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Kiran Kumar Mohapatra
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Chandini Pradhan
Department of Soil Science and Agricultural Chemistry Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

Subhashis Saren
Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
Kiran Kumar Mohapatra
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Soil fertility status of some villages in Sader block of Balasore district under North Eastern coastal plain agro climatic zone of Odisha, India

Kiran Kumar Mohapatra, Chandini Pradhan and Subhashis Saren

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Abstract
A soil fertility status inventory work was carried out in some villages of Sader Block belonging to Balasore district located in the North Eastern coastal plain Agro Climatic Zone of Odisha, India. Results showed that Soil pH ranged between 5 and 8.1. Soil Organic Carbon (SOC) content ranged between 0.43 to 13.1 g kg^{-1}. Available nitrogen content varied in between 57.5 to 285 kg ha^{-1}. Available phosphorus content varied from 0.7 to 31.5 kg ha^{-1}. Available potassium content varied widely from 40 to 558 kg ha^{-1}. DTPA extractable micronutrient (Fe, Mn, Zn and Cu) varied from 36.8 to 150, 10.8 to 38.9, 0.2 to 0.8 and 1.3 to 2.05 mg kg^{-1} respectively. Hot water soluble boron content ranged from 0.08 to 1.94 mg kg^{-1}. Most of lower range were found in upland soils while the higher values for all the parameters were found in low land soils.

Keywords: Fertility status, agro climatic zone, available nitrogen, micronutrient

Introduction
Sader blocks belong to Balasore district which comes under North Eastern Coastal Plain Agro Climatic Zone of Odisha (Nanda *et al*., 2008) [17]. According to USDA soil taxonomic (7th approximation) the soils of Balasore district are classified under the *Inceptisols* and *Entisols* (Sahu and Mishra, 2005) [21]. Proper nutrient management helps in maximizing marketable yields whereas excessive us2e of chemical fertilizer may be harmful to the environment. Hence, evaluation of soil fertility status of different land types of an area is of primary importance for a balanced application of fertilizers and manures as well as to increase the productivity per unit of cultivable land. In the present scenario, soil testing is now considered as an important tool for the recommendation of fertilizer doses for various crops. Again, GPS (Global Positioning System) based soil fertility evaluation not only gives ideas about fertility status of the soil but also helps in monitoring the soil health from time to time.

Focusing on these concepts, six villages of sader blocks of Balasore district namely Kasipada, Agoragohir, Mirigimundi, Pinchhabania, Nuagao and Kadamoud were selected for studying the GPS based soil fertility status in order to identify the major soil fertility related crop production constraints. Although soil fertility status and maps have been prepared for different blocks of Odisha, but no such intensive work had been done for these villages of the district which have vast areas of agricultural lands. Therefore, an attempt was made in the present investigation to prepare soil fertility status of six selected villages of the district. Soils were analyzed for some of the basic soil physical and chemical properties which includes mechanical analysis (soil texture), soil color, bulk density, soil pH, EC and SOC. Soil fertility status is evaluated focusing on the most important nutrients for the plant such as nitrogen, phosphorus, potassium, sulphur and micronutrients. This study will help in finding out soil fertility related crop production constraints along with suggesting remedial measures for higher crop production.

Materials and Methods
Experimental site
Six villages were selected for studying the GPS based soil fertility status namely Kasipada (Lat. 21.614104° N, Long. 87.024155° E), Agoragohir (Lat. 21.611° N, Long. 87.020° E),

Mirigimundi (Lat. 21.620° N, Long. 87.0242° E), Pinchhabania (Lat. 21.614104° N, Long. 86.995° E), Nuagao (Lat. 21.638° N, Long. 87.056° E) and Kadamoud (Lat. 21.606° N, Long. 87.026° E) are situated in Sader block of Balasore district.

Normal Annual Rainfall of Balasore district is 1592 mm and the mean Annual Rainfall is 1723 mm. The mean maximum summer temperature is 45℃ and the mean minimum winter temperature is 9℃. The relative humidity varies between 30 to 90 percentage. The climate is Humid Sub-tropical climate. The soil order of this Agro Climatic zone are *Alfisols*, *Aridisols*, *Entisols* and *Ultisols*.

Soil sampling and analysis

The landform of the study area was determined through traversing the area and elevations above MSL of different points were recorded using GPS instrument (Garmin make; model: 76MAPCSx). Total 120 numbers of composite surface (0–15 cm) soil samples were collected from the study area which includes 20 samples from each village from different land types such as upland, medium land and low land. Composite soil samples were collected along with latitude and longitude of the plots with the help of GPS instrument. Soils were analyzed for its textural class by international pipet method (Piper, 1966) [18], pH (1:2) (Chopra and Kanwar, 1998) [6], EC (1:2) (Sparks, 1996), organic carbon (Walkley and Black, 1934) [26], available nitrogen (Subbiah and Asija, 1956) [23], phosphorus (Bray and Kurtz, 1945) [3], potassium (Hanway and Heidel, 1952) [10], Exchangeable Ca and Mg by Versenate (EDTA) method: (Gupta 1999) [9]. Sulphur (Chesnin and Yien, 1950), DTPA extractable micronutrient Lindsay and Norvell (1978) [11] and hot water extractable boron (John *et al*., 1975).

Results and Discussion

Most of the soils of Kasipada, Agoragohira, Mirigimundi, Nuagao and Kadamouda villages belonged to Clay to Clay loam textural classification. The soils of Pinchhabania village were found Sandy clay to sandy clay loam textural classes (Table 1). Similar result was reported by PMKSY (2016), district level implementation committee Balasore, Odisha. Munsell Soil Color Charts color of these soil varied from light brown gray to strong brown in most of soil. Whereas soil color of Pinchhabania varied between yellowish brown to brown. Bulk density of soil varied in between 1.3 to 1.56 gm cm^{-3}. Higher bulk density values were observed in Pinchhabania village (1.53 to 1.56 gm cm^{-3}). Soil bulk density showed positive relationships with sand content and Clayey soils tend to have lower bulk densities (Chaudhari *et al*., 2013) [4]. Though sand content in the soils of Pinchhabania village were high which increased the bulk density.

Table 1: Physical properties of soils

Name of Village	Soil texture	Soil color	Bulk density (g cm^{-3})
	Range	Range	Range
Kasipada	Clay-clay loam	light brown gray- Strong Brown	1.35-1.5
Agoragohira	Clay-clay loam	light brown gray- Strong Brown	1.37-1.48
Mirigimundi	Clay-clay loam	light brown gray- Strong Brown	1.28-1.53
Pinchhabania	Sandy clay –sandy clay loam	Yellowish Brown- Brown	1.53-1.56
Nuagao	Clay loam to loamy	Pale brown	1.31-1.52
Kadamouda	Clay-clay loam	light brown gray- Strong Brown	1.3-1.37

Soil reaction

Soil pH (1:2) of surface soil samples of Kasipada village were found to varied in between 6.3 to 7 i.e. slightly acidic to neutral with a mean value of 6.6; that of soils of Agoragohir village varied between 5.3 to 7 i.e. moderate acidic to neutral with a mean value of 6.1; that of Mirigimundi varied between 5.2 to 7.1 i.e. moderate acidic to neutral with a mean value of 6.2; that of soils of Pinchhabania village varied between 5.8 to 8.1 i.e. slightly acidic to slightly alkaline with a mean value of 7.1; that of soils of A Nuagao village varied between 5.1 to 7.1 i.e. moderate acidic to neutral with a mean value of 6.1; that of soils of Kadamouda village varied between 5.3 to 7.4 i.e. moderate acidic to neutral with a mean value of 6.3 (Table 2). The data showed a gradual increase in soil pH value from upland towards low land, under low land condition continuous submergence maintained which help the soil pH to neutral in reaction (Redman, 1965) [20]. In case of low land condition, removal of basic cations with runoff water from upland and medium land during intensive rainfall and their subsequent deposition in the low land. Hence, the soil acidity appears to be a major crop production constraint in the study area. Similar findings have also been reported earlier by Priyadarshini *et al*., (2017) and Dash *et al*., (2018) [7].

Table 2: Chemical properties of soils

Name of Village	Land Type	pH (1:2)		EC (1:2) (dS m^{-1})		OC (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Kasipada	L	6.6-6.8	6.7	0.085-0.16	0.12	4.7-8.7	6.9
	M	6.4-6.7	6.5	0.07-0.14	0.10	6.3-7.3	6.8
	U	6.3-7	6.6	0.07-0.12	0.09	5.5-6.6	6.1
Agoragohira	L	5.9-7	6.4	0.09-0.36	0.23	0.43-6.3	5.3
	M	5.3-5.8	5.6	0.03-0.15	0.10	5.5-10.3	7.9
	U	5.3-6.3	5.8	0.05-0.11	0.08	0.9-5.1	2.9
Mirigimundi	L	5.8-7.1	6.6	0.12-0.31	0.24	5.5-9.1	8.6
	M	5.6-6.3	5.9	0.11-0.30	0.20	4.8-7.2	6.7
	U	5.2-6.4	5.6	0.06-0.12	0.09	2.1-5.6	4.7
Pinchhabania	L	5.8-6.0	5.8	0.07-0.24	0.15	6.6-7.6	7.1
	M	5.7-6.3	6.0	0.04-0.17	0.094	4.8-5.1	5.0
	U	6.8-8.1	7.5	0.06- 0.12	0.091	0.7-8.5	4.3

Nuagao	L	5.8-7.1	6.7	0.11-0.19	0.15	3.6-5.8	5.2
	M	5.6-6.8	5.9	0.07-0.18	0.12	1.2-5.1	4.3
	U	5.1-5.5	5.3	0.46-0.09	0.085	0.5-2.7	1.9
Kadamouda	L	5.9-7.4	6.8	0.12-0.35	0.2	4.0-13.1	7.8
	M	5-6.6	5.9	0.12-0.34	0.19	3.3-8.3	5.7
	U	5.35-6.5	5.8	0.08-0.15	0.11	3.8-6.8	4.8

*L= Low land, M=Medium land, U= Up land

Electrical conductivity

Electrical Conductivity (1:2) of surface soil samples of the entire study area was found to be less than 1dS m^{-1} (Table 2). Hence, all the soils under the study area are safe for all types of crop production with respect to the soluble salt content.

Organic carbon

Soil Organic Carbon (SOC) of surface soil samples of Kasipada village were found to vary in between 4.7 to 8.7 g kg^{-1} with a mean value of 6.9 g kg^{-1}; that of Agoragohira village varied between 0.42 to 10.3 g kg^{-1} with a mean value of 5.4 g kg^{-1}; that of Mirigimundi varied between 2.1 to 9.1 g kg^{-1} with a mean value of 6.6 g kg^{-1}; that of Pinchhabania village varied between 0.7 to 8.5 g kg^{-1} with a mean value of 5.5 g kg^{-1}; that of Nuagao village varied between 1.9 to 5.2 g kg^{-1} with a mean value of 3.8 g kg^{-1}; that of Kadamouda village varied between 4.8 to 7.8 g kg^{-1} with a mean value of 6.1 g kg^{-1} (Table 2). The results clearly showed a gradual increase in SOC from upland towards low land surface soil samples which could be attributed to higher cropping intensity aided with more crop residue incorporation in the same. Again, due to higher water table, the oxidation of organic matter is slower in low land areas than that of upland areas. In the entire study area organic carbon status was found to be low to high which enables the soil for growing a wide range of crops. Similar findings have also been reported by Mishra (2013) [13], Digal *et al.*, (2018) [8], Swain *et al.*, (2019) [24].

Available nitrogen

Available soil nitrogen content of surface soil samples of Kasipada village were found to vary in between 94 to 172 kg ha^{-1} with a mean value of 142.6 kg ha^{-1}; that of soils of Agoragohira village varied between 150 to 175 kg ha^{-1} with a mean value of 165.33 kg ha-1; that of soils of Mirigimundi varied between 185 to 250 kg ha^{-1} with a mean value of 211.6 kg ha-1; that of soils of Pinchhabania village varied between 125 to 150 kg ha^{-1} with a mean value of 138 kg ha-1 that of soils of Nuagao village varied between 150 to 215 kg ha^{-1} with a mean value of 180 kg ha-1 that of soils of Kadamouda village varied between 165 to 217 kg ha^{-1} with a mean value of 185.66 kg ha^{-1} (Table 3). Similar result was also reported by Tripathi *et al*., (2015) [25]. The results clearly showed a gradual increase in average N content from upland to low land which could be attributed to the increased SOC in the low land than that of upland and medium land (as N is released from the soil organic matter by the activity of microorganisms). Available N was found to be positively correlated with organic carbon (r=0.12*) (Table 5). In the entire study area available soil nitrogen content varied between low to medium. Similar results were reported by Behera *et al*., (2016) [2].

Table 3: Primary nutrients status of the study area

Name of Village	Land Type	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Kasipada	L	125-150	172	15.5-24	20.5	48-106	93.8
	M	150-175	162	10.5-21.1	15.2	50-81.6	72.3
	U	57.5-150	94	5.4-22.1	13.4	66-120	69
Agoragohira	L	150-175	175	1.6-15.2	10.6	296-558	296
	M	112.5-185	171	3.0-8.5	5.80	78.4-141	117
	U	125-165	150	0.85-1.6	2.90	49-98	73.9
Mirigimundi	L	175-285	250	6.9-22.6	18.9	174-456	363
	M	185-215	200	7.5-13.7	10.2	156-415	358
	U	125-212	185	2.5-9.9	7.9	145-269	212
Pinchhabania	L	145-185	150	6.7-31.5	18.9	65-107	86.6
	M	102-162.5	138	1.5-19.6	16.8	40-72.5	56.5
	U	112-137.5	125	2.3-15.6	13.3	48-78	55.2
Nuagao	L	180-245	215	11.2-20.1	18.5	75.3-145	95.3
	M	112-223	175	12.3-18	15.2	45-96	75.3
	U	125-175	150	7.2-14.7	13.5	41-98	42.5
Kadamouda	L	187-237	217	3.7-13.5	9.01	84-502	226
	M	137.5-225	175	0.7-9.03	5.93	113-236	156
	U	112-212	165	1.8-13.3	6.80	111-169	118

*L= Low land, M=Medium land, U= Up land

Available phosphorus

Available soil phosphorus content of Kasipada village were found to vary in between 13.4 to 20.5 kg ha^{-1} with a mean value of 16.36 kg ha^{-1}; that of Agoragohira village varied between 2.9 to10.6 kg ha^{-1} with a mean value of 6.43 kg ha^{-1}; that of Mirigimundi varied between 7.9 to 18.9 kg ha^{-1} with a mean value of 12.3 kg ha^{-1}; that of Pinchhabania village varied between 13.33 to 18.9 kg ha^{-1} with a mean value of 16.3 kg ha^{-1}; that of Nuagao village varied between 13.5 to 18.5 kg ha^{-1} with a mean value of 15.7 ha^{-1};that of Nuagao village varied between 5.9 to 9.01 kg ha^{-1} with a mean value of 7.24kg ha^{-1} (Table 3).The results clearly showed a gradual increase in average P content from upland to low land which could be attributed to the increased SOC in the low land than that of upland and medium land (as organic fractions of available phosphorus is mobilized to plant available form by the activity of microorganisms). Available P was found to be negatively correlated with exchangeable (r=-0.44**) (Table 5). In the entire study area available phosphorus was found within the range of low to high. Similar trends of available P were also observed by Tripathi *et al*., (2015) [25] and Barik *et al*., (2017) [1].

Available potassium

Available soil potassium content of Kasipada village were found to vary in between 48 to 120 kg ha^{-1} with a mean value of 78.3 kg ha^{-1}; that of Agoragohira village varied between 49 to 558 kg ha-1 with a mean value of 162.3 kg ha^{-1}; that of Mirigimundi widely between 145 to 456 kg ha^{-1} with a mean value of 311 kg ha^{-1}; that of Pinchhabania village varied between 40 to 107 kg ha^{-1} with a mean value of 68.9 kg ha^{-1} that of Nuagao village varied between 41 to 145 kg ha^{-1} with a mean value of 71.03 kg ha^{-1} that of Kadamouda village varied between 84 to 502 kg ha^{-1} with a mean value of 166.6 kg ha^{-1} (Table 3). The results clearly showed a gradual increase in average K content from upland to low land which could be attributed to the increased clay content in the low land than that of upland and medium land (potassium ion being a cation present in the exchange site of negatively charged clay particles). Available K was found to be positively correlated with amount of clay content. In the entire study area available potassium content was found within the range of low to high. Similar results were also observed by Mishra *et al*., (2017) [1] and Dash *et al*., (2018) [7].

Exchangeable Ca and Mg

Exchangeable Ca and Mg content of Kasipada village were found to vary in between 4.11 to 11.8 and 0.05 to 11.6 mg 100 g^{-1} with a mean value of 9.52 and 3.2 mg $100g^{-1}$; that of Agoragohira village varied between 2.9 to 18.8 and 0.8-5.7 mg $100g^{-1}$ with a mean value of 11.9 and 3.35 mg $100g^{-1}$; that of Mirigimundi varied widely between 5.7 to 18.3 and 0.7 to 8.1 mg $100g^{-1}$ with a mean value of 16.3 and 5.63 mg $100g^{-1}$; that of Pinchhabania village varied between 3.5 to 11.8 and 0.5 to 4.4 mg $100g^{-1}$ with a mean value of 6.02 and 2.15 mg $100g^{-1}$; that of Nuagao village varied between 0.9 to 8.9 and 0.6 to 5.1 mg $100g^{-1}$ with a mean value of 3.7 and 1.83 mg $100g^{-1}$; that of Kadamouda village varied between 3.5 to 16.3 and 1.4 to 12 mg $100g^{-1}$ with a mean value of 12.2 and 3.87 mg $100g^{-1}$ (Table 4).

Table 4: Secondary nutrients status of the study area

Name of Village	Land Type	EX. Ca (mg/100g)		Ex. Mg (mg/100g)		S (mg kg^{-1})	
		Range	Mean	Range	Mean	Rang	mean
Kasipada	L	10.4-11.8	9.75	0.05-2	1.5	2.5-5.2	4.0
	M	10.4-11.8	10.9	2.5-11.6	6.1	2.4-3.0	2.9
	U	4.11-11.8	7.93	2.5-2.6	2.1	2.5-2.8	2.6
Agoragohira	L	10.2-18.8	14.5	0.8-3.5	2.05	3.2-4.6	3.7
	M	11.5-13.7	11.7	4-5.7	4.85	3.1-3.3	3.2
	U	2.9-14.9	9.5	1-5.3	3.15	2.2-2.9	2.8
Mirigimundi	L	5.7-18.2	15.2	1.2-6.9	5.6	3.0 -10.5	5.6
	M	7.3-18.3	15.6	0.8-6.3	5.2	3.1-3.6	3.3
	U	8.9-21.2	18.2	0.7-8.1	6.1	3.0-3.3	3.1
Pinchhabania	L	3.5-7.8	5.65	0.5-3.1	1.25	3.2-10.2	5.3
	M	4.5-4.7	4.6	1.8-4.4	3.1	3.2	3.2
	U	4.1-11.8	7.9	2.6-1.5	2.1	2.0-2.7	2.3
Nuagao	L	1.3-8.9	4.6	0.9-5.1	2.4	3.1-3.2	3.15
	M	0.9-5.4	3.6	0.6-5.1	2.1	2.1-3.3	2.8
	U	1.3-4.1	2.9	0.5-2.1	1	1.8-3.1	2.6
Kadamouda	L	8.5-13.8	10.77	2.5-8.4	2.87	4.1-5.8	5.6
	M	3.5-12.4	10.04	1.4-8.9	2.87	2.9-4.8	4.1
	U	12.3-16.3	15.86	1.4-12	5.98	1.7-3.8	3.2

*L= Low land, M=Medium land, U= Up land

Available sulphur

Available soil sulphur content of Kasipada village were found to vary in between 2.4 to 5.2 mg kg^{-1} with a mean value of 3.16 mg kg^{-1}; that of Agoragohira village varied between 2.2 to 4.6 mg kg^{-1} with a mean value of 3.2 mg kg^{-1}; that of Mirigimundi varied widely between 3.0 to 10.5 mg kg^{-1} with a mean value of 4.1 mg kg^{-1}; that of Pinchhabania village varied between 2 to 10.2 mg kg^{-1} with a mean value of 3.6 mg kg^{-1} ; that of Nuagao village varied between 1.8 to 3.2 mg kg^{-1} with a mean value of 2.85 mg kg^{-1} ; that of Kadamouda village varied between 1.7 to 5.8 mg kg^{-1} with a mean value of 4.3 mg kg^{-1} (Table 4). The results clearly showed a gradual increase in average S content from upland to low land which could be attributed to the increased SOC content in the low land than that of upland and medium land (as S is also released from the soil organic matter by the activity of micro-organisms). Available S was found to be positively correlated with organic carbon. In the entire study area available sulphur was found to be in the range of low to medium. Similar results were also observed by Nahak *et al*., (2016) [16] and Mishra (2016) [7].

Table 5: Correlation between different soil properties

	pH	EC	OC	N	P	K	Ca	Mg
Ph	1							
Ec	0.160	1						
OC	-0.161	0.378*	1					
N	-0.148	0.165	0.12*	1				
P	0.182	-0.034	-0.096	-0.137	1			
K	-0.033	0.615**	0.377*	0.024	-0.015	1		
Ca	-0.135	0.138	0.286	0.135	-0.44**	0.263	1	
Mg	0.037	0.171	-0.038	-0.129	-0.04	-0.026	-0.134	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Available Micronutrient

DTPA extractable micronutrients content (mg kg^{-1}) i.e. Fe (82.68), Mn (22.12), Cu (1.82) was sufficient but Zn (0.284) was present below its critical level in Kasipada; that for

Agoragohira Fe (36.8), Mn (35.52), Cu (1.718) was sufficient but Zn (0.312) was deficient; similarly, for Mirigimundi and Kadamouda Fe (58.2 and 71.2), Mn (27.9 and 38.8), Cu (2.05 and 2.74) was sufficient but Zn (0.5 and 0.57) was deficient. But soils of Pinchhabania and Nuagao was sufficient in DTPA extractable Fe, Mn, Cu and Zn. Hot water extractable boron content of the surface soil samples of Kasipada, Agoragohira and Kadamouda village were found to be sufficient (> 0.5mg kg^{-1}) and the highest Hot water extractable boron was recorded at Kasipada (1.96 mg kg^{-1}). Soils of the remaining villages (Mirigimundi, Pinchhabania and Nuagao) were deficient in available B content (Figure 1).

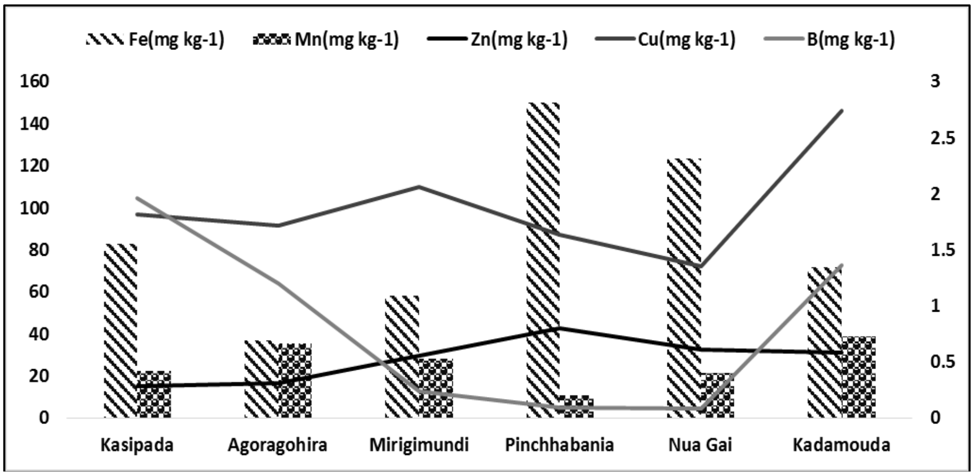

Fig 1: Micronutrient status of the study area

From the present study, it can be concluded that soils of Kasipada, Agoragohira, Mirigimundi and Kadamouda are clay to clay loam in soil texture, moderate to slightly acid in soil reaction, medium in soil organic carbon content, low in available N content, low to medium in P and K content, high in exchangeable Ca and Mg, low in available S content, with respect to micronutrient; Fe, Mn, Cu and B are sufficient, where Zn content are deficient. Soils of Pinchanbania and Nuagao are slightly acidic to neutral in soil reaction, low to moderate in organic carbon, low in available N, moderate in available P, low in K content, sufficient in micronutrient content except B. The deficient nutrient may be replenished to avoid the crop suffering from their deficiency and optimum utilization of nutrients. Integrated nutrient management may be adopted for sustainable soil fertility management as well as to achieve higher crop production.

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