66	4.63	12.76	0.54
Range	0.99-2.65	0.28-0.94	3.82-5.12	9.15-15.67	0.33-0.83
Critical limit	0.2	0.6	4.5	2.0	0.5
Sufficient	80	32	58	80	33
Deficient	0	49	22	0	47

4.4 Correlation between physico-chemical properties and available nutrients

Correlation analysis helps reveal how soil's physical and chemical properties affect nutrient availability.

Understanding these relationships is essential for creating effective soil management strategies to improve fertility and boost agricultural productivity in the Sayala block.

Table 4: Correlation between physico-chemical properties and available nutrients in soil samples of Sayala block, VNMKV Parbhani

Available Nutrients	Ph	EC	OC	CaCO3
Nitrogen	0.05	0.10	0.13	0.00
Phosphorus	0.00	0.10	0.274^{*}	-0.292^{**}
Potassium	-0.315^{**}	0.15	0.03	-0.227^{*}
Sulphur	-0.251^{*}	0.16	0.13	-0.297^{**}
Ferrous	0.11	0.11	0.04	-0.19
Copper	-0.285^{**}	-0.335^{**}	0.257^{*}	-0.16
Manganese	0.16	0.02	0.276^{*}	-0.02
Zinc	0.10	0.08	0.174	-0.17
Boron	-0.340^{**}	0.13	0.21	-0.14

**Correlation significance @ 1% Level, *Correlation significance@ 5% Level (r > 279) (r > 220)

From the results it was indicated that the effect of pH, Electrical Conductivity, Organic Carbon and Calcium Carbonate content on available nitrogen did not reach to level of significance. The organic carbon was associated positively with available Phosphorous which is evident by value (r=274), the positive correlation between phosphorous and organic carbon suggests that microbial decomposition of organic matter releases inorganic phosphate and chelates polyvalent cations, thus enhancing phosphorous availability (Malhotra, 2014) [8] The $CaCO_3$ showed negative relationship with available phosphorous (r=-292) further it was indicated that pH and $CaCO_3$ was negatively and significantly correlated with available Potassium and Sulphur which is expressed higher (r=-0.315 and r=-0.227) and (r=-251 and r=-0.297) values respectively. However the effect of pH, EC, Organic Carbon and Calcium Carbonate content on Iron and Zinc did not reach to the level of significance. pH and Electrical Conductivity were found to be in negative relationship with copper. Significant and positive relationship of Organic carbon with Copper and Manganese was evident from higher r value (r=0.257 and r=0.276), A positive and significant was observed between organic carbon and available copper, likely due to the chelating effect and retention of Cu by organic matter in the topsoil (Rajput *et aL*., 2018) [12]. Organic matter enhances soil structure and stimulates microbial activity, which facilitates the mineralization and mobilization of manganese (Khan *et aL*., 2019) [6]. pH is also negatively associated with Boron (r=-0.340).

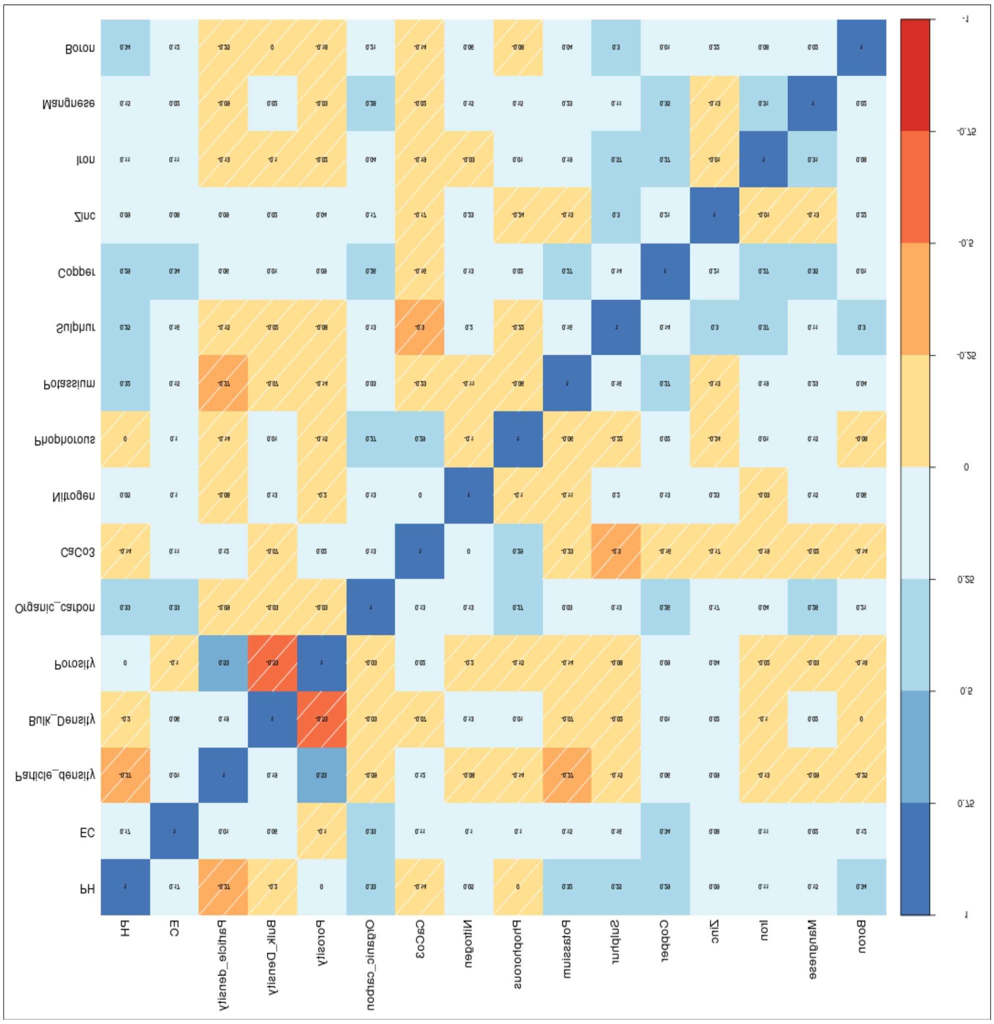


Fig 1: spearman correlation matrix of nutrient availiability of soils of Sayala block, VNMKV Parbhani.

5. Conclusions

This study indicates that the soils in the study area are moderately compact but not restrictive, soils have good porosity and structure. Suggesting potential for good agricultural productivity with proper management. The pH of soil sample indicated variations from neutral to moderately alkaline conditions while EC values classify the soils as non saline indicating no risk of salinity stress for crops. The organic carbon indicates the low to medium in organic matter, which indicated need for organic amendments to enhance the soil fertility and structure. $CaCo_3$ indicates that the soils are moderately to highly calcareous. High $CaCO_3$ content can lead to reduced availability of phosphorus and micronutrients, and influence soil pH buffering. The available N, P, and K in the soils of Sayala block was found low in nitrogen, medium in phosphorus and high in potassium which clearly suggested that need for nitrogen and phosphorus fertilization to meet crop demand. Micronutrients like Fe, Mn, and Cu were adequate though Zn levels were found low which suggested a potential deficiency. The correlation between soil pH and nutrient availability revealed that the availability of Potassium, Sulphur, Copper and Boron showed positive correlation. The EC showed significant correlation with the copper. The nutrients phosphorous, copper and manganese shows the positive correlation with organic carbon. The phosphorous shows the positive correlation with $CaCO_3$ and potassium and sulphur shows negative correlation with the $CaCO_3$.

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