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GIS-Based Assessment and Thematic Mapping of Micro-Nutrient (DTPA-Extractable, Fe, Zn, Cu and Mn) status in Honnavalli Micro - Watershed of Hassan District of Karnataka

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Abstract

The study was undertaken at Honnavalli micro-watershed of Hassan district during 2018-19 in order to assess the soil fertility status and to prepare the soil fertility and fertilizer recommendation mapping for sustainable production of major crops *viz.,* paddy, maize, ragi and chilli cultivated in the study area. The 105 grid soil samples were drawn over an area of 420 ha of the study area and analysed for DTPA- extractable micronutrients (Fe, Zn, Cu and Mn). The results revealed that overall, in Honnvavalli micro-watershed, micronutrients, Cu and Mn were foundin sufficient range. The 80 per cent of area (336 ha) found Fe in sufficient rangeand remaining 20 per cent (84 ha) was deficient. The 33 per cent of area (140 ha) found Zn in sufficient range while, remaining 67 per cent (280 ha) was deficient. The surface soil fertility maps of DTPA-extractable micronutrients (Fe, Zn, Cu and Mn) were prepared on the basis of soil fertility ratings through ArcGIS.

Keywords: Geographic information system (GIS), Micro-watershed, ArcGIS, Micronutrients, Thematic map

Soil is the most wondrous gift of nature to all the earthlings. It is vital natural resource base performing 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. It has become more imperative now than ever before, to protect and preserve quality of soil resource to sustainably build productivity growth. Since on slaught on soil quality, more than nature is the act of all stake holders-farmers, builders and common folks, they have to be part of protection and conservation programme also.

In that pursuit, the present research work was carried out on assessment of soil micro-nutrients (Fe, Zn, Cu and Mn) status and mapping 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. In the present day, concept of watershed-based approach has emerged as a potential means to achieve sustainable production in rainfed areas. Our aim of optimizing the utilization of land resources (Aurbacher and Dabbert 2009) 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. Due to the shrinking available land resources for agriculture in India, there is an over whelming need to manage and conserve the natural resource base by adopting site specific and viable land management technologies. 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 the farmers 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 formats. GIS can be used in producing a soil fertility map of an area, which will help in formulating balanced fertilizer recommendations 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. Honnavalli micro-watershed lies in Hassan district of Karnataka state where in important crops *viz.,* Paddy, Maize, Coffee, Aracanut, Ragi, Banana, Chilli *etc*., are largely grown. Hence an attempt was made to delineate the soil micro-nutrient status and mapping with anaim of providing balanced nutrition using geographic information system (GIS) techniques for sustainable crop production in the study area.

Material and Methods

The Honnavalli micro-watershed is located in Alur taluk of Hassan district, Karnataka state and is having total 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 and 953 meters above mean sea level. The zone covers 14 taluks of 5 districts. It has an area of 1.22 million ha. consists of the Malnad, the Western Ghats and parts of the Plateau region (Fig. 1). Preliminary traverses of the entire Honnavalli micro-watershed was carried out with the help of cadastral map, satellite imagery and 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. The major crops grown were paddy, maize, ragi and ginger during

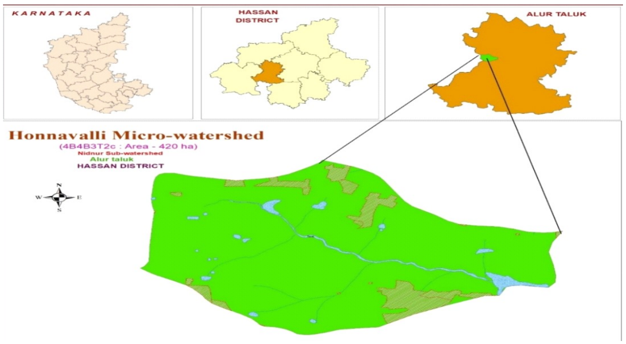

Fig. 1 : Location map of Honnavalli micro-watershed

the *kharif* season, cauliflower in *rabi* and during summer, chilli, maize, ginger and fodder *etc.*

Database

Space Borne Multi Spectral Digital Data

The satellite data used for the study was provided by Karnataka State Remote Sensing Application Centre, Bengaluru. The merged data of Cartosat-1 (PAN) and Resourcesat-2 (LISS IV) MX in the form of digital and geo-coded were analysed in the GIS environment along with cadastral maps. These inputs were used for soil sample collection during the study.

Topographic Maps

The required topographic map at 1:4000 scale covering the study area of micro-watershed (4B4B3T2c) was collected from the Survey of India and utilized for the study.

Database Creation and Organization

For study purpose, the digital cadastral map of micro-watershed procured from the Karnataka State Remote Sensing Application Centre (KSRSAC), Bengaluru was used. For database creation and union of various thematic maps, the Geographic Information System (GIS) with ArcGIS software was used.

Field Equipments

Field equipments used for the studies and for grid sampling were soil digging tools like spade, polythene cover and markers and Global positioning system (GPS) - (Model- Garmin 72H) instrument was utilized for correct location of the grids and also for collecting surface soil samples to study the spatial variability of soil fertility status. The GPS was conceived as a ranging system from known positions of satellites in space to unknown positions on land, sea and space. The antenna detects the electromagnetic waves arriving from the satellites, converts the wave energy into an electric current, amplifies the signal strength and sends the signals to the electronic receiver. The latitude and longitude on the screen were utilized for fixing the grid point for collection of the soil samples. During the present investigation, GARMIN, GPS 72H receiver in stand-alone mode was used to collect the information regarding the geographical location of the ground truth sites and soil sampling sites.

Lab Equipments

Equipment available at remote sensing laboratories in the Dept. of Soil Science and Agricultural Chemistry at University of Agricultural Sciences, Bengaluru was used. Soil samples were analysed using laboratory facilities of the Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru.

Preparation of Digital Database

The digital data was processed to transform it for improving the image contrast and to generate photo-products for subsequent interpretation. The imagery was georeferenced with a sub-pixel accuracy using first order polynomial transformation.

Preparation of Base Map

A tracing film was overlaid on the toposheet covering the study area. Boundaries of the micro-watershed and important land features like roads, streams, tanks *etc*. were extracted. Thus, a map having the common land features was used as a base map for preparing different the matic maps. The cadastral map procured from KSRSAC was used for the study to identify the survey numbers.

Delineation of the Study Area

Study area was delineated with the help of topographic maps and the watershed atlas was prepared by KSRSAC. The data pertaining to the study area was extracted as a subset for further processing.

Assessment of Soil and Mapping

Collection of Soil for Micronutrients Analysis

Composite soil samples (105) from the surface (0 -15 cm) were collected over the Honnavalli micro-watershed covering an area of 420 ha at 400 m grid intervals. The soil samples were analysed for DTPA extractable micronutrients *viz.,* Iron, Zinc Copper and Manganese (mg kg^{-1}).

DTPA Extractable Micronutrients-Iron, Zinc Copper and Manganese (mg kg^{-1})

The micronutrients *viz.,* zinc, iron, copper and manganese were extracted by DTPA (Diethylene Triamine Penta Acetic acid) extractant (0.005 M) + 0.01 M $CaCl_2$ + 0.1 N Triethanolamine at pH 7.3 in the ratio of 1:2 soil to extractant after shaking for two hours as explained by Lindsay and Norvell (1978). The concentration of Zn, Fe, Mn and Cu (mg kg^{-1}) was estimated by Atomic Absorption Spectrophotometer using appropriate hallow cathode lamp.

$$\text{Available micronutrients Zn, Fe, Mn and Cu (mg kg}^{-1}) = \frac{(\text{Sample ppm-Blank ppm}) \times \text{Volume of extractant}}{\text{Weight of soil (g)}}$$

Preparation of Point Map

The latitude and longitudes of sample sites of soil were collected from the study area using a hand held GPS instrument GARMIN GPS72H receiver. The GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS. The ArcGIS 10 software was used in this study. 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 ArcMap. The spatial and the non-spatial database developed are integrated for the generation of spatial distribution maps.

Preparation of Thematic Maps for Soil Properties

The principal method of preparation of thematic maps is Krigging. It is centred on the existence of a spatial structure where observations close to each other are more alike than those that are far apart (spatial auto-correlation). The average degree of dissimilarity between unsampled values and a nearby data value is measured by experimental variogram and thus can depict auto-correlation at various distances. A suitable model is derived by using weighted least squares and parameters from analysis of the experimental variogram.

The incorporation of variable interdependence and the available error surface output are some of its advantages. A disadvantage is that Kriging requires more input from the user and it requires substantially more computing and modeling time. The spine interpolation is a Radial Basis Function (RBF) in ArcGIS. The steps for Krigging using ArcGIS 10 are presented as a flow diagram (Fig. 2). After the map is prepared, it is clipped to the study area shape and final mapping was carried out as per the flow diagram 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 all properties such as pH, EC, available N, available P (P_2O_5) and available K (K_2O) were plotted using Arc/Info software. The interpolation technique used was ordinary Krigging.

Preparation of Soil Fertility Maps using GIS

A database file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (vector data) showing the outline of the Honnavalli micro-watershed area was created in ArcView 3.1.

The database 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 ArcView, spatial analyst 'Interpolate grid option' was selected. On the output 'grid specification dialogue', the output grid extent chosen was the same as Honnavalli micro-watershed. Then map was reclassified based on ratings of respective nutrients.

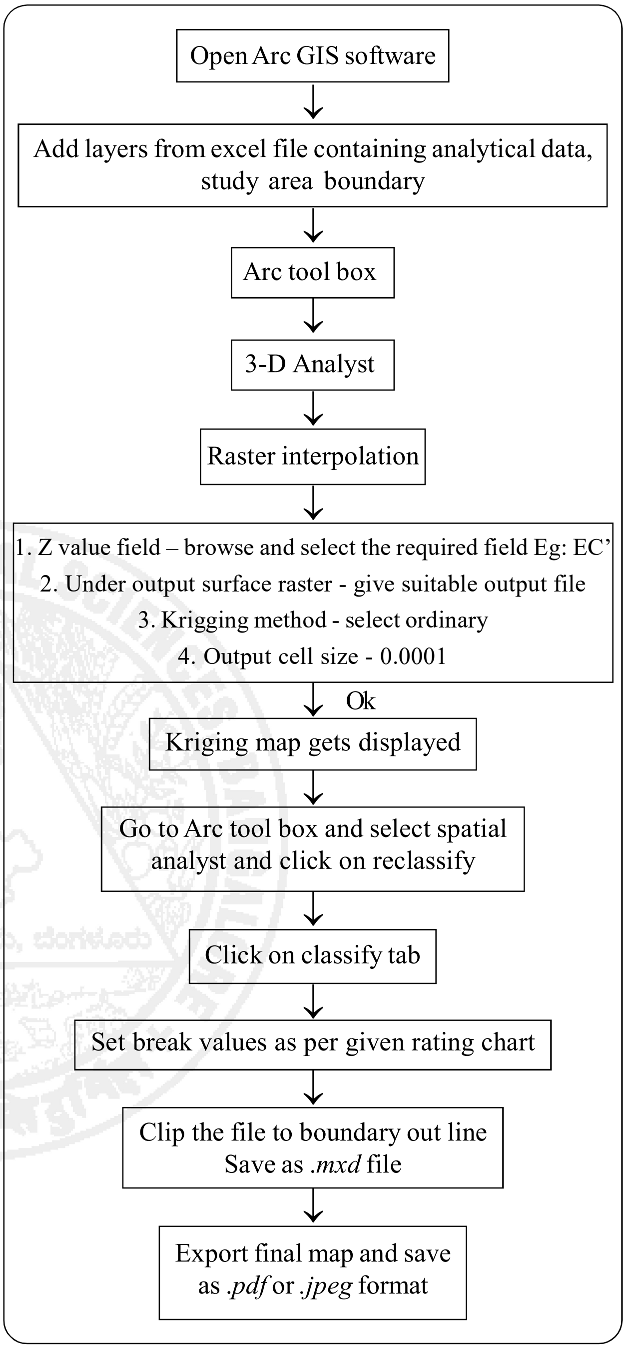

Fig. 2 : Soil fertility map using Krigging function in Arc GIS

Results and Discussion

Computation of Results using Geostatistical Procedures

To study the spatial variability of the soil properties, ground truth analysis was done using GARMIN GPS instrument through geo referenced points locating longitude and latitude of the Honnavalli micro-watershed and data obtained from the study area for various surface soil properties were analysed using proper statistical procedures. By using interpolation method, the Spatial variability maps were prepared *i.e.,* Krigging. The summary of the results on spatial variability of the soil micronutrients at Honnavalli micro-watershed is presented in Table 1.

TABLE 1

Descriptive statistical analysis of spatial variability of soil micronutrients (mg kg^{-1}) of Honnavalli micro-watershed

Soil micro nutrient	Range	Mean	SD	CV (%)
Fe	3.39 - 38.50	13.39	7.75	57.87
Mn	1.12 - 22.36	9.67	5.71	59.08
Cu	0.74 - 3.60	1.70	0.72	42.81
Zn	0.16 - 2.82	0.77	0.59	76.28

GIS-Based Spatial Variability Mapping

By using GIS techniques, maps were prepared for spatial variability of surface soil micronutrients through spatial interpolation of point-based measurements for soil properties. Interpolation techniques included, inverse distance weighing and Krigging, commonly used in agriculture (Franzen and Peck, 1995).

Soil fertility maps were generated for the zinc, copper, iron and manganese using Krigging method at 1:4000 scale. The study area was divided in to different fertility zones where each zone represented a specific range of fertility status of micronutrients. Soil test values were grouped into different categories such as sufficient and deficient based on the variability in the soil micronutrient status. The final maps thus, generated gave the extent of spatial variability in soil properties. The spatial variability of micronutrients status in the study area are presented in Table 2. The results of the spatial variation maps generated are presented below.

Map for Available Iron

The extent of DTPA-extractable iron ranged from 3.39 to 38.50 mg kg^{-1} with a mean value of 13.39 mg kg^{-1}

TABLE 2

The extent of spatial distribution of DTPA-extractable micronutrients of Honna valli micro-watershed

Micronutrient class	Area of Honnavalli micro-watershed	
	Ha	Per cent
Available iron		
Sufficient (>4.5 ppm)	336	80
Deficient (<4.5 ppm)	84	20
Available manganese		
Sufficient (>1 ppm)	420	100
Available zinc		
Sufficient (>0.6 ppm)	140	33
Deficient (<0.6 ppm)	280	67
Available copper		
Sufficient (> 0.2 ppm)	420	100

with standard deviation of 7.75 and coefficient of variation of 57.87 per cent. It was estimated that 80 per cent of the samples were sufficient for available iron (>4.5 ppm) and remaining 20 per cent were deficient in available iron content (<4.5 ppm). The sufficient iron content was attributed to acidic soil pH (<6.5) and organic matter acting as chelating agent might have protected the iron from oxidation and precipitation, which consequently increased the solubility and availability of iron. Similar results were also reported by Chandrashekara *et al.* (2014).

The sufficient available iron status (>4.5 ppm) is occupied by maximum area of 336 ha (80 %) whereas remaining 84 ha (20 %) of the study area is deficient in available iron content (<4.5 ppm). The spatial variability map for available iron status of Honnavalli micro-watershed is depicted in Fig. 3.

Map for Available Manganese

The available manganese status in surface soils varied from 1.12 to 22.36 mg kg^{-1} and mean value of 9.67 mg kg^{-1} and standard deviation of 5.71 with coefficient of variation 59.08 per cent. The 100 per cent of the study area was with sufficient (>1 ppm) available manganese content. This was attributed to the presence

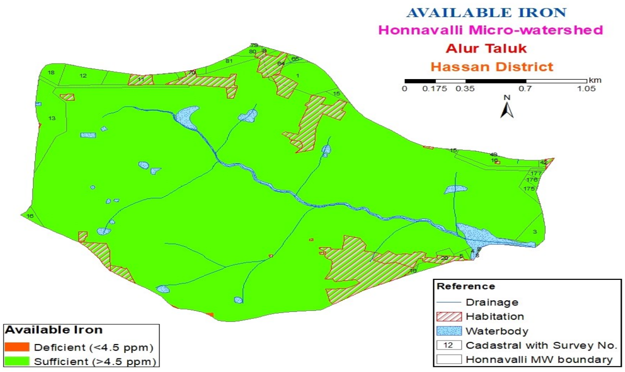

Fig. 3: Spatial distribution of available iron in Honnavalli micro-watershed

of reduced (Mn^{+2}) form in surface soil, which contributed to available manganese pool. The low pH, redox conditions coupled with high soil organic constituents predominantly regulates the availability and solubility of manganese (Kusuma Patil, 2012).

The entire Honnavalli micro-watershed area recorded sufficient available manganese content (>1 ppm) and covered with an area of 420 ha (100 %). The spatial distribution map of available manganese status of study area is presented in Fig. 4.

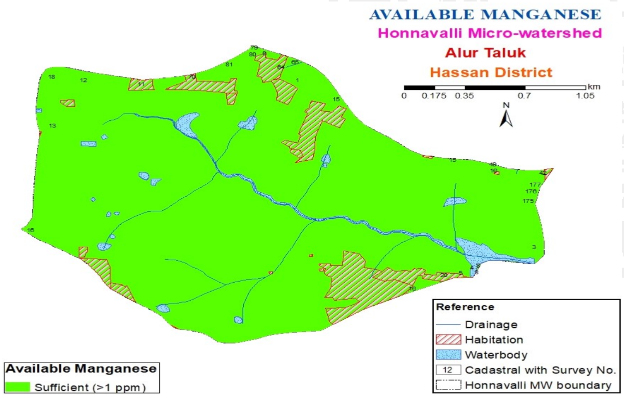

Fig. 4: Spatial distribution of available manganese in Honnavalli micro- watershed

Map for Available Zinc

The soil available zinc varied from 0.16 to 2.82 mg kg^{-1} and mean value of 0.77 mg kg^{-1} and standard deviation of 0.59 with coefficient of variation 76.28 per cent. Majority (67 %) of the micro-watershed area was deficient (<0.6 ppm) and 33 per cent area was with sufficiency range, as the soil pH predominantly regulates the solubility and availability of micronutrient cations in the soil. Some of the soils were alkaline in nature which might have resulted in zinc precipitation as hydroxides and carbonates.

The spatial variability of available zinc status of Honnavalli micro-watershed area was categorized into two classes *viz.,* deficient (<0.6 ppm) and sufficient (>0.6 ppm). The maximum area of 280 ha (67 %) was with deficient available zinc status and remaining 33 per cent (140 ha) under sufficient condition. The extent of spatial variability of available soil zinc is depicted in Fig. 5.

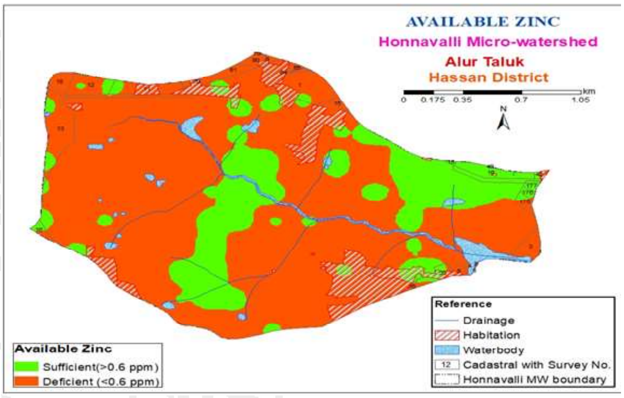

Fig. 5 : Spatial distribution of available zinc in Honnavalli micro- watershed

Map for Available Copper

Available copper in micro-watershed of Honnavalli ranged from 0.74 to 3.60 mg kg^{-1} and mean value of 1.70 mg kg^{-1} and standard deviation of 0.72 with coefficient of variation 42.81 per cent. All the soil samples (100 %) of the study area were sufficient in available copper content. This higher concentration of available copper might be associated with chelating of organic compounds, released during the decomposition of organic matter left after harvesting of crop and also low organic matter content in the study area. The similar results were reported by Kusuma Patil (2012).

The entire Honnavalli micro-watershed area of 420 ha (100 %) was found sufficient for available copper content (> 0.2 ppm). The spatial variability map for available copper status of the study area is depicted in Fig. 6.

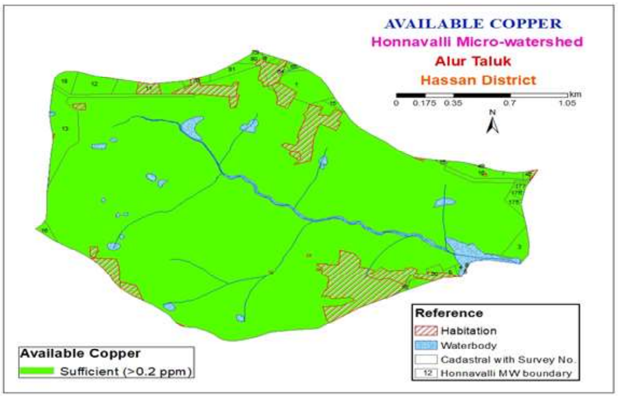

Fig. 6: Spatial distribution of available copper in Honnavalli micro-watershed

The present study was undertaken for the assessment of spatial variability of soil micro-nutrient (DTPA-extractable, Fe, Zn, Cu and Mn) status, by using ArcGIS software for thematic mapping using interpolation technique and kriging method. These maps help in avoiding the under and over use of chemical fertilizers and sustain the soil health.

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