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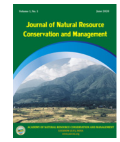

Scientific approach for developing soil information system in mango orchards

Tarun Adak* and Vinod Kumar Singh

ICAR- Central Institute for Subtropical Horticulture, Lucknow-226101, Uttar Pradesh, India
**Corresponding author Email: cishtarunadak@gmail.com, Tarun.Adak@icar.gov.in*

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ABSTRACT

The present study aimed to assess the soil indicators for developing an information system for mango orchards of famous Malihabad, Lucknow, UP, India. Scientific analysis showed maximum nutrient indexing values as 2.00, 2.00, 2.00, 1.00, 2.50, 1.50, 2.00 and 2.00 for soil organic carbon, soil available phosphorus, potassium, nitrogen, zinc, copper, manganese and iron, respectively. The distribution pattern indicated 100 per cent low in Cu and N, and a medium level for Mn and Fe. Soil phosphorus and soil organic carbon had 100 per cent in medium (14 mango orchards) and low (10 mango orchards) distribution, while potassium had only in 8 mango orchards. Histographic distribution of soil physical indicators showed that the maximum frequency level (30 per cent) falls into the porosity of 35 to 40 per cent, whereas the 16 per cent frequency level of water holding capacity in 18 to 19 per cent intervals. Bulk density and particle density were 1.5 to 1.6 with a 30 per cent frequency level and 2.4 to 2.5 g/cc with a 17 per cent frequency level. It was inferred from the information system that soil indicators were low to medium ranks significantly related to lower productivity of <20 t ha^{-1}. The histographic distribution of the soil information system showed a wider pattern and emphasized the urgent scope of improving the soil health condition of mango orchards.

Keywords: Soil indicator, scientific analysis, distribution, information system, mango

INTRODUCTION

Developing a soil information system in mango orchards is a new approach for both scientific outputs and growers' profitability. Acceptance of soil information systems in fruit orchards is wider, and farmers often depend on reliable Information about their orchards. This is directly linked to productivity *vis-à-vis* profitability from each orchard. Adak *et al.* (2021) systematically documented and suggested revisiting the policy issues for soil nutrition *vis-à-vis* mango orchard productivity. Not only that, key global soil map properties need to be developed accurately (Dharumarajan *et al*., 2020) to benefit the farming community. Further, to improve sustainability and nutrient enrichment in guava, Adak *et al.* (2022) scientifically developed precision farming nutrient technology to help the growers' community across agroecology. Sankaran and Dinesh (2020) explained how to conserve the biodiversity of tropical fruits under India's expansive soil and climatic conditions.

Moreover, Ganeshamurthy *et al.* (2021) expressed zinc deficiency in India's fruit orchards vis-à-vis yield attenuation. Soil health information is crucial for the scientific management of fruit orchards. Thus, a scientific portfolio is necessary to assess and develop a robust soil information system. The system may be a precursor for any expert system to be developed for mapping nutrients in orchards over areas. This system certainly helps policy planners think over the practices adopted by farmers and motivates growers to adopt advanced protocols to raise the soil's health condition. Thus, The crucial parameters must be developed, and system productivity should be correlated. Many factors directly influence the productivity and needed to assess them, as orchard management has been going on for a long time. Hence, long-term orchard agronomical practices significantly impact the soil process and, in turn, either short-term or long-term, hampering nutrient acquisition *vis-à-vis* the productive capacity of orchards. The lack of systematic Information in mango orchards of the subtropical Lucknow region has enabled us to assess and develop the soil-based information system of each mango orchard. Such Information would certainly benefit growers of the region and sensitize growers from other areas involved in either commercial or non-commercial mango production to develop their own soil health information.

MATERIAL AND METHODS

The field study was conducted in mango orchards of Malihabad, Lucknow, Uttar Pradesh, India. Mango orchards at the bearing stage were selected from twenty-two orchards of villages, namely orchard 1- Kanar fixed orchard I, orchard 2- Hafizkhera fixed orchard I, orchard 3- Metheynagar fixed orchard I, orchard 4- Allupur fixed orchard II, orchard 5- Hafizkhera fixed orchard II, orchard 6- Naibasti Dhaneva fixed orchard I, orchard 7- Navipanah fixed orchard II, orchard 8- Kakori fixed orchard II, orchard 9- Mehmoodnagar fixed orchard II, orchard 10- Naibasti Dhaneva fixed orchard II, orchard 11- Ulrapur fixed orchard I, orchard 12- Allupur fixed orchard I, orchard 13- Metheynagar fixed orchard II, orchard 14- CISH block orchard II, orchard 15- CISH block orchard III, orchard 16- Kakori fixed orchard I, orchard 17- Malihabad fixed orchard I, orchard 18- Kanar fixed orchard II, orchard 19- Malihabad fixed orchard II, orchard 20- Ulrapur fixed orchard II, orchard 21- Mehmoodnagar fixed orchard I and orchard 22- Navipanah fixed orchard I. Soil samples from root zone basins were collected from each orchard in each village. Samples were air-dried and processed in the laboratory to analyze soil organic carbon, soil available nitrogen, phosphorus, potassium and DTPA extractable zinc, copper, iron and manganese. Undisturbed core soil samples at 0-10 cm, 10-20 cm, and 20-30 cm soil depths were also collected in order to assess the soil's physical indicators. Soil bulk density, water holding capacity, porosity and particle density were estimated. The soil nutrient index was calculated for each nutrient in each orchard. The percentages of soil samples that fall under low, medium and high levels were also tabulated after calculation. An information system based on high, medium or low soil fertility was designated. Histographic distribution of all these soil indicators was incorporated to have an idea of the distribution of these key soil information systems. Analysis of each element was given due focus as it significantly linked to the productive capacity of mango orchards.

RESULTS AND DISCUSSION

Scientific analysis of soil indicators and its pattern of distribution

The scientific analysis of each soil indicator and its pattern of distribution were systematically calculated across twenty-two mango orchards (Tables 1 and 2). It has been observed that soil indicators across these mango orchards lie in the nutrient index values of 1.00 to 2.50. The indexing value of soil organic carbon has been noted as 1.00, 1.25, 1.50, 1.75, 2.00 across eighty-eight soil samples of twenty-two orchards. Soil available nitrogen has 1.00 index values while phosphorus has 1.75 and 2.00. In the case of potassium, 1.25, 1.50, 1.00, 1.75 and 2.00 index values were recorded. Zn has 1.25, 2.25, 2.5, and 1.75 for micronutrients, and Cu has 1.00 values. The nutrient indexing value of Mn and Fe was estimated as 2.00 in each nutrient. The distribution pattern of each soil indicator was calculated to understand key elements in orchards as low to medium or medium to high ranks. Many of these mango orchards (orchard-1, orchard-5, orchard-7, orchard-12, orchard-13, orchard-14) have 100 per cent low soil organic carbon while some of these orchards (orchard-2, orchard-3, orchard-4, orchard-6, orchard-8, orchard-9, orchard-10, orchard-15, orchard-16, orchard-17) had 75 to 50 per cent in low to medium ranks. In the case of nitrogen, except for orchard 11, all others are designated in low distribution (100 per cent). Soil phosphorus had 100 per cent in medium distribution in 14 mango orchards; in contrast, potassium was only in 8. Most orchards showed medium to high (75 to 100 per cent distribution) zinc, whereas copper showed low (100 per cent distribution). Almost all the mango orchard soils had a 100 per cent distribution pattern at the medium level for Mn and Fe.

Soil management system significantly alters the soil indicators' behaviour. The magnitude and degree of such variability range from often wide to narrow scale. Short-term management also impacts the

Table 1. Soil information system consisting of nutrient indexing values in each mango orchards

	Orchard number	SOC (%)	P ppm	K ppm	N ppm	Zn ppm	Cu ppm	Mn ppm	Fe ppm
Kanar Fixed I	1	1.00	2.00	1.75	1.00	2.25	1.00	2.00	2.00
Hafizkhera fixed I	2	1.25	1.75	2.00	1.00	2.50	1.00	2.00	2.00
Metheynagar Fixed I	3	1.25	1.25	1.25	1.00	2.00	1.00	2.00	2.00
Allupur fixed II	4	1.25	2.00	1.25	1.00	2.00	1.00	2.00	2.00
Hafizkhera fixed II	5	1.00	1.75	1.25	1.00	1.25	1.00	2.00	2.00
NBD fixed I	6	1.25	2.00	1.00	1.00	2.00	1.00	2.00	2.00
Navipanah fixed II	7	1.00	1.75	2.00	1.00	2.00	1.00	2.00	2.00
Kakori fixed II	8	1.50	2.00	1.75	1.00	2.00	1.00	2.00	2.00
Mehmoodnagar fixed II	9	1.25	2.00	2.00	1.00	2.25	1.00	2.00	2.00
NBD fixed II	10	1.50	2.00	1.75	1.00	2.00	1.00	2.00	2.00
Ulrapur fixed I	11	1.25	2.00	1.00	1.00	2.00	1.00	2.00	2.00
Allupur fixed I	12	1.00	2.00	1.50	1.00	2.00	1.00	2.00	2.00
Metheynagar Fixed II	13	1.00	2.00	1.00	1.00	1.75	1.00	2.00	2.00
CISH block II	14	1.00	1.75	1.00	1.00	2.50	1.50	2.00	2.00
CISH block III	15	1.50	1.75	2.00	1.00	2.25	1.00	2.00	2.00
Kakori fixed I	16	1.25	2.00	1.75	1.00	2.25	1.00	2.00	2.00
Malihabad fixed I	17	1.50	2.00	2.00	1.00	2.00	1.00	2.00	2.00
Kanar Fixed II	18	1.75	2.00	1.25	1.00	2.25	1.00	2.00	2.00
Malihabad fixed II	19	1.75	2.00	2.00	1.00	2.25	1.00	2.00	2.00
Ulrapur fixed II	20	2.00	1.75	1.75	1.00	2.00	1.00	2.00	2.00
Mehmoodnagar fixed I	21	1.00	2.00	1.75	1.00	2.00	1.00	2.00	2.00
Navipanah fixed I	22	1.75	2.00	2.00	1.00	2.25	1.00	2.00	2.00

physio-chemical behaviour, while long-term practices certainly influence the pattern of nutrient interactions in soil. Thus, the scientific community needs to assess the soil's health condition and develop a database system to show the nutrient deficiency levels across orchards in the same or different areas. In this direction, Adak *et al.* (2018) recorded the changes in soil physical and chemical indicators in Dashehari mango orchards under various nutrient practices. Scientific efforts were needed to estimate the yield sustainability and recommend best practices to farmers. Even for saline-sodic soil, biochar management in orchards may improve the soil's health condition (Cui *et al.,* 2022). The pattern of nutrient distribution and other soil properties per se should be evaluated on time. Adak *et al.* (2019) systematically developed nutrient indexing in indigenously grown mango orchards of ecological importance to indicate the condition of subtropical orchards. Rashmi *et al.* (2020) scientifically opined that micronutrient imbalance must be diagnosed in fruit crops like sapota and lime to ensure optimal fruit productivity. Of course, Ganeshamurthy *et al.* (2020) emphasized the need for immediate intervention to sustain orchard efficiency.

Moreover, Mishra and Riley (2015) reported the environmental impacts on the spatial distribution of soil organic carbon and its stock. As soil organic carbon is an important indicator, its content and stock estimation are essential for policy planners to improve biological health status. The soil organic stock of 1.3 to 3.0 kg/m^2 at 0-5 to 15-30 cm depth was estimated in the Western Ghats (Dharumarajan *et al.,* 2020). All these factors ultimately add to the sustainability indicators and environment-related parameters and significantly improve policy planning (Srinivasa Rao *et al.,* 2019). Zong *et al.* (2022) critically suggested developing a climate-resilient system to ensure food security. Thus, soil and weather-based indicator systems significantly assess the scenario *vis-à-vis* projected practices to be followed.

Information system based on scientific ratings

Key soil indicators were assessed to develop any information system, and based on fertility ratings, they were designated as low to high ranks (Table 3). Thus, The scientific analysis suggested a wide scope for improving soil health. The current mango orchard information indicated that almost all the orchards (18) are low in soil organic carbon, with only four being medium-ranked. For soil phosphorus, except for one orchard, all others were in medium, while nine orchards were in low and 13

Table 2. Soil information system consisting of percentages of soils under low, medium and high condition

	Levels	SOC (%)	P ppm	K ppm	N ppm	Zn ppm	Cu ppm	Mn ppm	Fe ppm
Kanar Fixed I	L	100	0	25	100	0	100	0	0
	M	0	100	75	0	75		100	100
	H	0	0	0	0	25			
Hafizkhera fixed I	L	75	25	0	100	0	100		
	M	25	75	100	0	50	0	100	100
	H	0	0	0	0	50			
Metheynagar Fixed I	L	75	75	75	100	0	100	0	0
	M	25	25	25	0	100	0	100	100
	H	0	0	0	0	0	0	0	0
Allupur fixed II	L	75	0	75	100	0	100		
	M	25	100	25		100	0	100	100
	H	0	0	0			0		
Hafizkhera fixed II	L	100	25	75	100	75	100		
	M		75	25		25		100	100
	H								
NBD fixed I	L	75		100	100		100		
	M	25	100			100		100	100
	H								
Navipanah fixed II	L	100	25		100		100		
	M		75	100		100		100	100
	H								
Kakori fixed II	L	50		25	100		100		
	M	50	100	75		100		100	100
	H								
Mehmoodnagar fixed II	L	75			100	0	100		
	M	25	100	100		75		100	100
	H					25			
NBD fixed II	L	50	0	25	100	0	100		
	M	50	100	75		50		100	100
	H	0				50			
Ulrapur fixed I	L								
	M	75		100	100		100		
	H	25	100			100		100	100
Allupur fixed I	L	100		50	100		100		
	M		100	50		100		100	100
	H								
Metheynagar Fixed II	L	100		100	100	25	100		
	M		100			75		100	100
	H								
CISH block II	L	100	25	100	100	0	50		
	M		75			50	50	100	100
	H					50	0		
CISH block III	L	50	25		100	0	100		
	M	50	75	100		25	0	100	100
	H					75	0		
Kakori fixed I	L	75		25	100	0	100		
	M	25	100	75		25	0	100	100
	H	0	0	0	0	75	0		
Malihabad fixed I	L	50			100		100		
	M	50	100	100		100		100	100
	H								
Kanar Fixed II	L	25		75	100	0	100		
	M	75	100	25		75		100	100
	H					25			

Contd...

	Levels	SOC (%)	P ppm	K ppm	N ppm	Zn ppm	Cu ppm	Mn ppm	Fe ppm
Malihabad fixed II	L	25			100	0	100		
	M	75	100	100		75		100	100
	H					25			
Ulrapur fixed II	L		25	25	100		100		
	M	100	75	75		100		100	100
	H								
Mehmoodnagar fixed I	L	100		25	100		100		
	M		100	75		100		100	100
	H								
Navipanah fixed I	L	25			100	0	100	0	
	M	75	100	100		75		100	100
	H					25			

Table 3. Soil information system consisting of low, medium and high fertility condition

	Orchard number	SOC (%)	P ppm	K ppm	N ppm	Zn ppm	Cu ppm	Mn ppm	Fe ppm
Kanar Fixed I	1	L	M	M	L	M	L	M	M
Hafizkhera fixed I	2	L	M	M	L	H	L	M	M
Metheynagar Fixed I	3	L	L	L	L	M	L	M	M
Allupur fixed II	4	L	M	L	L	M	L	M	M
Hafizkhera fixed II	5	L	M	L	L	L	L	M	M
NBD fixed I	6	L	M	L	L	M	L	M	M
Navipanah fixed II	7	L	M	M	L	M	L	M	M
Kakori fixed II	8	L	M	M	L	M	L	M	M
Mehmoodnagar fixed II	9	L	M	M	L	M	L	M	M
NBD fixed II	10	L	M	M	L	M	L	M	M
Ulrapur fixed I	11	L	M	L	L	M	L	M	M
Allupur fixed I	12	L	M	L	L	M	L	M	M
Metheynagar Fixed II	13	L	M	L	L	L	L	M	M
CISH block II	14	L	M	L	L	H	L	M	M
CISH block III	15	L	M	M	L	M	L	M	M
Kakori fixed I	16	L	M	M	L	M	L	M	M
Malihabad fixed I	17	L	M	M	L	M	L	M	M
Kanar Fixed II	18	M	M	L	L	M	L	M	M
Malihabad fixed II	19	M	M	M	L	M	L	M	M
Ulrapur fixed II	20	M	M	M	L	M	L	M	M
Mehmoodnagar fixed I	21	L	M	M	L	M	L	M	M
Navipanah fixed I	22	M	M	M	L	M	L	M	M

L: Low, M; medium and H: High

orchards in medium for potassium status. Of course, scientific analysis showed lower nitrogen availability in 22 orchards. For micronutrients like Zn, orchard-2 and orchard-14 fell in high, orchard-5 in low, and the rest (19) were in medium rankings. Interestingly, it was inferred from the dataset that all orchards were low in Cu and medium in Mn and Fe content in soil. The productivity distribution pattern showed that orchards vary widely in terms of productivity level, with only 63.6 per cent between 8.01 and 12 t/ha. In comparison, 36.4 per cent of orchard showed below 8 t/ha (Fig. 1). productivity information is

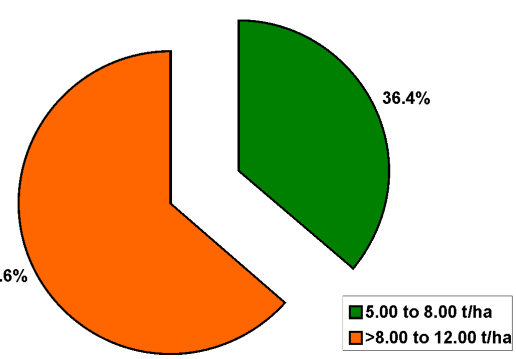

Fig. 1. Productivity distribution pattern in mango orchards

related to the soil character information. Further, histographic distribution of the overall soil information system showed a wider pattern (Fig. 2 and 3). The frequency level (>25%) was in the 0.4 to 0.53 class interval of soil organic carbon, while >50% frequency level was in the 97.6 to 122.5 mg/kg content level of nitrogen. The maximum frequency (30%) for phosphorus was in the 33.1 to 38.2 content level, followed by >20% in the 27.9 to 33.0 mg/kg level. In the case of potassium, almost 30% of the frequency level had a 136.05 to 165.73 class interval, followed by >20% in a 106.38 to 136.05 mg/kg class interval. Micronutrient distribution varies from higher frequency to lower frequency level. Available Zn had the highest frequency (>60%) in 0.34 to 0.92, followed by a 20% frequency level in 0.93 to 1.51 mg/kg. For available Cu, 0.38 to 1.32 mg/kg was in almost 50% frequency level. The histographic distribution level in Mn and Fe was widely distributed. Maximum frequency (>40%) was in 4.16 to 6.53, followed by 25% in 6.54 to 8.91 and lowest was in % (11.3 to 13.67 contents levels). Similarly, for Fe, the highest and lowest frequency was in 60 and 5% in the ranges of 2.16 to 4.15 and 8.16 to 10.15 mg/kg, respectively. The soil physical indicators like bulk density had a lower range of 1.28 to 1.32 to a higher range of 1.66 to 1.71g/cc across soil depths in twenty-two mango orchards, while particle density showed 2.19 to 2.25 and 2.61 to 2.65 g/cc. Minimum and maximum water holding capacity of 17.22 to 17.30 and 23.14 to 24.02 per cent, whereas porosity of 29.22 to 30.18 and 46.69 to 49.81 per cent across mango orchards was estimated. The histographic distribution showed a wider distribution pattern across frequency levels with well-distributed class intervals (Fig. 4). Such distribution suggested improving the physical indicators, particularly water holding capacity and porosity in soil through soil management systems. Land use systems influence the soil's physical

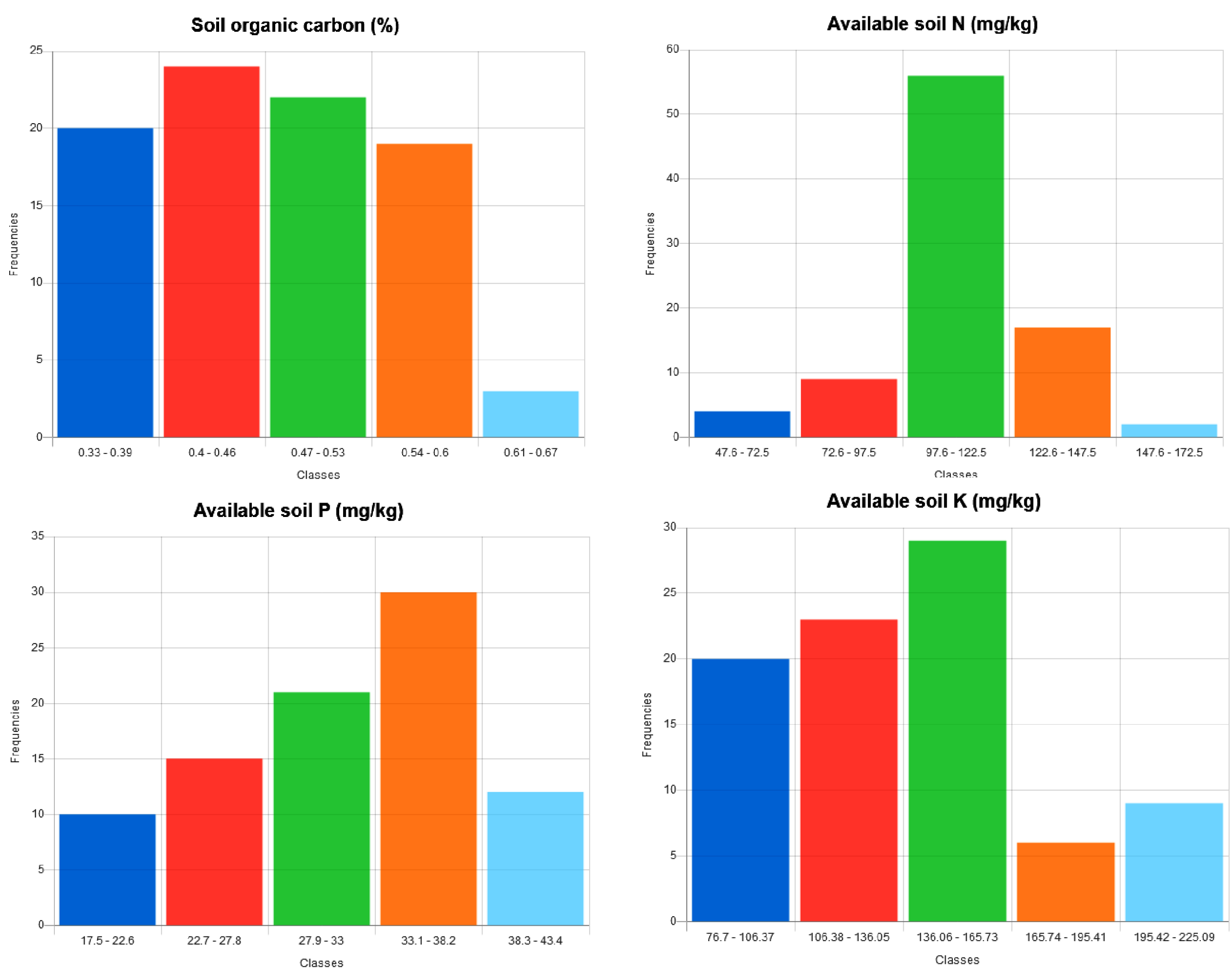

Fig. 2. Histographic distribution pattern of key soil information systems

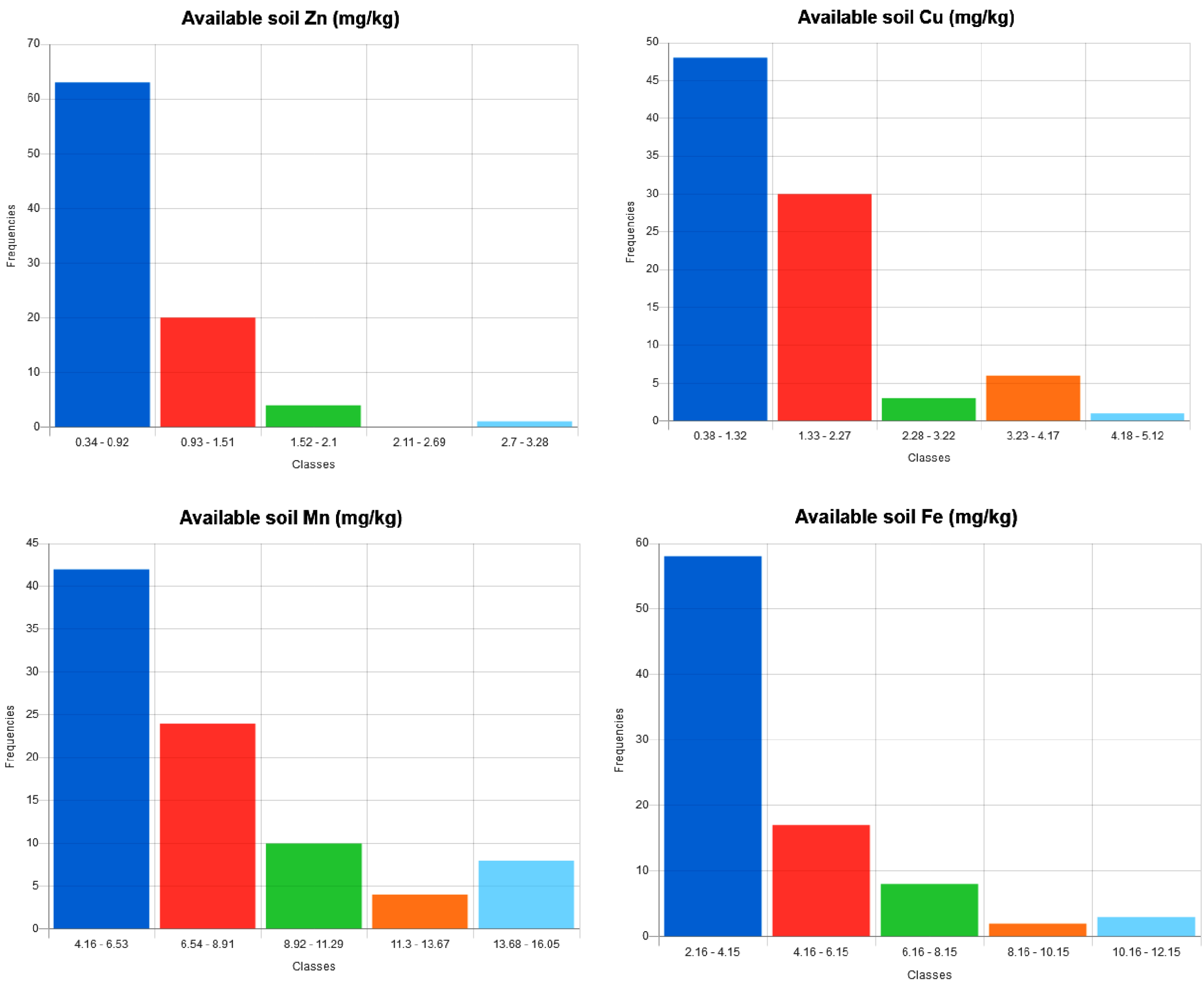

Fig. 3. Histographic distribution pattern of key soil information systems

indicators via management procedures. Soil organic carbon contents in soils significantly impact the soil systems, so an assessment of organic and inorganic components needs to be developed (Sreenivas *et al.*, 2016). Fernández *et al.* (2021) reported total organic carbon between 7.9 to 69.2 g/kg and 6.6 to 14.1 g/kg in natural vegetation vs agricultural practices in Mollisol, while total porosity was recorded as 56.0 to 68.2 vs 33 to 45.8 per cent in the two systems respectively. Of course, bulk density of 0.85 to 1.1 and 1.22 to 1.37 g/cc was noted across systems and structural instability index was estimated at 0.39 to 0.61 vs 1.28 to 1.68 indicating the fact that land use practices do impact the soil physico-hydrological behaviour tremendously. The main aim of any field is to improve its performance in terms of efficiency through which productivity and profitability in different agroclimatic zone can be improved via scientific approaches of soil and water conservation (Eder *et al.,* 2021). Thus, soil management protocol plays a crucial role in contributing to sustainability. Babu *et al.* (2021) suggested managemental strategies to food security after critical scientific analysis of climatic indices. Even soil performance, fruit yield *vis-à-vis* biochemical constituents can be assessed in fruit like mango cv. Mallika through scientific management procedures (Shukla *et al.,* 2020). The yield performance was given main focus in order to harness the natural resources cum greater net returns by farmers (Adak *et al.*, 2022b). All these resource conservation and management practices should be viable enough for growers to adopt and practice at their own land/orchard, and digital technologies may help enhance these practices at their doorstep.

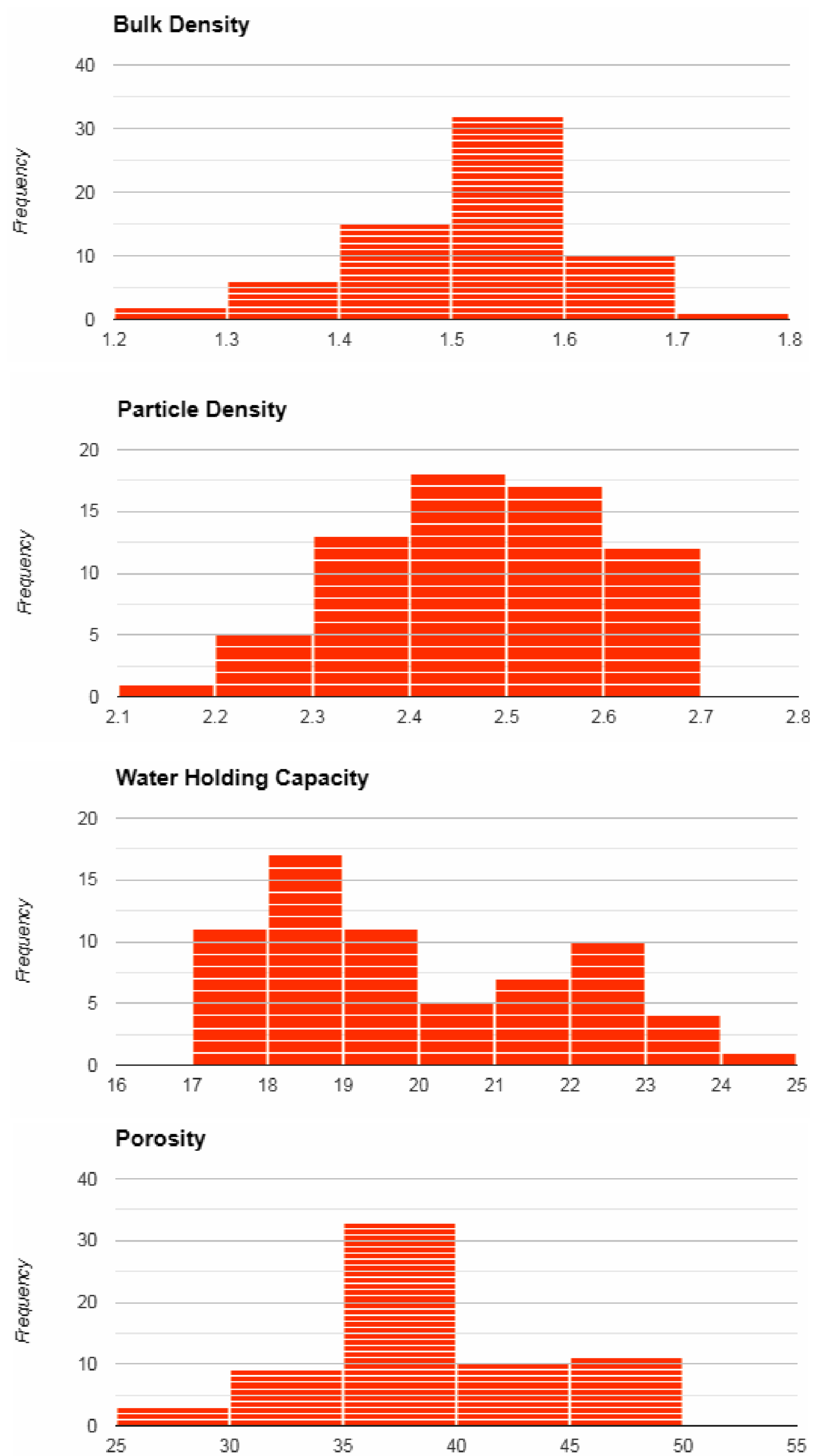

Fig. 4. Histographic distribution pattern of key soil information systems

In this context, Verma and Adak (2021) sincerely try to enhance fruit growers' economic prosperity by using digital tools. The web-based agro advisory system, expert system for identifying and giving solutions to problems, mobile apps, IoT-based water management, etc., have widely been accepted and benefitted the growers. The objective was to improve the orchard performance, for which scientific approaches in developing an information system based on soil and tree indicators were developed.

CONCLUSION

The present study was conducted to assess the soil health condition of mango orchards. Soil indicators were widely evaluated, nutrient indexing was estimated, the percentage of soil samples was designated in three categories, and an information system was developed based on soil parameter values. Histographic distribution was ascertained to understand the distribution pattern of key soil information system and suggested to improve the distribution from lower to higher frequency levels with greater contents. It was inferred from the analysis that there is a serious challenge to enhance the soil condition in terms of its indicators. Lower productivity was the outcome as a function of all these soil parameters.

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