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Mapping Soil Nutrient Content Using Geo-statistical Techniques in Kuppam Mandal of A.P, India

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A B S T R A C T

Nutrients are essential for crop growth. Plants absorb nutrients from soil. The quantity and availability of these nutrients varies in various scales, between region, field or within field also. To manage this variation in soil nutrient status precision farming is a technology currently available for sustainable agriculture. This technology enables farm management on the basis of small-scale spatial variability of soil and crop parameters in the field. This study was carried out in Kuppam mandal of Andhra Pradesh. The objective of this study is to determine and map soil nutrient content, both major and micro nutrients variability in Kuppam mandal using geostatistical technique. The major and micronutrients were analyzed and mapped by Geostatistical techniques to quantify the level of spatial nutrient available and predict availability of nutrients at unsampled location also. Results indicated that 99.8% samples are low and 0.2 sample are medium in available Nitrogen, 13.4% are low, 19.7 % in medium and 66.7% are high in available Phosphorus, 47.1% samples low, 39.8% medium and 13.1 % samples are high in available Potassium, 78.9% sample sufficient and 21.1 % samples are deficient in Zinc, 63.6 % samples sufficient and 36.4% are deficient in Iron, 96.7 % sample sufficient and 3.3% samples deficient in Copper, 92.8% samples are sufficient and 7.2 % samples deficient in Manganese. The study revealed the potential and ability of geostatistical techniques in determining and mapping soil nutrient content of study area. Furthermore nutrient maps can be used for balance d fertilization and efficient fertilizer management.

Keywords

Geostatistical technique, Kuppam, Precision farming, Soil nutrient analysis, Soil nutrient mapping.

Article Info

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Introduction

Precision agriculture is a practice that has been managed by Remote Sensing (RS) and Geographic Information Systems (GIS) Technology application. This provides the spatial variability more accurately and will be useful to understand and control more precisely what happens on the farm (Mc Cauley *et al.*, 1997). Precision farming has become increasingly significant in the agricultural operations for the site-specific management. The management and manipulation of farming operation are vital decision-making process in improving crop productivity where there is a need to ensure efficiency in the management of agriculture. Information on soil properties in crop field is very important and useful for fertilizer requirement and also to the specific management of the crop and soil. The study of physical, Chemical, Physico-chemical properties and more precisely availability of major and micro nutrients, is the most important concept in precision farming (Malek *et al.*, 2007).

This study was planned with a general objective to produce a nutrient status thematic map for both major and micro nutrient variability in Kuppam mandal of Andhra Pradesh. The specific objective is to determine and map nutrient content especially Nitrogen, Phosphorus and Potassium (NPK) and micro nutrient variability in the study area. Later, this map will be used for efficient fertilizer management and convergence in to agricultural action plan of Kuppam mandal.

Materials and Methodology

Soil sampling, processing and storage

The entire quality of soil testing results and fertilizer recommendation depends upon soil sampling. Each sample collected must be a true representative of the area being sampled. The accuracy and Utility of the results obtained from the laboratory analysis depends on the sampling precision. For achieving this, 1381 samples were collected at the rate of one sample per every 10 hectares of cultivable land in 64 villages with the help of Global Positioning System (GPS) and latitude and longitude were also recorded. Samples were then kept in labeled plastic bags and brought back to the laboratory for further treatment and analyses. The soil samples were air-dried and sieved to pass 2 mm mesh sieve.

The available nitrogen was determined by alkaline permanganate method outlined by Subbaih and Asija (1956) and the results are expressed in kg ha^{-1}.The available phosphorus content was determined by extracting the soil with 0.5 m $NaHCO_3$ (Olsen *et al.*, 1954) and estimated by developing blue colour using ascorbic acid as reductant on colorimeter (Olsen and Watanabe, 1965). Available potassium in the soils was extracted by neutral normal ammonium acetate and determined by the flame photometer (Jackson, 1973).The available micronutrients *viz*., Zinc, Copper, Iron and Manganese were determined in the DTPA extract of soil (pH 7.3) using Atomic Absorption Spectrophotometer as outlined by Lindsay and Norwell (1978).

Soil variation is spatial variable. Spatial variation has been recognized for many years (Burrough, 1993). Quantification of spatial variability of soil fertility parameters is essential for formulating land management and fertilizer utilization efficiency. Hence, in this study the spatial distribution of soil properties namely pH, EC, available macro and micro nutrients is assessed. Spatial variability maps were prepared using interpolation method, Kriging.

Results and Discussion

The soil nutrient status thematic map of available nitrogen in the study area is shown in Figure 1. The available N ranged between 10 and 376 kg/ha. According to Soil Survey Staff (1997), these ranges could be classified as low and medium. Out of 1381 samples analysed for available nitrogen 1378 samples were recorded low available nitrogen status, which amounts for 99.8% and only 0.2% samples (3 samples) are having medium available nitrogen (Table 1). The low content of the total N in the area were due to denitrification, leaching or volatilization of nitrogen from soil. One more reason for very low available nitrogen, might be due to high slope (Cai *et al*., 1996). Higher slope usually move away the nitrogen to downward direction. The soils have very low available Nitrogen, the holdings are small and the farmers are resource poor and so the yields are very low (Cann, 1994). If we apply recommended doses of nitrogen fertilizers there is a chance to increase the productivity by 15%. The available P_2O_5 content has got a very wide range 5.6 to 634 kg/ha. 185 (13.4%) sample were recorded low available P_2O_5 status, 272 (19.7%) samples recorded medium and a maximum of 924 (66.9%) samples recorded high for available phosphorus status and presented in Figure 2. The high available phosphorus status is due to the continuous application of phosphatic fertilizers season after season. One more reason is the application of phosphatic fertilizers in top dressings and Phosphorus does not leach easily like NO_3 (Chen *et al.*, 1999). In contrast to nitrogen, even after repeated trainings and awareness programmes conducted, farmers are applying the phosphatic fertilizers as top dressing also, which resulted in high P_2O_5 content in 66.9% of samples (Table 1). Here quantity of fertilizer application can be reduced if we go based on soil test values and cost of cultivation can be reduced.

Table.1 N P K status in villages of Kuppam mandal

Village Name	Total	N			P			K		
		L	M	H	L	M	H	L	M	H
Dasegownuru	4	4	-	-	-	-	4	3	1	-
Guttapallecolony	3	3	-	-	-	1	2	3	-	-
Boggupalle	3	3	-	-	-	-	3	-	3	-
Bairappakottala	2	2	-	-	-	1	1	1	1	-
Bandasettipalle	14	14	-	-	2	1	11	8	5	1
Seegalapalle	11	11	-	-	-	-	11	10	1	-
Jarugu	13	13	-	-	-	3	10	10	3	-
Parrakuntlapalle	13	13	-	-	-	-	13	7	4	2
Challarlapalle	6	6	-	-	-	2	4	3	3	-
Yanamanasinapalle	9	9	-	-	1	-	8	4	5	-
Oorunayanapalle	5	5	-	-	-	-	5	3	2	-
Oorunayanikothuru	4	4	-	-	-	2	2	-	2	2
Gudlanayanipalle	11	11	-	-	1	-	10	6	4	1
K.d.palle	8	8	-	-	2	1	5	3	5	-
Yanadipalle	9	9	-	-	-	3	6	6	2	1
Adavibuduguru	90	90	-	-	15	19	56	51	31	8
Kangundi	42	42	-	-	6	7	29	22	15	5
Rajanam	15	15	-	-	-	1	14	5	7	3
Kangundi bc colony	29	28	1	-	3	1	25	20	7	2
Kangundi sc colony	27	27	-	-	6	7	14	15	8	4
Mottakadirinur	21	21	-	-	-	4	17	9	10	2
Chinnaubba	20	20	-	-	3	1	16	6	10	4
T.sadumuru	30	30	-	-	3	7	20	12	16	2
Ponnamguru	85	85	-	-	19	12	54	61	22	2
R.village kuppam	32	32	-	-	8	5	19	20	9	3
Paipalem	65	65	-	-	4	4	57	29	23	13

Vasanadu	48	**48**	-	-	3	**3**	**42**	14	23	**11**
Nadumurur	20	**20**	-	-	4	**1**	**15**	5	10	**5**
Vendugampalle	15	**15**	-	-	-	**-**	**15**	5	5	**5**
Noolukunta	26	**26**	-	-	1	**6**	**19**	11	9	**6**
Sajjalapalle	10	**10**	-	-	1	**3**	**6**	3	5	**2**
Nimmakampalle	5	**5**	-	-	1	**1**	**3**	-	3	**2**
Kothapalle	11	**11**	-	-	-	**3**	**8**	4	5	**2**
Beyanapalle	17	**17**	-	-	2	**6**	**9**	8	8	**1**
Pallarlapalle	27	**27**	-	-	7	**13**	**7**	9	11	**7**
Gonuguru	21	**21**	-	-	3	**5**	**13**	1	12	**8**
Kakimadugu	24	**23**	1	-	2	**8**	**14**	3	15	**6**
Kunjegownuru	21	**20**	1	-	4	**8**	**9**	10	9	**2**
Mattapalle	12	**12**	-	-	1	**-**	**11**	4	[illegible]	[illegible]
Urlaobanapalle	27	**27**	-	-	1	**2**	**24**	9	14	**4**
Akararallapalle	35	**35**	-	-	2	**7**	**26**	15	16	**4**
Kathimanupalle	7	**7**	-	-	-	**-**	**7**	1	3	**3**
Chinnabangarunatham	7	**7**	-	-	3	**1**	**3**	5	1	**1**
Peddabangarunatham	18	**18**	-	-	4	**5**	**9**	6	11	**1**
Avulanatham	17	**17**	-	-	1	**4**	**12**	2	11	**4**
Chikkunatham	20	**20**	-	-	5	**2**	**13**	8	12	**-**
Peddagopannapalle	9	**9**	-	-	-	**5**	**4**	2	5	**2**
Adavimulakalapalle	23	**23**	-	-	4	**2**	**17**	9	8	**6**
Kanumapacharlapalle	15	**15**	-	-	4	**4**	**7**	10	4	**1**
Vasanadu gollapalle	7	**7**	-	-	-	**2**	**5**	5	-	**2**
Bodaguttapalle	9	**9**	-	-	2	**1**	**6**	4	4	**1**
Bairanganapalle	17	**17**	-	-	3	**-**	**14**	9	6	**2**
Bandasettipalle	9	**9**	-	-	4	**2**	**3**	6	2	**1**
Kamathamuru	8	**8**	-	-	-	**2**	**6**	2	2	**4**
Illajanuru	9	**9**	-	-	-	**2**	**7**	5	4	**-**
Mulakalapalle	13	**13**	-	-	1	**2**	**10**	6	3	**4**
V56	4	**4**	-	-	-	**-**	**4**	1	3	**-**
Venkatesapuram	7	**7**	-	-	-	**4**	**3**	3	4	**-**
Varamuru	10	**10**	-	-	4	**3**	**3**	8	2	**-**
Guttappanayanipalle	10	**10**	-	-	2	**4**	**4**	3	4	**3**
Marapalle	7	**7**	-	-	-	**-**	**7**	3	2	**2**
Boggupalle	8	**8**	-	-	2	**3**	**3**	4	4	**-**
Peddaboggupalle	14	**14**	-	-	3	**4**	**7**	8	4	**2**
Kuttiganipalle	8	**8**	-	-	1	**-**	**7**	1	3	**4**
Chinnakurabalapalle	8	**8**	-	-	1	**-**	**7**	5	3	**-**
Total no. of samples	1381	**1378**	**3**	**0**	**185**	**272**	**924**	**651**	**549**	**181**
Percentage	100	**99.8**	**0.2**	**0.0**	**13.4**	**19.7**	**66.9**	**47.1**	**39.8**	**13.1**

Contd….

Table.2 Micro nutrient status in villages of Kuppam mandal

Village Name	Total	Zn		Fe		Cu		Mn	
		S	D	S	D	S	D	S	D
Dasegownuru	4	4	-	2	2	4	-	4	-
Guttapallecolony	3	2	1	1	2	3	-	3	-
Boggupalle	3	3	-	1	2	3	-	3	-
Bairappakottala	2	1	1	1	1	2	-	1	1
Bandasettipalle	14	11	3	12	2	14	-	13	1
Seegalapalle	11	10	1	10	1	10	1	11	-
Jarugu	13	11	2	11	2	13	-	13	-
Parrakuntlapalle	13	13	-	8	5	13	-	13	-
Challarlapalle	6	5	1	3	3	6	-	6	-
Yanamanasinapalle	9	8	1	9	-	9	-	8	1
Oorunayanapalle	5	3	2	3	2	5	-	5	-
Oorunayanikothuru	4	3	1	1	3	4	-	4	-
Gudlanayanipalle	11	11	-	6	5	11	-	11	-
K.d.palle	8	7	1	2	6	8	-	7	1
Yanadipalle	9	6	3	4	5	9	-	9	-
Adavibuduguru	90	86	4	68	22	88	2	87	3
Kangundi	42	42	-	35	7	42	-	42	-
Rajanam	15	15	-	13	2	15	-	15	-
Kangundi bc colony	29	18	11	21	8	25	4	29	-
Kangundi sc colony	27	25	2	16	11	23	4	26	1
Mottakadirinur	21	16	5	16	5	19	2	20	1
Chinnaubba	20	14	6	9	11	20	-	19	1
T.sadumuru	30	22	8	11	19	28	2	25	5
Ponnamguru	85	45	40	57	28	81	4	76	9
R.village kuppam	32	21	11	20	12	32	-	28	4
Paipalem	65	62	3	32	33	64	1	61	4
Vasanadu	48	42	6	25	23	48	-	48	-
Nadumurur	20	17	3	8	12	20	-	20	-
Vendugampalle	15	15	-	7	8	15	-	11	4
Noolukunta	26	23	3	12	14	24	2	19	7
Sajjalapalle	10	6	4	6	4	10	-	9	1
Nimmakampalle	5	4	1	1	4	4	1	5	-
Kothapalle	11	9	2	1	10	11	-	10	1
Beyanapalle	17	13	4	12	5	17	-	17	-
Pallarlapalle	27	17	10	18	9	27	-	23	4
Gonuguru	21	13	8	3	18	20	1	19	2
Kakimadugu	24	17	7	18	6	24	-	19	5

Kunjegownuru	21	**16**	**5**	**15**	**6**	**19**	**2**	**19**	2
Mattapalle	12	**10**	**2**	**8**	**4**	**12**	**-**		
Urlaobanapalle	27	**24**	**3**	**15**	**12**	**26**	**1**	**26**	1
Akakarallapalle	35	**32**	**3**	**19**	**16**	**35**	**-**	**34**	1
Kathimanupalle	7	**6**	**1**	**4**	**3**	**7**	**-**	**6**	1
Chinnabangarunatham	7	**2**	**5**	**4**	**3**	**7**	**-**	**7**	-
Peddabangarunatham	18	**10**	**8**	**9**	**9**	**18**	**-**	**16**	2
Avulanatham	17	**16**	**1**	**14**	**3**	**17**	**-**	**17**	-
Chikkunatham	20	**17**	**3**	**14**	**6**	**20**	**-**	**19**	1
Peddagopannapalle	9	**8**	**1**	**9**	**-**	**9**	**-**	**7**	2
Adavimulakalapalle	23	**19**	**4**	**12**	**11**	**23**	**-**	**23**	-
Kanumapacharlapalle	15	**10**	**5**	**7**	**8**	**15**	**-**	**15**	-
Vasanadu gollapalle	7	**7**	**-**	**6**	**1**	**7**	**-**	**7**	-
Bodaguttapalle	9	**8**	**1**	**5**	**4**	**9**	**-**	**9**	-
Bairanganapalle	17	**16**	**1**	**10**	**7**	**17**	**-**	**15**	2
Bandasettipalle	9	**3**	**6**	**7**	**2**	**9**	**-**	**8**	1
Kamathamuru	8	**3**	**5**	**6**	**2**	**8**	**-**	**8**	-
Illajanuru	9	**8**	**1**	**7**	**2**	**9**	**-**	**8**	1
Mulakalapalle	13	**10**	**3**	**3**	**10**	**13**	**-**	**13**	-
V56	4	**3**	**1**	**4**	**-**	**4**	**-**	**4**	-
Venkatesapuram	7	**2**	**5**	**5**	**2**	**7**	**-**	**7**	-
Varamuru	10	**5**	**5**	**8**	**2**	**10**	**-**	**10**	-
Guttappanayanipalle	10	**9**	**1**	**8**	**2**	**10**	**-**	**10**	-
Marapalle	7	**7**	**-**	**3**	**4**	**7**	**-**	**7**	-
Boggupalle	8	**8**	**-**	**5**	**3**	**7**	**1**	**8**	-
Peddaboggupalle	14	**14**	**-**	**8**	**6**	**14**	**-**	**12**	2
Kuttiganipalle	8	**8**	**-**	**7**	**1**	**8**	**-**	**8**	-
Chinnakurabalapalle	8	**3**	**5**	**6**	**2**	**8**	**-**	**8**	-
Total no. of samples	1381	1089	292	878	503	1335	46	1282	99
Percentage	100	78.9	21.1	63.6	36.4	96.7	3.3	92.8	7.2

Contd….

Fig.1

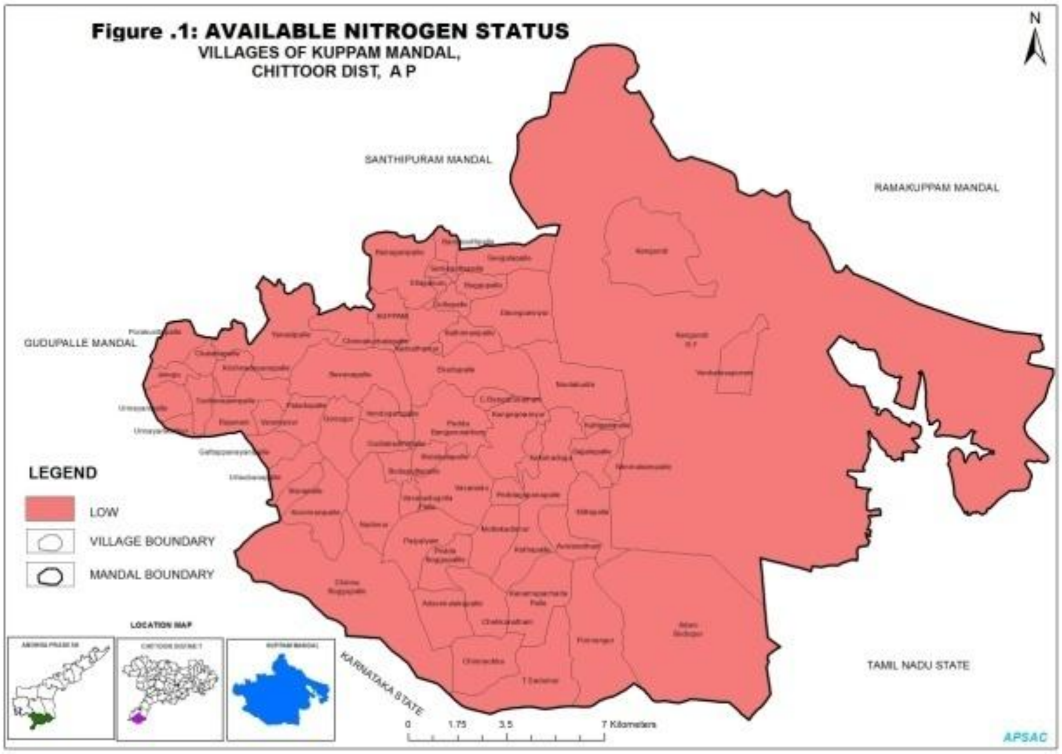


Figure .1: AVAILABLE NITROGEN STATUS
VILLAGES OF KUPPAM MANDAL,
CHITTOOR DIST, A P
N
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
LEGEND
LOW
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
KARNATAKA STATE
TAMIL NADU STATE
0
1.75
3.5
7 Kilometers
APSAC

Fig.2

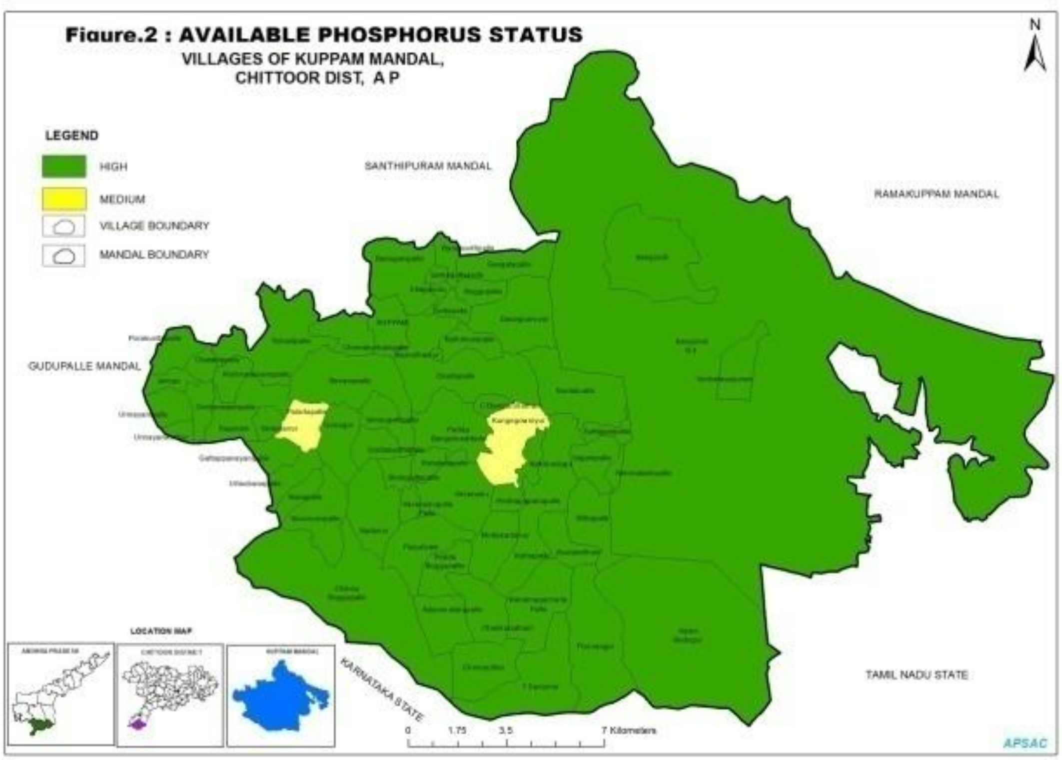


Figure.2 : AVAILABLE PHOSPHORUS STATUS
VILLAGES OF KUPPAM MANDAL,
CHITTOOR DIST, A P
N
LEGEND
HIGH
MEDIUM
VILLAGE BOUNDARY
MANDAL BOUNDARY
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
LOCATION MAP
KARNATAKA STATE
TAMIL NADU STATE
0
1.75
3.5
7 Kilometers
APSAC

Fig.3

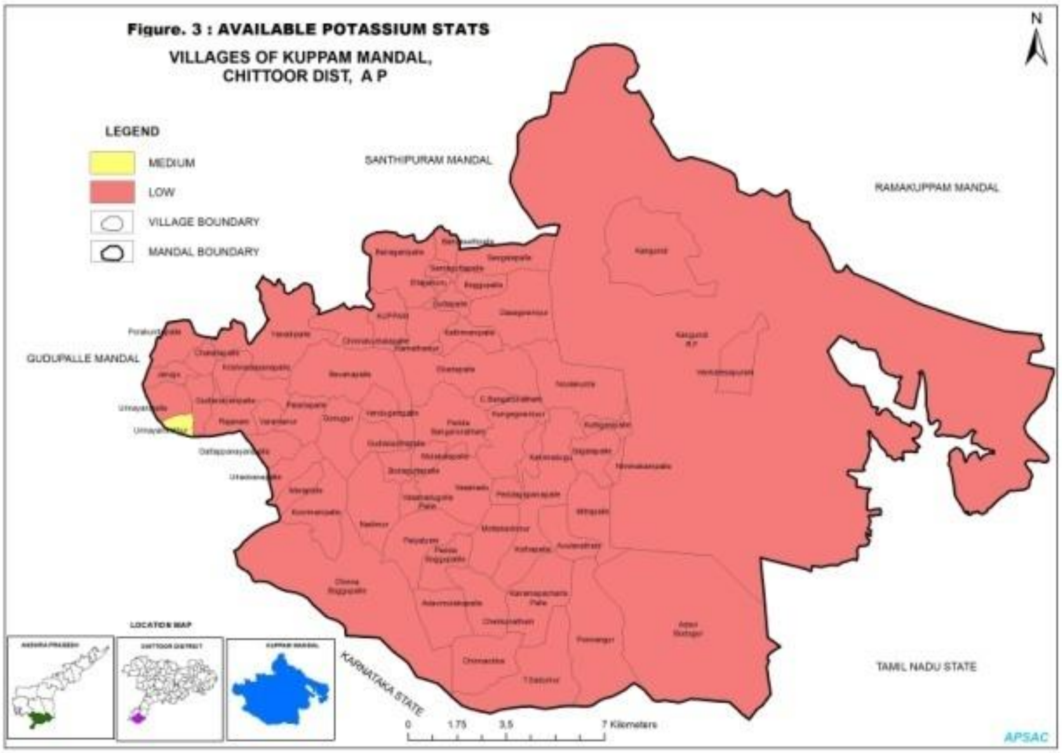


Figure. 3 : AVAILABLE POTASSIUM STATS
VILLAGES OF KUPPAM MANDAL,
CHITTOOR DIST, A P
LEGEND
MEDIUM
LOW
VILLAGE BOUNDARY
MANDAL BOUNDARY
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
TAMIL NADU STATE
KARNATAKA STATE
LOCATION MAP
0
1.75
3.5
7 Kilometers
APSAC
N

Fig.4

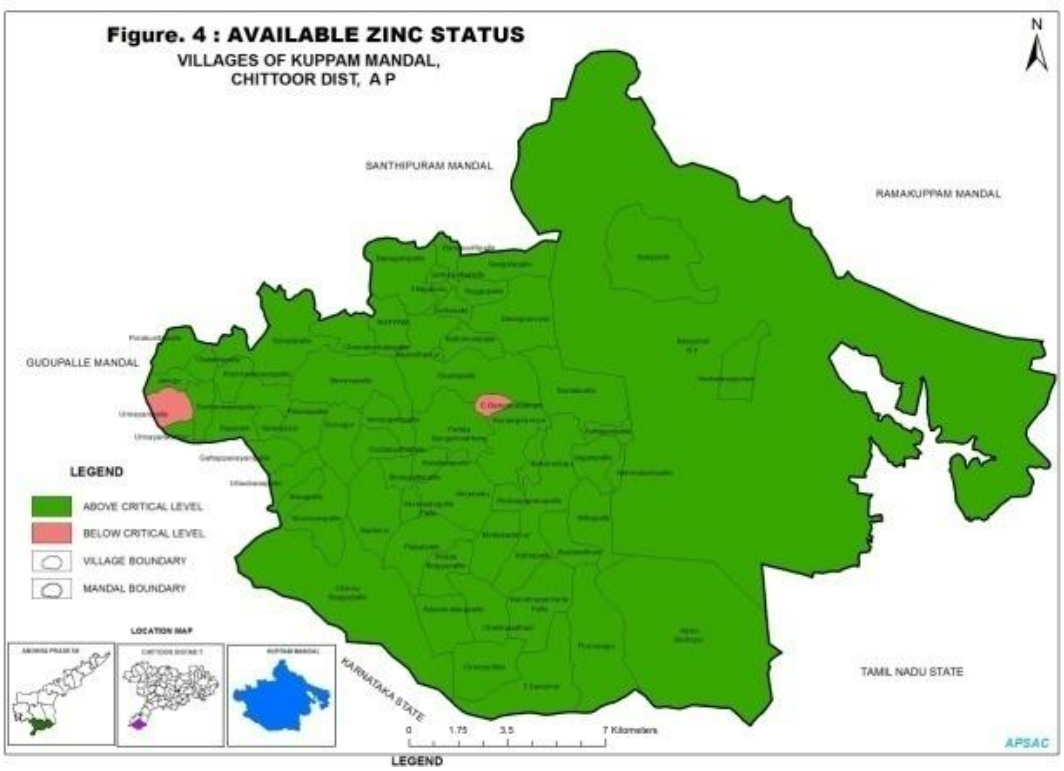


Figure. 4 : AVAILABLE ZINC STATUS
VILLAGES OF KUPPAM MANDAL,
CHITTOOR DIST, A P
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
LEGEND
ABOVE CRITICAL LEVEL
BELOW CRITICAL LEVEL
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
KARNATAKA STATE
TAMIL NADU STATE
0
1.75
3.5
7 Kilometers
APSAC
N
LEGEND

Fig.5

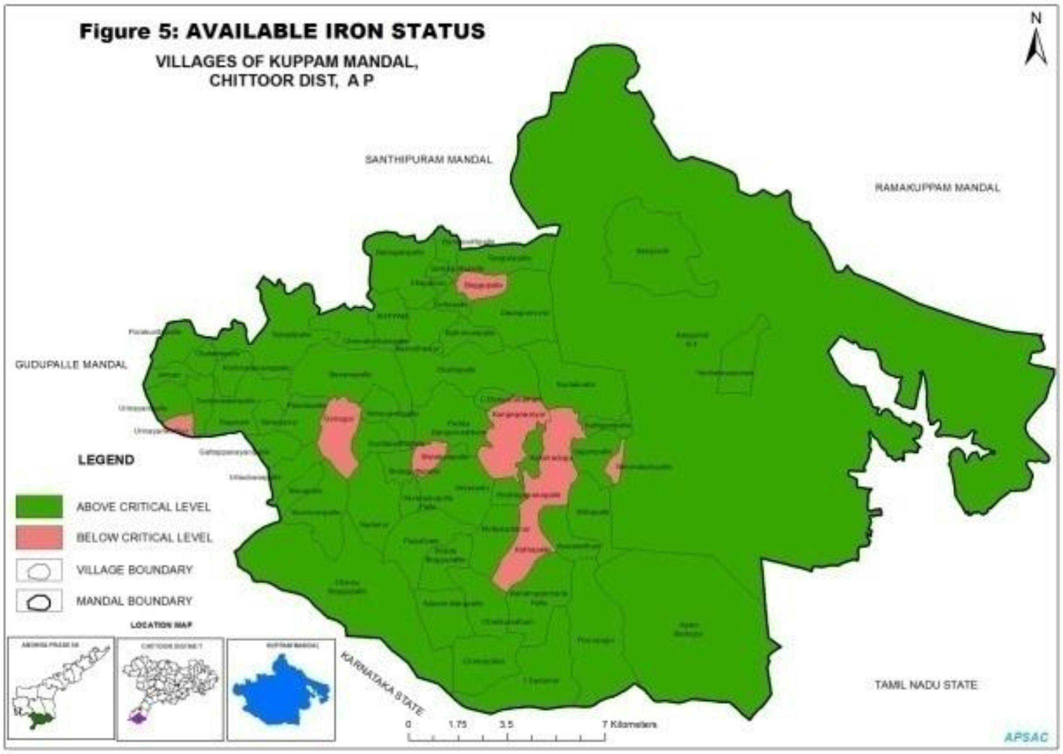


Figure 5: AVAILABLE IRON STATUS
VILLAGES OF KUPPAM MANDAL, CHITTOOR DIST, A P
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
LEGEND
ABOVE CRITICAL LEVEL
BELOW CRITICAL LEVEL
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
KARNATAKA STATE
TAMIL NADU STATE
0 1.75 3.5 7 Kilometers
APSAC
N

Fig.6

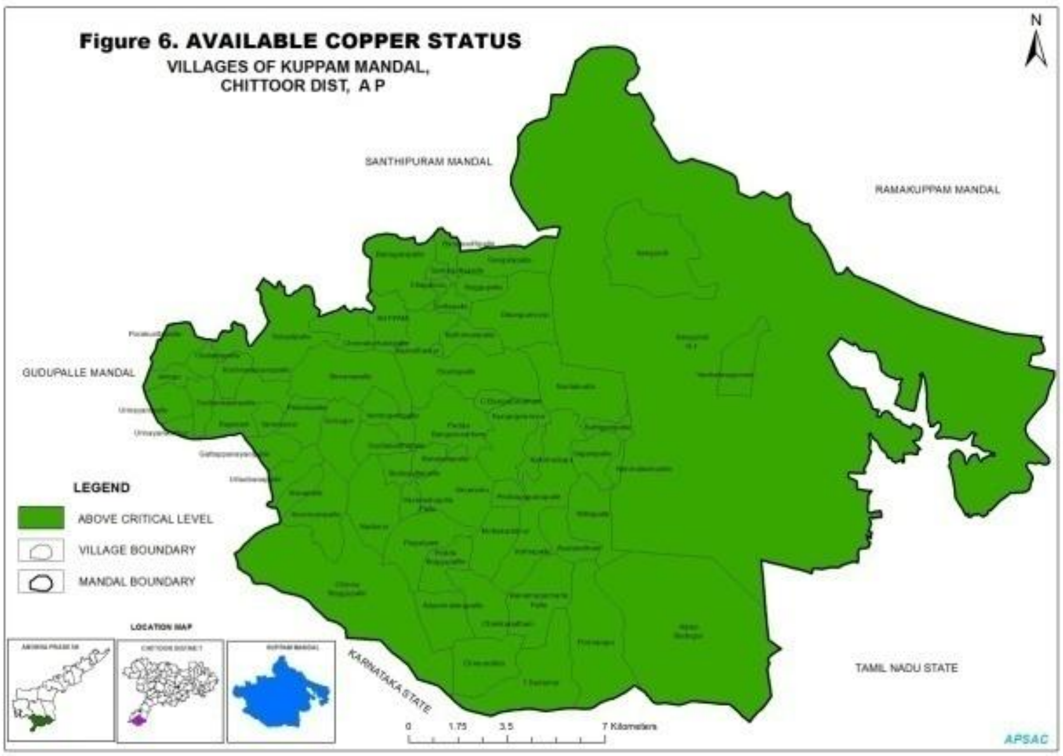
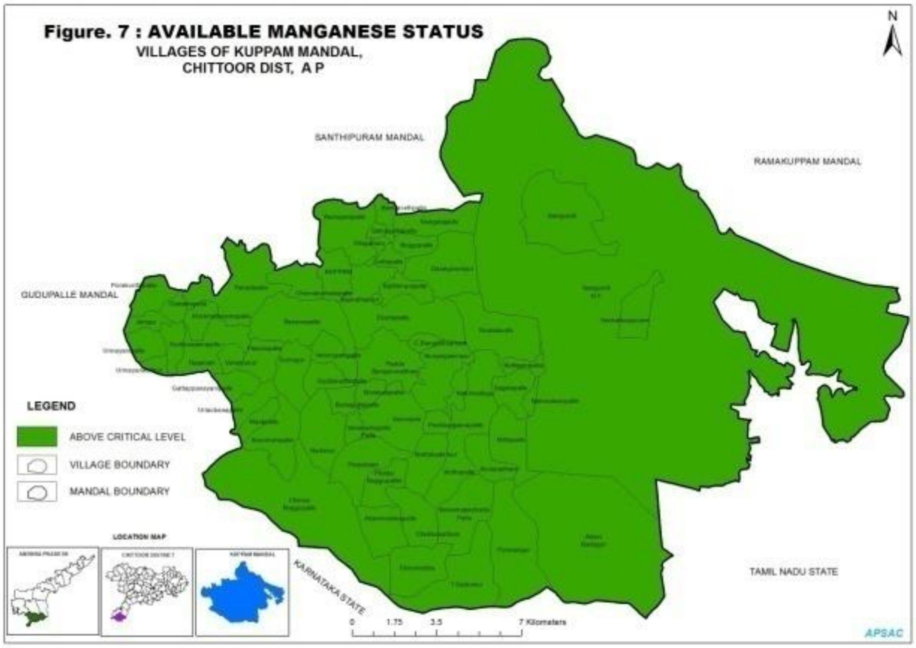


Figure 6. AVAILABLE COPPER STATUS
VILLAGES OF KUPPAM MANDAL, CHITTOOR DIST, A P
SANTHIPURAM MANDAL
RAMAKUPPAM MANDAL
GUDUPALLE MANDAL
LEGEND
ABOVE CRITICAL LEVEL
VILLAGE BOUNDARY
MANDAL BOUNDARY
LOCATION MAP
KARNATAKA STATE
TAMIL NADU STATE
0 1.75 3.5 7 Kilometers
APSAC
N

Fig.7



The spatial content of the available K_2O is presented in Figure 3 shows that 651 (47.1%) samples recorded low, 549 (39.8%) samples recorded medium and only 181 (13.1%) samples recorded high status (Table 1). Earlier we use to say that most of our soils are rich in potassium but this result shows the depletion of potassium reserves and need for balanced fertilization. As against the general perception, most of the soils in the study area are having low to medium Potassium content. So application of required quantities of potassium fertilizers based on soil test results is required to achieve the yield enhancement (Bansal, 1999).

With the intensive cropping of high yielding varieties deficiencies of Zinc (Zn) initially, and subsequently deficiencies of Iron (Fe) and Manganese emerged as threats to sustaining high levels of production (Singh 2008). The DTPA extractable nutrients were analysed and the available Zinc status was sufficient in 1089 (78.9%) samples and 292 (21.1%) (Table 2) samples recorded deficiency of Zinc (Figure 4). Available iron was sufficient in 878 (63.6%) samples and deficient in 503 (36.4%) (Table 2) samples (Figure 5). Copper is sufficient in all most all the soil samples 1335 (96.7%) (Table 2) and deficient in only 46 (3.3%) samples (Figure 6). Manganese is also sufficient in majority 1282 (92.8%) samples and deficient in only 99 (7.2%) samples (Figure 7) and (Table 2).These results clearly shows that there is a scope to increase the yield by applying micronutrients also where ever needed.

In conclusion, from the study it can be concluded that most of the soils of Kuppam mandal are having very low available nitrogen and also the farmers are using less nitrogenous fertilizers than the required against the general perception of high nitrogen use. So by applying sufficient quantities of nitrogen higher yields can be achieved. The practice of phosphorus top dressing is there in this mandal also, we have to educate the farmers to avoid this, by which cost of cultivation can be reduced. Generally all our soils are rich in potassium, but due to continuous cultivation and imbalanced fertilization potassium deficiency is also observed. Micronutrient deficiencies were also observed though not in major area, but it is a matter of concern to achieve the double digit growth. Soil nutrient status thematic maps were generated by using Geostatistical – variogram analysis and spatial interpolation (kriging). These maps will be used to make site specific fertilizer recommendations to any crop for precision agriculture to achieve sustainability.

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