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Spatial Fertilizer Recommendations for Ragi and Chilli Using GIS and GPS Techniques through STCR Approach

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ABSTRACT

The study was undertaken at Honnavalli micro-watershed of Hassan district in order to assess the soil fertility status and to prepare the soil fertility and fertilizer recommendation mapping for sustainable production major crops like ragi and chilli cultivated in the study area. The 105 grid soil samples are drawn over an area of 420 ha area of the study area and analyzed for major nutrients (Available Nitrogen, P_2O_5 and K_2O). The surface soil fertility maps of available nitrogen, phosphorus and potassium are prepared on the basis of soil fertility ratings. The site-specific fertilizer recommendations for ragi and chilli in Honnavalli micro-watershed were made through soil test crop response (STCR) targeted yield approach of fertilizer adjustment equations with the help of thematic maps of spatial variability of N, P and K status. Using STCR targeted yield of rice (45 q ha^{-1}) approach we recommended the nitrogen fertilizer (290, 286, 283, 281, 279, 276, 268 and 259 kg ha^{-1}), phosphorus (79, 77, 73, 70, 55 and 25 kg ha^{-1}) and potassium (94, 70, 58, 52, 45, 40 and 28 kg ha^{-1}). Similarly, in chilli (10 q ha^{-1} dry chilli) recommended dose of nitrogen fertilizer (104, 94, 87, 81, 79, 71 and 49 kg ha^{-1}), phosphorus (104, 94, 87, 81, 79, 71 and 49 kg ha^{-1}) and potassium (55, 48, 41, 34, 27 and 14 kg ha^{-1}) based on the soil test NPK value of the studied area.

Keywords: Geographic information system (GIS), Global positioning system (GPS), Micro-watershed, STCR, Soil fertility status, Fertilizer recommendation map

SOIL is the most wondrous gift of nature to all the earthlings. It is vital natural resource base perform fundamental functions for the benefit of humankind and environment. On count of this benevolence, Indians treat soil as 'mother' and cherish fondly that they were brought into being by it (soil). Share of India in global degraded soil area is about 10 per cent. It was largely impelled by anthropogenic misuse of soil via non-scientific, indiscriminate and non-sustainable intensive agricultural practices. In that pursuit, the present research work carried out on assessment of soil fertility status and fertilizer recommendation mapping for major crops grown in catchment area of Honnavalli micro-watershed of Hassan district by using geographical information system (GIS) techniques as a tool for precise and sustainable soil management (Denton *et al.,* 2017). Our aim of optimizing the utilization of land resources with intensification of agriculture resulted either in fast depletion of soil fertility status or occasionally in their accumulation. It is therefore important to monitor the fertility status of soil from time to time with a view to maintain the soil health. Hence, geo-referenced information on the location, extent, quality of land and display of spatial data is a must.

Geographic information system (GIS) is defined as a powerful set of tools for collecting, storing, transforming and displaying spatial data from real world (Zhang *et al.,* 2010). Precision agriculture (site-specific farming) involving remote sensing, global positioning system and geographical information system can be of great use for their assessment and management of soil fertility. This helps to identify the right input at the right time in the right amount, which not only avoid wastage of inputs but also reduce the pollution due to excessive use of inputs. Geographical Information System (GIS) analyses and displays multiple data layers derived from various sources and provides valuable support to handle voluminous data being generated through conventional and remote sensing technology both in spatial and non-spatial format. GIS can be used in producing a soil fertility map of an area, which will help in formulating balanced fertilizer recommendation (Yang *et al.,* 2012) and to understand the status of soil fertility spatially and temporally. Thus, GIS can be employed in various spheres of agriculture. Digital maps are very powerful tools to achieve this.

The proper method of fertilizer recommendation should consider crop needs and nutrient already exist in the soil. Desired balance of nutrients in the soil can be created by soil test-based fertilizer recommendations which also ensure an increase in the efficiency of fertilizer use. Among the various methods of soil fertilizer recommendations, fertilizer recommendation based on target yield concept (STCR approach) are used for fertilizer recommendation mapping. Since fertilizer is a costly input, soil test-based fertilizer will be applied based on the site specifications, crop specific requirements and soil test values.

Soil test-based application of fertilizer reduces the total amount of fertilizer applied to a given field. Further, variable rate application of fertilizers coupled with target yield approach economizes fertilizer use by avoiding wastage of costly fertilizer due to over and under application. Thus, the concept of grid-based fertility assessment and fertilizer recommendation will be helpful to supply the nutrients as per the crop demand to improve crop growth and yield. Honnavalli micro-watershed lies in Hassan district of Karnataka state where in important crops like paddy and maize are largely grown. Hence, an attempt was made to delineate the soil fertility status and fertilizer recommendation mapping with aim of providing balance nutrition through soil test-based fertilizer recommendation, using geographic information system (GIS) techniques for sustainable crop production in the study area.

MATERIAL AND METHODS

General Description of the Study Area

The Honnavalli micro-watershed is located in Alur taluk of Hassan district, Karnataka state (India) and having total geographical area of 420 hectares lies between 12° 56' 4.176" - 12° 56' 58.234" North latitude and 75° 54' 1.635" - 75° 54' 55.337" East longitude at 953 meters above mean sea level. The Honnavalli micro-watershed belongs to Agro-climatic zone No. VII of Karnataka (Southern Transition Zone) at about 10 km from Alur town. The zone covers 14 taluks of five districts. It has an area of 1.22 million ha. The zone consists of the Malnad, the Western Ghats and parts of the Plateau region. The average minimum and maximum temperature recorded was 18.20°C and 29.12 °C, respectively. The lowest temperature (14.83 °C) recorded in the month of December and high temperature (33.82 °C) in the month of April. The soils in the micro-watershed are majorly Alfisols and Inceptisols in some parts of micro-watershed.

Soil Testing and Fertilizer Recommendations

Soil testing is an important tool to assess the soil fertility and other soil properties, which are essential for better soil productivity. Soil testing includes soil sampling, processing, N P_2O_5 and K_2O analysis in laboratory, interpretation of results, making recommendation of fertilizer nutrients and manures for getting optimum yield of different crops being grown on the specific soil.

Mapping of Fertilizer Recommendation

Preliminary traverse of the entire Honnavalli micro-watershed was carried out with the help of cadastral map (1:4000 scale), satellite imagery (the merged data of Cartosat-1 (PAN) and Resourcesat-2 (LISS IV) and Survey of India toposheets. The field boundaries and survey numbers given on the cadastral sheet were located on ground by following permanent features like roads, cart tracks, canals, streams, tanks etc. and wherever changes noticed were incorporated on the cadastral map. GARMIN, GPS 72H receiver was used to collect the information regarding the geographical location of the ground truth sites. One hundred five composite surface (0-15 cm) soil samples were collected on 400 m grid intervals. The soil samples were processed, passed through 2 mm sieve and were analyzed for available N, P_2O_5 and K_2O and Organic carbon. Based on the location data obtained, prepared point feature showing the position of samples in MS excel format and linked with the spatial data by join option in Arc Map. The spatial and the non-spatial database developed are integrated for the generation of spatial distribution maps.

A data base file consisting of data for X and Y coordinate in respect of sampling site location was created. A shape file (vector data) showing the outline of Honnavalli micro-watershed area was created in Arc View 3.1. The data base file was opened in the project window and in X-field X-coordinates was selected and in Y-field Y-coordinates was selected. The Z field was used for different nutrients. The Honnavalli micro-watershed shape file was also opened and from the 'Surface menu' of Arc View spatial analyst 'Interpolate grid option' was selected. On the output 'Grid specification dialogue', output grid extends chosen was same as Honnavalli micro-watershed. Then map was reclassified based on ratings of respective nutrients. After the map was prepared, it was clipped to the study area shape and final mapping was carried out and exported as *.jpeg* or *.pdf* format. By interpolation of point data soil spatial variability maps were prepared. Initially, the geo-referenced soil test results for available N, available P (P_2O_5) and available K (K_2O) were plotted using ARC/Info software. The interpolation technique used was ordinary kriging. The fertilizer recommendations developed using fertilizer adjustment equations from STCR were displayed in the form of spatial fertilizer recommendation map by linking the information with soil fertility maps. The fertilizer recommendation maps for different management zones in terms of nitrogen, phosphorus and potassium were derived by kriging interpolation method in GIS environment. The Fertilizer adjustment equations developed by AICRP on STCR, University of Agricultural Sciences for zone VII were utilized for fertilizer recommendations are as follows.

Fertilizer Adjustment Equations for the Study Area for Ragi (45 q ha^{-1}) without FYM (organic matter)

F.N = 3.76 T - 0.28 SN ($KMnO_4$-N)

F.P_2O_5 = 1.83 T - 0.687 SP_2O_5 (Brays P_2O_5)

F.K_2O = 2.17 - 0.24 SK_2O (NH_4OAC K_2O)

Fertilizer Adjustment Equations for the Study Area for Dry Chilli (10 q ha^{-1}) with FYM

F.N = 15.50608 T - 0.17297 SN ($KMnO_4$-N) - 0.62342OM

F.P_2O_5 = 6.43276 T- 0.51573 SP_2O_5 (Brays P_2O_5) - 0.30331OM

F.K_2O = 7.29618 T - 0.15454 SK_2O (NH_4OAC K_2O) - 0.265326OM

Where, FN, FP_2O_5 and FK_2O are fertilizers N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the yield target in q ha^{-1}; SN, SP_2O_5 and SK_2O, respectively, are alkaline $KMnO_4$-N, Bray's P_2O_5 and NH_4OAc-K_2O in kg/ha and OM is organic matter supplied through farm yard manure (FYM)

RESULTS AND DISCUSSION

Application of fertilizer based on the general recommendation by assuming the homogenous units in farm fields. Such a single rate of fertilizer recommendation leads to under or over fertilization of the areas due to the existence of the nutrient variability within fields and this practice reduces fertilizer use efficiency. Soil test-based, site-specific management was initially developed to map spatial variability of nutrient within individual fields and to correlate this nutrient variability with yield variability. Mapping nutrient variability requires intensive sampling across the study area. GIS based site specific management helps for the better fertilizer management in the field. STCR approach of fertilizer prescription is more scientific, fully quantitative and situation specific (soil-crop-agroclimatic condition). Yield target can be lowered or increased by looking into the economic resources of the farmers and availability of fertilizers. Hence costly input fertilizer sources will be better managed for greater efficiency and soil health.

Fertilizer Recommendation Maps

For the purpose of site-specific nutrient management, ranges were derived and thematic maps were prepared. Thematic maps of Honnavalli micro-watershed were prepared by using spatial variability of soil available nitrogen, phosphorus and potassium and it is used to establish fertilizer recommendations for ragi and chilli. The study area was classified into different ranges by considering the soil test value of the major available nutrient. The actual N, P and K fertilizer nutrient recommendations were derived using the fertilizer prescription equations based on the targeted yield approach for Hassan district, developed by the AICRP on Soil Test Crop Response, University of Agriculture Sciences, GKVK, Bengaluru.

Fertilizer Recommendations for Ragi

The general recommendation of NPK fertilizers dose for ragi is 50-40-25 (N-P_2O_5-K_2O kg ha^{-1}) in Rainfed condition according to package of practices, UAS, GKVK, Bengaluru. The spatial NPK fertilizer recommendations for ragi crop were presented in Table 1.

The soil tested value of available nitrogen in Honnavalli micro-watershed is divided in to eight ranges for thematic mapping of study area. The result depicts that the maximum 184 ha (44%) area falls under <250 kg ha^{-1}, followed by 52 ha (11%) area under >500 kg ha^{-1}, 44 ha (09%) area with range of 400-500 kg ha^{-1}, 32 ha (08%) area ranges between 250-275 kg ha^{-1}, 32 ha (08%) area ranges between 350-400 kg ha^{-1}, 24 ha (06%) area with 325-350 kg ha^{-1}, and remaining 16 ha (04%) area ranges between 275-300 kg ha^{-1}. Using STCR targeted yield (45 q ha^{-1}) approach we recommended the fertilizer nitrogen at 22, 45, 66, 75, 81, 87, 93 and 110 kg ha^{-1} for the areas of soil test value of available nitrogen ranges <250, 250-275, 275-300, 300-325, 325-350, 350-400, 400-500 and >500 kg ha^{-1}, respectively (Fig. 1).

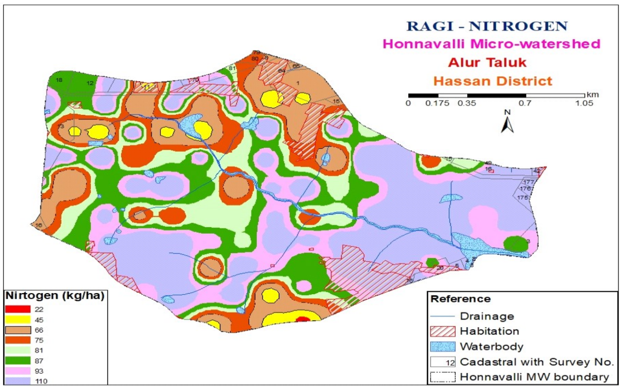

Fig. 1: Spatial nitrogen fertilizer recommendation map for ragi in Honnavalli micro-watershed

The soil tested value of available phosphorus in Honnavalli micro-watershed is divided in to six ranges for thematic mapping of study area. The result depicts that the maximum area of 136 ha (32%) falls under 5-10 kg ha^{-1}, followed by 116 ha (28%) area ranges between 10-15 kg ha^{-1}, 84 ha (20%) area with <5 kg ha^{-1}, 40 ha (9%) area belongs to 15-20 kg ha^{-1}, 24 ha (06%) area belongs to >60 kg ha^{-1} and remaining minimum area of 20 ha (05%) ranges between 20-60 kg ha^{-1}. Using STCR targeted yield (45 q ha^{-1}) approach we recommended the fertilizer phosphorus

TABLE 1

Soil test-based fertilizer recommendation for ragi in Honnavalli micro-watershed

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})
<250	184	44	110	<5	84	20	79	<100	116	28	94
250-275	32	08	93	5-10	136	32	77	100-140	64	15	70
275-300	16	04	87	10-15	116	28	73	140-180	60	14	58
300-325	36	09	81	15-20	40	09	70	180-200	44	10	52
325-350	24	06	75	20-60	20	05	55	200-225	28	07	45
350-400	32	08	66	>60	24	06	25	225-250	32	08	40
400-500	44	09	45	-	-	-	-	>250	76	18	28
>500	52	11	22	-	-	-	-	-	-	-	-

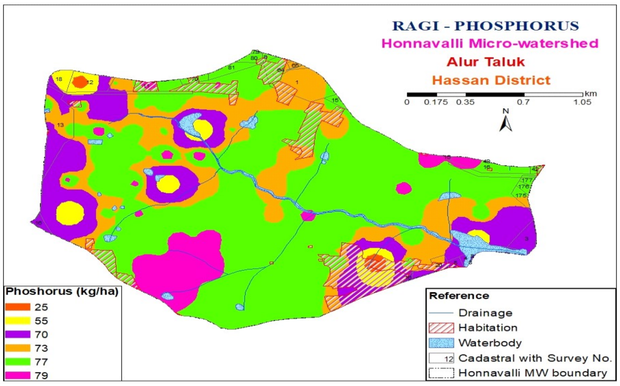

Fig. 2 : Spatial phosphorus fertilizer recommendation map for ragi in Honnavalli micro-watershed

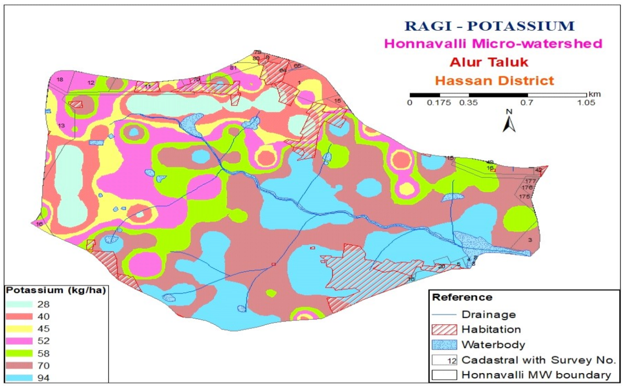

Fig. 3 : Spatial potassium fertilizer recommendation map for ragi in Honnavalli micro-watershed

at 79, 77, 73, 70, 55 and 25 kg ha^{-1} for the areas of soil test value of available phosphorus ranges <5, 5-10, 10-15, 15-20, 20- 60 and >60 kg ha^{-1}, respectively (Fig. 2).

The soil tested value of available potassium in Honnavalli micro-watershed is divided into seven ranges for thematic mapping of study area. The result depicts that the maximum 116 ha (28%) area under <100 kg ha^{-1}, followed by 76 ha (18%) area falls under >250 kg ha^{-1}, 64 ha (15%) area with range of 100-140 kg ha^{-1}, 60 ha (14%) area ranges between 140-180 kg ha^{-1}, 44 ha (10%) area comes under 180-200 kg ha^{-1}, 32 ha (08%) area ranges between 225-250 kg ha^{-1} and remaining 28 ha (07%) area ranges between 200-225 kg ha^{-1}. Using STCR targeted yield (45 q ha^{-1}) approach we recommended the fertilizer potassium at 94, 70, 58, 52, 45, 40 and 28 kg ha^{-1} for the areas of soil test value of available potassium ranges <100, 100-140, 140-180, 180-200, 200-225, 225-250 and >250 kg ha^{-1}, respectively (Fig. 3).

Basavaraj *et al*. (2017) observed higher ragi yield (57.96 q ha^{-1}) under STCR targeted yield approach of fertilizer prescription compared to package of practice (28.60 q ha^{-1}). Amit (2011) obtained higher ragi grain yield (34.46 q ha^{-1}) in soil test based NPK over all the treatments. Improvement in growth parameters and yield due to application of fertilizers on soil test basis may have increased the supply of adequate nutrients. Similar findings were reported.

Fertilizer Recommendations for Chilli

The general recommendation of NPK fertilizers dose for chilli is 100-50-50 (N-P_2O_5-K_2O kg ha^{-1}) in Rainfed condition according to package of practice, University of Agricultural Sciences, GKVK, Bengaluru. The NPK fertilizer recommendations for chilli crop are presented in Table 2.

The soil test value of nitrogen content in Honnavalli micro-watershed is divided in to seven ranges for thematic mapping of study area. The result depicts that the maximum 180 ha (43%) area falls under <250 kg ha^{-1}, followed by 76 ha (18%) area under >425 kg ha^{-1}, 56 ha (13%) area with range of 275-325 kg ha^{-1}, 32 ha (08%) area ranges between 250-275 kg ha^{-1}, 28 ha (07%) area ranges between 375-425 kg ha^{-1}, 24 ha (06%) area with 325-350 kg ha^{-1}, and remaining 20 ha (05%) area ranges between 350-375 kg ha^{-1}. Using STCR targeted yield (10 q ha^{-1} dry chilli) approach we recommended the fertilizer nitrogen at 104, 94, 87, 81, 79, 71, and 49 kg ha^{-1} and FYM (25 t ha^{-1}) for the areas of soil test value of available nitrogen ranges <250, 250-275, 275-325, 325-350, 350-375, 375-425, and >425 kg ha^{-1}, respectively (Fig. 4).

The soil test value of available phosphorus in Honnavalli micro-watershed is divided in to four ranges for thematic mapping of study area. The result depicts that the maximum area of 224 ha (53%) falls under <10 kg ha^{-1}, followed by 120 ha (29%) area ranges between 10-15 kg ha^{-1}, 44 ha (10%) area ranges between 15-20 kg ha^{-1} and remaining minimum area

TABLE 2

Soil test-based fertilizer recommendation for Chilli in Honnavalli micro-watershed

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})
<250	180	43	104	<10	224	53	53	100-140	112	27	55
250-275	32	08	94	10-15	120	29	50	140-180	68	16	48
275-325	56	13	87	15-20	44	10	48	180-240	60	14	41
325-350	24	06	81	>20	32	08	18	240-280	92	23	34
350-375	20	05	79	-	-	-	-	280-320	32	08	27
375-425	28	07	71	-	-	-	-	>320	48	12	14
>425	76	18	49	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

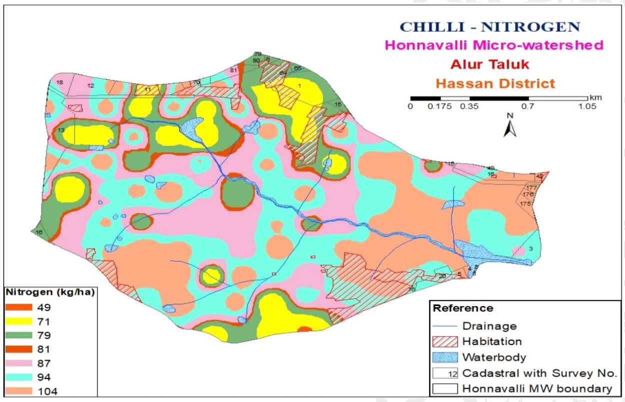

Fig. 4 : Spatial nitrogen fertilizer recommendation map for chilli in Honnavalli micro-watershed

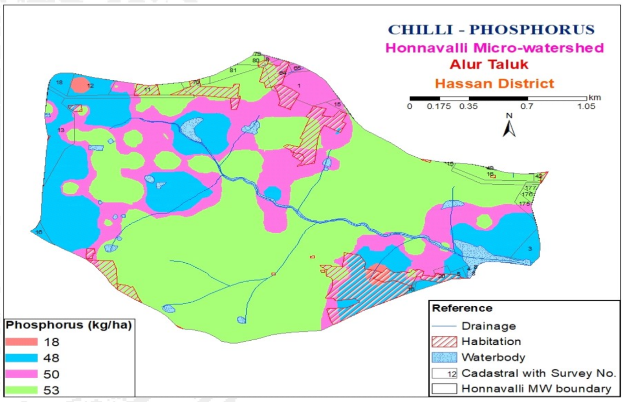

Fig. 5 : Spatial phosphorus fertilizer recommendation map for chilli in Honnavalli micro-watershed

32 ha (08%) area belongs to >20kg ha^{-1}. Using STCR targeted yield approach we recommended the fertilizer dosage for phosphorus at 53, 50, 48 and 18 kg ha^{-1} for the areas of soil test value of available phosphorus ranges <10, 10-15, 15-20 and >20 kg ha^{-1}, respectively (Fig. 5).

The soil test value of available potassium in Honnavalli micro-watershed is divided into six ranges for thematic mapping of study area. The result depicts that the maximum 112 ha (27%) area under 100-140 kg ha^{-1}, followed by 92 ha (23%) area falls under 240-280 kg ha^{-1}, 68 ha (16%) area with range of 140-180 kg ha^{-1}, 60 ha (14%) area ranges between 180-240 kg ha^{-1}, 48 ha (12%) area comes under >320 kg ha^{-1} and remaining 32 ha (08%) area ranges between 280-320 kg ha^{-1}. Using STCR targeted yield approach we recommended the fertilizer dosage for potassium at 55, 48, 41, 34, 27 and 14 kg ha^{-1} for the areas of soil test value of available potassium ranges 100-140, 140-180, 180-240, 240-280, 280-320 and >320 kg ha^{-1}, respectively (Fig. 6).

Basavaraj *et al.* (2018) revealed that for achieving a target yield of 10 q ha^{-1} in dry chilli with soil test value of 280:23:130 kg ha^{-1}, the fertilizer N, P_2O_5, K_2O doses required are 106.63, 52.47 and 52.87 kg ha^{-1}, respectively. The variation in nutrient application to be made are 15.50 kg N ha^{-1}, 6.43 kg P_2O_5 ha^{-1} and 7.29 K_2O ha^{-1} to increase or decrease one quintal

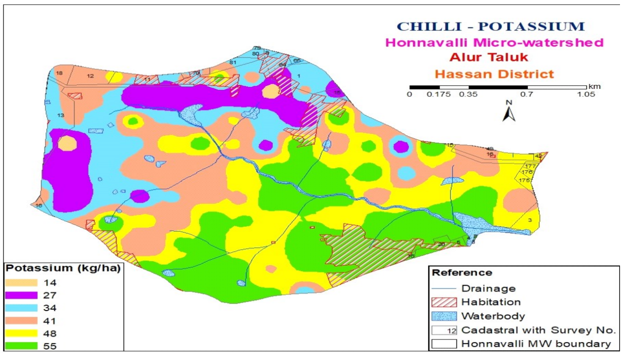

Fig. 6 : Spatial potassium fertilizer recommendation map for chilli in Honnavalli micro-watershed

(10 ± 1 q ha^{-1}). These results clearly showed that the fertilizer requirements varied with the soil test values for the same level of crop production. Hence, balanced fertilization through soil testing becomes essential for increasing the crop production. Similar results were also reported by Ahmed *et al.* (2015) and Durga *et al.* (2017).

Soil test-based application of plant nutrients for the targeted yield helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization. The study provides the site specific nutrient recommendations for both ragi and chilli in Honnavalli micro-watershed based on soil test nutrient status has great implication on reducing excessive fertilizer consumption there by reduces cost of inputs and can achieve higher benefit cost ratio to the small and marginal farmers of India apart from maintaining soil health and nutrient balance.

References

Ahmed, S., Basumatary, A., Das, K. N. and Medhi, B. K., 2015, Targeted yield-based fertilizer prescriptions for autumn rice (*Oryza sativa* L.) in inceptisols of Assam, India. *Indian J. Agri. Res.*, **49** (5) : 437 - 441.

Amit, M., 2011, Revalidation of fertilizer recommendation for fingermillet in different soils of Kuthalagere watershed. *M. Sc. (Agri.) Thesis,* University of Agricultural Sciences, Bangalore, Karnataka (India).

Basavaraj, P. K., Prakash, S. S., Mohamedsaqeebulla, H, Deyp and Subbarao, A., 2017, STCR targeted approach of fertilizer recommendation for different crops and soils of Karnataka. AICRP on STCR, University of Agricultural Sciences, Bangalore, Karnataka (India).

Denton, O. A., Aduramigba, V. O., Ojo, A. O., Adeoyolanu, O. D., Are, K. S., Adelana, A. O., Oyedele, A. O., Adetayo, A. O. and Oke, A. O., 2017, Assessment of spatial variability and mapping of soil properties for sustainable agricultural production using geographic information system techniques (GIS). *Cogent Food Agric.*, **3** : 1.

Durga, M. L., Raju, D. V. S., Pandey, R. N., Kanwar Pal Singh, Prabhat Kumar, Renu Pandey, Gopalkrishnana, S. and Suresh Chandra, 2017, Soil test and targeted yield based primary nutrient management of marigold in an Inceptisol. *Indian J. Agri. Sci.,* **87** (4) : 500 - 504.

Yang, J. Y., Xie, Y. W., Du, S. L., 2012, A GIS-based fertilizer decision support system for farmers in Northeast China : A case study at Tong-le village. *Nutr. Cycl. Agroecosystems,* **93** : 323 - 336.

Zhang, Qiang, Yang, Zhiping, Li, Yong, Chen, Deli, Zhang, Jianjie and Mingchang, 2010, Spatial variability of soil nutrients and GIS-based nutrient management in Yongji County, China. *Int. J. Geogr. Inf. Sci.,* **24** (7) : 965 - 981.

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