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Spatial variation of soil properties in paddy fields of Polonnaruwa district

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Abstract

Identification of spatial variation of soil chemical properties in paddy fields and adoption of remedial measures are needed to maintain a good soil health. It has been well accepted that thematic maps of soil properties can use to identify the variations and introduce soil test based fertilizer recommendations for optimum crop yield while conserving the environment. Therefore, this study was conducted to prepare thematic maps of soil parameters in Polonnaruwa district. Soil samples in depth of 0-15 cm were collected from 2.5 km by 2.5 km grids. Sampling points were demarcated by Global Positioning System (GPS). Collected soil samples were analyzed for available soil P by Olsen's method, exchangeable-K by 1N NH_4OAc (pH=7) extraction method, exchangeable Zn by EDTA extraction, soil pH by 1:2.5 (soil:water), electrical conductivity by 1:5 (soil:water) and soil organic carbon contents by Walkley-Black method. Tested values were mapped using ArcGIS 10.5 and legends were prepared based on the optimum and critical values of each parameters. Available soil phosphorous maps of Polonnaruwa district showed that 32% of land have optimum P content and 58% of them have excess of P. Soil exchangeable K is low (< 80 mg/ kg) as 98% of land area and only 2% of area is in the optimum K level. About 32% of the land has low Soil pH and soil salinity is not critical in 98% of paddy field in the district. About 82% of the area shows critical level of Zn (<1 mg/kg) and 98% of them show very low level of organic matter (< 3%). The land parcels where remedial measures should be applied can be easily identified through the prepared maps even without analyzing soil samples in each field at any time.

Key words: Rice, Soil chemical properties, Spatial variation, Polonnaruwa

Introduction

A majority of the paddy fields in Sri Lanka are cultivated with high yielding rice varieties having the yield potentials of about 10 t/ha. High yielding varieties need optimum rate of nutrient supply to produce optimum yield benefits (Abeysiriwardena and Sandanayake, 2000). Phosphorus and potassium are two of the key fertilizer elements required by rice, and a crop yielding 6 t/ha grain yields removes around 18 kg of P and 120 kg K per season per hectare (Wickramasinghe *et al*., 2009). Since part of the applied P and K become unavailable and lost in many ways, high rate of P and K fertilizer has been recommended to rice crop. Application rates were 45 kg P_2O_5/ha and 50 kg K_2O/ ha for Dry and Intermediate zones according to 2013 fertilizer recommendation. It has been observed that even without application of P and K fertilizer for 30 years in an experimental field, rice crop has produced grain yield of around 3 t/ha per season (RRDI, 2013). It suggest that soil has an ability to supply around 9 kg/ha of P and 60 kg/ha of K per season without application of P and K for 30 years in that particular location. Hence, when grain yield is around 3 t/ha, application of higher level of P and K fertilizer increases the accumulation of soil P and K in paddy soils (Kendaragama *et al*., 2003). Excessive use of fertilizer is a waste of resources and over use of fertilizer has been attributed to eutrophication in water bodies. Therefore, judicial application of P and K fertilizer has become a necessity to efficient utilization of P and K and while avoiding any detrimental effects to the environment. Soil test based fertilizer application for rice was introduced in 1993 to manage P and K fertilizer efficiently, but it is not being practiced by majority of the farmers at the moment. It is known that farmers are reluctant to test their soils as they do not know the importance of efficient P and K management under the present fertilizer subsidy program. If measures can be taken to distribute subsidized P and K fertilizer according to soil P and K levels in the soil, farmers may avoid the unwanted P and K application. Therefore, mapping of available soil P and exchangeable K levels in soil would be helpful in determining P and K fertilizer requirement of a particular location. In addition, availability of information on acidity, conductivity and exchangeable Zn should also be estimated beforehand (Bandara, 2006 and Sirisena, 2013) to arrive at correct soil management options. Therefore, objective of this study was to assess the P and K status of paddy soils in the district and map them to find out the P and K requirement based on

spatial distribution. In addition to map the soil pH, electrical conductivity, exchangeable Zn and soil organic matter to implement measures to enhance the rice production in the district.

Materials and methods

Polonnaruwa district in North Central Province was selected as the study area. Location map of the study area and the distribution of paddy fields in the district are shown in Figure 1.

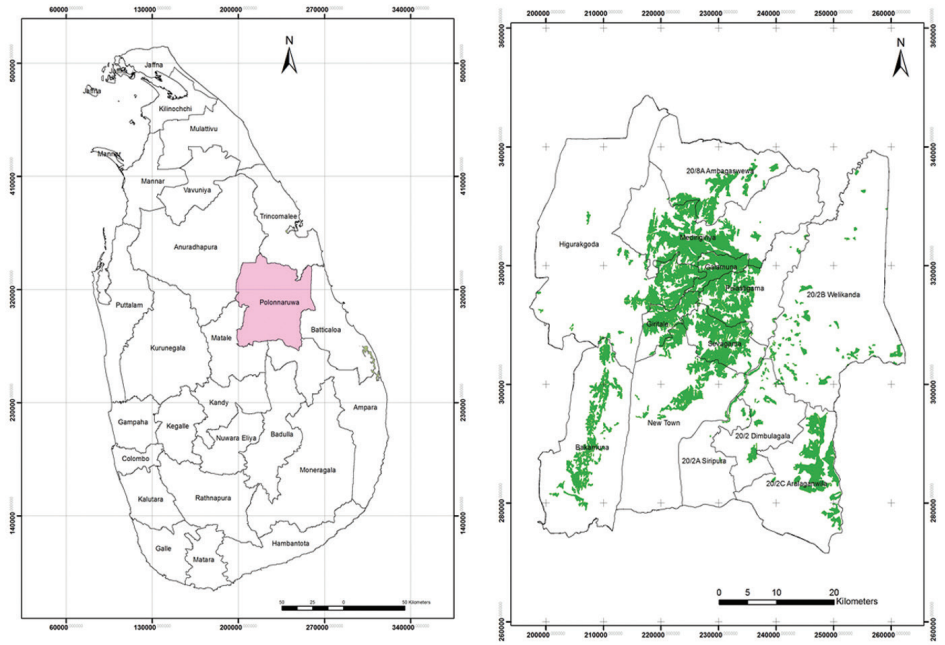

Figure 1. Location map of Polonnaruwa district and distribution of paddy area in the district
Map Source: Stereo compilation, Sri Lanka Survey Department (1999) [Scale:1:50,000]

Analogue and digital maps of 1:50,000 prepared by the Survey Department of Sri Lanka were used as base maps. About 346 soil samples were collected and the area for sampling was demarcated by 2.5 km by 2.5 km grids to represent the whole district. Two soil samples were collected from the upper and lower positions of one selected representative paddy track belongs to one grid for analysis. Samples were collected using a soil auger up to the depth of 15 cm from the top. Coordinates of the soil sampling position were taken by Global Positioning System (GPS) of each sampling points. Collected soil

samples were air dried and sieved through 2 mm sieve and used for the standard chemical analysis (Dharmakeerthi *et al*., 2007).

Chemical analysis was carried out at the soil testing laboratories of Rice Research and Development Institute (RRDI), Batalagoda and Field Crops Research and Development Institute (FCRDI), Mahaillupallama of the Department of Agriculture. Soil samples were analyzed for available soil P by Olsen's method, exchangeable-K by 1N NH_4OAc (pH 7) extraction method, exchangeable Zn by EDTA extraction, soil pH by 1 soil: 2.5 water and Electrical Conductivity by 1 soil: 5 water. Soil organic carbon contents were analyzed by Walkley-Black method and converted to organic matter by multiplying 2 (Dharmakeerthi *et al*., 2007).

Analyzed data were recorded in Excel and ArcGIS 10.5 was used to prepare thematic soil maps for available soil P, exchangeable soil K, soil pH (1: 2.5), exchangeable soil Zn and Electrical Conductivity (1: 5) in the district at RRDI. According to the soil test values reported by the Soil Test based Fertilizer Recommendation (DOA, 1997), three categories were assigned for available-P, i.e. < 5 mg P/kg, 5-10 mg P/kg and > 10 mg P/kg. Four categories were identified for exchangeable-K, i.e. < 40 mg/kg, 40-80 mg/kg, 80-160 mg/kg and > 160 mg/kg. Zn levels were categorized as < 1 mg/kg, 1-4 mg/kg, > 4 mg/kg (Bandara, 2005). Soil pH values were grouped into six categories as < 4.5, 4.5-5.5, 5.5-6.5, 6.5-7.5 and > 7.5. EC values were grouped into three as < 0.15 dS/m, 0.15-0.4 dS/m, and 0.4-0.8 dS/m, and > 0.8 dS/m (Lathiff, 2007). Soil organic matter content was categorized as < 2%, 2% to 3% and > 3%. Prepared maps made available to see all in the Google Earth Pro.

Results and discussion

Table 1 shows the percentage land extent of paddy fields of the Polonnaruwa district for different soil parameters. Prepared soil maps of available soil P, exchangeable soil K, soil pH (1: 2.5), exchangeable soil Zn, Electrical Conductivity (1: 5) and soil Organic Matter in the district are shown from Figure 2 to Figure 7 respectively.

Table 1. Percentage land extent of rice growing soils in paddy field of the Polonnaruwa district for different soil parameters

Soil Parameter	Value	Land extent (%)	Area(ha)
Available P content (mg/kg)	< 5	10	4,497
	5 – 10	32	14,132
	> 10	58	25,210
Exchangeable soil K (mg/kg)	< 40	22	9,667
	40 - 80	76	33,534
	> 80	2	639
Soil pH (1:5 soil : water)	< 4.5	0.3	131
	4.5 - 5.5	32	13,932
	5.5 - 6.5	67	29,356
	6.5 - 7.5	1	421
Soil EC (dS/m)	< 0.15	92	40,413
	0.15 - 0.4	7	3,278
	0.4 - 0.8	1	141
Soil Zn (mg/kg)	< 1	82	35,869
	1 - 4	15	6,862
	> 4	3	1,108
Soil Organic Matter (%)	< 2	66	28,912
	2 - 3	32	14,020
	>3	2	907

Available soil P

Analyzed soil P values varied from 1 to 53 mg/kg and showed the average as 8.9 mg/kg for Polonnaruwa district. These variations may be due to differences in absorption and desorption mechanisms of P in paddy soils and levels of P applications in the previous seasons or due to levels of Fe and Ca in these soils (Bandara, 2006). P fertilizer requirement (TSP) was estimated based on maps prepared through soil P maps. Based on the soil test, TSP was recommended as 55 kg/ha and 30 kg/ha for irrigated rice and 35 kg/ha and 20 kg/ha for rainfed rice where soil P was less than 5 mg/kg and in between 5 to 10 mg/kg respectively (Table 2). It is not recommended to apply TSP when the soil P values are more than 10 mg/kg. TSP requirement is 671 mt and 2,411 mt based on available soil maps and for the whole district blanket recommendation, respectively for the whole district.

Table 2. Soil Test values and recommended TSP fertilizer levels for paddy

Available P values (mg/kg)	TSP Recommend basal fertilizer levels (kg/ha)	
	Irrigated Paddy	Rainfed Paddy
< 5	55	35
5 - 10	30	20
> 10	Nil	Nil

Exchangeable soil K

Average values of exchangeable soil K is 53 mg/kg, with a maximum values of it as 133 mg/kg of Polonnaruwa district. The current soil test based K fertilizer recommendation for rice is presented in Table 3. The optimum K levels for paddy is in between 80 to 160 mg/kg. For the whole district K fertilizer (MOP) should be applied as recommended because there is no places having excess K.

Table 3. Soil Test values and recommended K fertilizer levels for Paddy

Exchangeable K values (mg/kg)	MOP Recommended fertilizer levels (kg/ha)			
	4 Weeks after establishment		6 Weeks after establishment	
	Irrigated	Rainfed	Irrigated	Rainfed
< 40	25	25	35	25
40 – 80	20	20	25	20
80 – 160	10	10	10	10
>160	Nil	Nil	Nil	Nil

Soil pH

Average soil pH (1:5) was 5.5 in the district. The optimum soil pH for rice cultivation is around 5.5-6.5. Sixty eight per cent of paddy fields have optimum pH and pH should be corrected at rest of the field by adding organic matter because of their acidity.

Electrical Conductivity

Average Electrical Conductivity (EC) in Polonnaruwa district is 0.1 dS/m. Maximum EC values of the district is 0.9 dS/m. When the EC is less than 0.15 dS/m, such lands will have no threat of soil salinity (Dharmakeerthi *et al*., 2007). Accordingly, 92% of the land extent is not subjected to soil salinity in Polonnaruwa district.

Exchangeable Zn

Eighty two percent of the total paddy area has very low level of Zn in the district. The optimum level of Zn for rice cultivation should be 1-4 mg/kg in soil and it covers only 15% of the area. Five kg/ha of $ZnSO_4$ has been recommended by the Department of Agriculture for paddy fields having less than 4 mg/kg of Zn (Bandara, 2006 and Sirisena, 2013).

Soil Organic Matter

Soil organic matter in the district is very low, showing the average as 2% and the maximum as 4%. Ninety eight percent of the paddy fields are very poor in organic matter content in the soil (Table 1). For an optimum crop production, organic matter content should be more than 3% (Bandara, 2005).

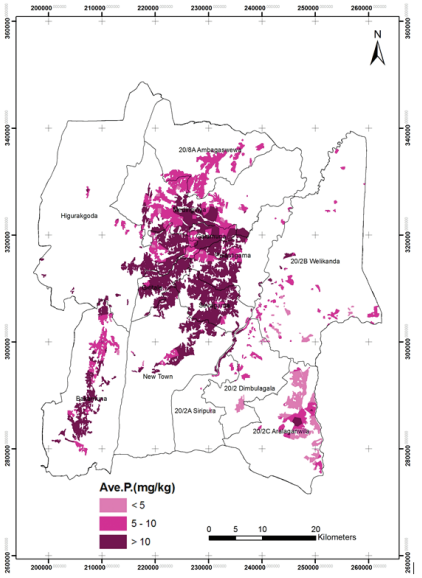

Figure 2. Spatial variation of soil available P in paddy field of the Polonnaruwa district

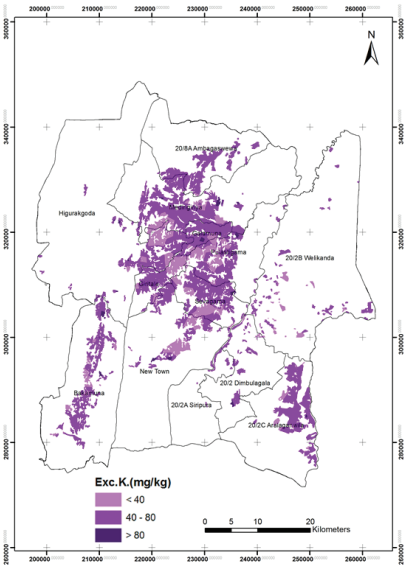

Figure 3. Spatial variation of soil exchangeable K in paddy fields of Polonnaruwa district

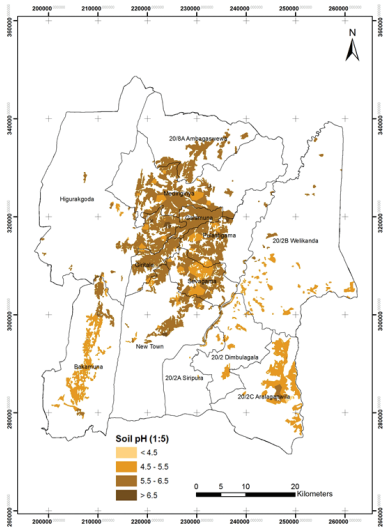

Figure 4. Spatial variation of soil pH in paddy field of the Polonnaruwa district

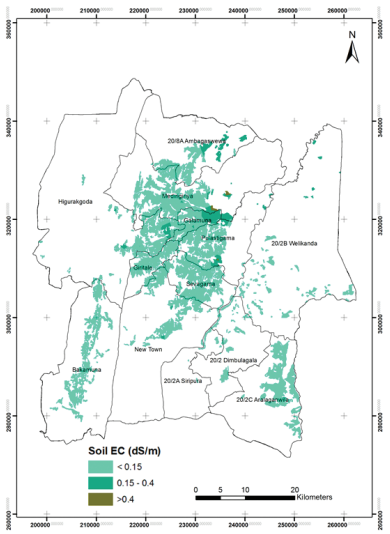

Figure 5. Spatial variation of soil Electrical Conductivity in paddy fields of Polonnaruwa district

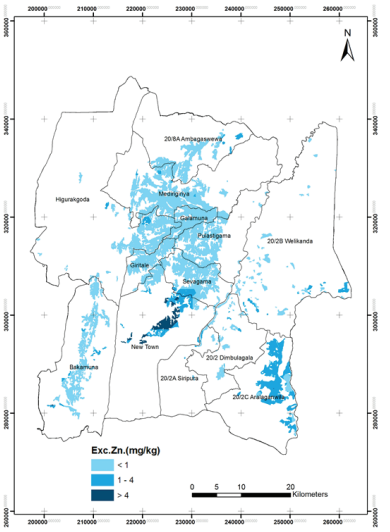

Figure 6. Spatial variation of soil Zn in paddy fields of Polonnaruwa district

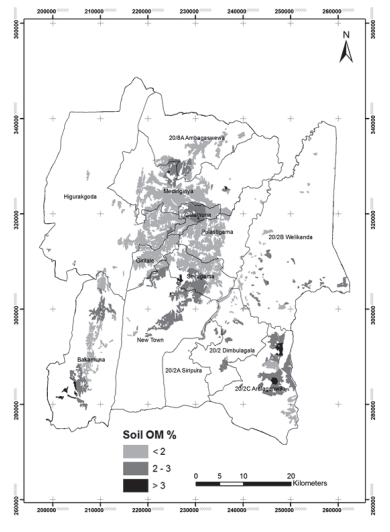

Figure 7. Spatial variation of soil organic matter in paddy field of the Polonnaruwa district

Conclusion

Available soil Phosphorous maps of Polonnaruwa district showed that 32% of land have optimum P content and 58% of them have excess of P. Soil exchangeable K is low (< 80 mg/ kg) as 98% of land area and only 2% of area is in the optimum K level. About 32% of the land have low Soil pH and soil salinity is not critical in 98% of paddy field in the district. About 82% of the area shows a critical level of Zn (<1 mg/kg) and 98% of them show very low level of organic matter (< 3%). The land parcels where remedial measures should be applied can be easily identified through the prepared maps even without analyzing soil samples in each field at any given time.

Acknowledgement

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