<u>Original Research Article</u>

Mapping of Soil Fertility Status in a Coastal Village of Odisha Using Geospatial Technology

ABSTRACT

The most fundamental decision-making tool for sustainable soil nutrient management is the assessment of soil fertility in a region. During 2021, a soil fertility status inventory was preparedthrough National Innovations on Climate Resilient Agriculture (NICRA) model village at Achyutadaspur in the Jagatsinghpur district of Odisha.A total of 125 surface soil samples were randomly collected from a depth of 0-15 cm with GPS locations and evaluated for soil pH, electrical conductivity, organic carbon, available N, P, K, S, Zn, and B using standard analytical procedures.GIS maps have been prepared using ArcGIS software based on the analysis report. The majority of the soil was found acidic around 62.4% area of the village, followed by neutral soil pH in 33.6% area.The organic carbon status of the soil was found low (79.2%) to medium (20.8%), available N was found low in 88% area and medium in 12% area, available P was found medium in 82.4% area and high in 17.6% area, available K was low in 27.2% area, medium in 64% area, and high in 8.8% area, and available S was low in 37.6% area and medium in 62.4% area, respectively.Among the available micronutrients, Zn was found low in 79.2% of the areaand medium in 20.8% of the area. Similarly, hot water extractable boron was found low in 85.6% of the region and medium in 14.4% of the area. By adopting soil map based fertilizer recommendation with improved practices in the Achyutadaspur village, 17.92% yield was increased over farmers practices. The benefit cost ratio (B:C ratio) of rice was found to be 1.89 whereas 1.65 in farmers practices.

Keywords: *Fertility status;fertility maps; rice; yield; coastal area*

1. INTRODUCTION

Soil is critical factor for agriculture and it is the cradle for all crops and plants. This is the reservoir of nutrients that play a crucial role for establishment and production [1].In India, the soil resources accessible for agriculture are decreasinghence, optimized the exploitation of these resources is highly required for agricultural intensification. As a result, it is necessary to assess the fertility status of the soil on a regular basis in order to maintain the soil health[2].Nutrient mining is an important threat in Indian agriculture since there is a large gap between nutrient addition and nutrient removal. The agricultural sector in India has loss of soil nutrients at a rate of 10 million tonnes per year[3]. The one of the major reasons for reduced production is indiscriminate application of fertilizers without knowledge of soil fertility status and crop nutrient requirements, which has a negative impact on soil and crop in terms of nutrient toxicity and inadequacy[4].Assessing the soil fertility status of a region is difficult to access and labour intensive due to presence of high spatial variability and heterogeneity [5].Jagatsinghpur is coastal district of Odisha situated in the East and South Eastern Coastal Plain Agro Climatic Zone.Primary, secondary, and micronutrient deficiencies have been identified intensively in coastal areas. Farmers have been impelled to apply high amounts of chemical fertilizers due to rising food grain demand. Chemical fertilizer overuse is a severe danger to the sustainability of agricultural production. Soil test-based fertilizer selection and management is an excellent method for enhancing agricultural soil productivity. Achyutadaspur village is one of the coastal villages of Jagatsinghpur having venerability of water logging, soil salinity and flood. So soil health management in such area is highly essential for sustainable crop production. Therefore, this village is selected as adopted village under National Innovations on Climate Resilient Agriculture (NICRA) project of KVK Jagatsinghpur. Keeping this in view, GIS based soil nutrient mapping ofAchyutadaspur village has been carried out and necessary advisory has been given to the farmers at each cadastral level.

2. MATERIAL AND METHODS

The study was conducted in NICRA adopted village (Achyutadaspur) of Jagatsinghpur district of Odisha. The district is situated in East and South East Coastal Plain Agro Climatic Zone of Odisha between 19°58' to 20°23' North Latitude and 86°03' to 86°45' East Longitudeand total geographical area of district is 1668 Square km and geographical area of the village is 204 ha, as shown in Fig.1.

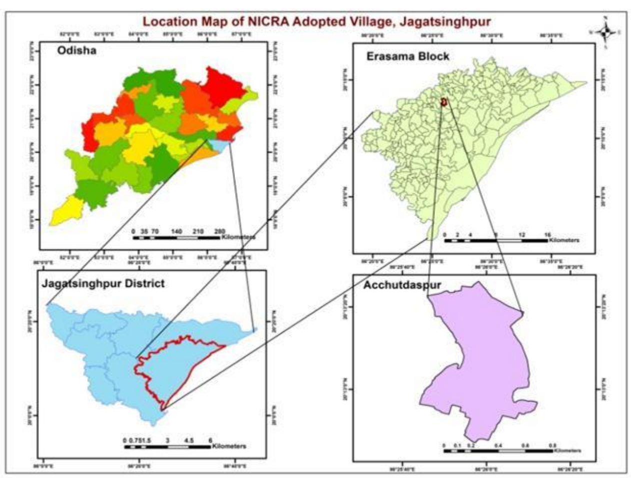

Fig.1Location map of study area

Total 125numbers of representative soil samples have been collected from the farmers field with the help of a soil auger for testing in KVK Jagatsinghpur soil testing laboratory. Surface soil samples within 0-15 cm depth were collected with geo-coordinates of the sapling location. The soil samples were mixed thoroughly and about 500 g of composite soil samples were taken for analysis. First the samples were air-dried, passed through 2 mm and 0.5 mm sieve and stored in properly labeled plastic bags for physical and chemical analysis. The prepared samples were analyzed for using standard analytical methods. Soil pH, EC and organic carbon were estimated by Jackson method [6] [7]. Available nitrogen was determined following Subbiah and Asija method [8]. Available phosphorus and potassium were determined by Bray and Kurtz [9]; Olsen et al. [10]. Available sulphur was determined by the procedure described by Massoumi and Cornfield [11]. Available Zn and B were determined by [12] and [13], respectively. The method involved in analyses of soil samples is depicted in List-1.

List-1 Analytical methodologies for Soil analyses

Parameter	**Methodology**	**References**
pH	1:2.5:: Soil : Water	Jackson (1967) [6]
EC	1:2.5:: Soil : Water	Jackson (1967) [6]
Organic carbon	Wet oxidation method	Jackson (1973) [7]
Available N	Hot alkaline $KMnO_4$ Method	Subbiah and Asija (1956) [8]
Available P	0.03 N NH_4F + 0.025 N HCL (pH 3.5) and 0.5 M $NaHCO_3$ at pH 8.5	Bray and Kurtz (1945) [9] and Olsen et al. (1954) [10]
Available K	Neutral N NH_4OAc extraction	Jackson (1973) [7]
Available S	Extraction with 0.15% CaCl2	Massoumi and Cornfield, 1963 [11]
Available Zn	DTPA extractant	Lindsay and Norvel, 1978 [12]
Available B	Hot water extraction	Berger and Truog (1939) [13]

Based on soil test results, a front linedemonstration (FLD) was conducted in rice cropduring *kharif*-2022 in the selected village (Achyutadaspur) of Jagatsinghpur district. Farmers followed the existing practice of transplanting the rice variety Swarna in local check plot. The complete package of practices approach demonstrated in farmers field through FLD including improved variety, recommended seed rate, seed treatment, sowing method, fertilizer dose, weed management and plant protection which are presented in Table 10.

3. RESULTS AND DISCUSSION

3.1 Soil Reaction (pH)

The soil reaction of the soil samples were identified as acidic to neutral in conditionwith the value ranged from 5.50 to 6.50with 6.08as a mean value. The current findings showed that 62.4% area of the village is acidic reaction whereas37.6% area is neutral reaction(Table 1 and Fig.2).The results are being in conformity with the observations made by Majhi *et al.*[14].

Table 1 pH status of the soil samples

Class	**Rating**	**% of area**
Acidic	<6.50	62.4

Neutral	6.50-7.50	37.6
Alkaline	>7.50	0

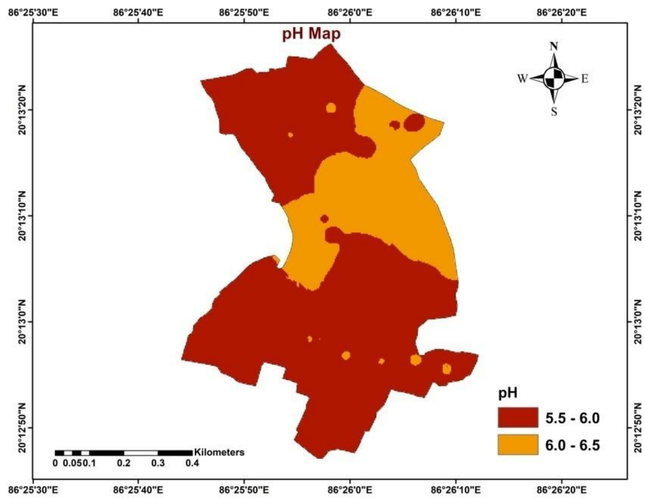

Fig.2: Soil pH GIS Map

3.2 Electrical Conductivity

The electrical conductivity of the soil samplestested ranged from 0.86 to 2.68 dSm^{-1},with a mean value1.49 dSm^{-1} (Table 2). The present findings observed that 33.6% of area of the village has normalsalinity (suitable for all crop types) whereas66.4% area of the village has critical EC(Fig. 3). Similar findings were also recorded by Majhi *et. al.*[14] and Mishra *et al.*, 2015[15].The low EC might be due to free drainage conditions which favored the removal and release of bases by percolating and drainage water and also application of saline groundwater in agricultural fields [16].

Table 2 Status of electrical conductivity in soil of the study area

Class	**Rating (dSm^{-1})**	**% of Area**
Low	<1.00	33.6
Medium	1.00-2.00	40.8
High	>2.00	25.6

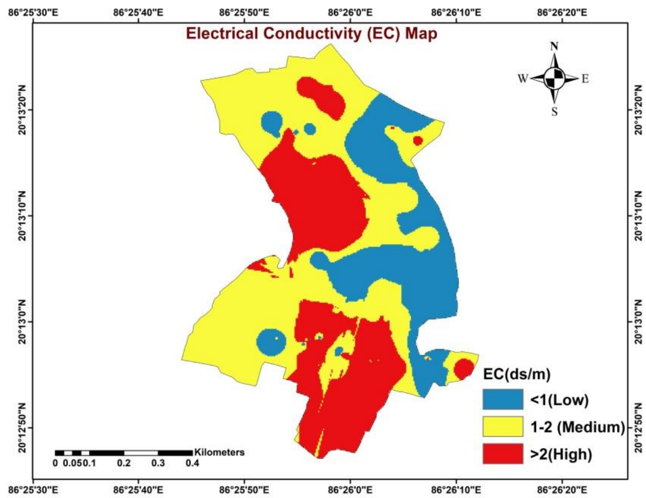

Fig. 3: Soil Electrical Conductivity (dSm^{-1}) GIS Map

3.3 Organic carbon

The organic carbon content of the soil samples ranged from 0.25 to 0.75%with a mean value of 0.47%. Based on the limits prescribed by (Nanda *et al.,* 2008) [17], the present it is observed that 79.2% are of the village is in lowin organic carbon content whereas 20.8% area is within the medium carbon range (Table 3 and Fig. 4). It may be due to low application of FYM and crop residue as well as rapid rate of decomposition [18].

Table 3 Status of organic carbon in soil of the study area

Class	Rating (%)	% of Area
Low	<0.50	79.2
Medium	0.50-0.75	20.8
High	>0.75	0

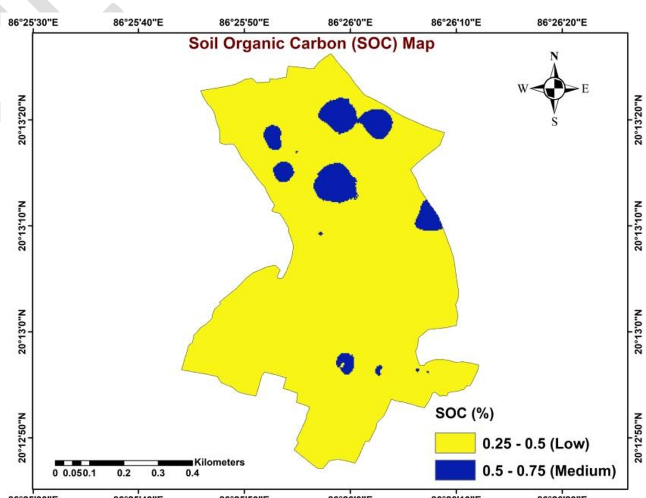

Fig. 4: Soil Organic Carbon (%) GIS Map

3.4 Available Nitrogen

The soil sample analysis revealed that the available nitrogen content ranged from 168 to 274 kg ha^{-1}, with a mean value of 229.48 kg ha^{-1}(Table4and Fig. 5). On the basis of prescribed limits byNanda *et al.,*[17], theresultshowedthat 92% soil of area has low in nitrogen content and 8% soil has medium available nitrogen status. It may be due to the nitrogen lost through various mechanism like ammonia volatilization, nitrification, chemical and microbial fixation, leaching, runoff and may be due to very low content of organic carbon [19].

Table 4 Status of available nitrogen in soil of the study area

Class	Rating (kg ha^{-1})	% of Area
Low	<250	92
Medium	250-500	8
High	>500	0

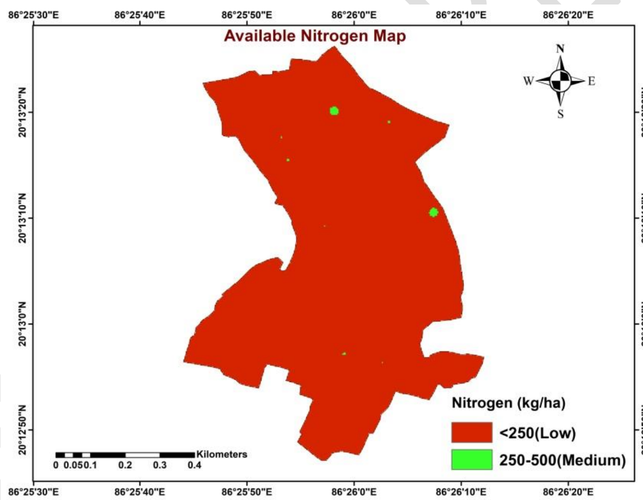

Fig. 5: Soil available N (kg ha^{-1}) GIS Map

3.6 Available Phosphorus

The available phosphorus contentof the area ranged from 9 to 35 kg ha^{-1},with a mean value of 17.57 kg ha^{-1} (Table 5and Fig.6). Based on the limits prescribed byNanda *et al.,*[17], the present results revealed that 82.4%area of the village has medium range of available phosphorus whereas 17.6% has high range of available phosphorus. It might be due to slightly acidic pH of soil which is making available phosphorus immobile [20].

Table 5 Status of available phosphorus in soil of the study area

Class	Rating (kg ha^{-1})	% of Area

Low	<9.0	0
Medium	9.0-22.0	82.4
High	>22.0	17.6

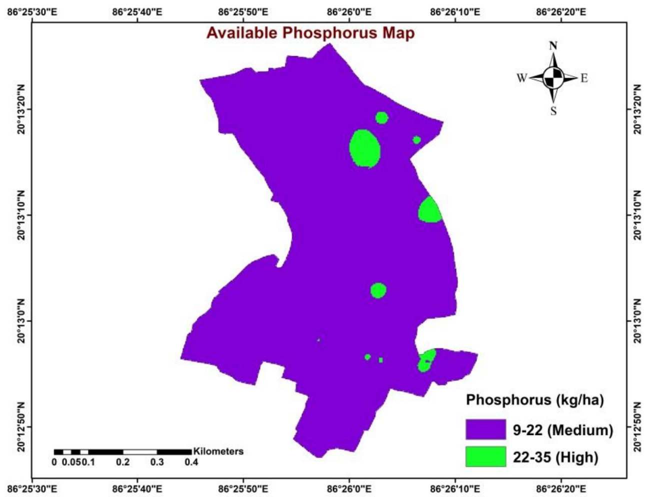

Fig. 6: Soil available P (kg ha^{-1}) GIS Map

3.7 Available Potassium

The available soil potassium content varied from between 118 to 280 kg ha^{-1},with a mean valueof 201.36 kg ha^{-1}. Based on the limits prescribed by Nanda *et al*. [17], the present results showed that 27.2% village has low range of potassium whereas 64%and 8.8% of the soil of the area has medium and high range of available phosphorus, respectively (Table 6and Fig. 7).

Table 6 Statusof available potassium in soil of the study area

Class	Rating (kg ha^{-1})	% of Area
Low	<118	27.2
Medium	118-280	64
High	>280	8.8

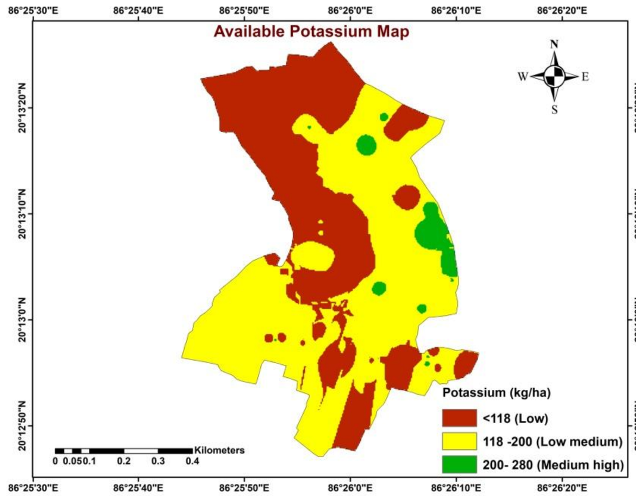

Fig. 7: Soil available K (kg ha^{-1}) GIS Map

3.8 Available Sulphur

The available sulphur status of the soil samples ranged between 5.18 to 20.00 mg kg^{-1}, with a mean value 10.08 mg kg^{-1}(Table7 and Fig. 8). Results revealed that 62.4% area of the village has medium range of available sulphurand 37.6% area of the village haslow range of available sulphur content. Deficiency of soil S might be due to the presence of variable properties of different components of organic matter, improper fertilizer and water management practices [21].

Table 7 Status of available sulphurin soil of the study area

Class	Rating (mg kg^{-1})	% of Area
Low	<10	37.6
Medium	10-20	62.4
High	>20	0

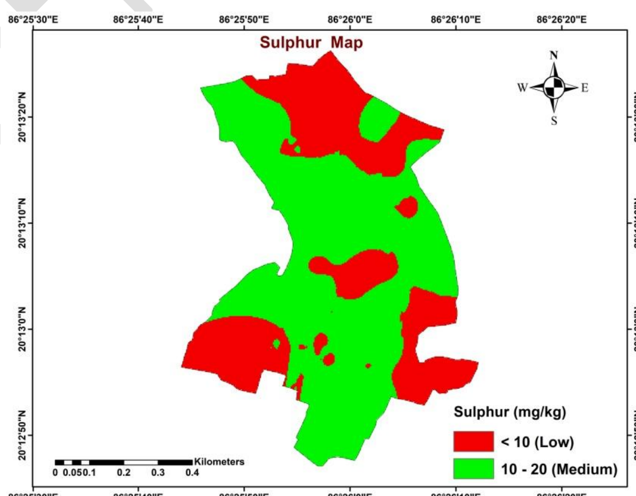

Fig. 8: Soil available S (mg kg^{-1}) GIS Map

3.9 Available Zinc

The available zinc content of the soil samples varied from 0.3 to 1.2 mg kg^{-1}, with a mean value 0.46 mg kg^{-1}.Results revealed that 79.2% area of the villagehaslowrange of available Zn whereas 20.8% area has mediumrange of available Zn(Table8 and Fig. 9). This revealed that majority of soil in the village is deficient in Zn.

Table 8: Status of available zinc in soil of the study area

Class	**Rating (mg kg^{-1})**	**% of Area**
Low	<0.60	79.2
Medium	0.60-1.20	20.8
High	>1.20	0

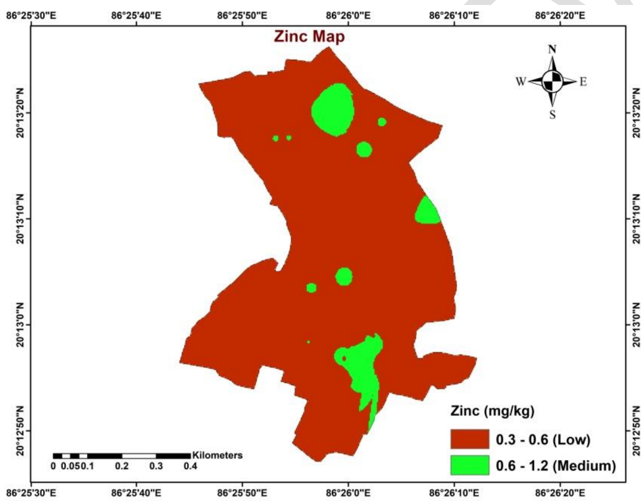

Fig. 9: Soil available Zn (mg kg^{-1}) GIS Map

3.10 Available Boron

The hot water extractable B content of the soil samples varied from 0.23 to 0.74 mg kg^{-1}, with a mean value of 0.40 mg kg^{-1} (Table9 and Fig. 10). The present results showed that 85.6% area of the village haslowrange ofavailable B content whereas 14.4% areaof the village has mediumrange of hot water extractable B content.

Table 9 Status available boron in soil of the study area

Class	**Rating (mg kg^{-1})**	**% of Area**
Low	<0.50	85.6
Medium	0.50-0.75	14.4
High	>0.75	0

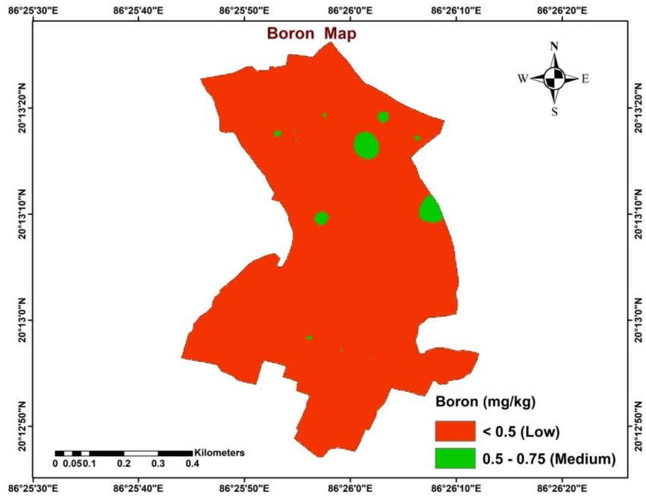

Fig. 10: Soil available B (mg kg^{-1}) GIS Map

3.11 Yield performance and economic analysis of demonstrationand farmers' practices during *Kharif* season of 2022

The yield data indicated that due to frontline demonstration, rice yield was found48.78 q ha^{-1}in demonstration plot and 41.34 q ha^{-1} in farmers practice plot during *Kharif* 2022(Table 11). The demonstration resultsalso revealed that 17.92% yield was increased over farmers practice in rice(Table 11).This result clearly indicated the higher yield in demonstration plots over farmers practice was due to adoption of improved practices following soil test results of the farmer's field. Similar findings in rice and others crops have been reported by Mishra et al. [22], Pandey et al. [23] and Phonglosa et al. [24].

Rice cultivation underimproved practices gave higher net return of Indian Rupee (INR) 46850 ha^{-1} as compared to farmers practices with INR 33434 ha^{-1} during *kharif* season of 2022. The benefit cost ratio (B:C ratio) of rice under improved practices was found to be 1.89 as compared to 1.65 under farmers practices (Table 12).Based on the cost of production and the current input and output prices, the improved technology's economic feasibility over farmers' existingpractices was determined and stated in terms of the B:C ratio.The cost increases in the demonstration were mostly attributable to the higher costs of purchasing pesticides, balanced fertilizer, and seeds.These results are also in conformity with the findings of Phonglosa et al. [24] and Girish et al. [23].

3.12 Recommendation

The soil spatial mapping of the village in GIS revealed that the majority of the soil in the village is acidic, so farmers are recommended to do various improved management practices like green manuaring, lime and other soil amendments application to neutralize the soil pH. Around 25.6% area in the village is now affected by soil salinity, hence ponding of fresh rain water in bonded lands are recommended to leaching the salt from root zone. In addition saline tolerant local rice varieties i.e., Luna Suvarna, Luna Barihal, Lunisri, Luna Ambiki are recommended in high saline fields. Organic carbon is low in most of the area which is associated with low available nitrogen. Hence, farmers are recommended to apply FYM and vermi-compost along with 25% higher dose of nitrogen above the recommended dose. In majority of area available phosphorus and potassium is medium, hence recommended fertilizer dose should be adopted in those patches. The secondary nutrient sulphur is medium in majority of the area and low in around 38% area. In low sulphur area farmers are advised to apply organic manure along with sulphur based fertilizers and amendments. Among the micro-nutrients, the majority of the land is deficient with zinc and boron. Khaira disease in rice due to zinc deficiency is observed in the village and fruit cracking is observed in areca nut, coconut, water melon etc due to boron deficiency. Therefore, farmers are advised to apply zinc and boron based fertilizer in soil or as foliar spray as per soil test based recommendations.

4. CONCLUSION

The collected soil samples on grid basis were tested in KVK soil lab. Soil pH, EC, OC, N, P, K, some secondary nutrient like S and micro nutrients like Zn and B were quantified using various standard methodologies in the soil lab. Then the gridded data were converted into thematic layers and interpolated using Kriging Technique in ArcGIS software to develop soil nutrient map of the district. Further, the nutrients maps were classified into high, medium and low zones to identify the nutrient deficient and sufficient zones. In this context, soil was found acidic around 62.4% area of the village, followed by neutral soil pH in 33.6% area. The organic carbon status of soil was found low (79.2%) to medium (20.8%), available N was found low in 88% area and medium in 12% area, available P was found medium in 82.4% area and high in 17.6% area, available K was low in 27.2% area, medium in 64% area and high in 8.8% area and available S was low in 37.6% area and medium in 62.4% area, respectively. Among the micronutrients, available Zn was found low in 79.2% area and medium in 20.8% area. Likewise hot water extractable boron was found low in 85.6% area and medium in 14.4% area. Using the GIS map cadastral level soil nutrient status was estimated easily using GIS using the gridded soil data which will be much helpful for farmers for getting proper fertilizer recommendation. Thus, the GIS based thematic maps are now able to downscale the regional soil health management practices to each cadastral level which is now specific to a particular farmer not to a group of farmers in a patch. It was also found that production of major crop (i.e. rice) in the Achyutadaspur village has been enhanced by adopting soil map based fertilizer recommendation along with improved practices in the farmers filed.

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Table 10. Improved practices and farmers practices of rice under Frontline Demonstrations

Sl. No.	Particulars	Improved practices for demonstration	Existing Farmer practices
1	Variety	Swarna *sub-1*	Pooja, Swarna
2	Field preparation	Ploughing, Harrowing and puddling	Ploughing, Harrowing and puddling
3	Seed rate	50 kg ha^{-1}	70 kg ha^{-1}
4	Seed treatment	Tricyclazole 75WP @ 2g kg^{-1} of seed	No seed treatment
5	Nursery management and transplanting	Nursery seeding is done during May to June and transplanting is done during July	Nursery seeding is done during May to June and transplanting is done during July
6	Sowing method	Line transplanting	Random transplanting
7	Fertilizer dose	Soil test based NPK @ 100:40:40 kg ha^{-1} + Zn@ 5 kg ha^{-1} + B @ 1 kg kg ha^{-1} + well decomposed FYM @ 5 tha^{-1}	Imbalance use of fertilizer
8	Weed management	Bispyribac Sodium 10% + Clomazone 48%@ 0.25 litre ha^{-1}	Butachlor @ 2.0 litre ha^{-1}
9	Plant protection	Need based plant protection measures	Injudicious use of plant protection chemicals

Table11. Yield performance of demonstrationand farmers' practices during *Kharif* season of 2022

Name of crop and variety	Improved yield (q ha^{-1})	Farmers practice (q ha^{-1})	Yield increase over FP (%)
Rice, Swarna Sub-1	48.75	41.34	17.92

Table12. Economic analysis of demonstrationand farmers' practices during *Kharif* season of 2022

Improved practice				Farmers Practice			
Cost of cultivation (INR ha^{-1})	Gross Return (INR ha^{-1})	Net Income (INR ha^{-1})	B:C ratio	Cost of cultivation (INR ha^{-1})	Gross Return (INR ha^{-1})	Net Income (INR ha^{-1})	B:C ratio
52600	99450	46850	1.89	50900	84334	33434	1.65

Note: INR=Indian Rupee; B:C=Benefit cost ratio