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Research Article

Variation in Soil Quality Parameters in the *Thaulla* Area of a Small Reservoir – A Case Study of Ulankulama Tank at Anuradhapura, Sri Lanka

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ABSTRACT

Thaulla is the upper peripheral gentle sloping land in human-built irrigation reservoir-lakes ("tanks") of Sri Lanka. This study investigated the role of the *Thaulla* area in one tank (Ulankulama Tank) by observing the variation in several soil parameters including pH, EC, N, P, K, Ca, Mg, Na, sand, silt and clay content in soils. The results indicated that the *Thaulla* area of the Ulankulama Tank acts approximately as a wetland as evidenced by the accumulation of P and recorded lower N content in *Thaulla* area. Moreover, the *Thaulla* area of this tank trapped elements such as Mg, Na, and Ca as shown by decreasing concentration in *Thaulla* area towards the water spread area. This was especially evident though the south western portion where most of water flows through the grasses. The results of this study could be helpful in rehabilitation and management of tank ecosystems.

Key words: Constructed wetland, *Thaulla* area, Tank cascade system, Ulankulama tank, Soil parameters

Introduction

Ancient minor irrigation clusters in Dry and Intermediate Zones of Sri Lanka are considered as one of the unique water conveying and management systems devised by humans. Limited water availability and high ambient temperatures are characteristic of the Dry Zone in Sri Lanka where monsoon rains are confined to two or three months of the year with a bimodal annual distribution. In addition, shallow groundwater in the hard rock region of the area is not readily accessible. Therefore, the small tank storage systems have provided the lifeblood for human existence in the Dry Zone of Sri Lanka by making water for irrigation available through the year.

These miner irrigation clusters which are referred to as Tank Cascade System (TCS) can be defined as a connected series of tanks organized within a meso catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet (Madduma Bandara, 1985). The main elements of a cascade are watershed boundary of the meso-catchment, the individual micro-catchment boundaries of the small tanks, the main central valley, side valleys, axis of the main valley, the component small tanks and the irrigated rice lands (Sakthivadivel *et al.,* 1996). Tanks as a main element of this system consist of some remarkable engineering structures and ecosystem approaches to control

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the water flows and improve the water quality. In this system, excess water from a reservoir along with the water used in its command area is captured by the next downstream reservoir. The water is thus continuously reused. The creators of TCS not only paid attention to the main system but also to the macro-land uses in the system such as paddy fields, villages, chena lands, tank beds, etc. and on micro-land uses such as *Iswetiya* (upstream conservation land), *Gasgommana* (upstream wind barrier made of tree plantations), *Kattakaduwa* (downstream wind barrier, locates in between the sluice and paddy), *Tisbamme* (land strip around the hamlet for protection) and *Thaulla* (upper peripheral gentle sloping land) (Mendis, 2006). This area and the adjacent reservation catchment were strictly protected by ancient farming communities. Plant debris and animal manure as a source of nitrogenous fertilizer had been used for the cultivation since early days. While there is the possibility that excess nutrients entered the water from the agricultural fields, eutrophication of these tanks have not been recorded until contemporary times (Mahatantila 2007). The upper periphery of the tank (*Thaulla*) may act as a constructed wetland, which removes excessive nutrients that drain into the tank. The main objectives of this study was to investigate soil features and variations within a *Thaulla* area of a Dry Zone tank with respect to the functions of constructed wetland.

Materials and Methods

The Ulankulama tank is situated at Maradankadawala in Kekirawa divisional secretariat in Anuradhapura district (Fig. 1). It belongs to the so-called Ulagalla cascade and located in the middle part of Ulagalla cascade. There is a 124 acre water spread area to which water drains from 3.8 miles^2 of gross catchment. Farmers cultivate 100 acres of command area using the waters of Ulankulama tank.

Soil samples were collected from 19 randomly selected points in the *Thaulla* area when the water level reached its average low level at the

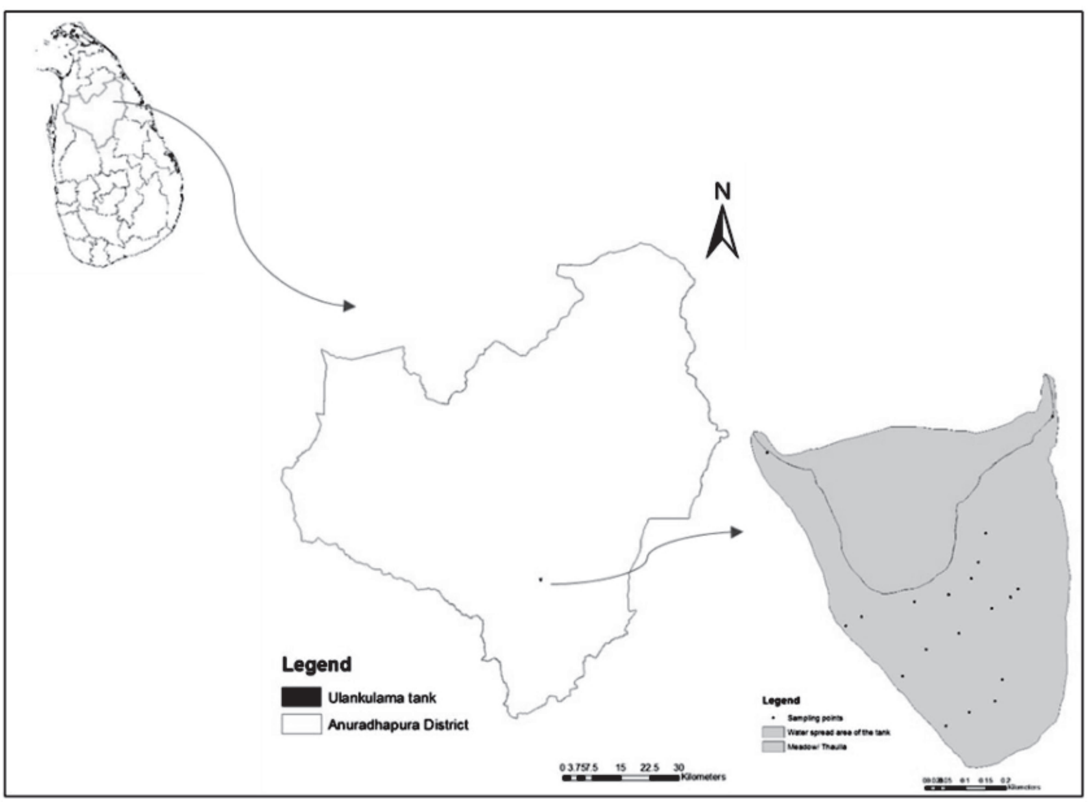

Fig. 1. Ulankulama tank in Anuradhapura district in Sri Lanka (sampling points, meadow, water spread area of the tank are also shown)

Fig. 2. Sampling points, closer catchment, water spread area of the Ullankulama tank. This figure also shows the land uses in the catchment and the arrow shows the main water movement directions

end of the dry season in September, 2015 (28.09.2015).

A stainless steel auger was used to collect these samples from two depths (0 -15, 15 -30 cm) from different points as shown in Fig. 2. Soils were then scooped and transferred into pre-cleaned polythene bags. Subsequently, collected soil samples were air dried and sieved (< 2 mm) and tested for major soil physicochemical and chemical properties.

The pH was determined by glass electrode/ pH meter system using soil to solution ratio of 1: 2.5 (Rowell, 1994) and EC of soil samples was determined by electronic digital conductivity meter using 1:5 soil-water suspension. Total N content was determined through the Kjedahl method (Bremner *et al*., 1982), total P content was determined by wet oxidation method (Akinremi *et al.,*2003), soil exchangeable Mg by Atomic Absorption Spectrophotometer (Anderson and Ingram, 1993), and soil exchangeable K, Na and Ca by Flame Photometer (Jackson, 1958) were determined in the study. Soil texture was also tested by using pipette method (Gee and Bauder, 1986).

Point samples values of N, P, K, Ca, Mg, Na, Sand Silt and clay content were interpolated to the *Thaulla* area using the interpolation method. Inverse Distance Weighting (IDW) in Arc GIS 10.2. IDW method is used to estimates the values at unknown points using the distance and values to nearby known points (Childs, 2004).

Results and Discussion

Average soil properties of Thaulla area

The Ulankulama tank is situated in DL1 agro ecological region with undulating terrain. Reddish Brown Earths (RBE) occupy the crest and the upper and mid-slopes of the landscape while Low Humic Gley (LHG) soils occupy the lower parts of the slope and upper parts of the valley bottom in this area. Average soil properties at average depth (0-30 cm) of the *Thaulla* area of Ulankulama tank are shown in table 1.

Thaulla area soils showed a slightly acidic reaction with comparatively low amounts of

Table 1. Average soil properties at average depth (0-30 cm) of *Thaulla* area of Ulankulama Tank

Parameter	Average soil properties
pH	6.13
Electrical Conductivity (µS cm^{-1})	225.84
Exchangeable K (ppm)	8.41
Exchangeable Na (ppm)	44.93
Exchangeable Ca (ppm)	302.16
Exchangeable Mg (ppm)	76.29
Total P (ppm)	1254.39
Total N (%)	0.046
Sand (%)	32.95
Silt (%)	40.53
Clay (%)	26.52

exchangeable K, Na and Ca (Portch and Hunter, 2002). Part of *Thaulla* consists of paddy fields and improved chena cultivation which lead to a release of a heavy load of chemical fertilizer through flowing water during the rainy period. Therefore, comparatively higher average concentration of total P is observed in the *Thaulla* area of the Ulankulama tank but the observed value for total N (0.046%) is lower than the prevailing extents (11.6% for RBE and 23.22% for LHG) (Nandasena, 2002). In wetlands and other aquatic systems, nitrogen was shown to be the most limiting nutrient (D'Elia *et al*., 1986; Reddy and D'Angeolo 1994). We also found that it is the most limiting element in the *Thaulla* area where water levels fluctuate over the course of a year. During the flooded period, anthropogenic nitrogen input is released from soil to the overlying water in the form of NH_4^+ (Reddy 1982; Reddy and D'Angeolo 1994). There may have NH_3 volatilization and assimilation of nitrogen species by plankton and other aquatic plants. We observed the rich growth of aquatic plants in the *Thaulla* area especially towards the water spread area of the tank. Unlike nitrogen, phosphorus cannot be lost from wetlands through metabolic process thus phosphorus tends to accumulate in the system (Reddy and D'Angeolo 1994). Several reviewers have shown the mechanism of phosphorus retention (Richardson 1985, Logan 1982, Reddy and D'Angeolo 1994). This study also showed that soils of *thaulla* function as a sink for phosphorus.

The average electrical conductivity arrays around 225 µS cm^{-1} refers with non-saline condition. According to sand, clay and silt percentages, soil belongs to the textural class of loam, based on the USDA soil textural triangle.

Spatial variation of soil properties

Wetland play a critical role in functioning as a sink for nutrients thus reducing the overall load to the water bodies. *Thaulla* of tanks can also be act as a small wetland. Inflow of Ulankulama tank passes specially paddy lands before it reaches to closer *Thaulla* of the tank. The *Thaulla* consist of various kind of herbaceous plants and at the edge of *Thaulla*, there are trees of different kinds especially at south eastern area as shown in the Google earth map. The arrow in the map (Fig. 2) shows the main water movement direction in *thaulla* area.

Fig. 3, 4 and 5 shows the spatial interpolated variation of EC, pH, exchangeable Mg, Na, Ca and total Nitrogen, phosphorous, and potassium at soil depth 0-15, 15- 30cm and average (0-30cm) respectively of *Thaulla* area of Ulankulama tank. It is observed that the concentration of these parameters decreases towards the water-spread area of the tank. The concentration decreases through the south west direction due to main water flow is from this direction and in addition the grasses were more abundant in these areas. Even though the main water flow towards the tank is from south-west direction, it was observed that considerable water flows from the entire catchment through the entire *Thaulla* during the higher rainy seasons.

Electrical conductivity is the quantity of ionic salts in the soil which determines the concentration of ionic charges in soil solution. The EC of the soil averaged over 0-30 cm depth varied 183 µS cm^{-1} to 225µS cm^{-1} with a CV of 0.81. It shows that these soils of *Thaulla* area are not saline. There is a decreasing trend of EC towards the water-body in 0-15, 15-30 cm and average depth 0-30 (Figs 3-5). This may be due

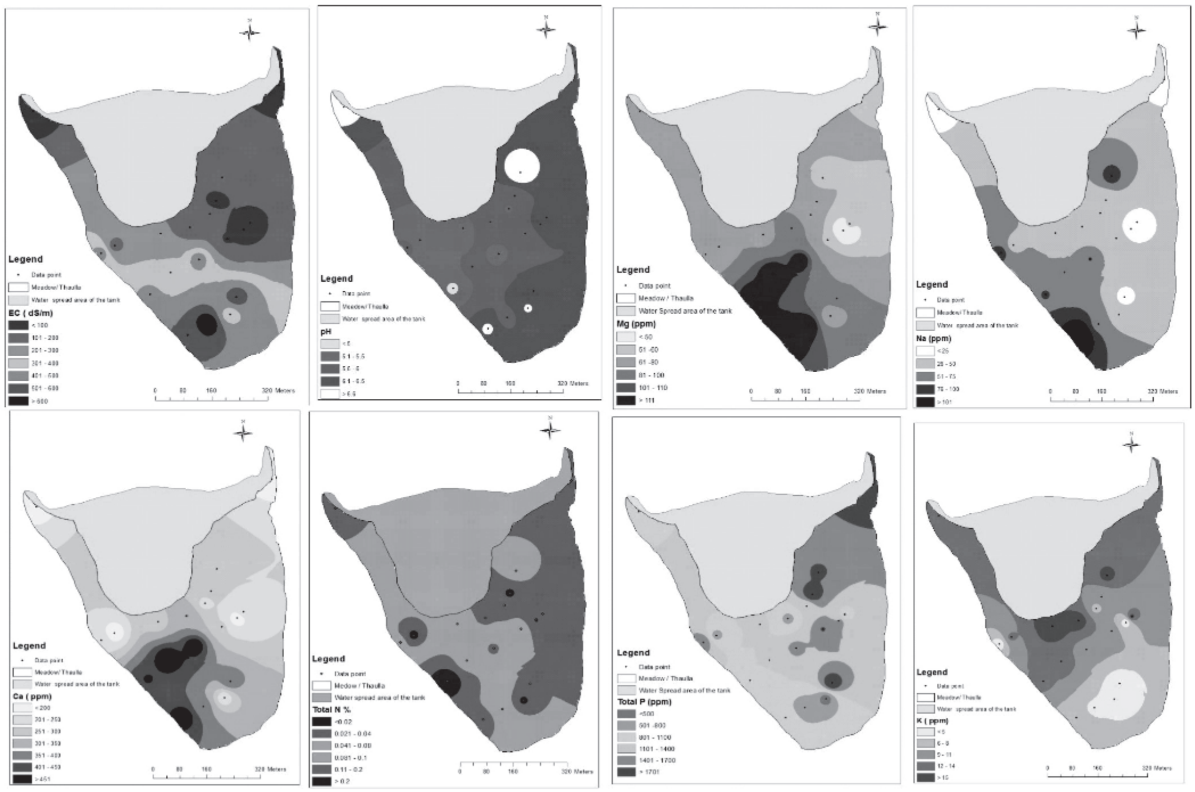

Fig. 3. Variation of EC, pH, exchangeable Mg, Na, Ca and total nitrogen, phosphorous, and potassium (0-15 cm soil) of *Thaulla* area of Ulankulama tank

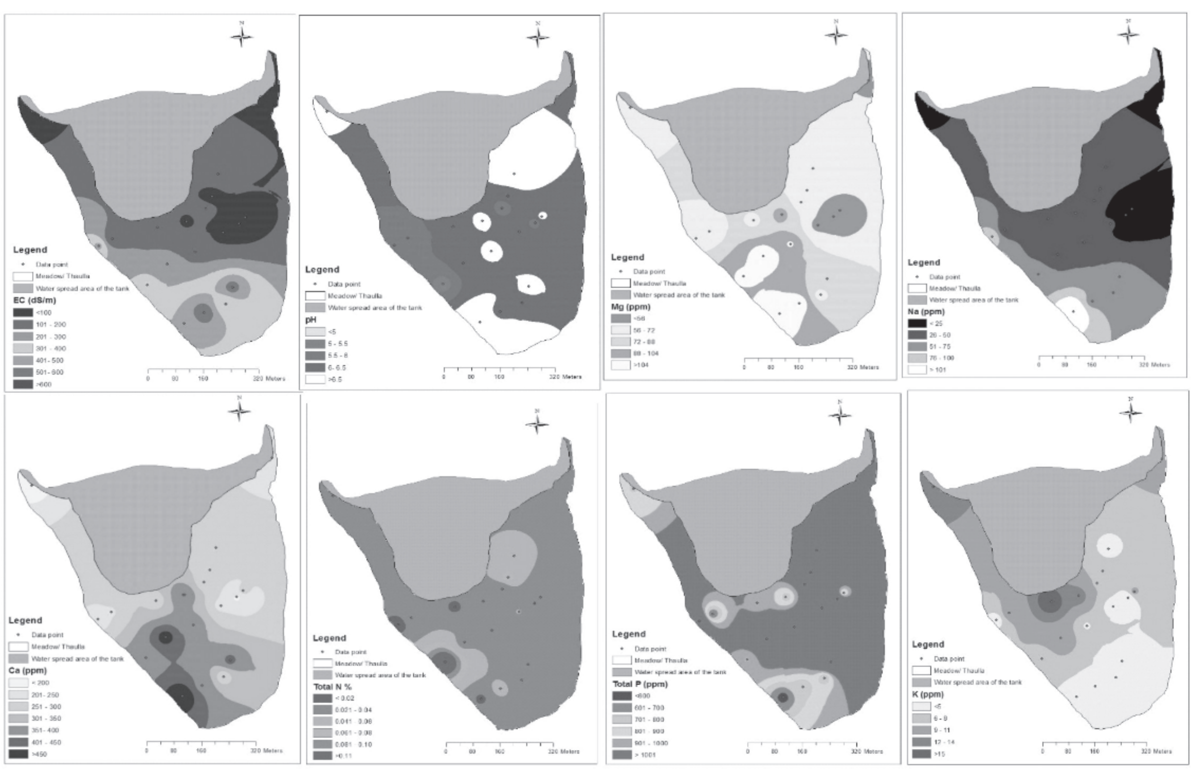

Fig. 4. Variation of average EC, pH, exchangeable Mg, Na, Ca and total nitrogen, phosphorous, and potassium (15-30 cm soil) of *Thaulla* area of Ulankulama tank

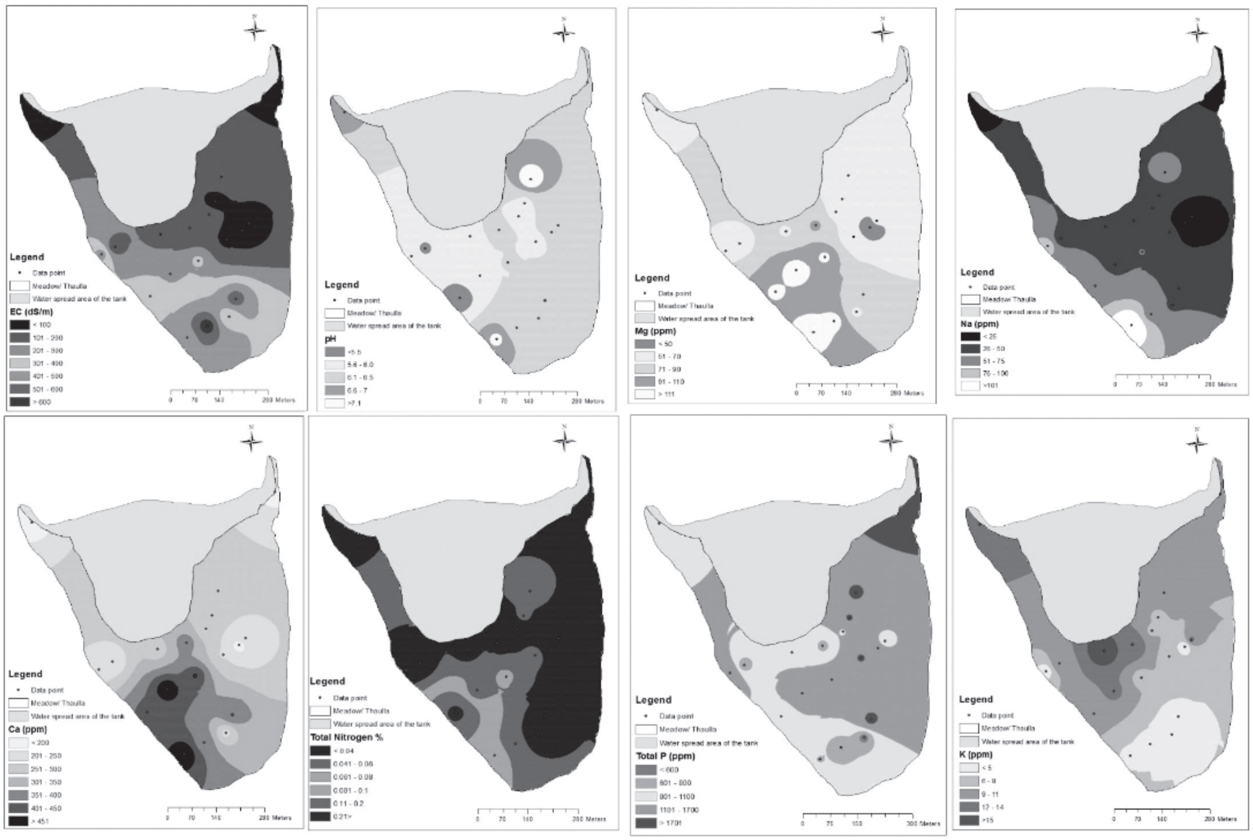

Fig. 5. Variation of average EC, pH, exchangeable Mg, Na, Ca and total nitrogen, phosphorous, and potassium (0-30 cm soil) of *Thaulla* area of Ulankulama tank

to absorption of ions to the *Thaulla* especially by the grasses. The pH is an important property of soil that determines the acidity or alkalinity and affects the chemical reaction between water and soil minerals. In addition, it is important soil physiochemical property to determine the salinity status of the soil. The pH of the *Thaulla* area during the sampling varied 5.09 to 7.57 with a CV of 0.09 indicating slightly acidic to basic condition of the soil. However, there was no clear trend of the variation of pH in *Thaulla* area (Figs.1-3).

Basic elements, e.g. exchangeable Mg, Na and Ca behaved in a similar way (0-15 cm, 15-30 cm and average) in the *Thaulla* area of Ulankulama tank (Figs. 3-5). Their concentrations decrease towards the water spread area especially though south-western portion where most of water flows through the grasses. Mg, Na and Ca enriched at the outer areas of the south-western water flowing areas. This suggests that basic cations are trapped by the *Thaullla* area, especially where grasses are abundant. The average exchangeable concentration of Mg, Na and Ca varies from 34 to 122 ppm, 11 to 154 ppm, and 123 to 505 ppm respectively in the *Thaulla* area. Behavior of exchangeable concentration of K is different those of exchangeable Mg, Na and Ca. Apparently K concentration increases towards the water spread area of the tank. However, K concentration changed from 3 to 19 ppm only with a CV of 0.54.

Though there is no considerable trend of total P and N concentration in the *Thaulla* area, it is clear that the P and N concentrations are higher in the eastern area (Figs. 3-5) where there are paddy fields and chena cultivation areas in *Thaulla* (Fig. 1). The higher concentration may be due to the addition of P and N fertilizers to the paddy fields and their wash off towards the water spread area. We also observed that the grasses are not that abundant in eastern and north-western area compared to those of south-eastern part of the *Thaulla* area. Variation of N concentration is only 0.01 to 0.2 ppm whereas P concentration varied from 423 to 3107 ppm. These higher values showed that there is an accumulation of P through the *Thaulla* area. Clay and silt percentages are comparatively higher in places where grasses are concentrated, suggesting the role of grasses in filtering particulates.

Further studies are needed to find out the relationship among nutrient retentions, clay mineralogy, organic carbon, and other soil quality parameters in *Thaulla* area.

Recent human development activities such as construction of buildings, hotels and roads, as well as changing land use patterns such as cultivation and fish farming are taking place on the *Thualla* areas of small tank systems of Sri Lanka. This study demonstrates some important ecological activities of the *Thaulla* area of a small tank in its approximate role as an artificial wetland. In order to continue these functions and sustain quality water of small tank, we need to restore the *Thaulla* area of all tanks in Sri Lanka.

Conclusions

This study showed that the dominant role of *Thaulla* area in trapping representative elements such as Mg, Na ,Ca and P. The reasons for this trapping may be the abundance of aquatic grasses and trees in the *Thaulla* area. Further, this study confirms the accumulation of P in the *Thaulla* area and the soil properties of *Thaulla* area approximately resemble the soil properties of wetland soils. These findings reconfirm the importance of ecological functions of *Thaulla* area of tanks. This study is useful in future land use planning in tank based agricultural areas and in taking the policy decisions to restore the *Thaulla* area where *Thaulla* is used for some other activities and degraded.

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