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Preparation of GPS and GIS based soil fertility maps and identification of soil related crop production constraints of RRTTS and KVK farm, Dhenkanal located in the mid-central table land agro climatic zone of Odisha, India

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Abstract
A detailed soil fertility status of RRTTS and KVK farm, Dhenkanal was investigated. The soil reaction was found to be acidic. EC was found to be in safe range for crop production. SOC status was found to vary between medium to high. Available soil N, Bray's P of the study area were found to be low to medium and that of available K content varied between medium to high. Available soil S content was found to be low. Soil micronutrient content such as Fe, Mn, Cu, Zn and B were found to be sufficient. Soil acidity was found to be the major crop production constraint of the study area. So, application of liming materials along with application of soil test based fertilizers and manures will help in optimising crop productivity as well as sustaining soil health.

Keywords: GPS, GIS, KVK, dhenkanal, soil fertility maps, Odisha

Introduction
Determination of soil available nutrient status of an area using Global Positioning System (GPS) helps in formulating site specific balanced fertilizer recommendations along with making critical decisions on nutrient management. Fertilizer use can be better optimised by utilizing knowledge of 'soil fertility maps' prepared with the help of Geographical Information System (GIS). Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soil to realize good crop yield. GPS and GIS based soil fertility maps not only give ideas about fertility status of the soil but also help in monitoring the soil health from time to time. Regional Research and Technology Transfer Station (RRTTS) for Mid Central Table Land Agro Climatic Zone of Odisha was established in the year 1982 at Mahisapat, Dhenkanal to carry out agricultural research works based on crop production constraints of this agroclimate comprising of 21 numbers of blocks belonging to four different districts namely Dhenkanal, Angul, Cuttack and Jajpur. Later, a Krishi Vigyan Kendra (KVK) was established in the year 2001 in the same campus of RRTTS, which has the most vital role in transferring technologies to farmers of the district by undertaking different On Farm Testings (OFTs), Front Line Demonstrations (FLDs) and training to farmers. About 19 ha land of the study area is being used for research trials, foundation seed production and upland orchard. But, ever since its establishment, plot wise GPS-GIS based soil fertility status of the farm has never been studied extensively. Since any systematic soil survey of this area has not yet been done, therefore, an attempt has been made in the present investigation to prepare plot wise GPS and GIS based soil fertility maps of RRTTS and KVK farm of Dhenkanal. It will help in finding out soil fertility related crop production constraints of the farm and to suggest remedial measures for higher crop production as well as for better scientific studies. Also, this work will serve as a foundation research work for future soil survey and other research activities.

Materials and Methods
1. Experimental site
The study area is situated between 20^0 37' N latitude and85^{0}36 'E longitude with an altitude of 328 feet above Mean Sea Level (MSL).

The study area is situated in the feet of 'Charakhola hills' which comes under Dhenkanal forest range. Based on slope and elevation, the study area has been divided into three major physiographic units such as gently sloping upland (332 feet above MSL, slope of 3-5%), very gently sloping medium land (305 feet above MSL, slope of 1-3%) and nearly levelled low land (298 feet above MSL, slope of 0-1%).

The climate of this region is hot and dry, sub-humid with dry summer and mild winter. Mean annual rainfall is 1432.3 mm out of which 75.5 % is received during monsoon (June to September). The climatic condition of Dhenkanal is much variable. It has mainly 4 seasons. Those are summer (March to mid-June), rainy (mid June to September), post monsoon (October to November) and winter (December to February). The mean maximum temperature and mean minimum temperature of the region are 33.1ºC and 21.7ºC, respectively as recorded at the local observatory. May is the hottest month with mean maximum temperature of 39.4ºC and December is the coldest month with mean minimum temperature of 13.5ºC (Fig. 1.).

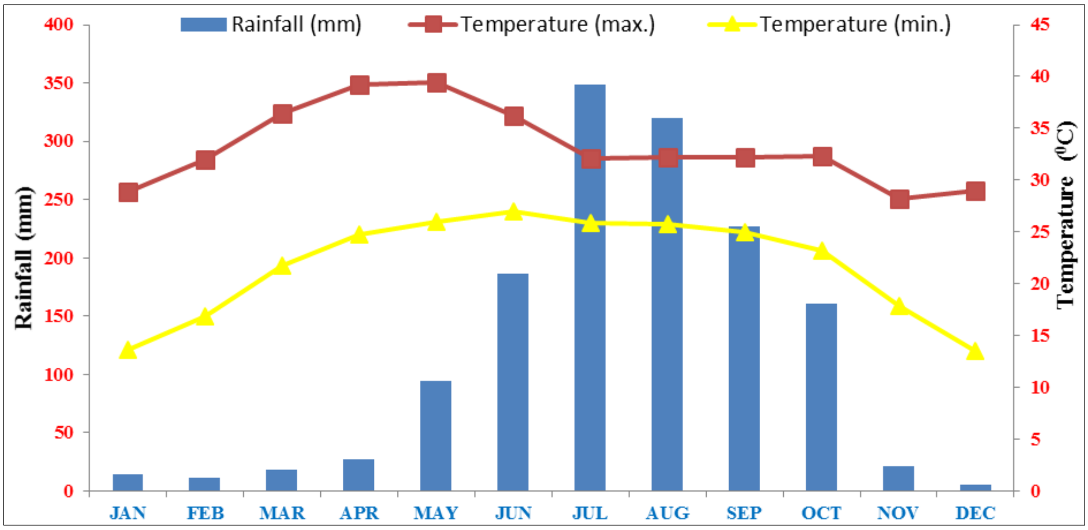

Fig 1: Meteorological data of the study area representing mean values from the year 2004 to 2017 collected from the meteorological station of the study area.

An agro forestry model based orchard was designed in the upland of the study area. During *kharif*, the medium land and low land are mostly used for foundation seed production of paddy. Some portion of the low land are not under cultivation due to severe flooding and water logging. In *rabi* season, green gram, black gram and to some extent vegetables like brinjal, tomato, chilli are grown in medium land and some portions of low land.

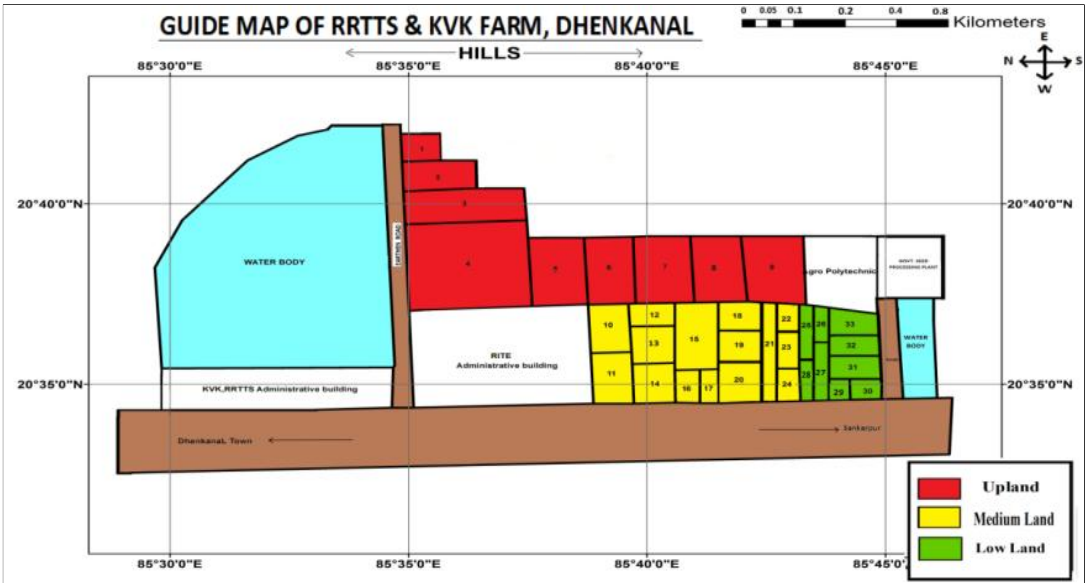

Fig 2: Physiography map of RRTTS and KVK Farm, Dhenkanal.

2. 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). A Total of 33 numbers of composite surface (0–15 cm) soil samples were collected from the study area which includes 4 samples (plot 1 to 4) from RRTTS farm situated in the upland and 29 samples from KVK farm comprising of 5 samples from upland (plot 5 to 9); 15 from medium land (plot 10 to 24); 9 from low land (plot 25 to 33). Composite soil samples were collected from each plot of 33 plots along with latitude and longitude of the plots with the help of GPS instrument. Soils were analysed for textural class by Bouyoucos Hydrometer method (Bouyoucos GJ,1962) [3], pH(1:2), EC(1:2), organic carbon (Walkley and Black, 1934) [21], available nitrogen (Subbiah and Asija, 1956) [20], phosphorus (Bray and Kurtz, 1945) [4], potassium (Hanway and Heidel, 1952) [6], sulphur (Chesnin and Yien, 1950) [5], DTPA extractable iron, manganese, copper and zinc (Lindsay and Norvell, 1978) [9], and hot water extractable Boron (John *et al.*, 1975) [8]. Base map of the study area was geo-referenced and digitized. Latitude, Longitude and soil analysis data were entered into attributed table and linked to Arc GIS software for making thematic soil fertility maps.

Results and Discussion

1. Soil texture

Texture of surface soil samples of the entire study area remained within sandy, loamy sand, sandy loam, sandy clay loam and sandy clay. The sand, silt and clay content in upland soils (plot 1 to 9) were found to vary in between 78.0 to 90.0, 3.0 to 12.4 and 7.0 to 14.0 percent respectively; that of medium land (plot 10 to 24) varied between 64.4 to 74.6, 2.4 to 21.6 and 13.8 to 31.0 percent respectively; that of low land (plot 25 to 33) soils varied between 52.2 to 76.8, 2.4 to 19.0 and 14.6 to 40.6 percent respectively (Table 1, Fig 3). The average clay content in soils of upland, medium land and low land surface soils were found to be 10.8, 21.3 and 29.4 percent respectively. The results clearly showed a gradual increase in clay content from upland surface soils towards low land soils, which could be attributed to washing away of clay particles from upland and medium land along with runoff water during rain fall and their subsequent deposition in the low land. Similar findings have also been observed by Nayak (2014) [14]; Mishra *et al*. (2014) [11] and Satpathy *et al*. (2015) [19].

2. Soil reaction

Soil pH (1:2) of surface soil samples of the entire study area was found to vary in between 4.13 to 5.97 with a mean value of 5.2. The soil pH of upland, medium land and low land soils varied in between 4.13 to 4.95, 5.09 to 5.39, 5.61 to 5.97 respectively. The average soil pH values of the soil in upland, medium land and low land were found to be 4.59, 5.23 and 5.76 respectively (Table 2, Fig.4.). The data showed that a gradual increase in soil pH observed from upland towards low land, which could be attributed to the 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) [18].

3. Electrical conductivity

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

4. Organic carbon

Soil organic carbon (SOC) of surface soil samples of the entire study area was found to vary in between 5.1 to 15.9 g kg^{-1} with a mean value of 9.5 g kg^{-1}.The SOC in upland, medium land and low land varied between 5.1 to 6.9, 4.9 to 9.9, 11.9 to 15.9 g kg^{-1} respectively. The average SOC values of the soil of upland, medium land and low land were found to be 5.8, 8.9 and 14.3 g kg^{-1} respectively (Table 2, Fig. 5.). The results clearly showed a gradual increase in average SOC in upland towards low land surface soil samples which could be attributed to higher cropping intensity followed by crop residue incorporation in the low land. Again, due to higher water table in case of low land, the oxidation of organic matter is slower than that of upland. In the entire study area organic carbon status was found to be medium to high which sustains higher crop production. Medium to higher organic carbon in the study area could be attributed to its presence in the bottom of dense forest of 'Charakhola hills'. Similar findings have also been reported by Mishra (1981) [12]

5. Available macro nutrients

a) Available Nitrogen

Soil available nitrogen content of surface soil samples of the entire study area was found to vary in between 209 to 358 kg ha^{-1} with a mean value of 281 kg ha^{-1}. The available N content in upland, medium land and low land soils was found to vary in between 209 to 285, 259 to 296, 321 to 358 kg ha^{-1} respectively. The average values of available N of the soils of upland, medium land and low land were found to be 227.7, 278.1, 339.8 kg ha^{-1} respectively (Table 3, Fig. 6.). In the entire study area available nitrogen was found to be in the range of low to medium. Similar results were also been observed by Behera *et al.* (2016) [2].

b) Available Phosphorus

Soil available phosphorus content in the entire study area was found to be varied between 5 to 39 kg ha^{-1} with a mean value of 18.3 kg ha^{-1}. The available P in the upland, medium land and low land soils was found to vary in between 5 to 13, 13 to 18, 20 to 39 kg ha^{-1} respectively (Table 3, Fig. 7.). The mean available P content in the soils of upland, medium land and low land was found to be 9.6, 16.2 and 30.6 kg ha^{-1} respectively. In the entire study area available phosphorus was found to be in the range of low to medium. Similar trend of results were also observed by Barik *et al.* (2017) [1].

c) Available Potassium

Soil available potassium content in the entire study area was found to vary in between 239 to 698 kg ha^{-1} with a mean value of 410.9 kg ha^{-1}. The available K of upland, medium land and low land soils were found to vary in between 239 to 340, 348 to 430, 460 to 698 kg ha^{-1} respectively. The average values of available K in the soils of upland, medium land and low land were found to be 293.4, 396.2, 552.8 kg ha^{-1} respectively (Table 3, Fig. 8.). The results showed that a gradual increase in available K content was found from upland towards low land, which could be attributed to increase in clay percentage in the low land. In the entire study area except plot number 4, available potassium was found to be high. This fact may be explained as the soils have been developed from the potash bearing parent materials such as feldspars. Similar results were also observed by Mishra *et al.* (2017) [18].

d) Available Sulphur

Soil available sulphur content of the entire study area was found to vary in between 3.6 to 15.5 kg ha^{-1} with a mean value of 8.3 kg ha^{-1}. The available S content of upland, medium land and low land soils was found to vary in between 3.6 to 4.8, 6.1 to 9.8, 10.2 to 15.5 kg ha^{-1} respectively (Table 3, Fig. 9.). The average values of available S of the soils in upland, medium land and low land were found to be 4.5, 8.2, 12.6 kg ha^{-1} respectively. In the entire study area available sulphur was found to be in low. Similar results were also observed by Nahak *et al.* (2016) [13].

A gradual increase in available N, P and S was observed from upland towards low land soils, which could be attributed to increase in organic matter content in the low land as these nutrients are released from the soil organic matter by the activity of micro-organisms.

6. Available micro nutrients

a) Available Iron

Available iron content of surface soil samples of the entire study area was found to be varied in between 31.1 to 99.9 mg kg^{-1} with a mean value of 61.5 mg kg^{-1}. The available Fe content in upland, medium land and low land soils were found to vary in between 31.1 to 39.2, 52.8 to 69.9, 70.5 to 99.9 mg kg^{-1} respectively (Table 4, Fig. 10.). The average values of available Fe content in upland, medium land and low land soils were found to be 35.5, 64.0, 83.4 mg kg^{-1} respectively. In the entire study area available Fe status was found to be sufficient.

b) Available Manganese

Available Manganese content of surface soil samples under study was found to vary in between 10.2 to 40.6 mg kg^{-1} with a mean value of 25.1 mg kg^{-1}. The available Mn content in upland, medium land and low land soils were found to vary in between 10.2 to 14.9, 15.8 to 29.5, 30.1 to 40.6 mg kg^{-1} respectively (Table 4, Fig. 11.). The average values of available Mn content of the soils of upland, medium land and low land were found to be 13.3, 24.8, 37.7 mg kg^{-1} respectively. In the entire study area available Mn status was found to be sufficient.

c) Available Copper

Available Copper content of surface soil samples of the study area was found to vary in between 0.6 to 2.9 mg kg^{-1} with a mean value of 1.99 mg kg^{-1}. The available Cu content in upland, medium land and low land soils were found to vary in between 0.6 to 1.4, 1.5 to 2.5, 2.5 to 2.9 mg kg^{-1} respectively (Table 4, Fig. 12.). The average values of available Cu content of the soils of upland, medium land and low land were found to be 0.93, 2.18, 2.73 mg kg^{-1} respectively. In the entire study area available Cu status was found to be sufficient.

d) Available Zinc

Available zinc content of surface soil samples of the study area was found to vary in between 0.6 to 1.6 mg kg^{-1} with a mean value of 1.13 mg kg^{-1}. The available Zn content in upland, medium land and low land soils were found to vary in between 0.6 to 0.9, 1.0 to 1.9, 1.2 to 1.6 mg kg^{-1} respectively (Table 4, Fig. 13.). The average values of available Zn content of the soils of upland, medium land and low land were found to be 0.74, 1.20, 1.41 mg kg^{-1} respectively. In the entire study area available Zn status was found to be sufficient.

e) Available Boron

Hot water extractable boron content of the surface soil samples under study was found to vary in between 0.63 to 1.28 mg kg^{-1} with a mean value of 0.91 mg kg^{-1}. The available B content in upland, medium land and low land soils were found to vary in between 0.63 to 0.92, 0.81 to 0.95, 1.04 to 1.28 mg kg^{-1} respectively (Table 4, Fig. 14.). The average values of available B content of the soils of upland, medium land and low land were found to be 0.71, 0.89, 1.15 mg kg^{-1} respectively. The entire study area available B status was found to be sufficient.

The data showed that, available micro nutrient contents were increased gradually from upland towards low land, which could be attributed to increase in organic carbon content in the low land, as metallic cations such as Fe, Mn, Cu, Zn often form chelates with organic matter. This type of result is in close conformity with results obtained by Mishra (2005) and Pattanayak (2016) [16].

Table 1: Mechanical Composition (Textural class) of the soils under study

Sl. No.	Land type	Sand		Silt		Clay	
		Range	Mean	Range	Mean	Range	Mean
		Percentage (%)					
1	Upland	78.0-90.0	81.6	3.0-12.4	7.6	7.0-14.0	10.3
2	Medium land	64.4-74.6	67.9	2.4-21.6	10.9	13.8-31.0	21.3
3	Low land	52.2-76.8	60.1	2.4-19.0	10.4	14.6-40.6	29.4

Table 2: Chemical properties of the soils under study

Sl. No.	Land type	EC(1:2) (dSm^{-1})		pH (1:2)		Organic carbon (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
1	Upland	0.011-0.018	0.014	4.13-4.95	4.59	5.1-6.9	5.8
2	Medium land	0.032-0.079	0.053	5.09-5.39	5.23	4.9-9.9	8.9
3	Low land	0.049-0.089	0.071	5.61-5.97	5.76	11.9-15.9	14.3

Table 3: Available macro nutrient status of the soils under study

Sl. No.	Land type	N		P		K		S	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
		(kg ha^{-1})							
1	Upland	209-285	227.7	5-13	9.6	239-340	293.4	3.6-4.8	4.5
2	Medium land	259-296	278.1	13-18	16.2	348-430	396.2	6.1-9.8	8.2
3	Low land	321-358	339.8	20-39	30.6	460-698	552.8	10.2-15.5	12.6

Table 4: Available micro nutrient status of the surface soils under study

Sl. No.	Land type	Fe		Mn		Cu		Zn		B	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
		(mg kg^{-1})									
1	Upland	31.9-39.2	35.5	10.2-14.9	13.3	0.6-1.4	0.93	0.6-0.9	0.74	0.63-0.92	0.71
2	Medium land	52.8-69.9	64.0	15.8-29.5	24.8	1.5-2.5	2.18	1.0-1.9	1.20	0.81-0.95	0.89
3	Low land	70.5-99.9	83.4	30.1-40.6	37.7	2.5-2.9	2.73	1.2-1.6	1.41	1.04-1.28	1.15

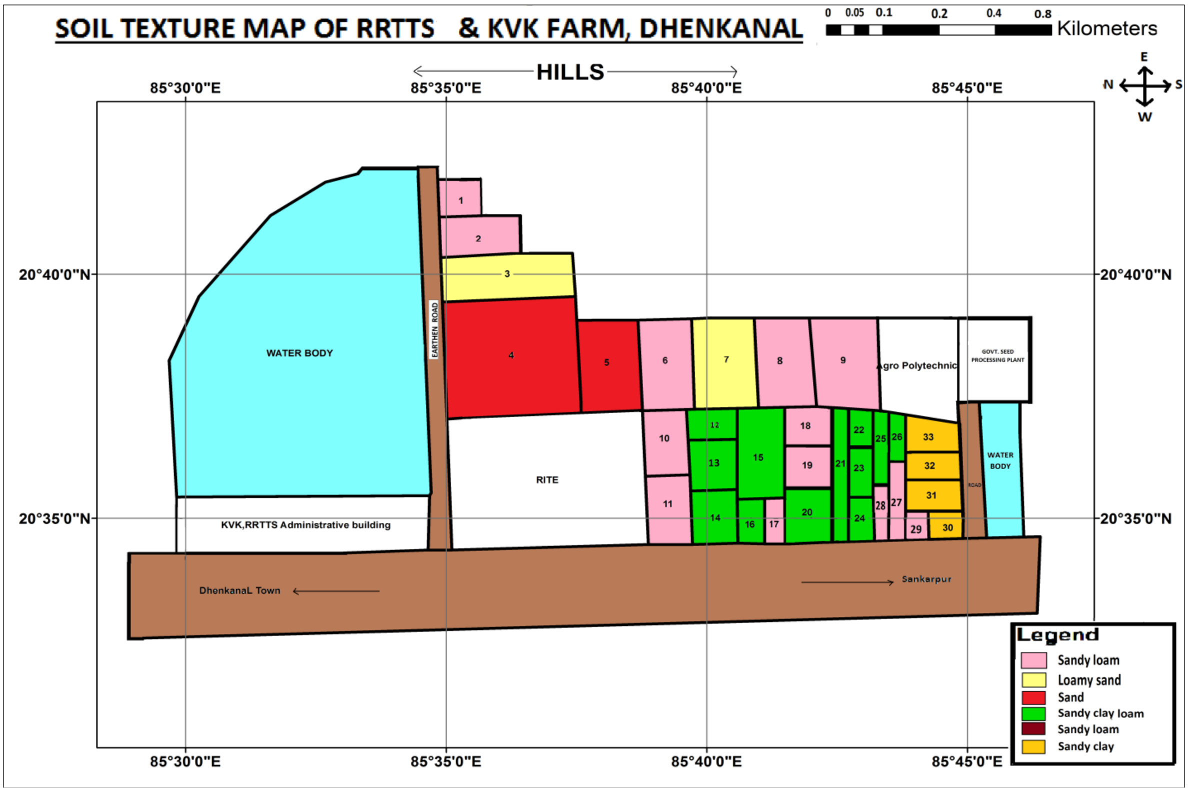

Fig 3: Soil textural class map of the study area

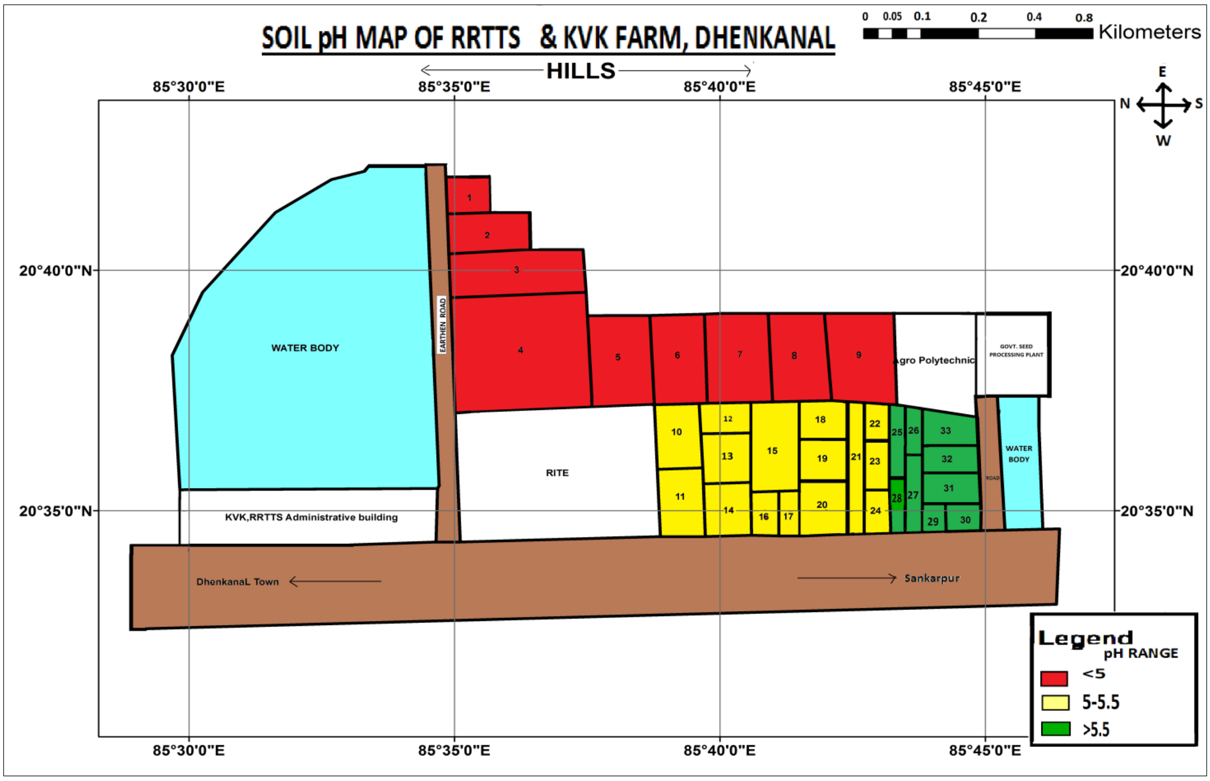

Fig 4: Soil pH map of the study area

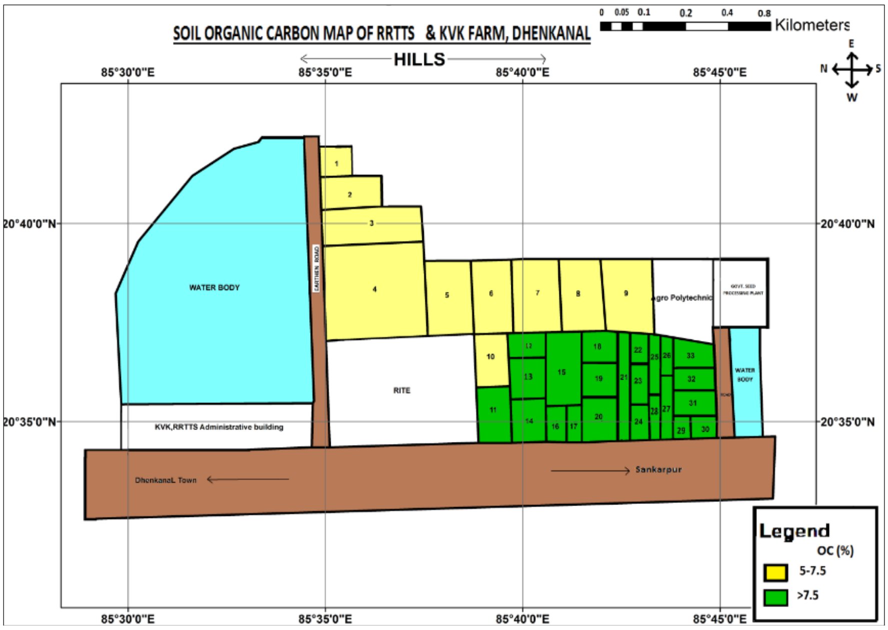

Fig 5: Soil organic carbon map of the study area

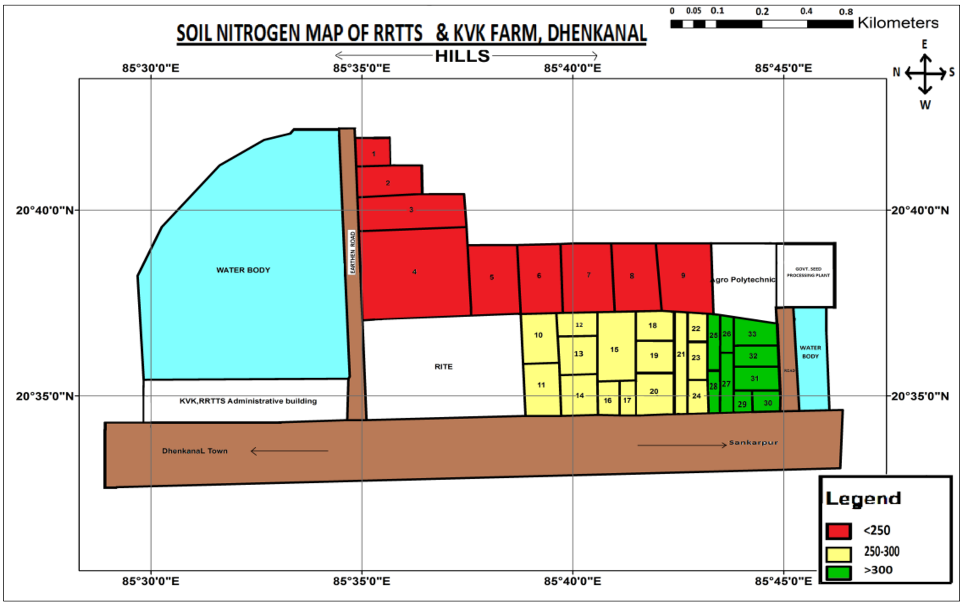

Fig 6: Soil available nitrogen map of the study area

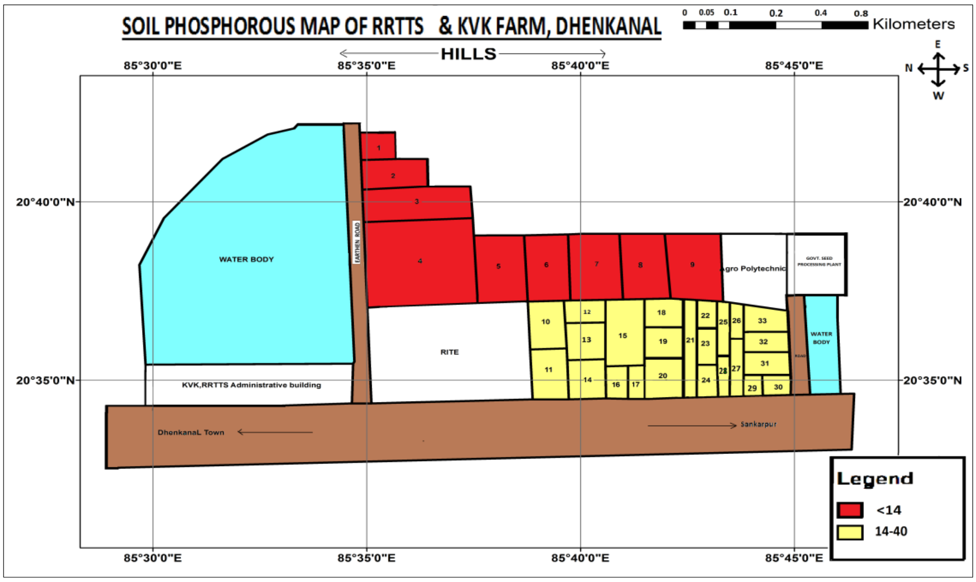

Fig 7: Soil available phosphorus map of the study area

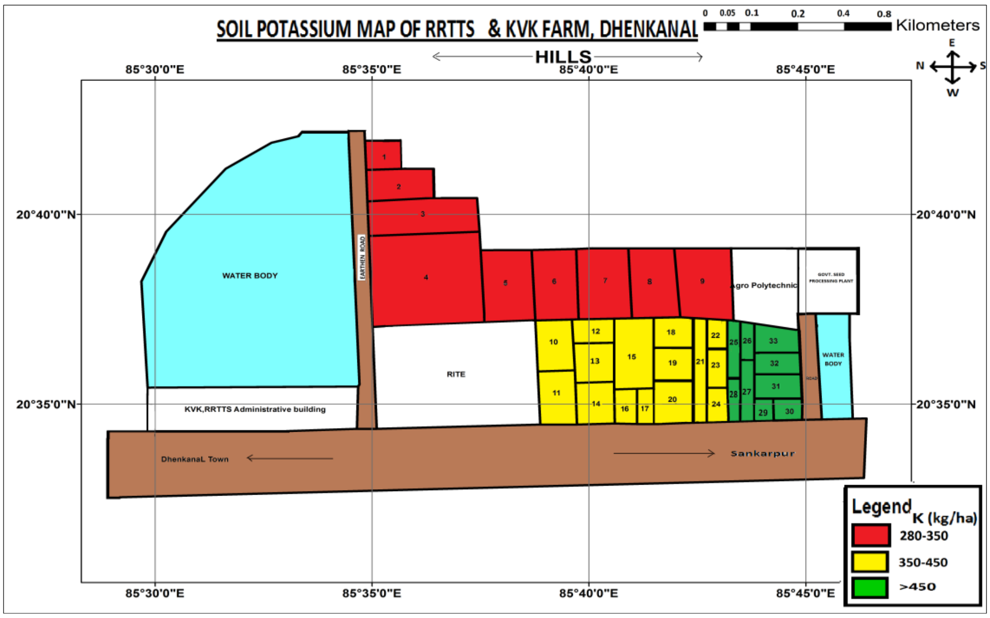

Fig 8: Soil available potassium map of the study area

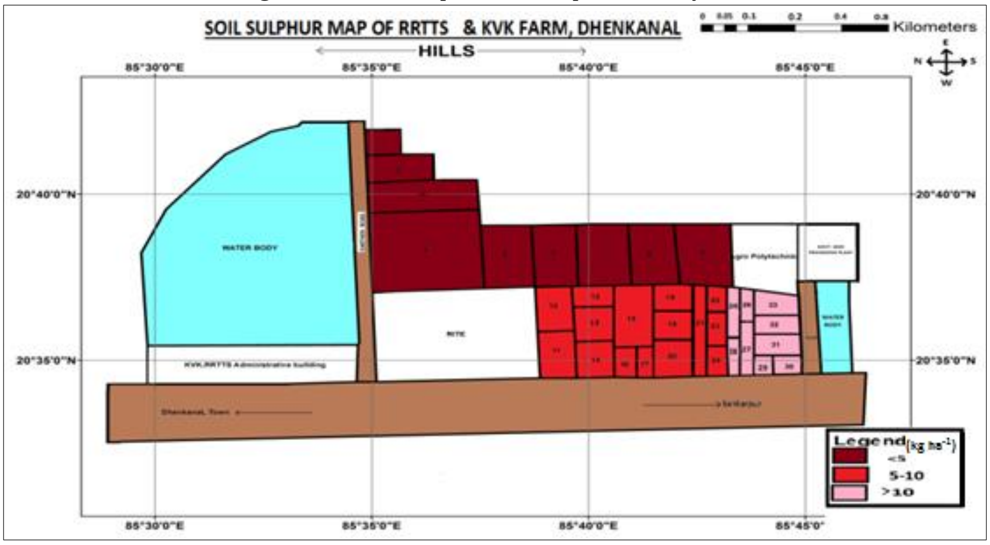

Fig 9: Soil available sulphur map of the study area

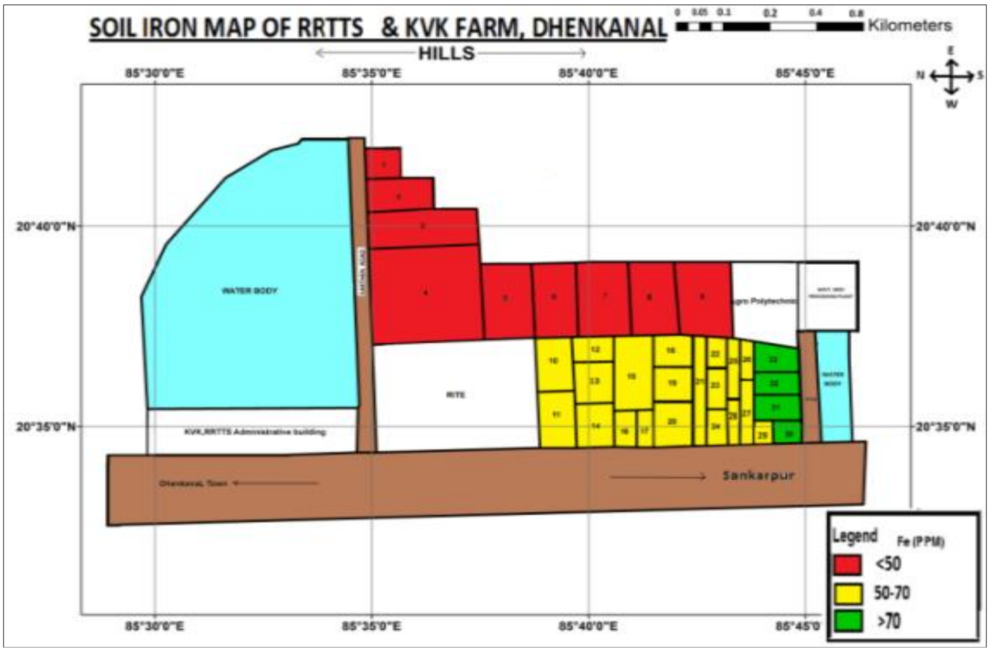

Fig 10: Soil available iron map of the study area

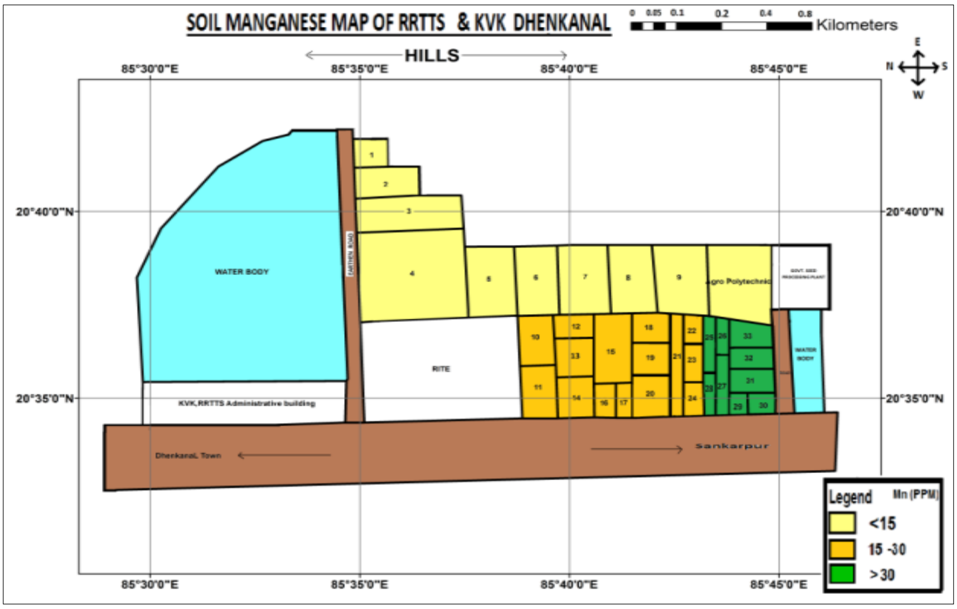

Fig 11: Soil available manganese map of the study area

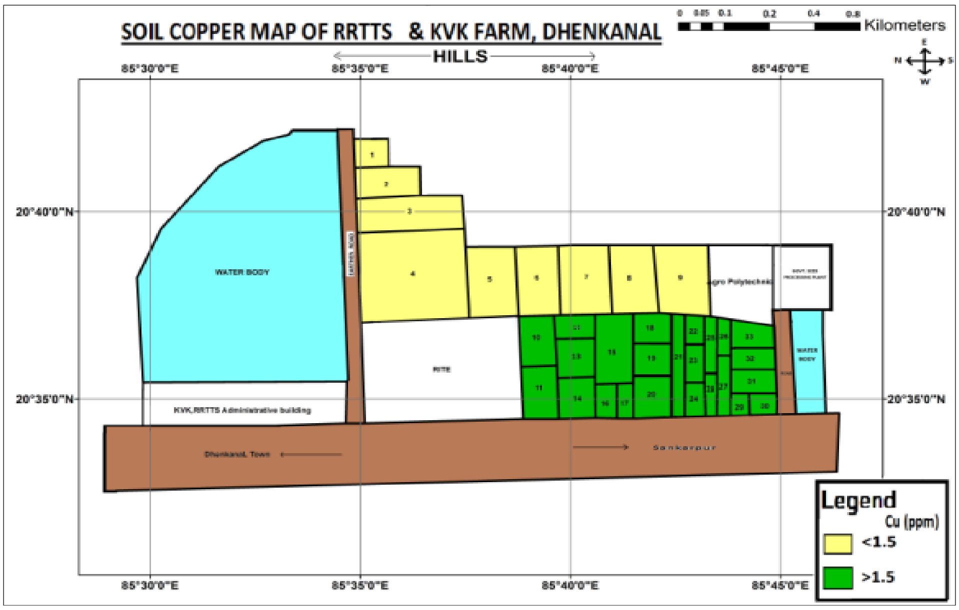

Fig 12: Soil available copper map of the study area

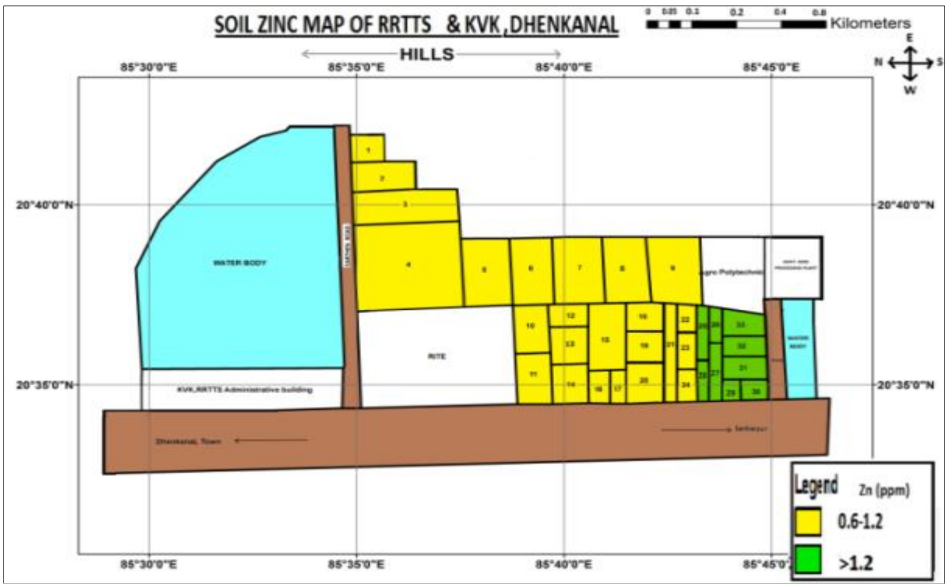

Fig 13: Soil available zinc map of the study area

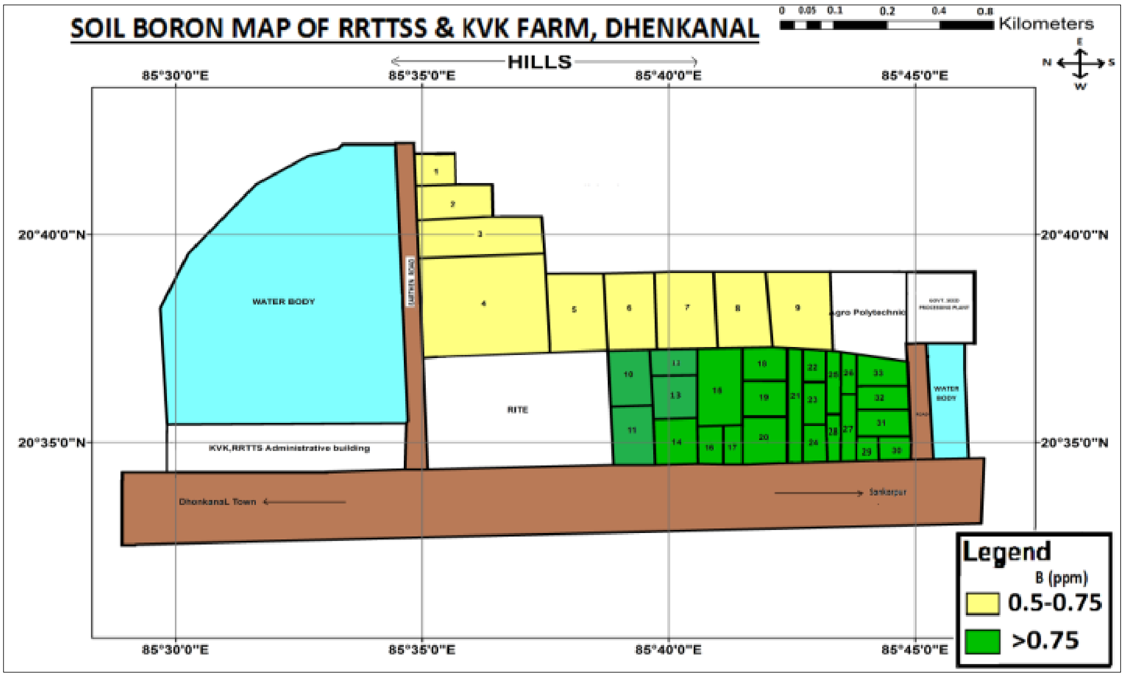

Fig 14: Soil available boron map of the study area

Summary

Twenty seven percent soils (Plot number 1 to 9) were found to be strongly acidic; 45 percent soils (plot no. 10 to 24) were found to be moderately acidic where as 27 percent soils (plot no. 25 to 33) were found to be slightly acidic in nature. Thirty three percent soils (Plot 1 to 11) were found to be having medium range of SOC whereas rest 67 percent soils (plot 12 to 33) were found to be of high organic carbon status. Twenty seven percent soils (Plot 1 to 9) were found to be low in available nitrogen content whereas rest 73 percent soils (plot 10 to 33) were found to be in medium range. Hence, 25 per cent more nitrogenous fertilizers than that of the recommended dose should be applied; that in rest other plots with the recommended dose of fertilizers. Twenty seven percent soils (Plot 1 to 9) were found to be low in available phosphorus status whereas rest 73 percent soils (plot 10 to 33) were found to be in medium range. Hence, 25 per cent more phosphatic fertilizers than that of the recommended dose should be applied; that of rest other plots with the recommended dose of fertilizers. Since all the plots of the farm were found to be higher in potassium status, 25 per cent less potassic fertilizers than that of the recommended dose should be applied. Since all the plots of the farm were found to lower in available sulphur status, 25 per cent more sulphur containing fertilizers than that of the recommended dose should be applied. In the soils of the study area, micronutrients like Fe, Mn, Cu, Zn and B were found to be in sufficient range.

Conclusion

Soil acidity was found to be the major crop production constraint in the study area. The entire study area was found to be of low in status in terms of available sulphur content. Also lower status of available nitrogen and phosphorus were found to be existed in plot 1 to 9 of the study area. Soil erosion and water logging were found to be the major constraints in upland and low land respectively. So, application of liming materials along with application of soil test based fertilizers and manures will help in optimising crop productivity as well as sustaining soil health.

Acknowledgement

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