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Site Specific Nutrient Management Options for Achieving Higher Yields in Cotton and Chickpea under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration among all authors. 'All authors read and approved the final manuscript.

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ABSTRACT

A study was undertaken to delineation of spatial variability of soil fertility status in order to prepare soil available nutrient maps for improved productivity in different crops grown in the study area of Kurnool revenue division in Kurnool district of Andhra Pradesh state using remote sensing and GIS techniques. The Knowledge of spatial-variability is critical for site specific nutrient management in soil fertility to obtain higher yields. Soil sample (350) were collected from surface from 350 selected sites for preparing precise digital maps using point, line and polygon tools of the Geographic Information System (GIS) with ArcGIS software 10.3 was used for database creation and for

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creating the union of various thematic maps. The spatial variability maps were generated and delineated into different zones for N, P and K. Soil available Nitrogen, Phosphorus and Potassium spatial variability values generated from the thematic maps of Kurnool division were used to establish fertilizer recommendations for cotton in kharif and Chickpea in rabi during 2018-19 seasons. The recommended doses of Nitrogen (RDN) that worked for cotton were 401 to 450, 351 to 400, > 450 and < 350 kg ha^{-1} for the areas with Nitrogen availability of 140 to 210, 210 to 280, <140 and > 280 kg/ha, respectively. The Phosphorous fertilizer recommendation for soils with available P of < 30 kg/ha and > 30 kg/ha was figured out as > 250 kg ha^{-1} and < 250 kg ha^{-1}, respectively. For soil available Potassium recorded 230 to 560, < 230 and > 560 kg/ha, the K recommendation was figured out as 301 to 400, > 401 and < 300 kg/ha, respectively. Recommended doses of Nitrogen (RDN) was worked out for chickpea were 51 to 75, > 76 and < 50 kg/ha for the areas with available N ranges of 184 to 280, < 184 and > 280 kg/ha, respectively. The Phosphatic fertilizer recommendation for soils of available P of < 23.5 and 23.5 to 40 kg/ha was figured out as > 200 kg/ha and 171 to 200 kg/ha, respectively. For the soil available potassium recorded 253 to 412, 413 to 570, < 253 and > 570 kg/ha, the K recommendation was figured out as 66 to 100, 31 to 65, > 100 and < 30 kg/ha, respectively.

Keywords: Soil test crop response equation; soil fertility; site specific nutrient management; soil test based fertilizer application.

1. INTRODUCTION

Site-Specific Nutrient Management (SSNM) is frequently used terminology in general with reference to addressing nutrient deficiencies that exist within fields and correcting them by nutrient application to match these locations or soil differences. In SSNM concept of Johnston et al. [1], fertilizer dosages were established, grounded on the nutrient removal by crops adjusting the soil residual nutrients. In this concept, both the macro nutrients and secondary nutrients were applied at dosages that are required to meet the crop removal and the blanket recommendation of micronutrients were done when the results of soil testing were tested to be deficit or marginal. This allows complete yield expression of crop in the absence of any nutrient deficiency. Satyanarayana et al. [2] reported new tools and strategies for SSNM with reference to macro nutrients. Tools connecting information technology gives the scope that the small-scale farmers can adopt Site Specific Nutrient Management (SSNM). With this point of view, the farmer becomes Nutrient Expert and Manager. Fertility mapping based on Geographical Information System (GIS) can evaluate the difference in distribution of innate nutrients and other soil characters limiting the crop yield across larger areas and thus facilitate strategic planning for appropriate nutrient management leading better yields and ecological safety.

In precision farming, the basic perception of management zone had been developed in response to larger variability with the purpose of driving efficient usage of agricultural inputs with reference to soil spatial variation and their properties. Site specific management zones are often called as homogenous sub-regions having similar yield limiting factors. This is confirmed with findings of Doerge, [3] and Khosla et al. [4]. The utmost important procedure to obtain data with regard to soil maps through spatial interpolation of point-based capacities of soil properties for sustainable development of soil resources and water.

Crops like sorghum, cotton, rice, chickpea and blackgram are largely cultivated in Kurnool district of Andhra Pradesh and are one of the prominent seed producing districts of Andhra Pradesh. Farmers of the district take up intensive crop management applications which includes excessive usage of inorganic chemical fertilizers and pesticides beyond recommended doses which results in higher cost of cultivation that coupled with declining net returns. Hence, an effort was done to describe the soil fertility zones by using Remote Sensing (RS) and GIS techniques so as to endorse the fertilizers for vital crops through site specific nutrient management (SSNM) and also by exploiting the spatial variability of fertility in the study field.

2. MATERIALS AND METHODS

The study area, comprises of five Mandals (Kurnool, Gudur, Kallur, C. Belagal and Kodumur) of Kurnool Agricultural Revenue Division, Kurnool District, Andhra Pradesh is located on NH 44. Its geographic limits are from

15°54′18″ to 15°33′15″ N latitudes and 77°36′18″ to 78°12′21″ E longitudes. It is located in scarce rainfall agro climatic zone of Andhra Pradesh. Considering the uniformity of soil sample distribution in the study area, three hundred and fifty (350) surface soil samples were collected at a depth of 0-15 cm in a systematic pattern from different locations during kharif and rabi, 2018-19 using GPS. These surface soil samples were collected by adopting the procedure given by Jackson [5].

2.1 Laboratory Analysis

The soil samples were air dried under shade, pounded with mortar and pestle and passed through 2.0 mm sieve and were analysed for various properties by adopting standard procedures. The methods employed are described below:

2.2 Available Nitrogen

The available nitrogen was determined by alkaline permanganate method outlined by Subbaih and Asija [6] and the results were expressed in kg ha^{-1}.

2.3 Available Phosphorus

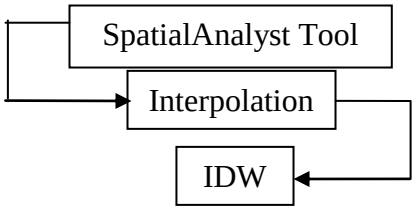
The available phosphorus content of soils was extracted by using Olsen's extractant as described by Olsen *et al.* [7] and phosphorus in the extract was determined by Murphy and Riley method (using ascorbic acid as a reducing agent) as described by Watanabe and Olsen [8] using spectrophotometer (Jasco V-530 UV/ Visible spectrophotometer) at 660 nm wavelength.

2.4 Available Potassium

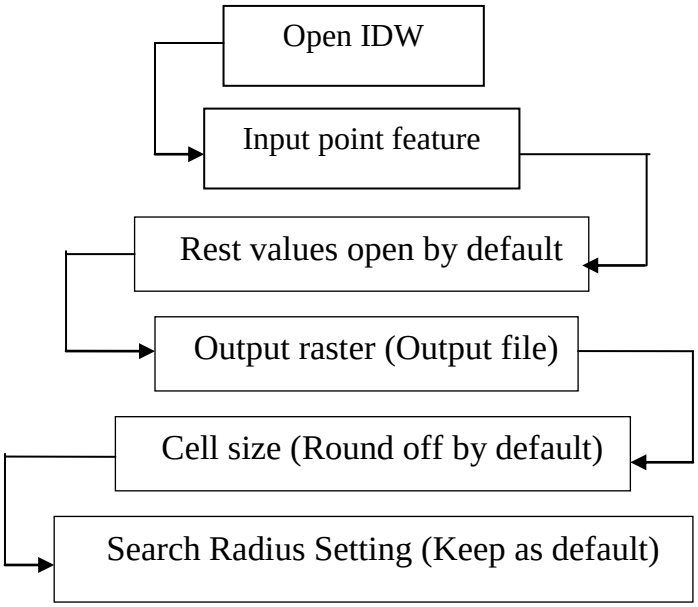
Available potassium in the soils was extracted by neutral normal ammonium acetate and determined by using the flame photometer [5].

2.5 Methodology for Developing Soil Fertility Maps by IDW Method

Step-1: For developing XY, use information of Survey No./Khasra No. to select the sample location and convert the geographic position of grid into XY.
Step-2: Convert XY into point layer
Step-3: In XY, insert field for attributes like N, P, K, …… integer type
Step-4: For Area of Interest, take village boundary layer in polygon format
Step-5: Bring both layers in Table of Contents
Step-6: Open Arctool Box



Step-7: Miscellaneous areas should not be a part of IDW analysis



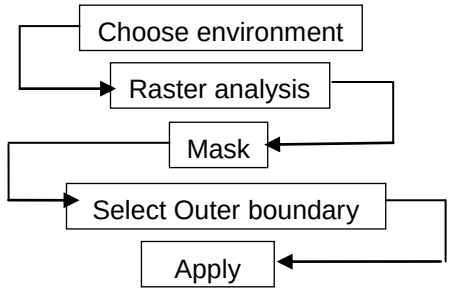
Step-8: Select IDW

Step-9: For barrier, use polyline (feature) of River, Road, Habitation, etc on miscellaneous area. For converting polygon to polyline, use conversion tool- Polygon to Line.

Step-10: Use all miscellaneous feature layer (Polyline) as barrier in IDW (Optional)

Step-11: For masking, choose IDW before applying for final output. Change the environment inside the AOI in raster analysis. Mask by selecting the village boundary.

Step-12: In IDW dialogue box,



2.6 Preparation of Thematic Maps

Preparation of thematic maps for available nitrogen, phosphorus, potassium by adopting geostatistical tool of IDW (Inverse Distance Weighted) in ArcGIS 10.3 environment.

2.6.1 Inverse Distance Weighting (IDW)

All interpolation methods have been developed based on assumption that nearby points have more correlations and similarities than distant observations. In IDW method, it is assumed that the rate of correlations and similarities between neighbors is proportional to the distance between them that can be defined as a distance reverse function of every point from neighboring points [9]. IDW method works best with evenly distributed points. The main factor affecting the accuracy of inverse distance interpolator is the value of the power parameter 'p'. [10]. The size of the neighborhood and the number of neighbors are also relevant to the accuracy of the results.

Soil available macro nutrients *viz.,* Nitrogen, Phosphorus and Potassium spatial variability values generated from the thematic maps of Kurnool division were used to determine fertilizer recommendations for cotton in *kharif* and chickpea in *rabi* during 2018-19 seasons. The actual Nitrogen, Phosphorus and Potassium fertilizer nutrient recommendations were derived using the fertilizer equations based on the targeted yield approach developed by All India Coordinated Research Project (AICRP) on Soil Test Crop Response, Hyderabad for cotton and chickpea. Fertilizer prescription equations for targeted yield of crops were developed for major two crops (chickpea and cotton) in study area of Kurnool division based on All India Coordinated Research Project (AICRP) on Soil Test Crop Response, Hyderabad. Fertilizer doses were fixed with the use of these equations for chickpea and cotton for obtaining targeted yields that lead to increase in crop productivity in the study field. The prescribed fertilizer recommendations for a soil test value for cotton and chickpea crops are given in Table 1.

Table 1. Fertilizer prescription equations for two major crops in the study area

S/No	Crop	Fertilizer adjustment equations
1.	Cotton (*kharif*)	FN = 15.63 T – 0.70 SN
		FP_2O_5 = 8.96 T – 2.15 SP
		FK_2O = 13.41 T – 0.304SK
2.	Chickpea (*rabi*)	FN = 5.03 T – 0.27 SN
		FP_2O_5 = 9.71 T – 1.82 SP
		FK_2O = 6.23 T – 0.22 SK

Where, T – Targeted yield (q/ha)
SN – Soil available N (kg/ha)
SP – Soil available P_2O_5 (kg/ha)
SK – Soil available K_2O (kg/ha)

At division level, SSNM of key nutrients for different crops were assumed on the basis of spatial variability of such nutrients. For this purpose, crop recommendations as proposed by IISS (Indian Institute of Soil Science), Bhopal over Four Decades of STCR Research - Crop Wise Recommendations was reserved as the standard reference.

The fertilizer recommendations established using fertilizer adjustment equations from Soil Test Crop Response can be denoted in the arrangement of spatial fertilizer recommendation map by relating the information with soil fertility maps. The fertilizer recommendation maps for diverse management zones in terms of nitrogen, phosphorous and potassium were derived by IDW interpolation method in Geographical Information System environment.

3. RESULTS AND DISCUSSION

3.1 Soil Test Based Fertilizer Recommendation

From the present study, balanced fertilizer recommendation for the study area in different crops was based on the available soil nutrient status from soil samples collected five Mandals (Kurnool, Gudur, Kallur, C. Belagal and Kodumur) of Kurnool Agricultural Revenue Division division as described below.

Considering major nutrients i.e. available N, P & K; 25% higher than the actual dose of fertilizer (RDF) for a crop in interest could be given in the experimental area as the available nutrient is low in soil. In case of high status of a nutrient in a field, 25% less than the recommended dose of fertilizer (RDF) can be given. When the nutrient content of fields lies in medium range, the actual recommended dose of fertilizer containing that nutrient is given as per the university recommendations (ZREAC proceedings, RARS, Nandyal) [11].

The Sulphur content of the studied field revealed that more than 30% soils of Kurnool division were deficient in Sulphur and hence Sulphur containing fertilizers like Gypsum, Phospho-gypsum, Single Super Phosphate could be recommended for these areas according to the crops grown. It was observed that in the study area, more than 76% of soils were deficient in zinc. The recommended dose of basal application of Zinc Sulphate @ 50 kg/ha can be applied once in three years for the crops in investigated area. Further, to arreviate Zinc deficiency symptoms in the standing crops, foliar application of $ZnSO_4$ @ 0.2 % for once or twice is recommended.

3.2 Soil Fertility Maps and Soil Test Crop Response Based Fertilizer Recommendations

3.2.1 Fertilizer recommendations for cotton

The recommended nitrogen for the investigated area is about 150 kg ha^{-1} for cotton crop in the traditional approach considering as a similar unit. Similarly, P and K requirements for cotton are 60 kg ha^{-1} (ZREAC proceedings, RARS, Nandyal). Same dose of fertilizer application throughout the area may lead to fertilizer underutilization or over utilization due to the spatial variability of nutrient status within the field. This not only decreases the FUE (Fertilizer Use Efficiency) and quality of soil but also upsurges the input cost. Hence, judicial SS fertilizer application needs to be followed precisely as a step towards sustained production. This could be obtained by applying variable fertilizers rates across the field to cope up the variation in fertility of soil. Fertility maps developed through kriging method could be utilized to demarcate the cultivated fields into different management zones that are having variations in fertility levels [12]. Recommended NPK for cotton crop in various defined zones of NPK were given on the basis of Soil Test Crop Response Equations. These equations consider the nutrient requirement of targeted crop yields as well as the soil inherent nutrients resources. The spatial variability of respective recommendations of available NPK for 2018-19 of cotton crop were furnished in tabular No. 2 for Kurnool division. Singh et al. [13] has reported that to produce anticipated yield of any crop, SSNM (Site Specific Nutrient Management) is required for balance and adequate nutrients supply without effecting the inherent soil fertility status.

The delineated area of Kurnool division during 2018-19 shows 4 zones, where the extreme area (77.71 %) comes under 140 to 210 kg/ha zone covering 100516.31 ha, followed by 21.95% of area (28386.84 ha) comes under 210 to 280 kg/ha, 0.23 per cent (292.73 ha) under < 140 kg ha^{-1} and 0.12 per cent under > 280 kg/ha. The recommended doses of N for cotton during 2018-19 were 401 to 450, 351 to 400, > 450 and < 350 kg/ha for the areas falls under available N ranges of 140 to 210, 210 to 280, < 140 and > 350 kg/ha zones, respectively (Fig.1).

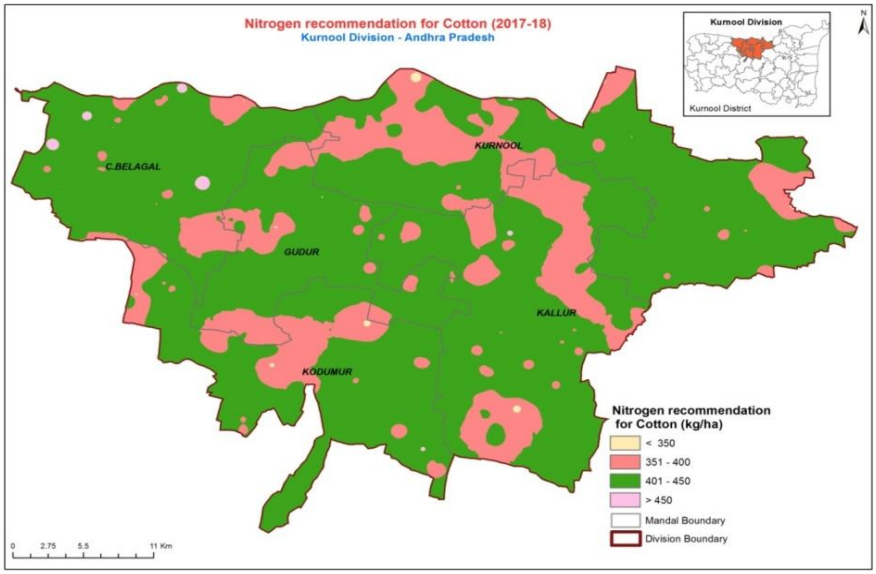


Fig. 1. STCR based Nitrogen recommendation map for Cotton during 2018-19

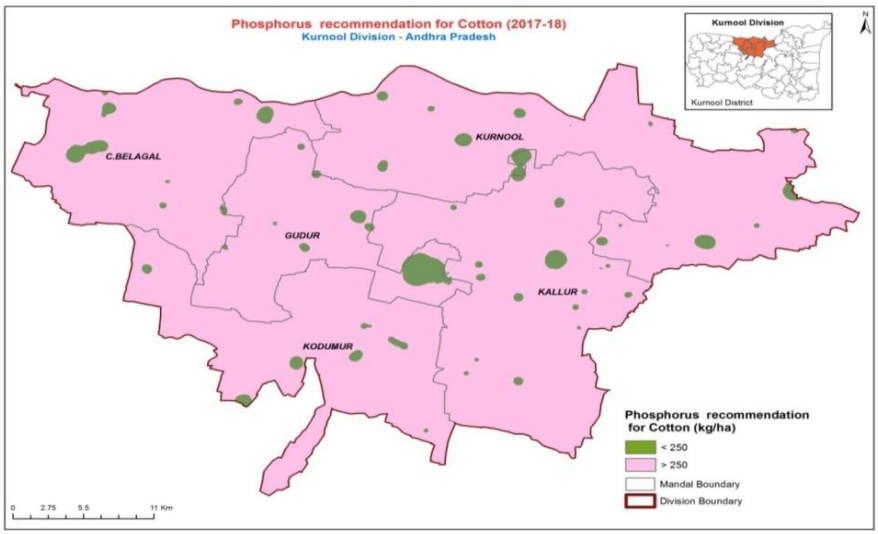


Fig. 2. STCR based Phosphorus recommendation map for Cotton during 2018-19

The delineated area of available Phosphorus during 2018-19 pertaining to Kurnool division showed that maximum area (97.08 %) comes under < 30 kg/ha zone covering 125576.13 ha with recommended phosphorus of > 250 kg ha^{-1} for Scarce Rainfall Zone, while the residual area of 2.92 % (3771.51 ha) falls under > 30 kg ha^{-1} with a recommended phosphorus of < 250 kg/ha (Fig. 2).

During 2018-19, areas delineated for available potassium in the investigated area shows 3 zones, where the maximum area in study zone (99.81%) comes underneath 230 - 560 kg/ha zone covering 129098.38 ha, followed by 0.15 % of area (188.41 ha) that comes under < 230 kg/ha and remaining small portion of area (60.85 ha) under > 560 kg/ha. The potassium recommendation for these zones were 301 to 400, > 401 and < 300 kg/ha for the areas below available potassium ranges of 230 to 560, < 230 and > 560 kg/ha zones respectively (Fig. 3).

3.2.2 Fertilizer recommendations for chickpea

Fertilizer recommendations for chickpea for 2018-19 in Kurnool division based on the spatial variability of NPK is mentioned in the Table 3.

The area delineated zones of available N during 2018-19 showed three zones, where maximum area (70.47 %) falls under 184 to 280 kg/ha zone covering 91154.78 ha, the range of recommended dose of Nitrogen (RDN) was 51 to 75 kg ha^{-1} followed by 29.39% (38020.97 ha) under < 184 kg/ha with a suggested dose of >76 kg ha^{-1} and remaining area of 171.89 ha is under > 280 kg /ha with a suggested dose of < 50 kg ha^{-1} (Fig. 4).

The spatial variability area of phosphorus availability in demarcated study zones during 2018-19 resulted in two zones, where the highest area (58.42 %) comes under < 23.5 kg/ha zone covering 75558.48 ha, the recommended dose of phosphorus for this range is > 200 kg/ha, while the leftover area of 41.58% (53789.16 ha) under 23.5 to 40 kg ha^{-1} with a recommendation of 171 to 200 kg ha^{-1} (Fig. 5).

Delineated areas of potassium availability in studied area for the year 2018-19 shows four zones, where, the maximum area (72.81%) falls under 253 to 412 kg/ha covering 94177.85 ha then followed by 26.73% of area (34569.64 ha) under 413 to 570 kg/ha, 0.45 per cent (576.43 ha) under < 253 kg ha^{-1} and remaining small portion of area (23.72 ha) under > 570 kg ha^{-1}. The recommended doses of potassium were 66 to 100, 31 to 65, > 100 and < 30 kg/ha for the study zones under potassium availability of 253 to 412, 413 to 570 and > 570 and < 253 kg/ha zones, respectively (Fig.6).

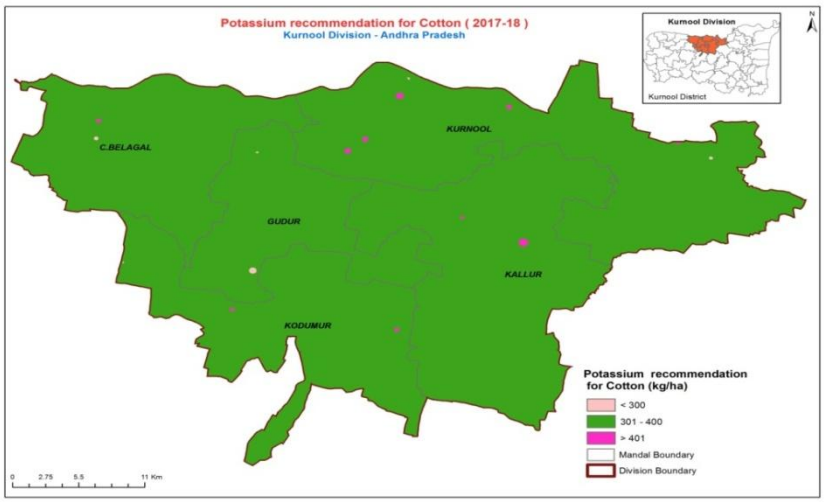


Fig. 3. STCR based Potassium recommendation map for Cotton during 2018-19

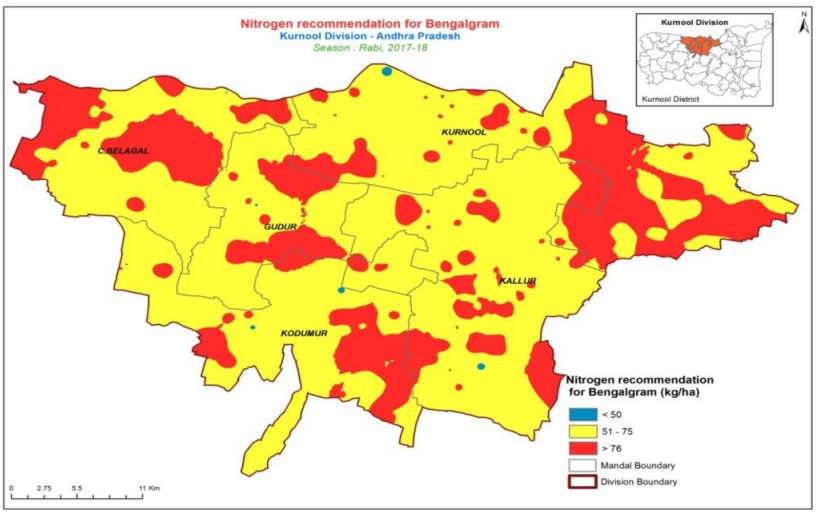


Fig. 4. STCR based Nitrogen recommendation map for Chickpea during 2018-19

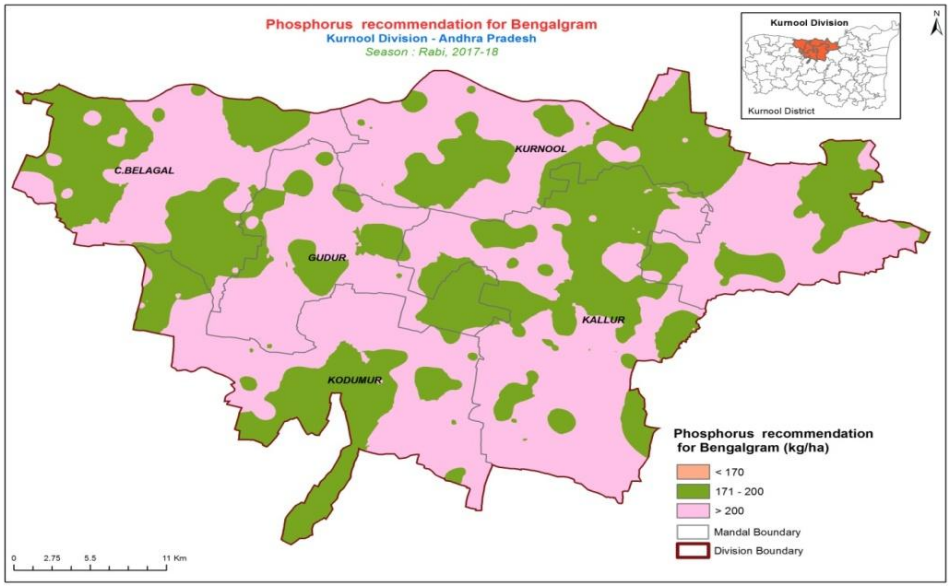


Fig. 5. STCR based Phosphorus recommendation map for Chickpea during 2018-19

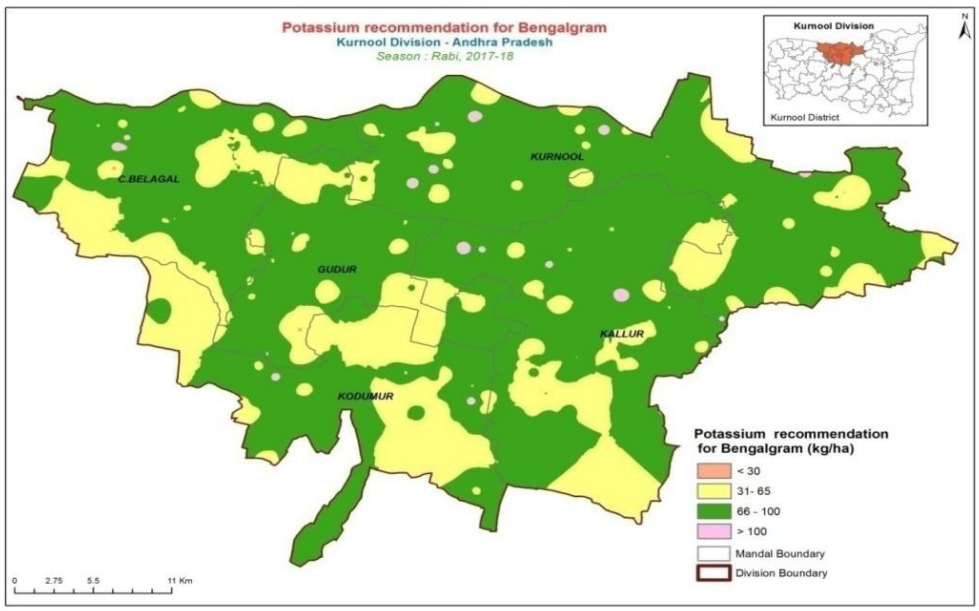


Fig. 6. STCR based Potassium recommendation map for Chickpea during 2018-19

As per the information emanated during the survey work, it can be concluded that all three major nutrients, NPK are being applied in larger quantities in accordance to the general recommendations. In some of the areas low levels of phosphorus was applied, where P requirement is higher than that of recommended dose resulting in decrease of grain yields and nutrient availability that leads to soil quality deterioration, increase in input cost per unit production and reduction in fertilizer use efficiency (FUE). Thus, study on spatial variability fertility status of soil in an area and corresponding recommendation and further application of fertilizers is necessary for improving the efficiency of fertilizer application and returns to the growers. Recommended dose of fertilizers were related with hypothetical nitrogen fertility map derivative of fertilizer adjustment equations and produced spatial N recommendation maps for potential yield by Patil et al. (2001). More variations identified in nutrient

Table 2. STCR Based Fertilizer Recommendation for Cotton in Kurnool division during 2018-19

Nitrogen				Phosphorus				Potassium			
Range	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**	**Range**	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**	**Range**	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**
>280	151.76	0.12	< 350	> 30	3771.51	2.92	< 250	> 560	60.85	0.05	<300
210 – 280	28386.84	21.95	351 - 400	< 30	125576.13	97.08	> 250	230 – 560	129098.38	99.81	301 - 400
140 – 210	100516.31	77.71	401 - 450	-	-	-	-	< 230	188.41	0.15	> 401
< 140	292.73	0.23	> 450	-	-	-	-	-	-	-	-

Table 3. Soil Test Based Fertilizer Recommendation for Chickpea in Kurnool division, 2018-19

Nitrogen				Phosphorus				Potassium			
Range	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**	**Range**	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**	**Range**	**Area (ha.)**	**Area (%)**	**Recommended (kg ha^{-1})**
> 280	171.89	0.13	< 50	> 40.0	-	-	-	> 570	23.72	0.02	< 30
184 – 280	91154.78	70.47	51 - 75	23.5 – 40.0	53789.16	41.58	171 - 200	413 – 570	34569.64	26.73	31 - 65
< 184	38020.97	29.39	> 76	< 23.5	75558.48	58.42	> 201	253 – 412	94177.85	72.81	66 - 100
-	-	-	-	-	-	-	-	< 253	576.43	0.45	> 100

levels supports the need for variable rate of fertilization [14]. Sen et al. [15] also stated that appropriate understanding of spatial nutrient variability as a core issue and integrating it into the fertilizer recommendation system can ascertain that fertilizer are used rationally and in a balanced manner. The economic analysis proved that Site Specific Nutrient Management aims in optimal fertilizer application to attain higher yield and higher fertilizer use efficiency resulting in decrease in production cost, protection of soil quality and health sustainability.

4. CONCLUSION

It can be concluded that the present study has revealed that based on soil available nutrient status more quantum of fertilizers needed to be applied than the recommended dose in order to obtain the targeted yields of respective crops. The Remote Sensing (RS) and GIS technologies are highly reliable in developing natural resource database to evaluate and integrate their potential on spatial basis. The use of geo-statistics enabled the assessment of heterogeneous nature of fertility variations. Integration of Geographical Information System with different models in present investigation was highly useful in generating the soil fertility and fertilizer recommendation maps. These investigations could be extended up to village level at micro level planning and management of crop fields provided real time availability of high spatial resolution satellite data. Further, the results provide actual estimates of fertilizer requirement for important crops of any area under study, thereby saving budget on fertilizer use at farmer's level as well as at planner's level.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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