Availability and Spatial Variability of Plant Nutrients in Paddy Fields of Wilgoda Irrigation Scheme in Kurunegala

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Abstract

A study was carried out in the maha season of 2008/2009 to gather information on the status of plant nutrients and their spatial variability in paddy fields in the Wilgoda irrigation scheme, where wastewater is used for irrigation purposes throughout the year. Soil samples were collected from 56 sampling points at upper (Peellawala), middle (Illuppitiya) and lower (Galayaya) parts of the area. Geographic positions of the sampling points were recorded using a Geographical Position System (GPS). Soil samples were analyzed for pH, available phosphorus (P), exchangeable concentrations of potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) and zinc (Zn). In comparison to nutrient contents recorded for paddy growing soils in other parts of Kurunegala by Mapa et al. (2005), this study showed higher levels of P, K, Mg and Na in all study sites. Significant variability in nutrient availability was observed both between sites as well as within a site. Although the inherent K content of paddy soils in Kurunegala is 29-39 mg kg-1, the recorded average K contents at Galayaya and Peellalwala were 59.7 and 67.0 mg kg-1, respectively. Around 20 % of the area had K contents above 78 mg kg-1, which is the critical K level for rice. The reported P content of paddy growing soils in Kurunegala is 7 mg kg-1 but 92 % of the area in Peelalwala had P contents above 12 mg kg-1. The majority of the paddy fields in Peelalwala and Galeyaya had Mg contents above 400 mg kg-1 compared to 89-396 mg kg-1 reported by Mapa et al. (2005). The sodium contents observed in Peellawala and Galayaya were 156 and 167 mg kg-1 respectively, which is significantly higher than the Na contents of 46-69 mg kg-1 reported for other Kurunegala paddy growing soils. These results reveal an increase in all nutrients in the upper part of the irrigation area (Peellawala) where wastewater first enters the paddy fields. Concentrations of highly soluble K, Na and Mg congregate in the lower site while less soluble P and Zn are deposited in the middle site. It can be suggested from these results that regular monitoring of plant nutrient availability in the Wilgoda scheme will help in understanding nutrient supply in wastewater and its movement across irrigated fields. The differences in plant nutrients within a site were particularly evident in the map of spatial variability, suggesting that site-specific fertilizer recommendations should be made to achieve the maximum yield with limited fertilizer costs.

Introduction

More than 90 % of rice cultivars grown in Sri Lanka are new improved varieties (NIV) and their yield potential is over 10 t ha-1 under favorable growing conditions (Jayawardene 2003). The present national average yield of 4.07 t ha-1 is far below these values (Central Bank 2006). Scientists suggest many reasons for this gap between potential yield and realized yield at the farm level, but from the soil science point of view, depletion and imbalance of plant nutrients are the major factors creating this difference (Panabokke 1978).

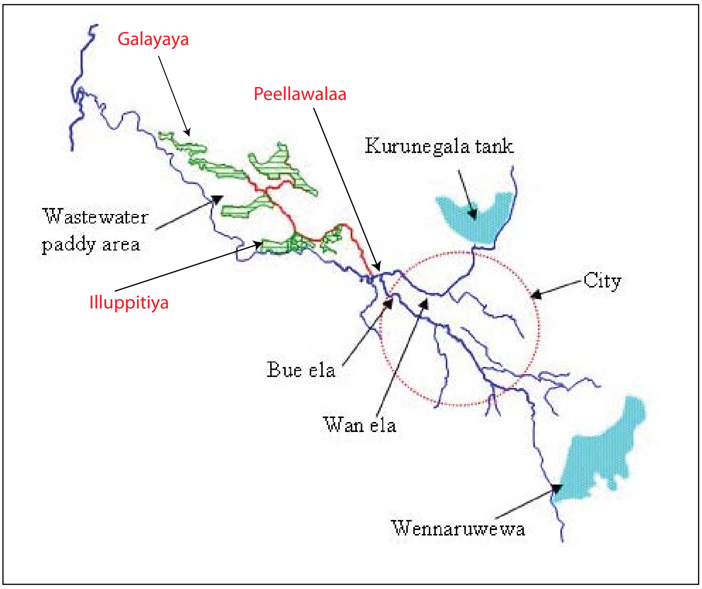
Kurunegala District is a major rice growing area in Sri Lanka where water is the limiting factor for potential rice yields (Central Bank 2006). Therefore, water from different sources is used for supplementary irrigation. Since high-quality water is not available in the required quantities, low-quality wastewater is also used to irrigate paddy fields on certain occasions. The identification of nutrient levels or hazardous compounds in these fields provides useful information to facilitate proper planning for the management of wastewater in agriculture. Amarasiri (2008) suggested that water quality parameters that have a direct effect on irrigated agriculture are organic content; concentration of salts; availability of nutrients and pathogen levels. Wastewater contains a considerable concentration of nutrients, including nitrogen (N), phosphorus (P) and potassium (K) (Amarasiri, 1973). The levels of accumulation of nutrients in paddy fields vary from place to place because of the level of water received and the movement of soluble plant nutrients. An imbalance in fertility levels may appear in paddy fields and measures have to be taken to improve the productivity of these lands by managing all these nutrients effectively. To achieve this goal, spatial nutrient availability within paddy fields should be understood properly.

This paper reports on the availability of plant nutrients and their spatial variability in paddy fields in the Wilgoda irrigation scheme, where wastewater is used for supplementary irrigation in both *yala* and *maha*.

Materials and Methods

Wennaru Wewa, which is situated at the southern end of the Kurunegala District Secretariat Division, has a capacity of 1.8 million m^3 (1,490 acre feet) and serves a command area of 186 ha in both the yala and maha seasons. There are two main canals that provide water for downstream irrigation. The left bank main canal irrigates 93 ha and feeds the Wilgoda Anicut (weir) via the Bue Ela. The Bue Ela and another stream, the Wan Ela, also drain the urban area of Kurunegala City as they flow via residential, commercial and cultivated areas, collecting untreated sewage and wastewater that is discharged into the canals. The Bue Ela and Wan Ela join at Wilgoda anicut, which is operated to provide irrigation water to the paddy fields. The Wilgoda scheme has 137 farmer families cultivating 53.4 ha of irrigable lands. They cultivate paddy twice a year and hardly grow any other crops. There are five paddy areas spatially distributed over the command area of Wilgoda. They are Peellawala, Illuppitiya, Kahatagaha, Nelugahapitiya and Galeyaya. Of these, Peellawala, Illuppitiya and Galayaya were selected for the study (Figure 1).

Figure 1. Schematic diagram of the study site.



The distribution pattern of the sampling points was chosen to be similar to the distribution pattern of the drainage classes of the rice tracts. Accordingly 17, 18 and 15 soil samples were collected from Peellawala, Illuppitiya and Galayaya, respectively (Figure 2). 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 of 500 g were collected from each sampling point. They were packed in polythene bags and transported to the laboratory, where they were air-dried, crushed and passed through a 2 mm sieve. Processed soil samples were analyzed for pH, available P, exchangeable K, Ca, Mg, Na, and Zn. All analyses were replicated twice. Sampling points were taken as parameters and attributes tables were created. Analytical data were tabulated and thematic maps were prepared using Arc View 3.3 software.

Figure 2. Sampling points in experimental sites.

Results

The soil parameters were mapped to understand spatial variation and the averages were also compared to data in the literature for other paddy areas in Kurunegala (Table 1).

Table 1. Some chemical properties of the soils in the feeding area of the Wilgoda scheme and for paddy growing soils in the Kurunegala District (IL1).

Soil property	Location			
	Peellawala	Illuppitiya	Galayaya	Kurunegala Districtct
PH value (1:2.5 water)	5.6 (0.02)	5.1 (0.25)	5.6 (0.06)	5.3 – 6.6
Olsen P (mg/kg)	11.50 (3.29)	10.51 (4.81)	8.53 (2.18)	6
Exchangeable K[a] (mg/kg)	59.76 (21.37)	44.59 (9.85)	67.03 (23.76)	20- 39
Exchangeable Zn[b](mg/kg)	1.92 (1.03)	1.25 (0.87)	0.74 (0.33)	NA
Exchangeable Fe[a] (mg/kg)	29.6 (0.71)	26.1 (2.65)	27.0 (1.00)	NA
Exchangeable Na[a] (mg/kg)	156.14 (42.12)	67.38 (35.42)	169.68 (118.80)	46- 69
Exchangeable Cu[a] (mg/kg)	Very low	Very low	Very low	NA
Exchangeable Ca[a] (mg/kg)	456.44 (85.15)	467.71 (273.12)	403.33 (77.21)	600 - 1,460
Exchangeable Mg[a] (mg/kg)	505.39 (63.84)	250.21 (26.16)	420.18 (79.85)	84 – 396

Source: Mapa et al. 2005

Note: Figures in brackets show the variation; [a]1N NH_4OAC (pH=7) Extraction [b]1N HCL Extraction

The soil pH in the area ranges from 5.1 to 5.6 in the top soil (Table 1) and varies from site to site. Peellawala, which is situated in the upper part of the canal, had the highest average pH of 5.6 and Illuppitiya, which is situated in the middle part of the canal, had the lowest average pH of 5.1 (Figure 3). The variation of soil pH within a site was higher in the Galayaya site. Thirty-eight percent of the area under Galayaya had a pH below 5.5 while 16 % of the area had pH above 6. The difference in pH in the lower and middle parts of the canal may be due to the movement of basic ions from the upper part of the canal to the lower part of the canal.

Calcium levels are on average below those recorded by Mapa et al. (2005) for rice growing soils in the low-country intermediate zone (IL1) but vary between and within the sampling sites, especially in Illuppitiya where there are areas with Ca concentrations as high as 1,000 mg kg-1 (Table 1 and Figure 4). The critical Ca concentration for rice is 600 mg kg-1 (Bandara 2005). As such, the Ca concentrations in many areas in the Wilgoda irrigation scheme are not ideal for rice production.

The magnesium content of the soils in the upper and lower parts of the area are higher than recorded by Mapa et al. (2005) and are greater than those in the middle part (Table 1 and Figure 5). It is assumed that Mg enters in the wastewater, reaches the upper part of the canal and ultimately accumulates in the lower part of the canal.

Similar to Mg concentration, the average Na concentration was higher in the upper and lower parts (Figure 6). Average Na concentrations in Peellawala, Illuppitiya and Galayaya are 156, 67 and 169 mg kg-1, respectively (Table 1). About 20 % of the area in Peellawala had Na contents above 200 mg kg-1.

Figure 3. Variation of pH in three experimental sites.

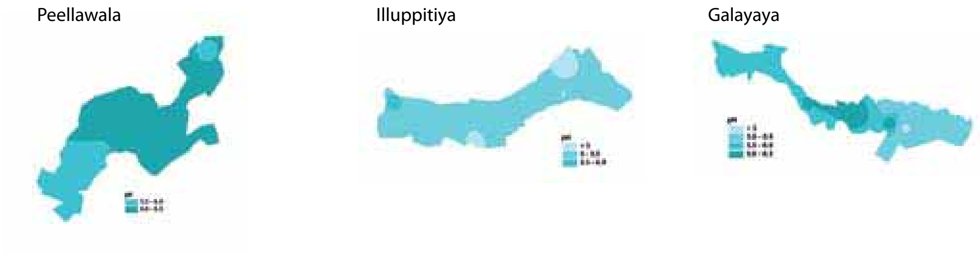


Figure 4. Variation of Ca concentration in three experimental sites.

Figure 5. Variation of Mg concentration in three experimental sites.

Figure 6. Variation of Na concentration in three experimental sites.

Illuppitiya, which is situated in between Peellawala and Galayaya, had a sodium content, below 100 mg kg-1 in the whole area, whereas 10 % of the land in Galayaya had sodium contents above 200 mg kg-1. Irrigation water containing soluble Na and poor drainage may be the reasons for increased Na levels in the top and bottom parts of the feeding area.

The average available P in the topsoil was 11.5, 10.5 and 8.53 in mg kg-1 in Peellawala, Illuppitiya and Galayaya, respectively, which is above the levels for other paddy areas in Kurunegala, (Table 1). Eighty-two percent of the area in Galayaya had a P concentration of 5-10 mg kg-1, while 92 % of the area under the Peellawala site had P values between 10-24 mg kg-1 (Figure 7). These figures suggest that the wastewater is supplying extra P or excess fertilizer is being added (Amarasiri 2008). This theory is further justified by the way the soil P content declines towards the end of the irrigation scheme. The critical P level reported for rice by Doberman and Fairhurt (2000) is 10 mg kg-1. Accordingly, Peellawala has enough P for rice but Galayaya does not.

The K levels in all three sample areas are greater than those for other paddy growing soils in the District (Table 1 and Figure 8). Average K concentration in Peellawela is 59 while that of Illupitiya and Galayaya is 44 and 67 mg kg -1 respectively (Table 1). About 20 % of the area in Peellawala and Galayaya has K levels above 78 mg kg -1. Total area in Illuppitiya has K levels below 78 mg kg -1 (Figure 8). As with P, the origin of the K may be the wastewater used to irrigate the fields or fertilizers applied to crops in excess of requirements (Amarasiri 1973). K is a highly soluble nutrient and that may be the reason for the higher level of K found in the upper part and lower parts of the scheme.

A significant variation in exchangeable Zn was found in the three experimental sites. Zn levels in Peellawala and Illuppitiya are higher than 1 mg kg-1, which is the critical Zn level for rice cultivation (Doberman and Fairhurt 2000). Except in a few isolated pockets, a low level of exchangeable Zn (<1 mg kg-1) was observed in Galayaya (Figure 9 and Table 1).

Figure 7. Variation of P concentration in three experimental sites.

Figure 8. Variation of K concentration in three experimental sites.

Figure 9. Variation of Zn concentration in three experimental sites.

Conclusions

The differences observed within a paddy growing area (known as a yaya) suggest that it is important to identify spatial changes in nutrient concentrations in wastewater and their attenuation as the water is distributed over the fields. This could be converted into thematic maps of nutrient parameters. This can be used to develop a simple but meaningful guidance on fertilizer application to supplement the generic guidance given for an area. The plot-to-plot differences were particularly evident, as shown in the maps, which may be due to the high nutrient concentration of the wastewater. Considering all these factors, attention should be given to exploring the full potential of the paddy lands in the Wilgoda irrigation scheme by preventing the accumulation of unnecessary levels Na and Mg, and recommending site-specific fertilizer management to make use the P, K and Zn nutrients brought with the wastewater.

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