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USE OF HIGH ACCURACY GPS FOR SOIL GEOCHEMICAL MAPPING IN PADDY FIELDS; A CASE STUDY IN KALUTARA, SRI LANKA

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ABSTRACT: Commonly, paddy fields in Sri Lanka are nearly flat grounds and no much geochemical variation is expected within a single field. Paddy fields in the wet zone along the western coastal areas show remarkable decrease in land areas used for rice cultivation mainly due to low productivity. Soil geochemical parameters in paddy fields are governing factors in rice production. Fertilizer dose is recommended for areas or fields and farmers apply the same amount of fertilizer to all paddy fields without considering local variations of the soil fertility levels of fields. Present study aimed to analyze local variation of cultivated paddy fields including topography and soil geochemistry using high accuracy GPS data by developing Digital Elevation Model (DEM) and GIS models.

Present research was carried out in paddy fields in Kalutara. The land was surveyed using GPS-RTK method with the aid of high accuracy GPS. Soil samples were taken in a grid at two different depths (15 cm and 30 cm) and analyzed for P, K, Mn, Fe, Cu, Zn and organic matter and pH was also measured. Results showed greater variation in all these parameters spatially as well as vertically in the soil profile, though this single field generally appeared as flat ground. Constructed maps demonstrated that certain parts of the field contained higher level of nutrient elements than standards while certain areas lesser than standards for rice cultivation. The DEM showed 3.8 m elevation difference from west to east direction within the same field. The observed variation in geochemistry of the paddy fields was closely related to the slope/aspect of the terrain.

This study revealed that topography of the terrain and existing geochemical parameters should be taken into consideration when recommending fertilizer dose to the field. It is recommended to develop a local topographic model showing elevation and spatial variation of soil chemical parameters to select optimal level of fertilizer.

1.0 Introduction

Rice is one of the most important food crops and the staple food for over 60% in the world population. Further, the population of rice consuming countries are growing continuously, and it is estimated that it is needed to produce 40 times more rice in 2030. Presently, rice cultivation is facing severe problems such as unavailability of suitable land, unfavourable climatic condition and not adoption of new technology (Gurdey, 2005). Other most important factor for rice cultivation is application of proper fertilizer doze to get optimised yield. Specially in Sri Lankan context, other than global issues, Sri Lanka facing severe problem of decreasing the present rice growing areas due to several reasons.

1.1 Rice cultivation in Sri Lanka

Rice is an important food crop, and it is consumed by more than half of the world population. Sri Lanka has 730,000 ha available land for rice cultivation. It is grown under both irrigated and rain fed conditions in the dry, intermediate, and wet zones of Sri Lanka during two cropping seasons: *maha* (October to March) and *yala* (April to August) and 560,000 ha (76%) are cultivated in *maha* season while 310,000 ha (42%) are cultivated in *yala* season. The Government spends considerable amount of money to develop rice cultivation in *maha* season. In Sri Lanka most paddy fields are confined to wet zone and yield is relatively lower compared to dry zone. Most paddy fields are wetlands, therefore the plant needs to be adapted to environment of the wetland. Farmers 'average yield and potential yield vary with deferent rice growing environments (Table 1).

Table 1: Average and potential rice yield in different ecosystems

Ecosystem	Season	2007AVG yield t/ha	Realizable potential t/ha	Target, t/ha	
				2010	2015
DZ & IZ major	*Maha*	4.95	8.0	6.0	6.5
	Yala	4.93	8.0	6.0	6.5
DZ & IZ miner	*Maha*	4.35	8.0	5.0	5.5
	Yala	4.30	7.0	5.0	5.5
DZ-rain fed	*Maha*	3.12	6.5	3.5	4.0
	Yala	3.67	5.5	3.8	4.0
IZ-rain fed	*Maha*	3.54	6.0	4.0	4.5
	Yala	3.49	6.0	4.0	4.5
WZ	*Maha*	3.21	5.0	3.8	4.25
	Yala	3.25	5.0	3.8	4.25

Source: Department of census and statistics 11-10-2015

1.2 Present issues in rice cultivation in Sri Lanka

Currently, agricultural inputs such as seeds, irrigation, fertilizers and pesticides are applied as evenly as possible over a given field, but the yield at the end of the growing season often varies across the field. Changes in soil texture, organic matter, salinity, subsoil characteristics and water holding capacity are factors that can cause changes in the yield. It is more economical to apply different amounts of agricultural inputs to identified sections of the field that have different soil properties. Developments of field maps with spatial variation of such properties are needed to overcome this problem. Thus introducing new technology and implementing GIS and GPS techniques would help to improve the productivity.

As most of the paddy fields in wet zone get abandoned and Rice Research Institute (RRI) has taken some initiatives to overcome the problem, which has not been solved. Since the standards and fertilizer recommendations are given regionally, it has not been successful due to local variation of the geochemical and other soil properties, which was not taken into consideration. Present study aimed to analyze local variation of such properties, and it will help to give proper recommendations in future. Thus, main objective of the present study was to determine spatial pattern of physical and geochemical parameters which affect rice cultivation using high precision GPS data along with GIS techniques.

2.0 Spatial analysis, geochemical aspect and agronomic practices in rice cultivation

The problem of spatial distribution of geochemical parameters has been addressed by several researches with different methods. Spatial and temporal variability of soil properties (Nayanaka, 2010) and geostatical analysis on soil qualities have been studied (Bo Sun *et al.*, 2003). A methodology for analyzing and mapping of land suitability in the paddy field was developed (Widiatmaka et al., 2014). Significant levels of variability in some common soil properties, mainly soil nutrients and other all physical and chemical parameters with rice production were observed in paddy fields (Trangmar *et al.*, 1987;Yanai *et al.*, 2000; Inamura *et al.*, 2004 and Yanai *et al.*, 2012). Soil pH, availability of P and K were found to get spatially set up both within anaerobic grain crop and aerobic terrain uses (Bo Sun *et al.*, 2003).

Most of previous researchers used spatial analysis techniques only on geochemical distribution in soil (Mzsuku, *et al.*, 2004), and they have not used accurate digital elevation model to analyze geochemical parameter. Though paddy fields distributed all over the island in Sri Lanka effect of small changes in topography on rice cultivation have not been considered. Present development of GIS techniques such as digital elevation model and Multi-criteria analysis (Samanta *et al.,* 2011, spatial analysis, GPS measurements and interpolation tools help to model spatial variation of geochemistry of soils.

3.0 Study area

The study area belongs to Kaluthara district in Western province and Bombuwala *Grama niladari* (GN) division of Sri Lanka and most paddy lands are located in low elevated terrains. The area falls in coastal geomorphological zone and general elevation is less than 15 m from mean sea level. Total study area is seven hectares, and it is managed by Rice Research Institute (RRI), Sri Lanka. Rice is cultivated in the study area in different times of the year for research purposes and marked elevation variation cannot be observed in the rice field (Figure1).

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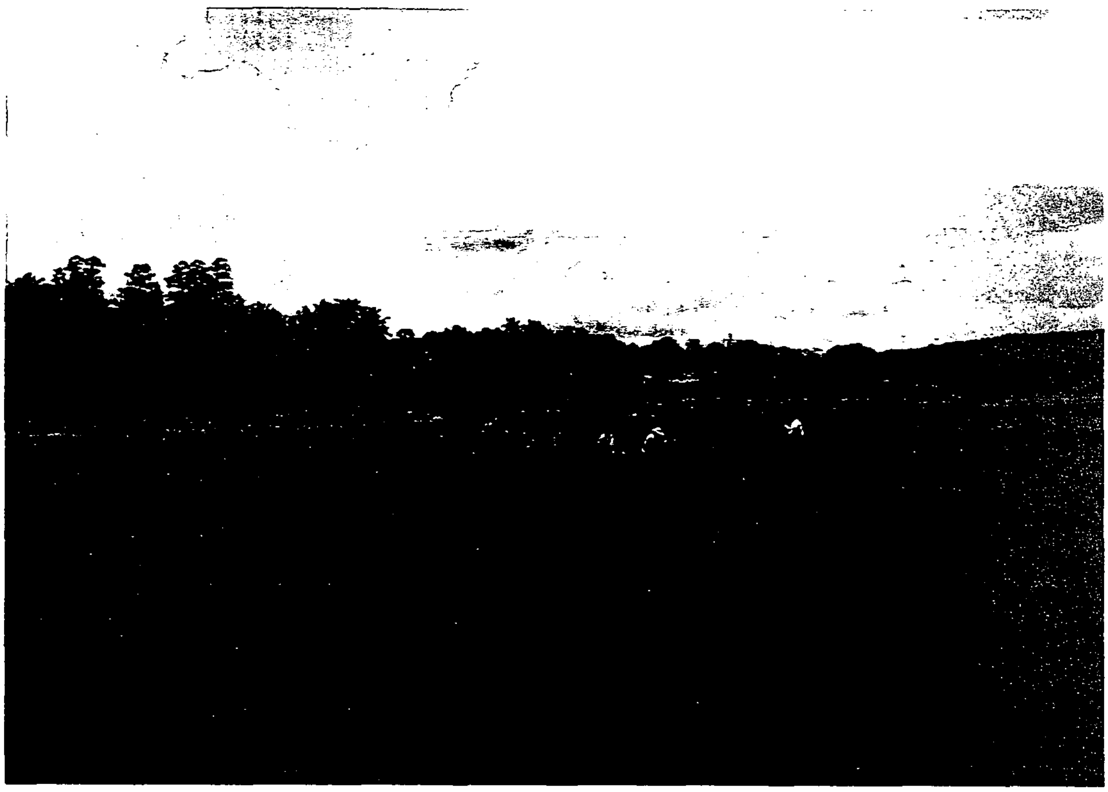

Figure 1. View of rice filed in Bombuwala showing almost flat ground.

Climatologically, the area is in the wet zone of Sri Lanka where the average annual rainfall recorded as 5,000 mm. Other characteristics features are high RH with tropical climate due to near vicinity of the western coast of Sri Lanka (4 - 5 km away from the coast).

3.1 Field study

Elevation variation in the study area was calculated using high accuracy GNSS. Locational data were collected using two types of GNSS receivers; Magellan explorist 510 GPS receiver and Navcom Land Pak 3040 high accuracy Precise GNSS receiver. Since the area appear as flat land having low elevation difference, 1 cm accuracy XY reading and 1.5 cm accuracy Z (MSL) reading were needed. Therefore, Navcom Land-pak SF 3040 precise GNSS receiver was used. Real Time Kinematic (RTK) method was used to collect GPS location since it gives precise readings during the survey. When using RTK, there should be a link between GPS base station and the rover (user). Since there was no a reference point to fix base station in the area, we fixed a base point using point transferring technique from known point (Figure 3.6), using high accuracy GNSS receiver. Subsequently, GNSS reference point, "GNSS base" was fixed in the site. Study area was marked as polyline format using high accuracy GNSS receiver. Spatial data were collected as points (with soil sample), line and polygon (boundaries) using GPS.

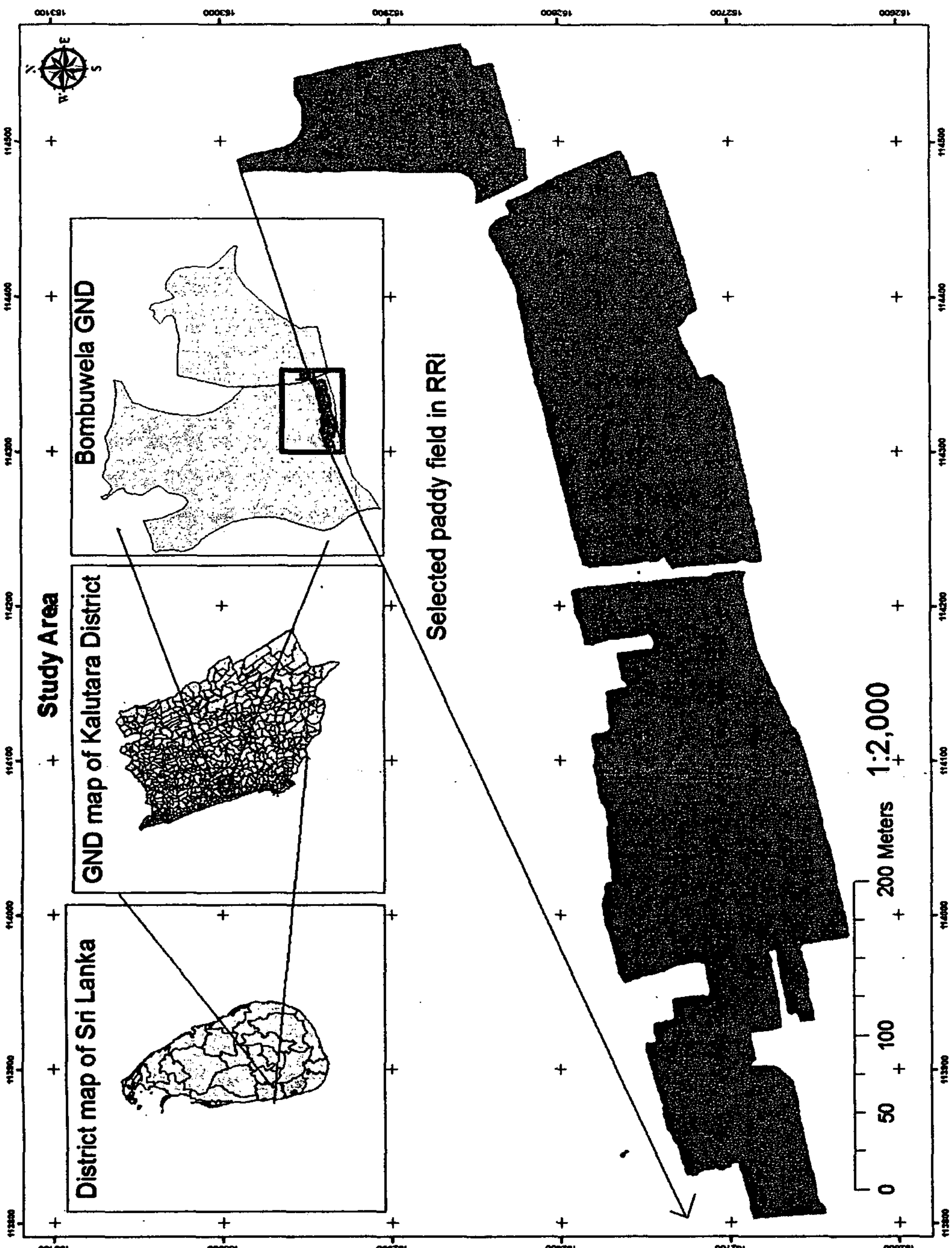

Figure 2. Map of the study area.

3.2 Soil sampling and analysis

Soil samples were collected along with GPS location and taken at two different depth ranges (0 -15 cm and 15-30 cm) using soil auger at a 40 m regular grid intervals throughout the 8.14 ha plot. At the subsurface, soil sampling was done at regular grid intervals of the same depths.

Soil Chemical analysis

Soil samples were analyzed using standard methods soil geochemical properties (pH, P, K, Cu, Zn, Mn and Organic matter) were measured.

GIS analysis procedure

All collected data were analyzed using ArcGis 10.1 platform and Erdas 2014 and processed digital maps. Digital Elevation Model (DEM) and water flow direction model were prepared using GPS point data (X,Y,Z). Geochemical parameters were interpolated and spatial maps were prepared using IDW method.

4.0 Results and Discussion

After development of digital elevation model (DEM) in the site major geochemical parameters were interpolated and the correlations among them were determined. All geochemical parameters studied show remarkable variation within the study area though the paddy fields show very similar topographic characteristics throughout the site.

Potassium distribution in surface soils (A) and subsurface soils (B) showed a difference which is also correlated with the elevation of the ground. In subsurface there is no remarkable variation of K distribution from high elevated areas to lower elevated areas whereas there was a remarkable variation of K distribution in surface soils (Figure 3). According to DEM and potassium maps, available potassium concentration of the study area vary and lower elevation areas had lower K concentration while higher elevation areas showed higher concentrations compared to standards recommended for rice cultivation.

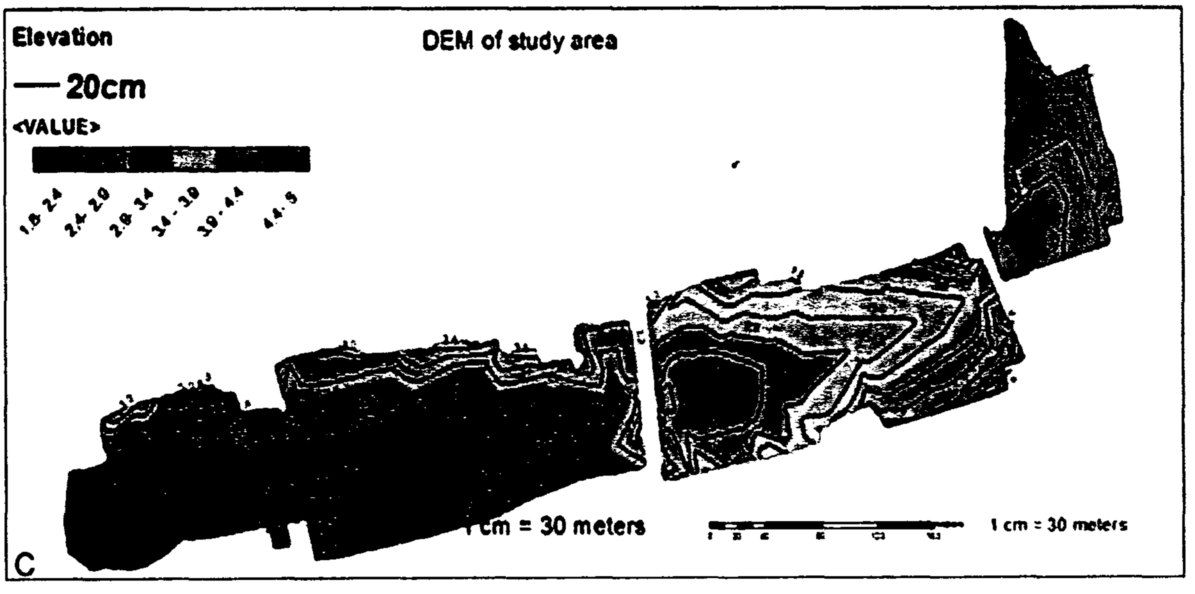

Figure 3. Digital Elevation Model (DEM) of the study area

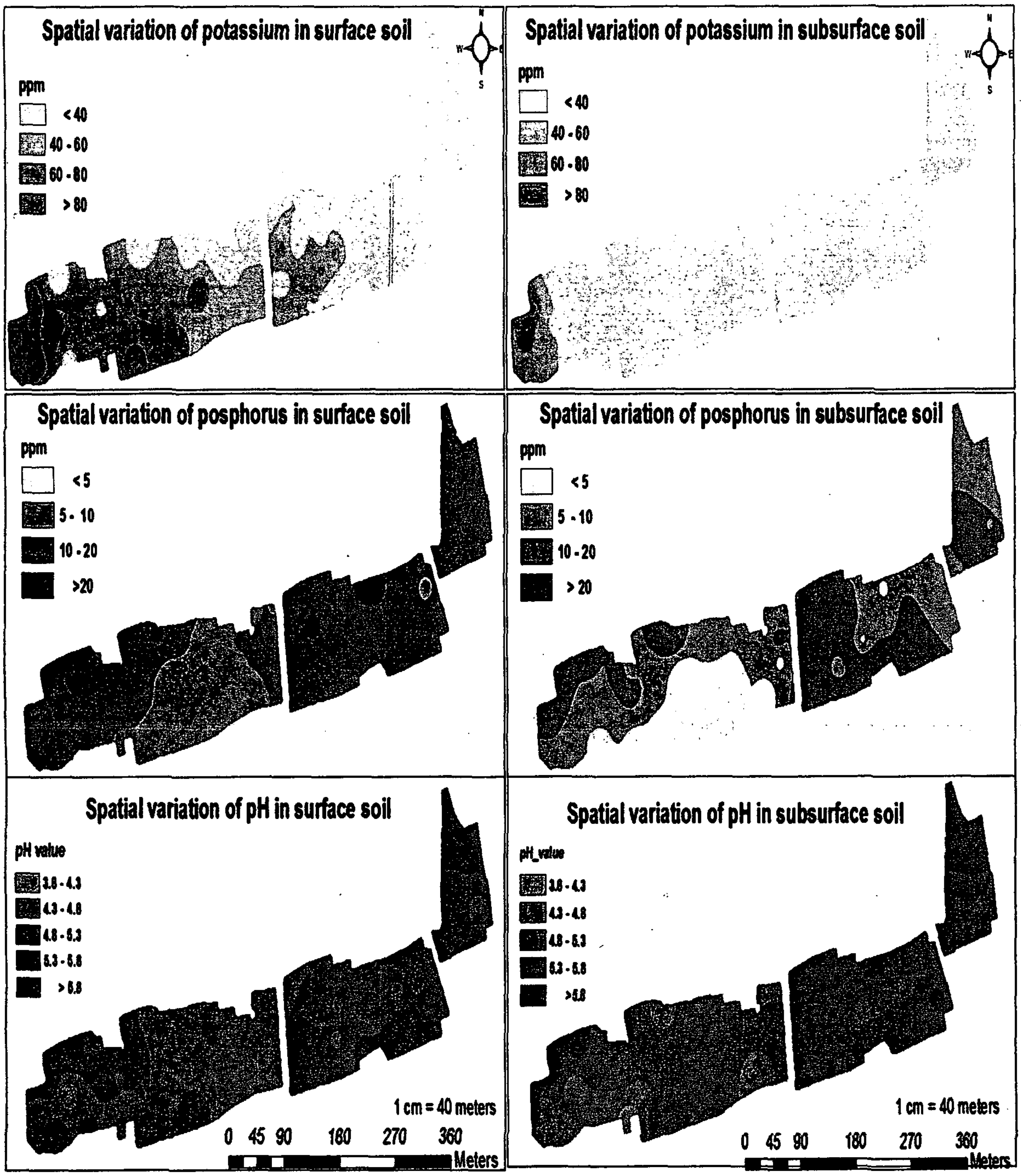

Figure 4. Spatial variation of pH, K and P in surface and sub-surface soils in the area

Phosphorus (P) distribution in surface soils and subsurface soils shows some variations which is further correlated with the elevation of the ground. In subsurface there is no remarkable variation of P distribution from high elevated areas to lower elevated areas while there is a remarkable variation of P distribution in surface soils (Figure 4). According to DEM (C) and P maps, available phosphorus concentration of the study area shows some areas having lower P concentrations while other areas having higher concentrations compared to standards recommended for rice cultivation.

Table 2. Variation of Geochemical parameters in surface and subsurface soils in the study area.

Geochemical constituent	Surface soil	Subsurface soils
Potassium	40-80 ppm	40-60 ppm
Phosphorus	5-20 ppm	5-20 ppm
Copper	0.35-1.26 ppm	035-1.37 ppm
Zinc	0.9-47 ppm	3.0-33.4 ppm
Iron	85-727 ppm	85-907 ppm
Manganese	2.2 -12.57 ppm	2.2-7.93 ppm
Organic matter	4-16 %	3.5-9 %
pH	3.8-6.3	3.8-6.3

Main elements of the surface soil of this area were calcium, phosphorus, manganese and potassium. The area records pH below 7, and it can be seen gradual decrease from upper side to lower side of DEM varying from 6.8 to 4.0. Low pH value was observed in lower part of DEM (Figure 3 and 4). Soil pH is a vital factor which governs availability of nutrients to plants. Soil pH can increase or decrease the solubility of phosphates (Biswas and Mukherjee, 2001). Important nutrients of plants, such as K, P, Cu, Zn, Mn, Fe and organic matter show remarkable variation with the elevation difference from upper part to lower part in the surface soils (Table 2). But K and pH variations are not significant in the subsurface (Figure 4 and 5). Spatial variation of soil nutrients in local scale due to topographic changes have been identified in the present study, and it was comparable with some previous studies (Cambardella *et al.*, 1994; Mzsuku *et al.*, 2005).

Digital Elevation Model (DEM) developed for the area of 8.1 ha shows 3.4 m elevation difference. The elevation difference between lower side of the DEM and sea level is 10 m, thus lower part of the land always get flooded during rainy seasons of the year.

Conclusions

Developed local topographic model showing changing pattern of elevation and spatial distribution of soil geochemical parameters would be useful to plan application of agrochemicals to the field in order to get the optimal yield. High accuracy GNSS measurements and high-tech GIS tools can be used for efficient analysis. Geo-chemical parameters of paddy field soils of Bombuwala demonstrated high variation with slope/aspect. As global records show on sea level changes, and it impacts on coastal areas, this type of model will also help to minimize the impact on agriculture as one of the important sector in food security of the country.

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