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GPS-GIS based Soil Fertility Status of Jam River Basin, Nashik and Ahmednagar District (M.S.), India

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Abstract:

Using GPS-GIS technology, the current study was conducted in May 2022 to determine the fertility status of primary, secondary and micronutrients in the soils of the Jam River basin, Nashik and Ahmednagar district. It also aimed to correlate soil characteristics with the nutrients that were made available and assess the study area's fertility index. The Global Positioning System (GPS) was utilized to create the maps of soil fertility. The geo-referenced surface soil (0-22.5 cm) samples (60) were collected from study area by using Differential Global Positioning System (D-GPS). The analogue soil fertility maps on 1:50000 scale was geo-referenced and digitized by using ArcGIS software. The results were categorized as per six tier system of rating as low, medium and high. The pH of soil of study area varied from 6.9 to 9.5. 90 % soil samples are normal in range, 6.66% having pH basic and 3.33 % soil samples are highly basic in nature. while EC of the soils varied from 0.12 to 9.78 dS m^{-1} and 83.33 % values were normal. The calcium carbonate content of soils varied from 2 to 25 percent. Organic carbon content varied from 0.41 to 1.91 percent and categorized as moderate (33.33%), moderately high (35%), high (15%) and very high (16.66%). The available nitrogen, phosphorus and potassium in soils of study area ranged from 208.32 to 629.44, 6.72 to 42.56 and 201.6 to 4793.6 Kg. ha^{-1} respectively. The soils were low (21.66%), Normal (76.66%) and high (1.66%) in available – nitrogen. Available phosphorus found low (36.66%), moderate (53.33%) and high (9.99%). Available potassium found moderate (5%) and high (95%). Calcium content is very high in all the samples. Whereas 16.66 % and 71.66% samples are normal in range for magnesium and Sulphur content respectively. Magnesium and sulphur had a substantial and favorable correlation with pH. Sulphur and magnesium had a favorable correlation with the EC. The created maps will be beneficial to the study area's farming population in helping them use nutrients for various crops efficiently, saving money on expensive inputs while increasing output, productivity, and crop quality.

Keywords: *GPS-GIS, Soil fertility, Jam River basin, pH, EC, NPK*

Introduction

Maps of soil fertility are typically drawn using GPS and GIS methodologies (Global Positioning System and Geographical Information System). The construction of dams and canals, as well as land surveying, all involve the usage of GPS in agriculture. Making important decisions on the management of nutrients can be aided by soil samples collected using GPS data. The amount of fertilizer needed must be determined in order to calculate the precise dosage of straight fertilizer as opposed to a ready-mixed complicated, compound fertilizer. Fertility maps created with the use of GPS-GIS technology can be used to better optimize the fertilizer applied. The amount of money spent on fertilizers can be adjusted based on how much soil nutrient supply is actually required for cropping systems. For improved nutrient management, fertilizer application can be tailored to the area and dosages required on different areas of fields. Thematic soil fertility maps require the collection of soil samples using GPS. This tool aids in determining the location's latitude and longitude. It is very important for agriculture's upcoming monitoring of the nutritional status of the soil in various towns and regions. The global positioning system (GPS) is a U.S. military-managed space-based navigation and positioning system that aids in pinpointing an object's precise location on the surface of the planet using geographic coordinates (French, 1996; Sehgal *et al.,* 1988). A computer system for recording, storing, accessing, and displaying geographic data is called a geographic information system (GIS). Chang (2002). The information regarding the area's fertility status can be changed once the soil fertility maps have been prepared. These maps offer site-specific advice and confirmation of soil fertility throughout the coming years. When soil micronutrient levels fall below the typical level at which crop output cannot be sustained, it is a result of the adoption of high yielding varieties, intensive cropping and the application of high NPK fertilizers (Kanwar, 2004). Micronutrient insufficiency has become a significant barrier to soil productivity and sustainability (Yadav and Meena, 2009).

Study Area

The high Mhasha hill in Sinnar tehsil in Nashik district is the source of the Jam River, a tributary of the Godavari River, which it meets near Kopargaon tehsil in Ahmednagar district. A total of 636.67 square kilometers makes up the basin. It travels 52.2 kilometers from the eastern part of Sinner Tehsil to the southwest part of Kopargaon Tehsil. The study region is situated between 19^{0}44'27" to 19^{0}52'18" N latitudes and 74^{0}6'28" to 74^{0}25'56" E longitudes in the Deccan Plateau, an eastern extension of the Kalsubai range (Fig.1). With average annual rainfall (Sinnar: 568.6 mm, Sangamner: 510.57 mm, and Kopargaon: 483.9 mm) from south-west monsoonal winds, blowing form June to September. This river benefits many communities in Sinnar, Kopargaon and Sangamner tehsil for irrigation and drinking needs. The current study examines the soil fertility status of the Jam River Basin using GPS-GIS.

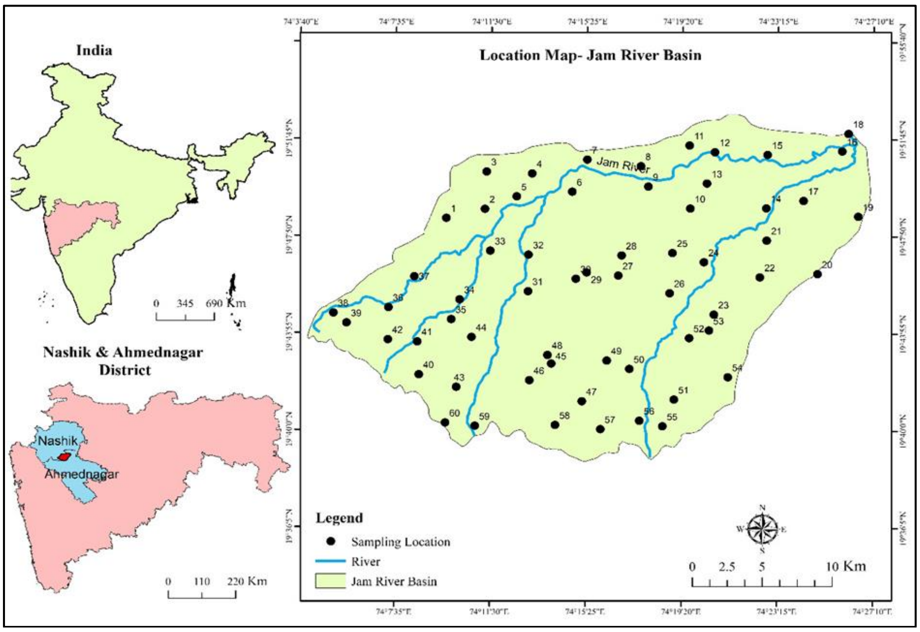

Fig.1 Study area map with soil sampling sites

Materials and Methods

Jam River Basin was selected to assess the soil nutrient status and delineate the fertility maps, 60 sampling sites were selected by grid method in such a way that it covers the whole area of the basin. Geo-referenced surface (0-22.5cm) soil samples from each selected site representing different soils were collected. The latitude and longitude of sampling sites were recorded with the help of differential Global Positioning system with detailed observation on cropping pattern and fertilizer use. The soil samples were collected with the help of wooden peg. The samples were air dried and ground using wooden mortar and pestle and passed through 2.0 and 0.5 mm sieves. For further analysis, the sieved soil samples were placed in plastic bags and properly labelled. Various parameters were examined in the soil analysis.

The pH was measured by in 1:2.5 soil water suspension using glass electrode pH meter and EC ($dS^{-1}m$) was measured in the supernatant solution of 1:2.5 soil water suspension using conductivity meter (Jackson, 1973). Calcium carbonate was measured by rapid titration method. Organic carbon by wet oxidation method (Nelson and Sommers, 1982). Available Nitrogen was estimated by alkaline $KMNO_4$ method. Available phosphorus was extracted by Olsens ($NaHCO_3$ extraction) method. Available Potassium was estimated by AAS (Neutral Ammonium extract method). Ca and Mg were estimated by AAS. Sulphur was estimated by spectrophotometer. Using Arc GIS software, the analogue soil fertility maps at a scale of 1:50000 were georeferenced and digitalized.

Results and Discussion

Status of pH, EC, $CaCO_3$ and Organic carbon content in soil

Table 1. pH, EC, $CaCO_3$ and Organic carbon content in soil of study area

Parameters	Category	Limits	% of samples	Total samples	Sample numbers
pH	Acidic	<6.5	--	--	--
	Normal	6.5-8.5	90	54	1-11, 13, 16, 18, 20-51, 53-60
	Basic	8.5-9.0	6.66	4	12, 17,19, 52
	Highly basic	>9.0	3.33	2	14, 15
EC (ds/m)	Normal	< 1.0	83.33	50	1-9, 18, 20-25, 27-60
	Moderately High	1-2	5	3	10, 14, 26
	High	2.01- 3	3.33	2	11, 13
	Very high	>3.0	8.33	5	12, 15-17, 19
CaCO3 (%)	Low	<1	--	--	--
	Normal	1.0-5.0	8.33	5	8, 11, 23, 27, 45
	High	>5.0	91.66	55	1-7, 9, 10, 12-22, 24-26, 28-44, 46-60
Organic carbon (%)	Very low	<0.20	--	--	--
	Low	0.21-0.40	--	--	--
	Moderate	0.41-0.60	33.33	20	2-3, 5, 7, 9-10, 20-21, 23, 29-32, 37, 41-43, 53,55, 59
	Moderately High	0.61-0.80	35	21	1, 4, 6, 8, 12, 19, 22, 24, 28, 33, 36, 39-40, 44, 48-50, 52, 54, 57, 60
	High	0.81-1.0	15	9	11, 13, 17-18, 25-26, 35, 46, 56
	Very high	>1.0	16.66	10	14-16, 27, 34, 38, 45, 47, 51, 58

(**Note:** The results were categorized as per six tier system of ratings, Mahatma Phule Krishi Vidyapeeth, Krishidarshani 2022.)

The soil samples from the Jam River basin were analyzed according to a set protocol, and the information on various criteria was rated on a scale of one to six. The pH status of studied soils is presented in Table 1 and depicted on map (Fig.2).

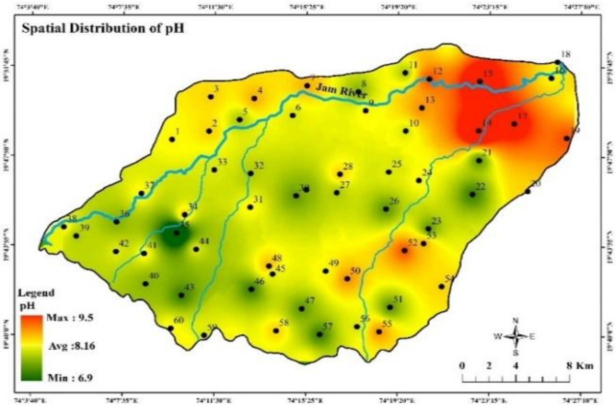

Fig. 2. Spatial distribution of pH

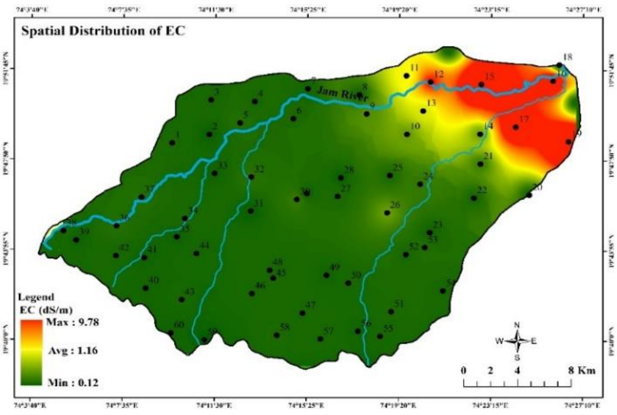

Fig. 3. Spatial distribution of EC

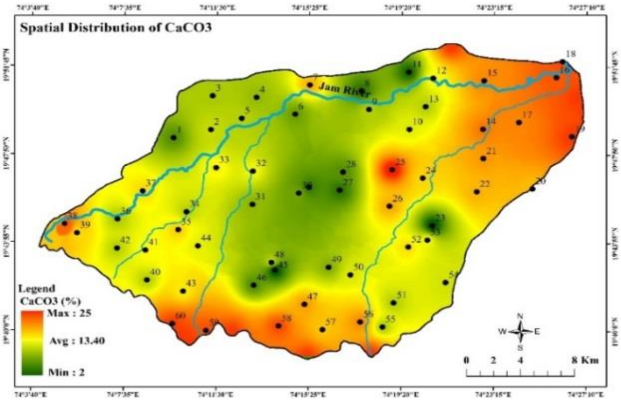

Fig. 4. Spatial distribution of $CaCO_3$

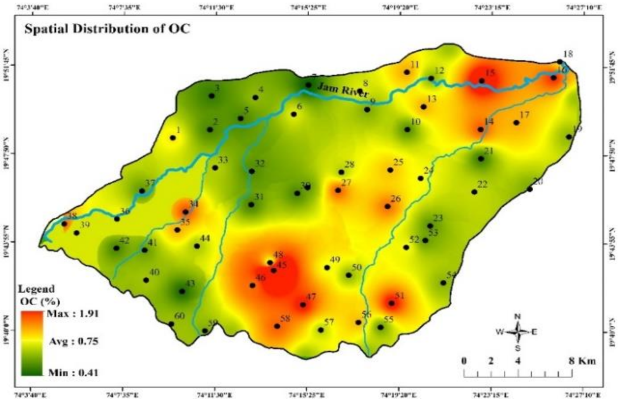

Fig. 5. Spatial distribution of OC

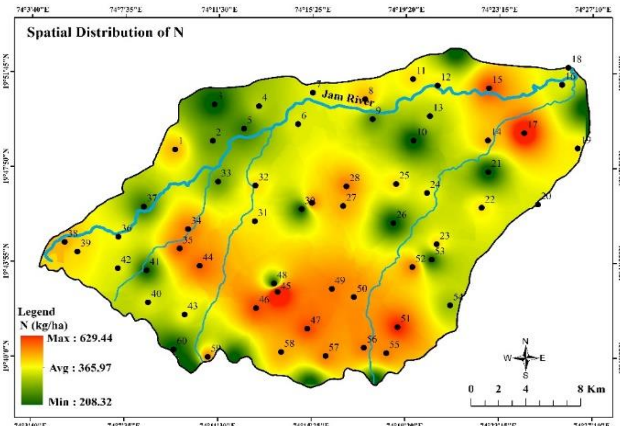

Fig. 6. Spatial distribution of N

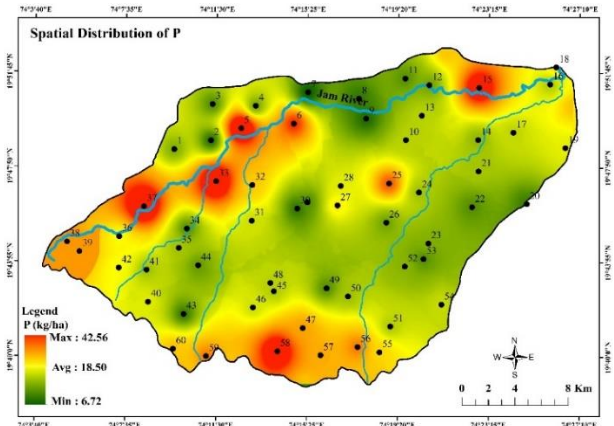

Fig. 7. Spatial distribution of P

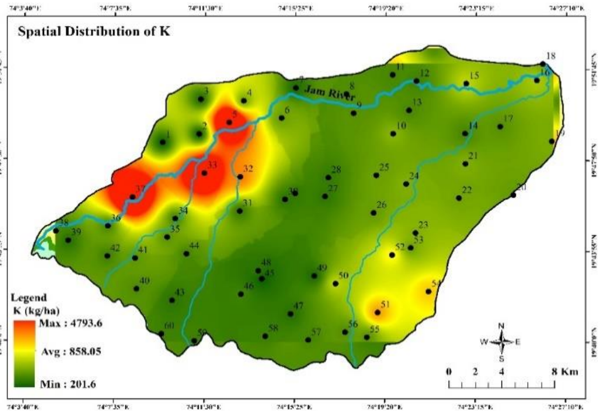

Fig. 8. Spatial distribution of K

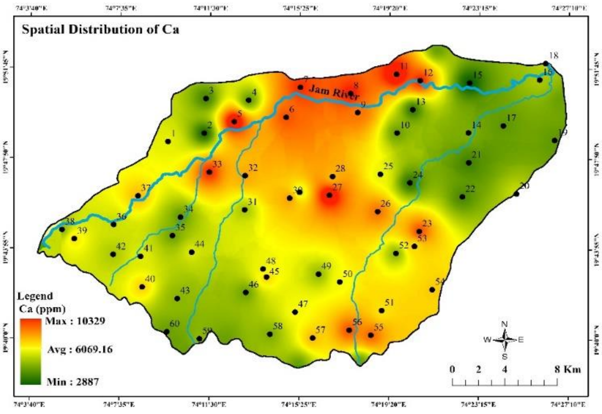

Fig.9. Spatial distribution of Ca

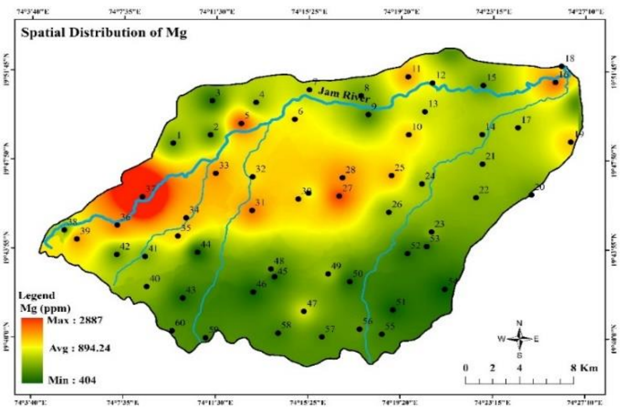

Fig.10. Spatial distribution of Mg

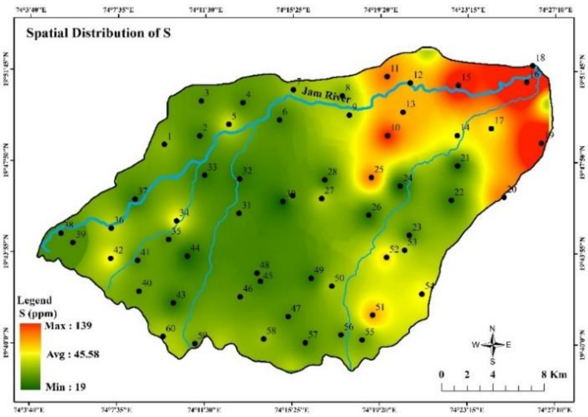

Fig. 11. Spatial distribution of S

It varies from 6.9 to 9.5. The average pH and Standard Deviation value of the soil is 8.16 and 0.37 respectively. 90 % soil samples are normal (6.5- 8.5) in range, 6.66% having pH basic (8.5-9.0) and 3.33 % soil samples are highly basic (>9.0) in nature. The high rainfall and leaching of bases like Ca, Mg, Na, K was the major factor contributed to the increase in acidity in these soils. Similar nature of observation for soil pH was also recorded by Sannappa and Manjunath (2013) in soils of Western Ghats of Karnataka, India.

The EC status of studied soils are presented in Table 1 and depicted on map (Fig.3). It varies from 0.12 to 9.78 ds/m. The average EC and Standard Deviation value of the soil is 1.16 ds/m and 2.14 respectively. 83.33 % values were normal (<1.0 ds/m). The CaCO3 status of studied soils are presented in Table 1 and depicted on map (Fig.4). It varies from 2 to 25 %. The average $CaCO_3$ and Standard Deviation value of the soil is 13.40 % and 5.44 respectively. 8.33 % values were normal in range (1-5%) and 91.66 % samples are high range. The content of $CaCO_3$ increased from escarpment towards the foot of hill, gentle sloping of land basin and flat land topography. This might be due to leaching of soluble calcium from hill slopes towards basin area.

The organic carbon status of studied soils is presented in Table 1 and depicted on map (Fig.5). It varies from 0.41 to 1.91 %. The average organic content and Standard Deviation value of the soil is 0.75 % and 0.25 respectively. The OC content is 33.33% moderate (0.41-0.60%), 35% samples are moderately high (0.61-0.80%), 15% samples are high (0.81-1.0%) and 16.66 % are very high (>1.0 %). The lack of FYM input, crop leftovers, the nature of the coarse-textured soil, and the high temperatures seen during the summer months may all contribute to the low and moderate levels of organic carbon in the soil. These factors favor a high rate of decomposition of organic matter in soil. Due to the growth of field crops, usage of organic manures, and fertilizers in that specific area, the mean value suggests that there may be a moderately high organic carbon content (Telele *et al.,* 1992).

Status of primary nutrient content (NPK) in soil

Table 2. NPK content in soil of study area

Parameters	Category	Limits	% of samples	Total samples	Sample numbers
N (Kg/ha)	Very low	<140	--	--	--
	Low	141-280	21.66	13	2-3, 5, 9-10, 21, 26, 30, 37, 41, 48, 53, 60
	Moderate	281-420	46.66	28	1, 4, 6-8, 11-14, 16, 18-20, 22-25, 27, 31-33, 36, 39-40, 42-43, 54, 58
	Moderately High	421-560	30	18	15, 17, 28-29, 34-35, 38, 44, 46-47, 49-52, 55-57, 59
	High	561-700	1.66	1	45
	Very high	>700	--	--	--
P (Kg/ha)	Very low	<7	3.33	2	7,9
	Low	8-14	33.33	20	1-4, 8, 11-12, 14, 20, 22-23, 26, 29-30, 34, 43-44, 49, 52-53
	Moderate	15-21	38.33	23	10, 13, 16-19, 21, 24, 27-28, 31, 35-36, 40-42, 45-46, 48, 50-51, 54-55
	Moderately High	22-28	15	9	25, 32, 38-39, 47, 56-57, 59-60
	High	29-35	1.66	1	6
	Very high	>35	8.33	5	5, 15, 33, 37, 58
K (Kg/ha)	Very low	<100	--	--	--
	Low	101-150	--	--	--
	Moderate	151-200	--	--	--
	Moderately High	201-250	5	3	1, 2, 45
	High	251-300	1.66	1	49
	Very high	>300	93.33	56	3-44, 46-48, 50-60

(**Note:** The results were categorized as per six tier system of ratings, Mahatma Phule Krishi Vidyapeeth, Krishidarshani 2022)

The available nitrogen, phosphorus and potassium status of studied soils are presented in Table 2 and depicted on map (Fig.6, 7 and 8). The available nitrogen, phosphorus and potassium content in soils of study area ranged from 208.32 to 629.44, 6.72 to 42.56 and 201.6 to 4793.6 Kg. ha^{-1} respectively. The average NPK is 365.97, 18.50 and 858.05 Kg. ha^{-1} respectively and Standard Deviation value for NPK is 90.07, 8.91 and 910.61 respectively. The 21.66 soils were low (141-280 Kg. ha^{-1}), 28 % samples are moderate (281-420 Kg. ha^{-1}), 1.66% samples are moderately high (421-560 Kg. ha^{-1}), 1.66% samples are high (561-700 Kg. ha^{-1}) in available – nitrogen. The 3.33% soils were very low (<7 Kg. ha^{-1}), 33.33 % samples are low (8-14 Kg. ha^{-1}), 38.33% samples are moderate (15-21 Kg. ha^{-1}), 15% are moderately high (22-28 Kg. ha^{-1}), 1.66% samples are high (29-35 Kg. ha^{-1}) and 8.33 % samples are very high (>35 Kg. ha^{-1}) in available phosphorus. The 5% samples are moderately high (201-250 Kg. ha^{-1}), 1.66% samples are high (251- 300 Kg. ha^{-1}) and 93.33 % samples are very high (>300 Kg. ha^{-1}) in available potassium content.

The data presented on the organic carbon content in study soils confirm the observer status of available nitrogen in study soils are in good accord with the current study report, supporting the well-established link between available nitrogen and organic carbon. The similar observation with respect to available nitrogen were recorded by Katariya (2011) in soils of the Water Management Project-Block A., Meena (2009) in Central Research Farm, Central Campus, M.P.K.V, Rahuri. The variance in N concentration could be attributed to prior crop fertilization, organic manure application, and soil management techniques. Due to their alkaline state and high $CaCO_3$ content, soils in the 36.66 percentile may have low levels of accessible phosphorus. Due to the preponderance of K-rich micaceous and feldspar minerals in the parent material, the accessible potassium content of the majority of the research region was somewhat high (Pulkeshi *et al.,* 2012).

Status of secondary nutrient content in soil (Ca, Mg, S)

Table 3. Ca, Mg and S content in soil of study area

Parameters	Category	Limits	% of samples	Total samples	Sample numbers
Ca (ppm)	Low	<500	--	--	--
	Normal	500-1000	--	--	--
	High	1000-1800	--	--	--
	Very high	>1800	100	60	1-60
Mg (ppm)	Low	<250	--	--	--
	Normal	251-500	16.66	10	3, 43-46, 50-54
	High	500-800	41.66	25	1-2, 4, 8-9, 14-15, 20-24, 26, 38, 40-42, 48-49, 55-60
	Very high	>800	41.66	25	5-7, 10-13, 16-19, 25, 27-37, 39, 47
S (ppm)	Low	<10	--	--	--
	Normal	10-50	71.66	43	1-9, 21-24, 26-33, 35-41, 43-50, 53, 55-60
	High	50-70	15	9	12-14, 17, 34, 42, 51-52, 54
	Very high	>70	13.33	8	10-11, 15-16, 18-20, 25

(**Note:** The results were categorized as per six tier system of ratings, Mahatma Phule Krishi Vidyapeeth, Krishidarshani 2022)

Calcium, Magnesium and Sulphur status of studied soils are presented in Table 3 and depicted on map (Fig.9,10 and 11). Calcium content in soil samples in study area varies from 2887 to 10329 ppm. The average Ca and Standard Deviation value of the soil are 6069.16 ppm and 1960.64 respectively. All the samples are very high category in calcium content (>1800 ppm). Magnesium content in soil samples in study area varies from 404 to 2887 ppm. The average Mg and Standard Deviation value of the soil are 894.24 ppm and 409.9 respectively. 16.66% samples are normal (251-500 ppm) in range. 41.66 % samples are high (500-800 ppm) in magnesium content and 41.66 % samples are very high (>800 ppm) in magnesium content. Sulphur content in soil samples in study area varies from 19 to 139 ppm. The average Sulphur and Standard Deviation value of the soil are 45.58 ppm and 25.64 respectively. 71.66% samples are normal (10-50 ppm) in range. 15 % samples are high (50-70 ppm) in Sulphur content and 13.33 % samples are very high (>70 ppm) in Sulphur content. Due to the application of organic manures and fertilizers in that specific area, the mean value suggests that there may be a somewhat high secondary nutrient content.

Conclusion

According to the study's findings, the soils in the Jam River basin are normal to highly basic in nature, normal in salt content, meaning they are not salinized, moderate to high in organic carbon content, and non-calcareous to slightly calcareous in terms of percent calcium carbonate equivalent content. Soils of study area were low to high in available nitrogen and that indicates nitrogen is the major limiting nutrient in the soils and also found majority samples were moderate (38.33%) in available phosphorus whereas moderately high (5%) to very high (93.33%) in available potassium content. The soils were normal (71.66%) to very high (13.33%) in available Sulphur and Calcium content is very high in all the samples. Whereas 16.66 % samples are normal in range for magnesium. This strategy is suggested as a way to assess sustainable soil management. The maps created as a result of the study will be helpful for producing homogenous units and assisting farmers in selecting the quantity and kind of macronutrients to be used in order to maximize economic returns. With the aid of GPS, the geo-referenced sampling sites can be visited again, allowing for the monitoring of changes in the status of nutrients over time, which is otherwise not achievable by conventional techniques of sampling.

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