Annals of the Sri Lanka Department of Agriculture. 2008.10:199-210.

SPATIAL VARIABILITY OF SOME SOIL FERTILITY PARAMETERS IN RICE FIELDS OF GIRITHALE IRRIGATION SCHEME

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ABSTRACT

In recent times, a considerable gap has emerged between the potential yield and the realized yield under farmer managed conditions. Though several factors contribute to this effect, imbalanced soil fertility is suspected to be a major factor. Therefore, reconnaissance was carried out in the feeding area of Girithale tank in Pollonnaruwa after 2007 *yala* season to identify the status and spatial variability of plant nutrients in the rice tract to recommend management practices to enhance productivity. Sampling points were identified using a comprehensive irrigation block out map and geographic positions were recorded using a GPS. Sampling area represented the two drainage classes in the catena and there were 76 sampling points covering the total feeding area of 2968 ha. In each sampling point, soils were augured up to 15 cm depth and composite soil samples were collected. Soil samples were air dried and analysed for pH, Electrical Conductivity (EC), available P, exchangeable concentrations of K, Ca, Mg, Na, and Zn. Most of the area covering the irrigation scheme had pH above 6.5. In some locations pH had gone up to 7.5 or above. Electrical conductivity varied from location to location but larger area had an EC of above 0.125 dS/m indicating medium level of salinity. Calcium, Mg and Na contents were considerably high (>600 ppm Ca and > 360 ppm Mg and > 100 ppm Na) in almost all the feeding area. Contents of above three were comparatively lower in the upper part but higher in the lower part of the feeding area. Soil P, K and Zn contents were lower than the critical levels recommended for rice (< 10 ppm for P, < 78 ppm for K, and < 1 ppm for Zn) in almost all the area. It can be suggested from these results that soil fertility characteristics of the Girithale irrigation scheme are not at the optimum level to achieve maximum potential of rice yields. Therefore, development and adoption of suitable management practices to prevent accumulation of Ca, Mg and Na and to improve P, K and Zn contents in soils are necessary to enhance and sustain the rice production in this area.

KEYWORDS: Rice, Soil fertility, Spatial variability.

INTRODUCTION

With the current population growth rate of 1.1%, in Sri Lanka, the estimated demand on rice in 2010 and 2020 would be 2.02 and 2.24 million tonnes respectively. When overall wastage is taken into account, the approximate rice requirement would be 3.46 and 3.83 million tonnes in 2010 and 2020 respectively (Abeysiriwardene and Sandanayake, 2000). In order to this demand, every effort should be made to explore the full potential of existing paddy lands in major rice growing areas of Sri Lanka. More than 90% of rice cultivars grown in Sri Lanka are New Improved Varieties (NIV) and their yield potential is over 10 t/ha under favourable growing conditions (Jayawardene, 2003). Present average yield of 4.07 t/ha is far below the above

(Central Bank, 2006). As such, a significant yield gap exists between potential yield and realized yield at farm level. Scientists suggest many reasons for this yield gap but from the soil science point of view, depletion and imbalance of plant nutrients are the major factors (Panabokke, 1978).

The Polonnaruwa district is a high potential rice growing area in Sri Lanka comprising four major irrigation schemes. The Girithale irrigation scheme is one where rice has been cultivated over several decades both in *yala* and *maha*. Nitrogen, P and K fertilizers are applied for each crop in each season with the adoption of all the other recommended cultural practices but average grain yield is found to be below 5 t/ha even under favourable climatic conditions (Central Bank, 2006). No organic manure is applied and N, P and K are the only nutrient sources used. In addition, water management appears erratic and drainage canals are also blocked at many places. Thus, the above factors may have hampered the soil fertility and there may be building up of excess quantities of some plant nutrients and depletion of some other. According to Dobermann and Fairhurst (2000), accumulation of excess amounts of Ca, Mg and Na may increase soil pH in the soil and hinder the availability of important plant nutrients such as P and Zn. Since cultural practices adopted and water management procedures are different from place to place, spatial variability in soil fertility may also have emerged causing an uneven productivity throughout the rice tracts. Hence, under these circumstances, low utilization of applied fertilizer is experienced leading to high cost of production and low crop yields. Therefore, identification of soil fertility status and understanding of its spatial variability are considered as important criteria to increase productivity through adoption of suitable management practices.

The objective of this study was to identify soil fertility status of paddy fields in the feeding area of the Girithale irrigation scheme and to understand the spatial variability to recommend site specific and suitable management practices.

MATERIALS AND METHODS

The study was carried out in the feeding area of the Girithale tank (Latitude 216597N, Longitude 310296E) of the Polonnaruwa district at the end of 2007 *yala* season. Distribution pattern of the sampling points was chosen as similar to the distribution pattern of feeding canals and the drainage classes of the rice tracts. Geographical positions of sampling locations were recorded using a Geographical Position System (GPS). In each location, soils were augured up to 15 cm and composite soil samples were prepared. Around 500g soil sample was collected from each sampling point and they were packed in polythene bags and transported to the laboratory for analysis.

Soil samples were air dried, crushed and passed through a 2 mm sieve to be used for chemical analysis. Processed soil samples were analysed for pH, Electrical Conductivity (EC), available phosphorus, exchangeable K, Ca, Mg, Na and Zn. All analyses were replicated twice to receive average values. Sampling points were taken as parameters and an attributes table was created. Analytical data were tabulated and thematic maps were prepared based on the result on the digitalized map in the Girithale scheme using Arc View 3.3 software.

RESULTS AND DISCUSSION

The distribution patterns of drainage classes and irrigation canal layout were initially examined in 1:24,000 topographical sheets. Seventy six sampling points were selected to cover the 2970 ha area representing around 39 ha per sample (Fig. 1).

Table 1. Some chemical properties of the soils of the feeding area of the Girithale irrigation scheme.

Soil property	*Value*		
	Minimum	*Maximum*	*Standard Deviation*
pH (1:2.5,soil:water)	6.06	8.09	0.49
EC (dS/m)	0.023	0.258	0.064
Olsen P(mg/kg)	2.0	22.50	3.97
Ex: K* (mg/kg)	25.5	241.9	27.0
Ex: Zn*(mg/kg)	0.13	1.93	0.37
Ex: Ca* (mg/kg)	509.0	1705.0	365.0
Ex: Mg* (mg/kg)	210.0	2039.0	316.0
Ex: Na*(mg/kg)	61.0	324.0	50.0

* 1N NH_4OAC (pH=7) Extraction

Some important chemical properties of soils of the Girithale feeding area and given in Table 1 and Figure 2 shows the distribution pattern of soil pH in the commanding area. According to these results soil pH of the area ranges from 6.06 to 8.09 in the top soil and average soil pH of the top soil was 6.78. In comparison to soil pH of 6.5 – 7.2 reported by Panabokke and Nagarajah (1964) in respective area, there is a potential of developing unfavorably high pH for rice cultivation in time to come (Focht, 1979). Higher content of basic cations in the soil and high evaporation during the dry season may have affected the increase soil pH in this area (IRRI, 2004). The optimum range of pH suitable for rice cultivation is 5.5-6.5 (Bandara, 2005) but seventy one percent of the total extent in the Girithale scheme had pH more than 6.5. As such, measures have to be implemented to reduce the pH of the soil.

Electrical conductivity depends on the soluble salt content in the soil. Higher the salt content higher will be the EC values. Results appearing in Table 1 show that maximum levels of EC reported are higher than the EC values reported for these soils earlier by Moormann and Panabokke (1961). According to observations, there were higher EC values in lower peneplain of the catena (Fig. 3). There were isolated pockets with very high EC (>0.2 dS/m) in top soil. Average EC (soil:water, 1:5) value was 0.063 dS/m (Table 1) and 3% of the extent showed EC values higher than 0.125 dS/m. Though soil sampling was done after the *yala* season and there were heavy rains during the sampling period, there were places where EC values are 10 times higher than the values reported for these soils by Moormann and Panabokke, (1961).

Application of poor quality irrigation water, exposure of wet soil surface to prolonged evaporation, poor drainage and soluble salt in parent materials may have caused the higher EC in these soils (Focht, 1979, Handawela, 1982). Therefore, there is a potential of development of salinity in lower peneplain of the catena.

Calcium and Mg are the most prominent cations in the dry zone soils of Sri Lanka. Spatial distribution of exchangeable Ca is shown in Figure 4. Around 99% of command area is reported to have exchangeable Ca levels higher than 600 mg/kg. The range of exchangeable Ca in the top soil was 509 – 1705 mg/kg (Table 1).

The range of exchangeable Ca levels in command area was higher in comparison values of 400 – 1200 mg/kg reported by Panabokke and Nagarajah (1964) for rice growing soils in Polonnaruwa. Ca saturation of Cation Exchange Capasity (CEC) should not be higher than 20% to have a good rice crop (Doberman and Fairhurt, 2000) but the area studied had average exchangeable Ca 52.5% of CEC (5cmol$_c$/kg) giving unfavourable conditions for rice.

Exchangeable Mg varied between 210 mg/kg to 2039 mg/kg (Table 1). These values are comparatively higher than the values of 360 – 720 mg/kg reported for rice growing soils in Polonnaruwa by Panabokke and Nagarajah (1964). The average exchangeable Mg level in top soil was 531 mg/kg. About 81% of the study area has more than 360 mg/kg of exchangeable Mg (Fig. 5). Exchangeable Mg levels were more than 1000 mg/kg in lower part of the catena and Ca and Mg cementations were also visible in most of the poorly drained paddy soils.

Calcium and Magnesium should be available in sufficient quantities and also in balanced ratio to avoid excessive uptake of one element. Therefore, Ca:Mg ratio has been identified as one of the important parameters in balanced nutrient uptake in rice (Dobermann and Fairhurt, 2000). The distribution pattern of Ca:Mg ratio of the study area is shown in Figure 6.

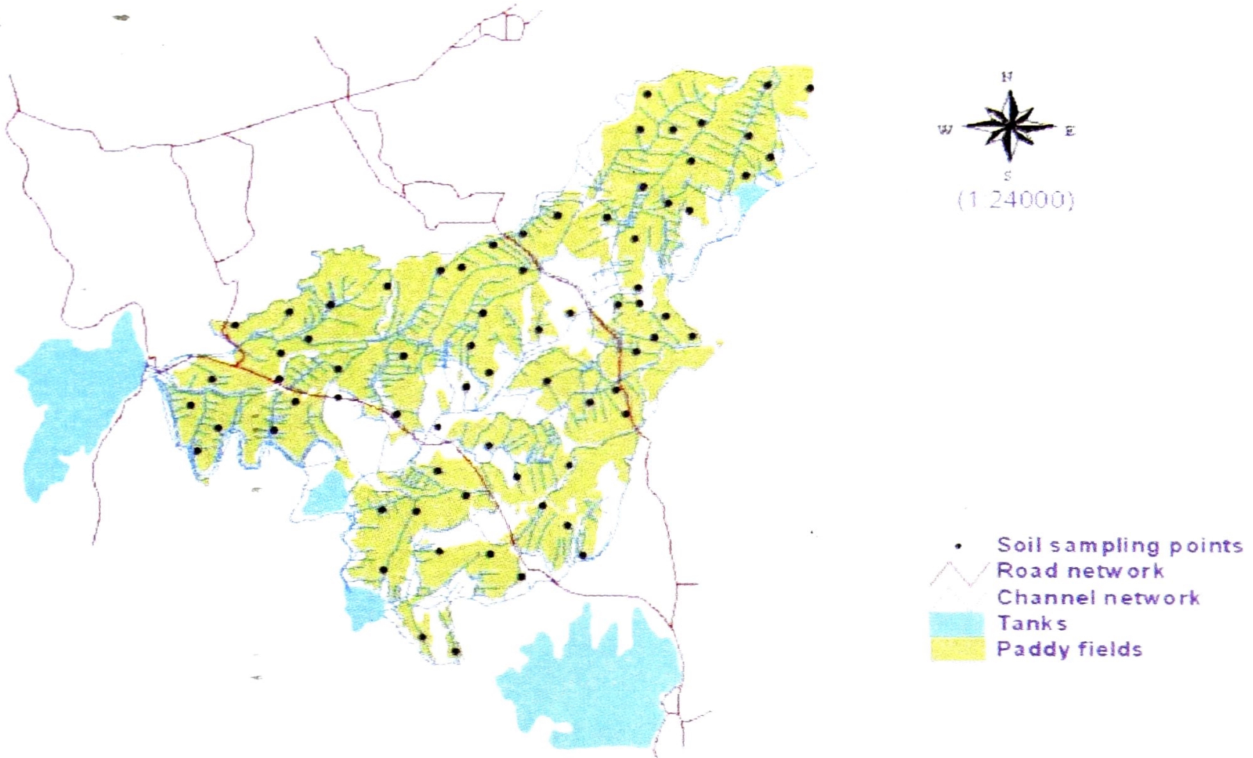

Figure 1. Sketch map of the Girithale major irrigation scheme indicating sampling points.

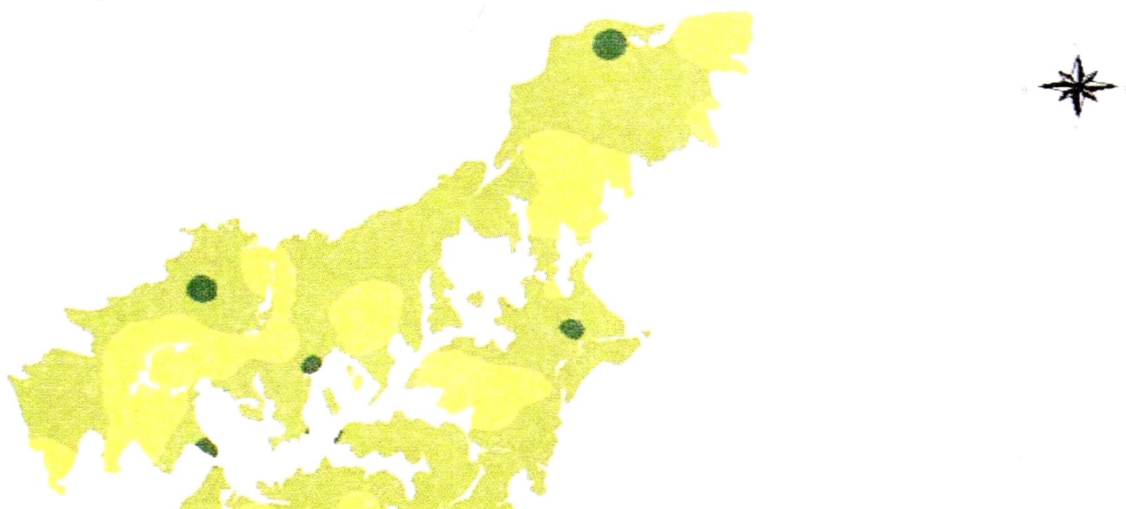

Figure 2. Spatial variability of top soil pH in the feeding area of Girithale irrigation scheme.

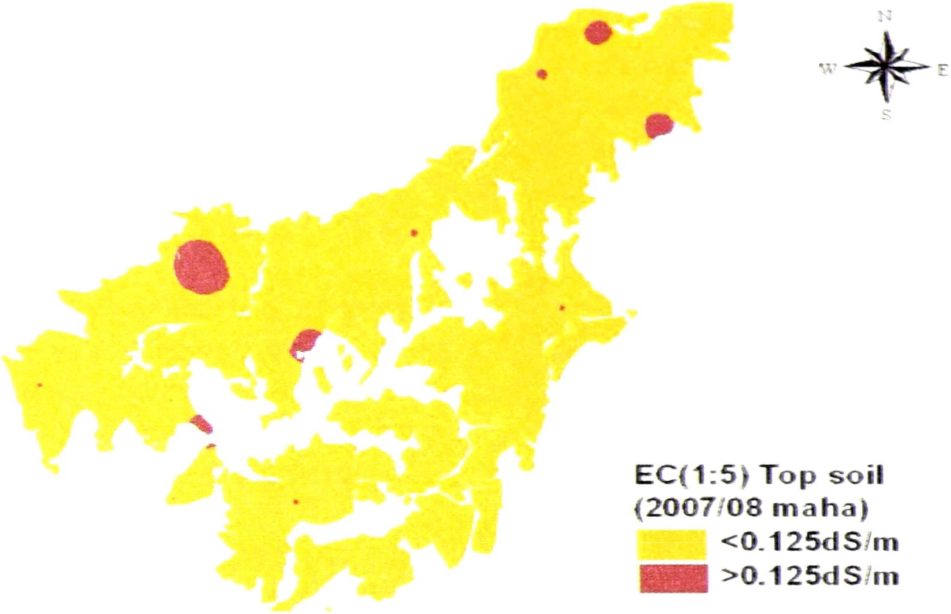

Figure 3. Distribution pattern of the EC in top soil of the feeding area of Girithale irrigation scheme.

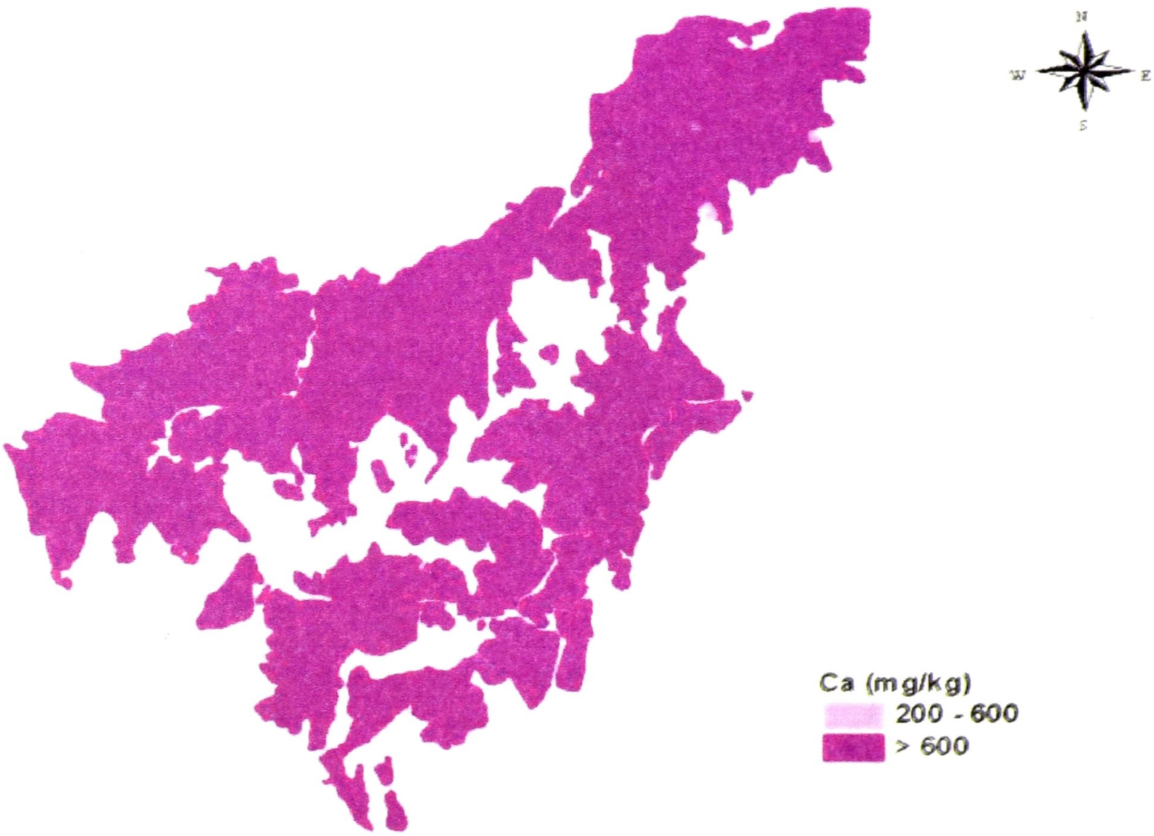

Figure 4. Distribution pattern of the exchangeable Ca in top soil of the feeding area of Girithale irrigation scheme.

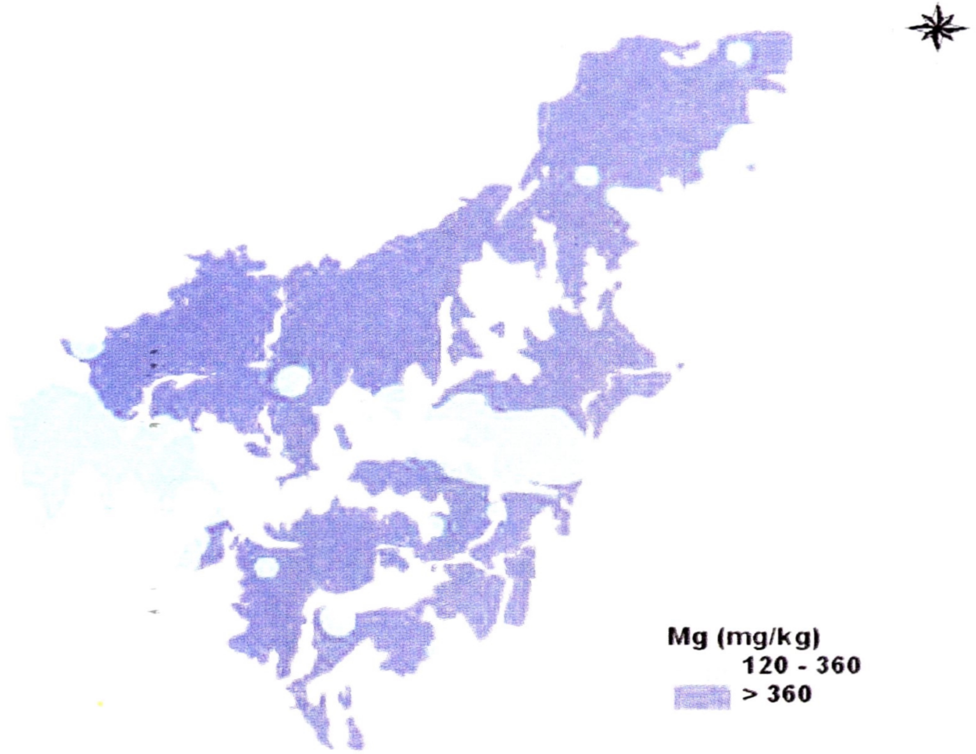

Figure 5. Distribution pattern of the exchangeable Mg in top soil of the feeding area of Girithale irrigation scheme.

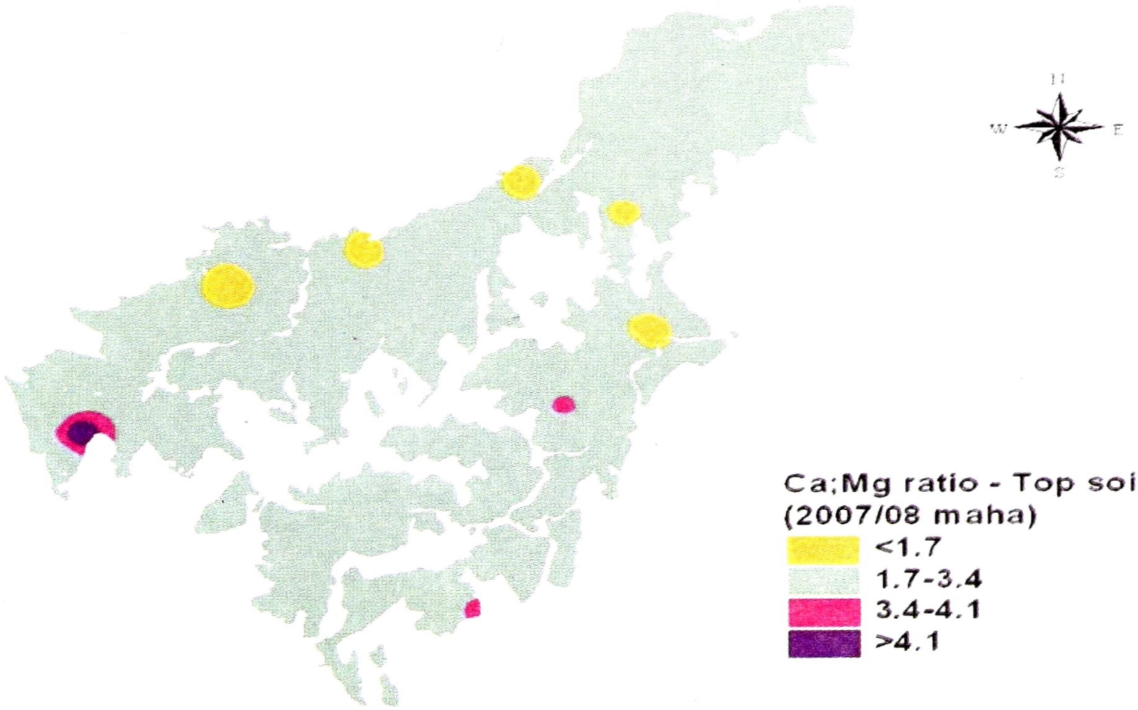

Figure 6. Variation of Ca:Mg ratio in plough layer of soil of the feeding area of Girithale irrigation scheme.

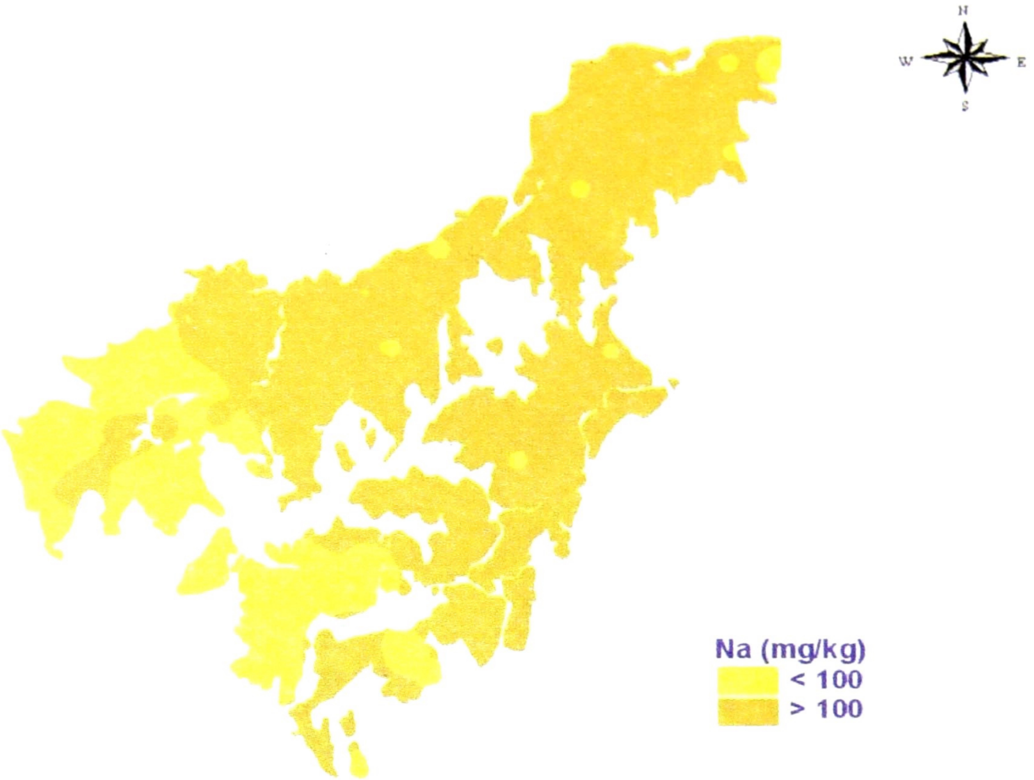

Figure 7. Distribution pattern of the exchangeable Na in plough layer of soil of the feeding area of Girithale irrigation scheme.

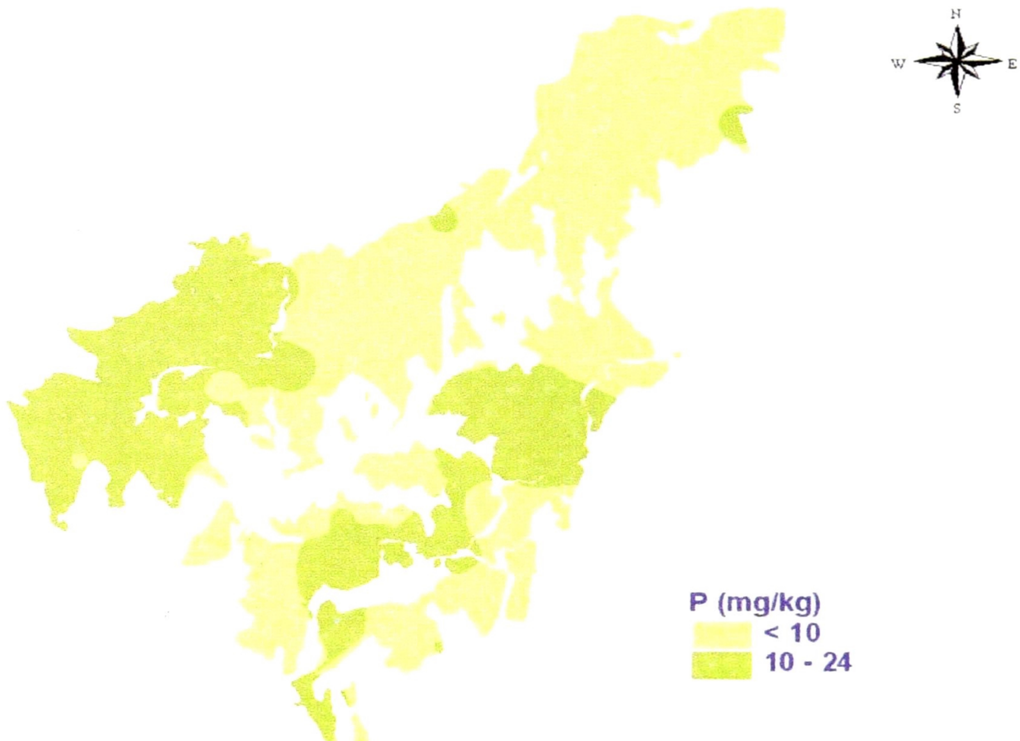

Figure 8. Spatial variation of available P in plough layer of soil of the feeding area of Girithale irrigation scheme.

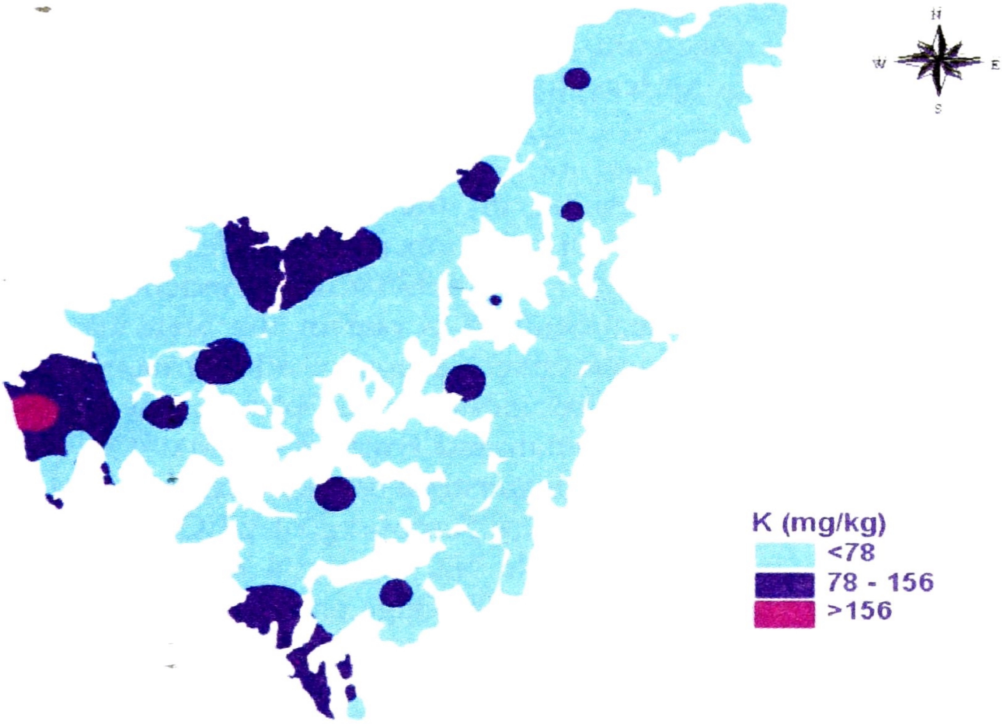

Figure 9. Distribution pattern of the exchangeable K in plough layer of soil of the feeding area of Girithale irrigation scheme.

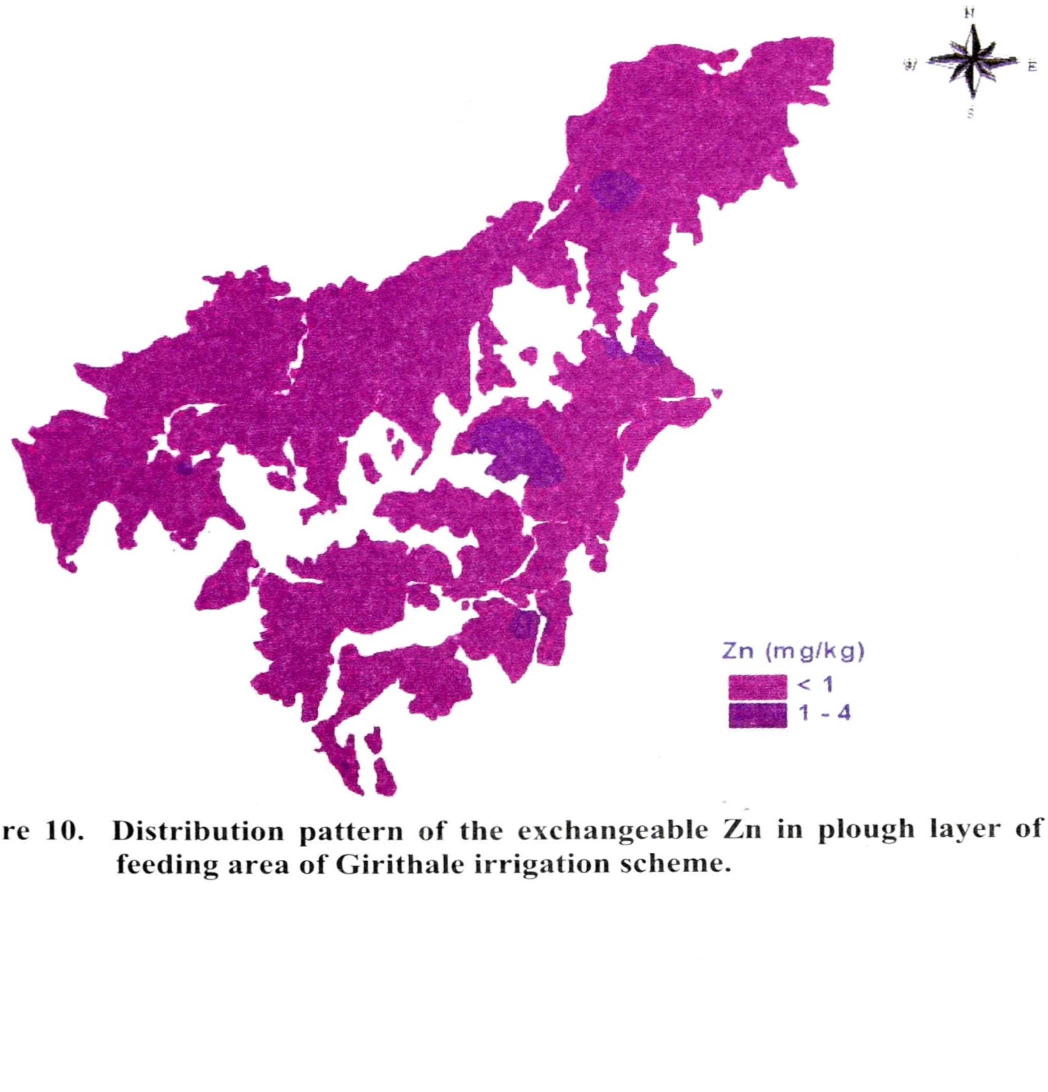

Figure 10. Distribution pattern of the exchangeable Zn in plough layer of soil of the feeding area of Girithale irrigation scheme.

Doberman and Fairhurt (2000) reported that Ca: Mg ratio of less than 1.7 is critical for rice cultivation. This study revealed that 90% of the study area had Ca: Mg ratio of less than 1.7 and the average Ca: Mg ratio was 1.28.

According to results in the Table 1. the average Na concentration was 123.8 mg/kg. Distribution pattern of exchangeable Na in the study area is shown in Figure 7. About 73%of total extent has more than 100 mg/kg of exchangeable Na. Sodium is one of the main cations which cause soil salinity. Primarily. excessive Na uptake affects the water uptake. although excessive Na supply causes deficiencies, particularly of K and Ca through antagonistic effects (Doberman and Fairhurt. 2000). Contribution of exchangeable Na to CEC should be lower than 10% which is the critical level when the soil samples have greater than 5cmol$_c$/kg of CEC. Irrigation water containing excessive amount of soluble Na may be a reason to increase Na level in the soil in association with poor drainage and use of low quality water over a number of years.

The average available P of the top soil was 8.83 mg/kg (Table 1). Distribution pattern of the available P (Olsen's) is presented in Figure 8. Nearly 62% of the extent has a P level less than 10 mg/kg. Kendaragama *et al.* (2003) reported that 69% of soils in the dry zone have P less than 10 mg/kg and significant yield reduction is observed due to low P in these paddy lands.

Earlier Senevirathne Banda *et al.* (2002) also reported that low supply of P is one of the major factors that limit rice yield in Low Humic Glay (LHG) soils in major irrigation schemes in Polonnaruwa. Since soil is becoming alkaline due to high concentration of Ca and Mg, there will be severe decline of available soil P in the future.

The distribution pattern of exchangeable K is shown in Figure 9. About 82% of study area had lower than 78 mg/kg but there are some isolated pockets which have more than 78 mg/kg of exchangeable K in soil.

The reason for the low level of exchangeable K may be the presence of sandy loam textured soil in 75% of area distributed in upper part of the catena. Wickramasinghe and Wijewardene (2000) reported that low organic matter content in soil causes low level of K in soil in addition to K fixation (Wickramasinghe *et al.*, 2003). Lower K level (<78 mg/kg (critical level for rice) can be observed in the upper part of the catena and below the main distribution irrigation canals. High amount of K is removed by the rice crop and most of the farmers do not recycle the rice straw and burn it in the threshing floors. That can also be the cause of depletion of K status in paddy soils (Bandara *et al.*, 2003).

In the study area, about 95% of the extent has less than 1 mg/kg of exchangeable Zn (Fig. 10) which is considered as the critical level and below that is insufficient for the rice crop (Doberman and Fairhurt, 2000). Low level of exchangeable Zn (<1 mg/kg) was observed through out the study area but some isolated pockets had more than 1 mg/kg of exchangeable Zn (Table 1).

According to Bandara and Silva (2000), Zn deficiency can be seen in the dry zone soil mainly in LHG soils which occur in the lower part of the catena. Zn availability in submerged soil reduces with the increasing soil pH (Yoshida *et. al.*, 1971) and high bicarbonate level also makes less availability of Zn in submerged soils. Therefore, it is possible to state that high pH in these soils may be the cause for low level of exchangeable Zn in the study area.

CONCLUSIONS

There is an accumulation of Ca, Mg and Na throughout the catena in the feeding area of the Girithale irrigation scheme and 12% of the paddy field extent already has EC levels more than 0.125dS/m due to accumulation of salts. Threat of accumulation is higher in the lower part of the feeding area. As such more and more paddy lands will have marginal level of production in the future due to unnecessary levels of Ca, Mg and Na. Imbalances in Ca and Mg may affect the absorption rate of Mg and K and will be harmful to rice production. The availability of P, K and Zn was low in the area and may be due to high pH, low rate of P and K application, fixation of P and K and possibly due to non use of organic manure. Considering all these factors further research is needed to find out suitable management practices to prevent accumulation of Ca, Mg and Na and to improve the levels of P, K and Zn to explore the full potential of the paddy lands in the Girithale irrigation scheme.

ACKNOWLEDGEMENTS

Authors wish to acknowledge the financial assistance given by SRICANSOL II project of the Soil Science Society of Sri Lanka to carryout this study.

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