Mysore J. Agric. Sci., 56 (3) : 56-62 (2022)

Application of Remote Sensing and Geographical Information System for Soil Fertility Mapping of V.C. Farm, Mandya, Karnataka

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AUTHORS CONTRIBUTION

M. A. ANANTHAKUMAR : Collection of high resolution satellite images, pre-field interpretation of map, GIS tools used for collection of samples and assigning work for the laboratory

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Received : November 2021

Accepted : September 2022

ABSTRACT

An intensive detailed soil survey was conducted during 2018-19 using Cartosat+ LISS satellite imagery with 1:12,500 scale base map. The study area was studied for its external land features and morphological properties in relation to different physiographic units developed under different landscape. The satellite image was super imposed on cadastral map in order to differentiate field boundaries of various blocks of V.C. Farm and spatial data base was developed. The surface soil samples (0-15 cm) were collected, processed and analysed for physico-chemical properties for non-spatial information. The non-spatial information of soil analytical data with spatial information was interrelated. The variability of data was assessed based on the ratings and soil fertility thematic maps were prepared. The results revealed that lower-pediplain and summit lands had deep to very deep soils with paddy and sugarcane crops under irrigated condition posing soil degradation. While, in mid-lands soils were shallow to medium depth with moderate to high hydraulic conductivity, low to very low water holding capacity and cultivated with pulses and fodder crops. The majority of area was under acidic to neutral soil reaction (p^H). However, A, B and D blocks showed relatively higher p^H (sodic to saline sodic). The soils of most of the blocks fall under medium to higher organic carbon status. The available nitrogen content was found to be lower, the available phosphorus and potassium was medium in most of the blocks except in block A which showed higher values for available phosphorus.

Keywords : Soil fertility, Remote sensing & GIS, Soil fertility

IN the present era of global warming, climate change and increasing population, need of sustainability is most critical thing in various fields which consume lots of natural resources, especially the agriculture field. As in countries like India with ever growing population, food requirement and limited land available for crop production, achieving sustainability should be the number one priority. The sustainability in agriculture can be achieved with proper utilization of natural resources. For this it is essential to know the status of natural resource used in the production.

In agriculture one of the major resources of production is soil. Enhanced soil productivity and assured sustainability are the major goals for higher productivity of crops to feed the increasing population of the nation. Scientific planning and management practices for further enhancement and sustaining the productive potential of soils require a proper understanding of the factors limiting its productivity. The capacity of a soil to produce crops is limited and the limits to production are set by intrinsic soil characteristics, agro-ecological settings, use and management. Despite the significant growth in production, the sustainability of some cropping systems has been showing signs of fatigue. Therefore, land resource inventory provides an insight into the potentialities and constraints of soil for its effective exploitation.

An intimate knowledge on the kind of soils and their spatial distribution is a prerequisite in developing rational land use strategy for agriculture, forestry, irrigation and improved drainage etc. Soil survey generates an accurate and scientific inventory of different soils, their kind and nature and extent of distribution so that one can predict their characters and potentialities. It also provides adequate information in terms of land form, terraces, vegetation as well as soil characteristics (*viz.,* texture, depth, structure, stoniness, drainage, acidity, salinity, etc.) which can be utilized for the planning and development activities in allied fields.

Geographic information system (GIS) helps to integrate spatial information of external land features such as present land use, physiography, surface soil texture, gravel content and other soil management activities to restore soil health (Adornado and Yoshida, 2008). GIS generated soil fertility maps may serve as a decision support tool for nutrient management. The Cauvery tributaries flowing in Mandya district covers the land with green carpet of crops mainly paddy and sugarcane leading to the development of problematic soils (sodic and saline sodic soils) due to uncontrolled irrigation. The aim of optimizing the utilization of land resources with intensification of agriculture resulted either in the fast depletion of nutrients as well as eutrophication. It is therefore important to monitor the fertility status of soil timely to monitor the soil health. Assessing soil fertility and productivity of larger areas manually is laborious and time consuming. Remote sensing, a tool for characterizing an object without having physical contact with the object is gaining importance in recent days. Advancement in GIS as a tool for analysing the imagery obtained by the remote sensing has improved the accuracy of the soil fertility characterization. Hence, an attempt was made to characterize fertility status of V.C. Farm soils of cauvery command area using remote sensing and geographical information system.

Material and Methods

Study area: Geographically, Vishweshwaraiah Canal Farm (V.C. Farm) located in Mandya District of Karnataka situated at 12°34’00"N to 12°34’30"N latitude and 76°48’45"E to76°50’15"E longitude with an elevation of 695 m above mean sea level. The location map of the study area is presented in Fig. 1.

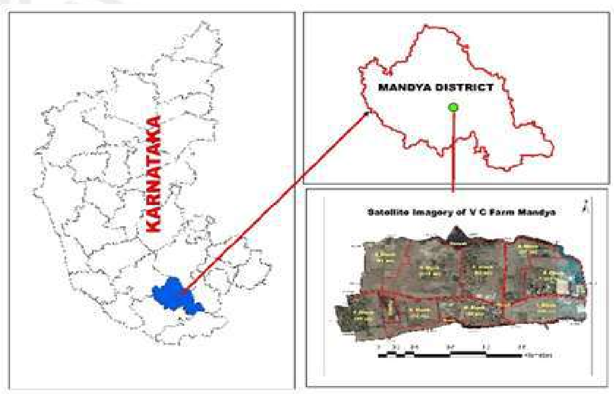

Fig. 1 : Location map of study area

An intensive detailed soil survey was conducted during 2018-19 using Cartosat + LISS (linear imaging self scanning sensor) satellite imagery with 1:12,500 scale

Table 1

Physico-chemical properties of soils of V.C. Farm, Mandya

Block details	pH (1:2.5)		EC (1:2.5) (dS/m)		Organic Carbon (%)		Av. Nitrogen (kg ha^{-1})		Av. Phosphorus (kg ha^{-1})		Av. Potassium (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
A	6.7-8.4	7.4	0.09-1.29	0.33	0.41-1.37	0.69	188-690	314	34-174	93.5	152-341	246
B	6.6-9.1	7.9	0.09-1.23	0.57	0.31-1.10	0.56	245-408	323	6.2-40.2	19.8	98-298	169
C	6.5-8.2	7.1	0.10-0.38	0.20	0.59-1.21	0.86	188-314	238	2.6-15.6	7.8	226-319	270
D	6.0-9.0	7.2	0.10 -2.78	0.32	0.41-1.72	1.03	125-596	304	3.7-47.9	21.4	104-419	275
E	6.6-8.0	7.2	0.12-0.32	0.23	0.62-1.37	1.02	157-314	248	4.1-56.7	16.7	224-346	264
F	6.0-7.6	7.2	0.10 -0.38	0.23	0.35-1.44	0.98	157-314	240	6.5-47.6	18.6	230-438	273
G	6.3-7.7	7.3	0.10-0.43	0.21	0.47-1.00	0.70	157-314	235	15.0-41.0	25.6	242-345	277
H	6.3-7.5	7.1	0.09-0.25	0.14	0.31-1.48	0.83	188-314	258	7.8-79.5	32.4	232-331	280
I	5.8-7.3	6.6	0.09-0.80	0.20	0.50 -1.18	0.84	220-321	270	4.1-72	36.2	179-344	275

as base map. The soils of the study area were studied in detail with respect to its external land features and morphological properties in relation to different physiographic units developed over varying landscape. A total of one hundred ninety-four surface soil samples were collected at a depth of 0-15 cm based on satellite image which is super imposed on the cadastral map from each field boundary of the different blocks of V.C. Farm. The collected samples were air-dried, ground with a wooden pestle and mortar, passed through 2 mm sieve and analysed for chemical and fertility parameters. The pH (1:2.5) and electrical conductivity (1:2.5), available phosphorus and potassium contents of the soils were measured using standard procedures as described by Jackson (1973), while organic carbon (OC) was determined by the procedure outlined by Walkley and Black described by Jackson (1973) and available nitrogen by Subbaiah and Asija (1956).

The field maps of 1:12,500 scale with geo-coordinates were scanned, geo-referenced and digitized using Arc GIS software 10.4.1. The field boundaries, soil boundaries and other related boundaries were differentiated and layers were generated. The non-spatial information of soil analytical data and spatial information of thematic layers were interrelated using Relation Data Base Management System (RDBMS). The variability of data was assessed using mean and range for each set of data and ratings were defined. Based on the ratings, the soil fertility maps were prepared using ARC GIS v 10.4.1.

Results and Discussion

The geology of the area comprises the Archean formations with Granite and Granite Gneiss as the dominant rocks, besides Alluvium of sub-recent to recent origin is also observed all along the lower pediplains. The soils of the area have been placed under two main groups *viz.,* Sedentary/*In-situ* soils and Alluvial/*transported* soils.

The soils of the study area are derived from Granite and Granite gneiss which are coarse textured loamy sand to gravelly sandy loam texture observed in very gentle to moderately sloping lands, while in summit it

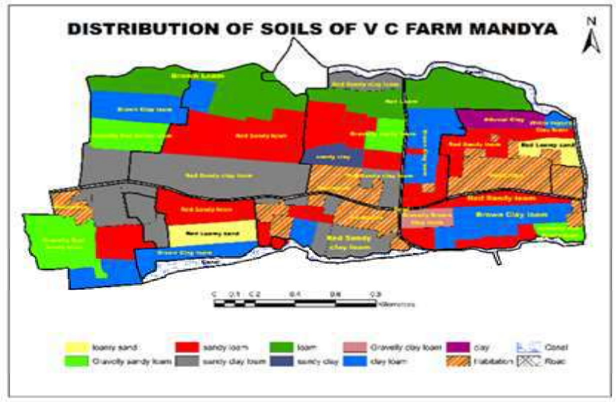

Fig. 2 : Distribution of Soils of V C Farm, Mandya

is medium in texture of sandy clay loam and in lower pediplain areas medium to fine textured of loam to clay loam soils. The fine textured soils are observed in the lower pediplain due to accumulation of fertile soil through erosion.

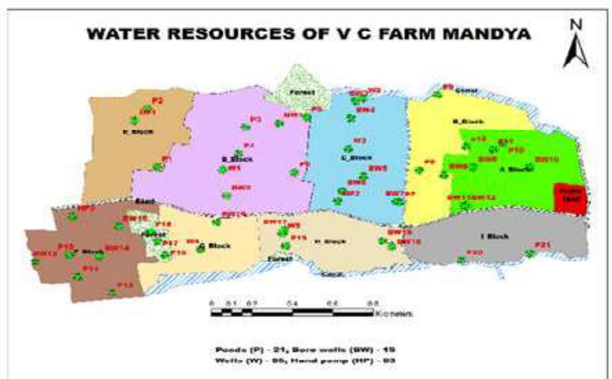

Fig. 3 : Water Resources of V. C. Farm, Mandya

The Cauvery is the main tributary flowing across the command area. The common practice of irrigating field through canals as well as storing and distributing from village tanks and ponds and borewell to ensure assured irrigation during water crisis. The map depicts the various water resources of V.C. Farm used for crop production, the contribution of water through ponds and bore wells.

Land Use-Land Cover

The total area of the V.C. Farm comprises of 319 ha, of which 150 has cultivated land, 130 ha plantation and 39 ha forest cover. Approximately, 25 per cent of the land occupied with roads, canals, tanks, habitation and other miscellaneous areas of aquaculture, garden and teak plantation. The major crops grown are paddy, sugarcane, maize, ragi, pulses and fodder crops.

In general, under lower pediplain and summit lands having deep to very deep soils the mono-cropping of paddy and sugarcane are grown under irrigated condition. While, in mid-land areas of shallow to medium soils having moderate to high hydraulic conductivity with low to very low water holding capacity the soils are cultivated with pulses and fodder crops.

Fig 4: Land Use Land Cover of V.C. Farm Mandya

Soil Reaction and Electrical Conductivity

Results showed that soils varied widely in their soil properties (Table 1). The pH values ranged from 5.8 in block I to 9.1 in block B, respectively.

Block B was observed with wide variation in soil pH (Fig. 5 & 9) along with highest mean value of 7.9, followed by block A (7.4) and D (7.2). These blocks B, D and A are being low lands, intensively cropped with paddy since 1990's (Sivashankaran *et al.*, 1993). Since paddy requires huge quantities of water which has led to accumulation of salts in the course of long term irrigation coupled with semi-arid condition in study area led to the development of soils with high pH. Whereas acidic values of pH were found in block I.

The Electrical Conductivity (EC) values are ranged from 0.09 in block A, B, H and I to 2.78 in block D respectively (Table 1 and Fig. 6 & 9).

Most of the soils of V.C. farm showed normal range of electrical conductivity. Though the extreme EC values found in block D, highest mean values were

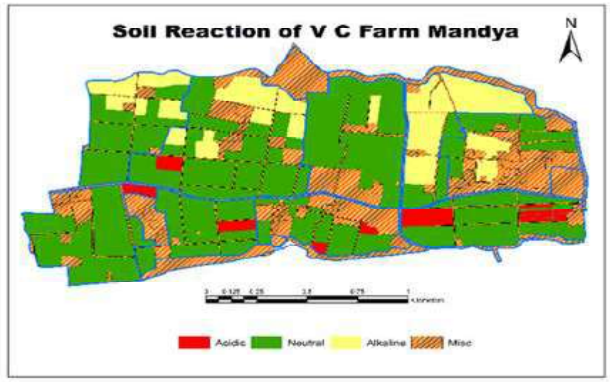

Fig 5: Soil Reaction of V. C. Farm Mandya

observed in block B (0.57 dS/m). Higher EC values in these blocks is mainly due to water logged condition and paddy cultivation, which might have led to accumulation of salts of Ca, mg and Na (Pillai and Natarajan, 2004). Blocks C, E, F, G, H and I had shown EC values < 0.25 dS/m (Table 1 and Fig. 10) these lower values might be due to higher elevation of these blocks in comparison to blocks B, D and A along with cultivation of crops which required well aerated soils, which avoids addition of salts to soil. Block B being observed with higher mean values of p^H (7.9) and EC (0.57 dS/m) might be categorised into saline soils. The land and crop suitability evaluation has to be reassessed for the suitability of dry irrigated contingent crops as outlined by (Harsha *et. al.*, 2020) for the degraded lands.

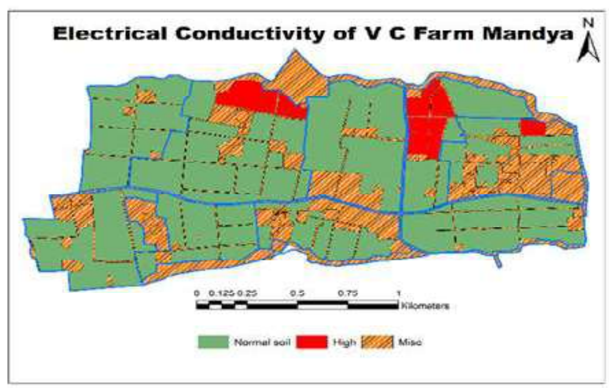

Fig. 6 : Electrical Conductivity of V. C. Farm Mandya

Soil Organic Carbon Status

Lowest content of organic carbon was observed in block B and H (0.31 %) and highest was observed in block D (Fig. 8). with respect to mean values highest organic carbon content was recorded in block D (1.03 %) and lowest mean value in block B (0.56 %) (Fig. 10). The soils of most of the blocks falls under medium to higher organic carbon status. Soils with low organic carbon status were found in blocks which recorded higher p^H and EC.

Since the study area is a well-managed farm, added with crop residues *viz.,* sugarcane trash, paddy straw and other leaf litter, which resulted in medium to high range of soil organic carbon content in most of the soils of this area. Whereas few soil observed lower content of organic carbon, which might be due to intensive crop production and higher values of p^H and EC, resulted in low biomass production and ultimately lower amounts of residue was added to soils (Nayak *et al.,* 2002).

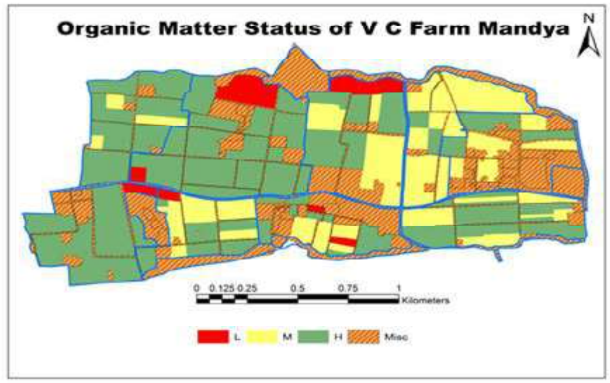

Fig 7: Organic Matter content in Soils of V. C Farm

Major Nutrient Status

Though the available nitrogen content in most of the blocks were found lower, block B was observed with highest mean available nitrogen (323 kg ha^{-1}) followed by block A (314 kg ha^{-1}) and D (304 kg ha^{-1}). Remaining blocks showed similar mean values ranging from 238-270 kg ha^{-1}) (Table 1). Low range of available nitrogen might be attributed to intensive cultivation and various losses *viz.,* leaching and volatilization in coarse texture and sodic soils, respectively Sivashankaran *et al.* (1993). Available phosphorous content was low in all the blocks ranging from 7.8 kg ha^{-1}) in block C to 36.2 in block I, except in block A where it was rated high with mean value of 93.5 kg ha^{-1}). The reason behind low levels of phosphorous availability might be due to sorption and precipitation of iron and aluminium phosphates in acidic soil and tri-calcium phosphates in sodic and saline sodic soil. The similar results reported by Bopathi and Sharma (2006). Avilable potassium content was observed to be medium in all the blocks with mean values ranging from 169 kg ha^{-1}) in block B to 280 kg ha^{-1}) in block H. The soils of block D and B had low ratings of available potassium (98 to 104 kg ha^{-1}). The main reason behind is the parent material from which soils are developed *viz.,* primary minerals of feldspar and mica associated parent material.

The digital data base helps in scientific planning and management practices for enhancement and sustaining the productive potential of soils. The high-resolution satellite image super imposed on the cadastral map provides insight information on natural resources. Representation of soil data as maps will help in

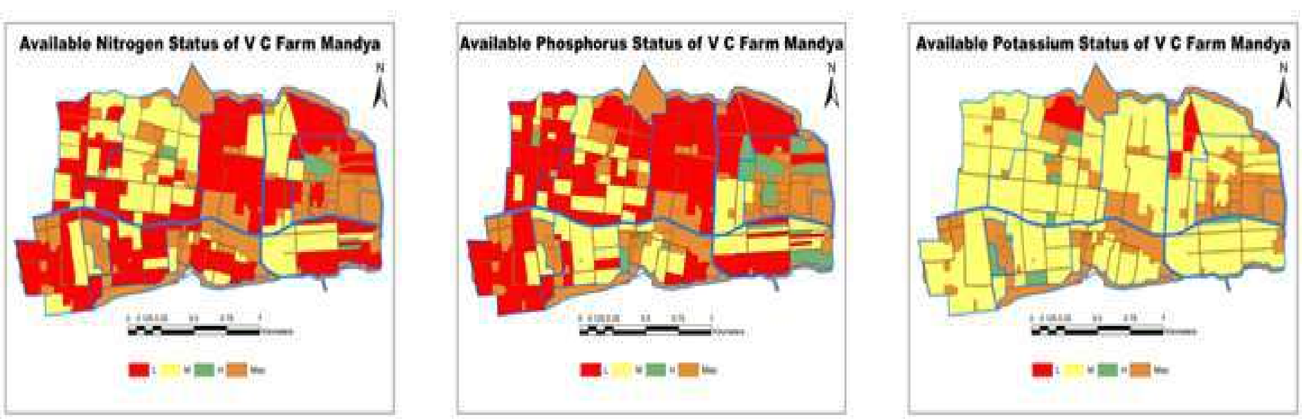

Fig. 8: Status and distribution of available nitrogen, phosphorus and potassium content in V. C. Farm Mandya

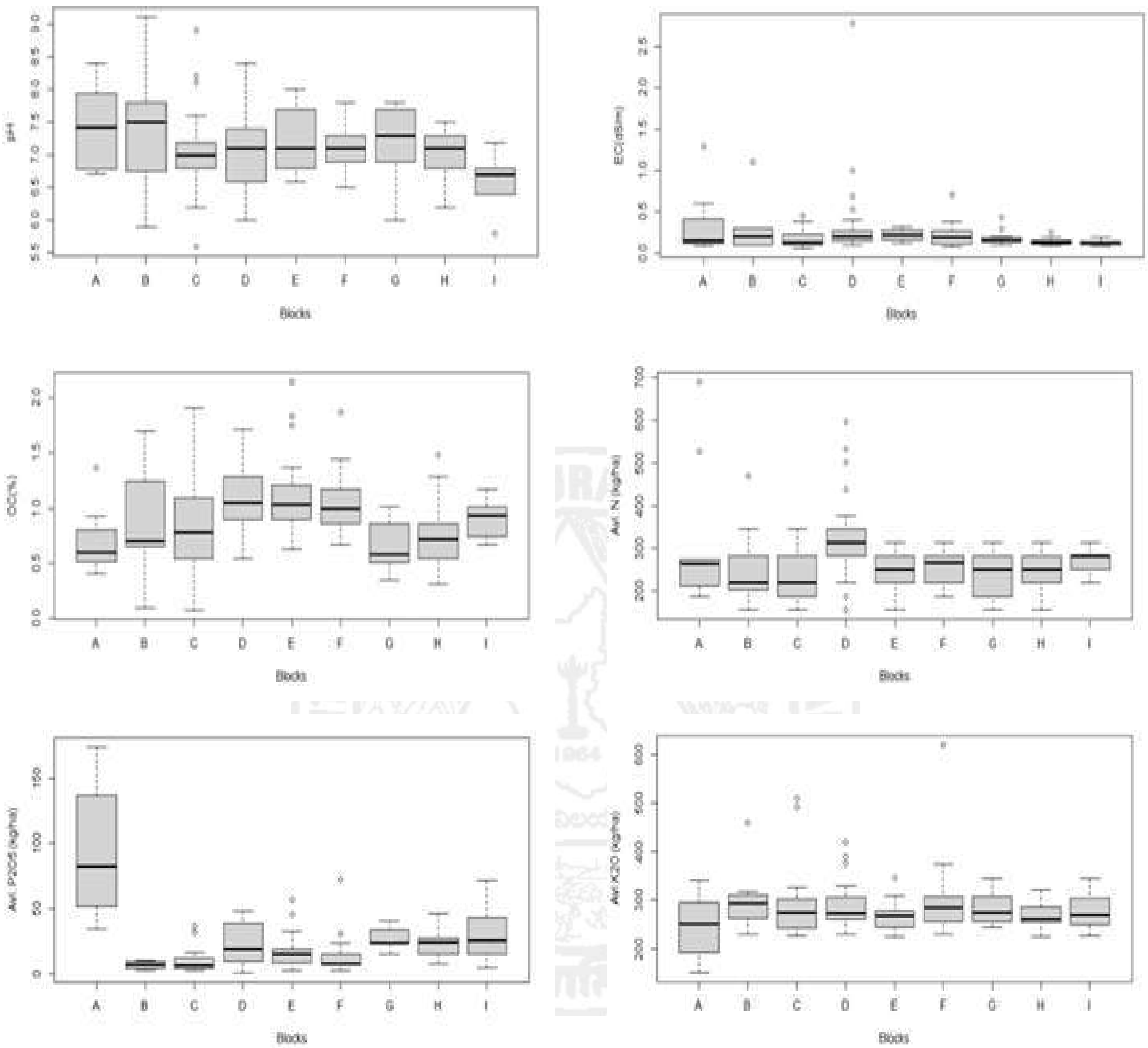

Fig. 9 : Box plots representing variability of soil fertility

visualisation of spatial distribution of various soils. The mono-cropping coupled with mismanagement of irrigation prone for soil degradation in particular development of sodic and saline-sodic soils. Based on the results of soil reaction and higher soluble salts, block B and D can be classified as saline and saline sodic soil due to lower topography coupled with poor drainage and cultivating mono-cropping of Paddy and Sugarcane. The soil prone for degradation has to be reassessed for suitability and measures to overcome in order to achieve optimum soil health.

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