**Management of Physical Properties of Reddish Brown Earth Soils at Uda Walawe (Walawa Series) for Sustainable Sugarcane Production**

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**ABSTRACT**

A study was conducted at the research farm of the Sugarcane Research Institute, Uda Walawe, Sri Lanka to investigate its soil physical properties which are important for planning in-situ soil and water management for sustainable sugarcane production. A total of 182 soil samples over 92.05 ha land were collected from two depths;10-20 cm and 40-50 cm below the earth surface, according to 100 m x100 m grid layout. The bulk density, porosity, texture and gravel content of the soil were assessed. The geographical information system was used for mapping and geo-statistical analysis of the soil properties.

The results revealed that the mean bulk density values varied from 1.48 $gcm^{-3}$ to 1.92 $gcm^{-3}$ at 10-20 cm depth with an average of 1.67gcm-3. The average bulk density value at 40-50 cm depth was 1.68 $gcm^{-3}$ with a variation from1.48 $gcm^{-3}$ to 1.96 $gcm^{-3}$. The predominant textural category of the soilwassandy clayloam as per the USDA (United States Department of Agriculture) system. Sandy clay, sandy loam and loamy sand soils also were found in few locations. The apparent gravel percentage detected in all soil samples averaged nearly20% and 19% for 10-20 cm and 40-50 cm depths respectively. The gravel content of soil samples was nearly 4% higher in 10-20 cm depth than that in 40-50 cm depth soil layer. The soil porosity values varied from 0.18 to 0.48 at 10-20 cm depth with an average of 0.34. According to the variation of soil properties and topography, guidelines on ploughing, irrigation, drainage, mulching, organic matter incorporation, soil conservation, etc.were prepared for management of the soil for sustainablesugarcane production.

Keywords: Reddish Brown Earth Soils, Soil Physical Properties, Sugarcane, Sustainable Production

## INTRODUCTION

Soil is a highly heterogeneous natural substance found on the earth crust, and occurrence of spatial and temporal variation of its properties is an inherent feature. The spatial variations of soil properties exist horizontally across the landscape and vertically between different soil layers (Rogerio *et al*., 2006). The information on the spatial variability of soil properties is vital for land management and adopting irrigation, drainage and soil conservation practices (FAO, 1988). Sugarcane is a crop grown in Sri Lanka with the intense use of heavy machinery for land preparation. Most of the sugarcane-growing lands in Sri Lanka consist of five major soil groups, namely, Reddish Brown Earths (RBE), Non-Calcic Brown (NCB), Immature Brown Loam (IBL), Alluvial and Low Humic Gley (LHG) (Mettananda, 1990; Panabokke, 1967). Out of these, nearly 4,680 ha in Sevanagala and Uda Walawe area is RBE (Bodhinayake, 2000).

RBE is the most widespread great soil group in Sri Lanka, occupying the largest area with large variations compared to all other soil groups. According to Joshua (1988), the average bulk density of RBE soil is comparatively high, and it tends to get compacted, limiting root distribution and penetration and reducing infiltration. RBE soil is often problematic if agricultural land preparation practices are carried out during wet seasons. Soil erosion risk is significant in RBE soils as a result of surface run-off of a considerable fraction of rainfall due to low rate of infiltration. The adverse effects of natural phenomenon of rainfall can be minimised by judicious management of soil and water resources. Thus, proper understanding of the variation of soil parameters which are important for managing soil and water resource is an essential prerequisite. Bulk density, porosity, infiltration, water-holding capacity and texture of soils are the most important parameters required for designing soil and water conservation practices for sustainable sugarcane cultivation (Dharmawardena, 2004). Therefore, the present study was conducted to evaluate the physical properties of sugarcane-growing soils at Uda Walawe where the Walawa series of RBE is the predominant soil group, for making suggestions to improve its sustainable management.

## MATERIALS AND METHODS

### Study Area

The study was conducted at the research farm of the Sugarcane Research Institute (SRI), Uda Walawe, Sri Lanka (latitudes 6 25'E and 6 35' N and longitudes 80 45'N and 81 00' E), which is in the low-country dry zone (DL1a) agro-ecological region of Sri Lanka (Punyawardana, 2008). The area receives an annual rainfall of about 1450 mm (Wijyawardhana et al., 2014). The average annual temperature is 28-32$^{0}$C (Witharama *et al.*, 2015). The climate is characterised by a bi-modal pattern of rainfall distribution where two-thirds of rainfall is received during September to January in *maha* season (Panabokke, 1996).

### Sampling Design

The sampling design of a soil study depends on the purpose for which the soil sampling is carried out (Mason, 1992). Often, it should sufficiently fulfil the requirements of geo-statistical analysis. Starks *et al*. (1989) have mentioned that properly-designed sampling network is a must for geospatial studies. In most cases, soil scientists use grid layout technique for collecting soil samples to evaluate the spatial variability of soil properties (Eduardo *et al*., 2014). On the other hand, data collected on grid layout can easily be used for geographical information analysis. In order to determine sampling locations, a grid map with 100 x 100 m checks covering the entire extent of 92.05 hectare of the research farm of SRI was prepared using Geographical Information System (GIS) software. The land pieces which were utilised for non-agricultural purposes, like, buildings, residences, playgrounds, roads and other abundant unproductive gravel lands were omitted from the sampling network. The most possible centre location of each grid (100m x 100m) cell was selected as the soil sampling point. The geographical coordinates of all sampling locations were recorded using Global Positioning System (GPS). Undisturbed soils samples were collected from two depths 10-20 cm and 40-50 cm, with two replicates using a soil core sampler. Sugarcane root density is usually high at about 40 cm depth from the surface (Bakker, 1999).

### Data Analysis

The mean values of the soil properties; bulk density, porosity, texture and gravel content were estimated, and the paired t-test was used to compare them (at $p < 0.05$) between the two depths, 10-20 and 40-50 cm. The SAS software (v 9.0) was used for the analyses.

### Soil Property Variability Mapping

Since the soil samples were collected according to a grid layout, grid surface was created separately for each estimated soil parameter by adopting the grid data interpolation method (Kriging) using the GIS software. This method was used in the present study because "Kriging" is the most common and widely-used grid interpolation method for similar kind of studies (Dreskovic and Samir, 2012). The Q-GIS software was used to construct spatial variability maps for soil bulk density, soil porosity, texture and gravel content.

## RESULTS AND DISCUSSION

### Bulk Density

The bulk density values ranged from1.06 $gcm^{-3}$ to 2.15 $gcm^{-3}$ at 10-20 cm soil depth and from 1.07 $gcm^{-3}$ to 2.18 $gcm^{-3}$ at 40-50 cm depth with averages of 1.68 $gcm^{-3}$ and 1.69 $gcm^{-3}$ respectively. The mean soil bulk density at 10-20cm depth was lowerthan that at 40-50 cm depth. There was no significant difference ($P > 0.05$) in bulk density values between the two depths. A study carried out by Seneviratne (1993) also reported that bulk density values were within the range from 1.62 $gcm^{-3}$ to 1.74 $gcm^{-3}$ with an average of 1.68 $gcm^{-3}$. The optimum range of the bulk density of soil for cultivation of sugarcane is between 1.3 $gcm^{-3}$ and 1.4 $gcm^{-3}$ (Trouse and Humbert, 1961). Out of the 182 soil samples analysed, only 6 samples were within this optimum range. The bulk density of 97% of the soil samples was higher than 1.4 $gcm^{-3}$. Figure 1 shows the spatial variation of soil bulk density at 10-20 and 40-50 cm soil depths.

The high bulk density in sub-surface soils may occur due to compaction as a result of the use of heavy machinery for land preparation, cane transportation and other agronomic operations. Also the leachate in the deeper soil layers (40-50cm) (Joshua, 1988) belong to the B-2 sub horizon of RBE soil (Mapa et al., 2009) has a considerable risk to form heavy soils. Somapala (1991) reported that clay and fine sand together with leachate leads to create cementing action in subsurface layer resulting high bulk density. This type of cemented soil layer usually has bulk density varying from 1.6 $gcm^{-3}$ to 2.05 $gcm^{-3}$ with an average of 1.57 $gcm^{-3}$ (Joshua,1988) which is significantly high compared to that in the naturel forest soil available in the same climate. The presence of a compacted layer in root zone soil limits root development, and hence, land preparation practices should be planned accordingly. The bulk density of sugarcane-growing soils could increase further if the land is prepared during wet periods as the soil reaches its maximum compaction limit under moist conditions. Therefore, land preparation activities using heavy machinery should be avoided during rainy seasons. The soil bulk density values beyond 1.7 $gcm^{-3}$ significantly reduces the sugarcane root growth (Kong, 1968) and has been found to be one of the major reasons for low ratoon crop productivity (Trouse, 1961).

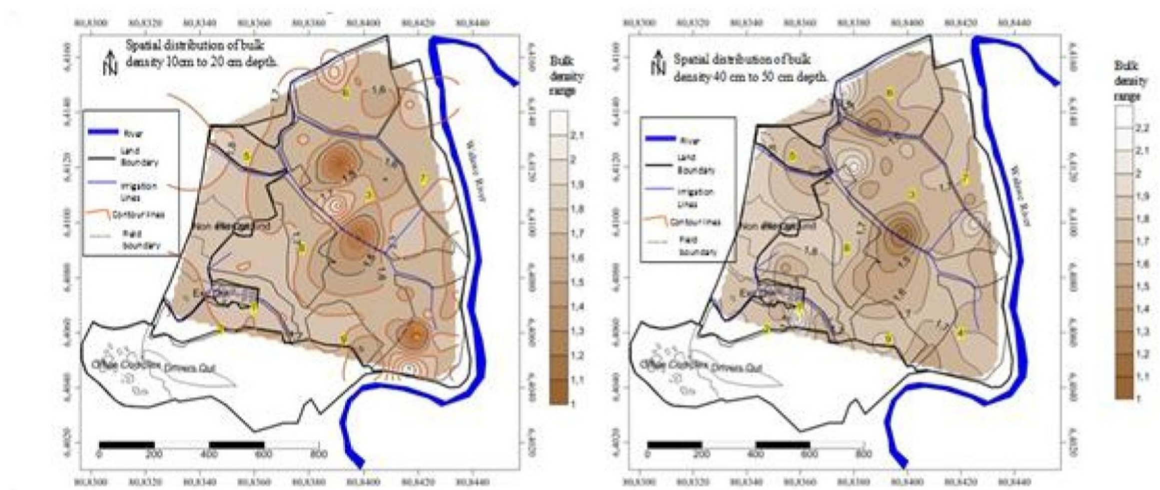


Figure 1.Spatial variation of soil bulk density ($gcm^{-3}$) in sugarcane research farm at Uda Walawe

**Soil Porosity**

Soil porosity ranged from 19% to 58% at 10-20 cm depth and from 15% to 55% at 40-50 cm soil depth with average values of 35% and 34% respectively. But, there was no significant difference in mean porosity values between 10-20 cm and 40-50 cm soil depths. However, there was a strong negative correlation ($\alpha = 0.05$) between soil porosity and bulk density values at 10-20 cm and 40-50 cm depths as shown by the correlation coefficient values of -0.91 and -0.87 respectively. Figure 2 shows the spatial variation of soil porosity in the study area.

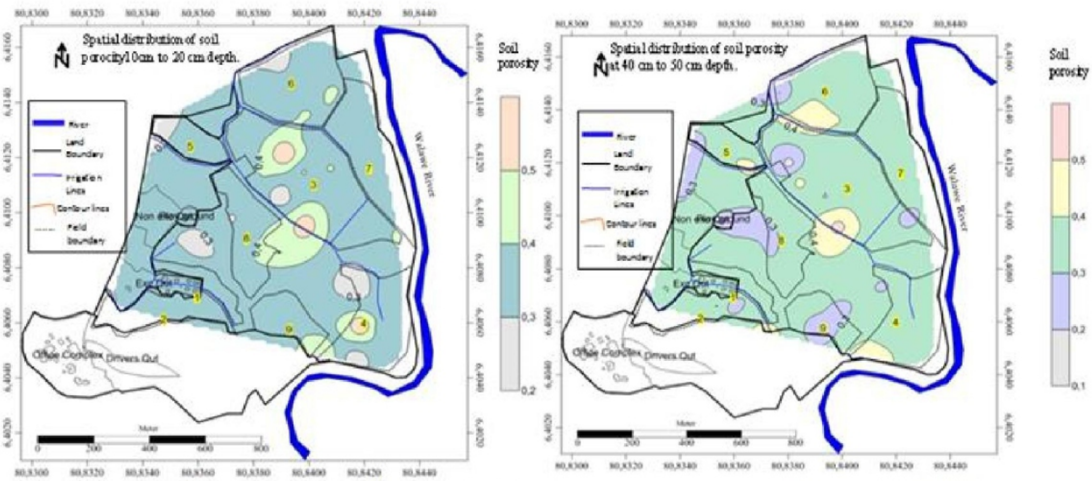


Figure 2. Spatial variation of soil porosity (v/v) in sugarcane research farm at Uda Walawe

According to Figure 2, the porosity values were low in most locations of the study area. Sugarcane crop requires soil porosity higher than 50% for achieving its maximum growth. Out of the 182 soil samples analysed, only 4 samples were within the favourable range. This is a good indication for the presence of soils with high bulk density. Out of the 182 samples, the porosity of 82% of soil samples were between 30-50%, and it was significantly lower than the optimum range required for the growth of sugarcane. Small volume of total pore spaces reduces soil aeration, affecting gas exchange between soil pore spaces and atmosphere. Adding organic matter, such as compost and farmyard manure, mulching and green manure cropping and fallowing will help to improve soil porosity. Sugarcane crop residues and trash and gliricedia leaves are possible mulching materials. Since the 10-20 cm layer shows lower porosity than 40-50 cm layer (Figure 2), the permeability of the top-soil horizons was also lower. This condition restricts infiltration and causes high surface run-off not only with heavy rains but even with light showers. Irrigation efficiency also reduces with less permeable soils. Therefore, it is advisable to practise deep tilling to improve the water adsorption into the soils, increase infiltration, minimise the surface run-off and reduce the risks of soil erosion.

**Soil Texture**

Sugarcane can be successfully grown on diverse soil types ranging from sandy soils to clay loams and heavy clays, but it grows well in deep, well-drained soils with medium and high fertile sandy loam (SL) soil (Tu Khao, 2007). According to Figure 3, most of the areas of the sugarcane research farm was characterised by sandy clay-loam soil texture category (USDA) and was predominant in both depths. Loamy sand (LS) and sandy loam (SL) soils were also found in several locations but in some limited areas in both10-20 cm and 40-50 cm depths. According to the USDA soil texture class, soil basic infiltration rates for loamy sand, sandy loam, sandy clay-loam and sandy clay soils are 22, 18, 16 and 08 mm/hr respectively. Adding organic matter to improve water-holding capacity and adoption of soil conservation practices, such as, mulching with sugarcane trash and contour farming are the strategies that can reduce surface run-off and soil erosion.

**Gravel Content**

The gravel content of the soil samples ranged from 0.2% to 65.7 % at the upper depth and from 0.1% to 70.2% at the lower depth with the average valuesof 20.1% and 19.3% respectively (Figure 4). However, there was no significant difference in the gravel contents ($P > 0.05$) between the two depths. Joshua (1988) reported that the gravel content of RBE soils varies between 10% and15% in the surface

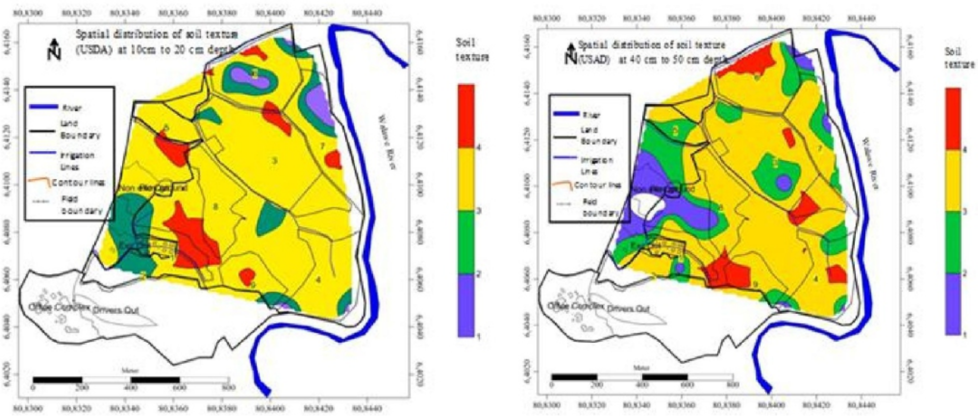


Figure 3: Spatial variation of soil texture: 1-loamy sand, 2- sandy clay, 3- sandy clay loam, 4-sandy loam in sugarcane research farm at Uda Walawe

layers and between 50% and70% in the sub-surface layers. In this case, the top-soil layer has contained high percentage of gravels at about 20% on gravimetric basis. As a consequence of erosion for a long period, sub-surface soil layers have become exposed. Similar results have been observed by Witharama *et al*. (2007) in sugarcane-growing soils at Sevanagala. Therefore, soil conservation practices should be followed, particularly in the upper part of the terrain.

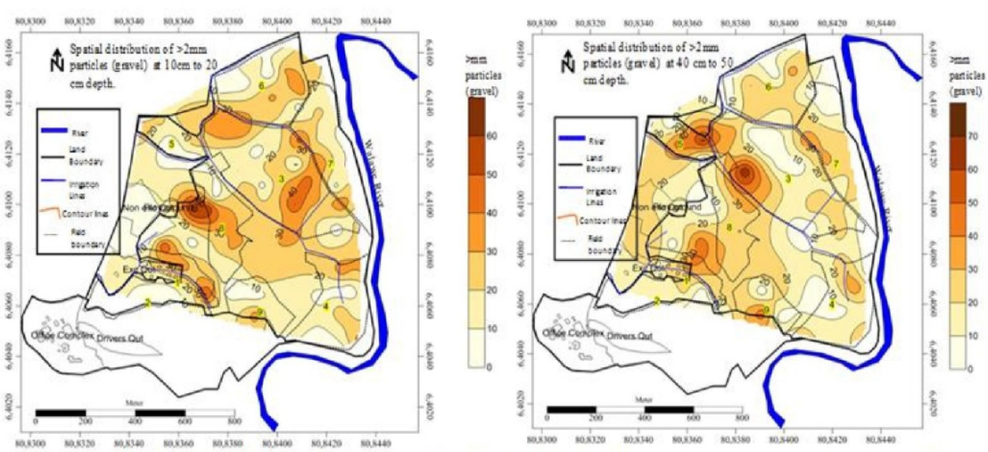


Figure 4: Spatial distribution of gravel content (%) of the soils in sugarcane research farm at Uda Walawe

## CONCLUSIONS

The soil property parameters estimated and their maps developed for the sugarcane research farm in Uda Walawe are helpful to determine suitable land preparation methods, and agronomic, soil conservation and water management practices that have to be followed in sugarcane cultivation.

Because of the high bulk density with low porosity particularly in the south-western part and some middle parts of the study area, adoption of the adequate soil tillage practices and incorporation of organic matter to soil is required to improve bulk density, porosity and infiltration to favourable levels.

The study area was predominantly with sandy clay-loam soil in texture; 88% in the upper depths and 79% in the lower depths. Although sugarcane has an ability to thrive well in a wide range of soil texture types, sandy loam is the best for growing sugarcane. The sandy loam soil was found only about 7% and 11% respectively at 10-20 and 40-50cm depths.

The presence of high gravel percentage in the top most layers in high-elevated areas gives evidence that this soil has got exposed to soil erosion for a long period. Soil conservation practices, like improving surface drainage network, avoiding land preparation during rainy seasons and proper mulching are proposed as the possible methods to minimise soil erosion.

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