IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 11, Nov 2018
www.ijasrm.com
ISSN 2455-6378

Comparison of Soil Characteristics in Tank Bed, Bund and the Command Area of an Ancient Village Tank in Anuradhapura, Sri Lanka

M.G.T.S. Amarasekara[1], K.B. Kulathilaka[1], D.T. Mendis[2] and C.R. Withanachchi[2]

[1]Dept. of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradapura, Sri Lanka.

[2]Dept. of Archeology and Heritage Management, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

Abstract

Thousands of small reservoirs (tanks) were constructed in dry zone, Sri Lanka by ancient kings to provide supplementary irrigation especially during dry seasons. Historic evidence show that selected soil types were used to fill tank bunds and were compacted using animal power. Hence this study was conducted to investigate the composition of soils in tank bund, bed and command area of an ancient abandoned village tank in Anuradhapura, Sri Lanka. Soil samples were drawn from different depths of excavated soil pits on tank bed, bund and command area for analysis. Varying bulk density values demarcated soil layers in the tank bund which had been subjected to different levels of compaction. Higher content of clay in all depths of the tank bed was reported indicating high rate of siltation. The texture of soil in different depths of the tank bund showed completely different nature compared to the texture of other two locations. This clearly illustrate that selected mixture of soils were used to fill the layers of the tank bund to minimize seepage loses. The deposition of sediments in large extents may be the major reason to abandonment of the tank.

Keywords: *Bulk density, siltation, soil texture, tank cascade system*

1. Introduction

The ancient irrigated agriculture in Sri Lanka was commenced about 2000 years ago in the areas under dry and intermediate zones of the country. The ancient kings built thousands of small tanks to collect and conserve rain water for agriculture and domestic requirements. Villages were usually concentrated around irrigation reservoirs to enable easy access to water for agriculture and other purposes. Dwellings were located immediately below the reservoir embankment, between the water and the paddy fields below. This facilitated easy control of the water supply to the fields and also supported maintenance of domestic gardens for fruit and vegetable production (Dharmasena, 1993). A village typically consisted of the residential area, paddy fields, a reservoir, a grazing ground, rain fed farming (*chena* cultivations) and village forest. Village tanks in dry and intermediate zones are normally located in a basin which has natural hydraulic system open to accept and reject the incoming water and overflowing without restriction. These tanks are basically consisted of earth dams constructed across the shortest distance of a small catchment outlet to store water. Seepage can be a problem of any earth dam especially for a reservoir having high ,or rapidly fluctuating water levels for long periods. If seepage is excessive this can lead to instability and eventual failure of all or part of the dam. However, small tanks which were constructed thousand years ago still have very stable dams with minimum seepage losses. It really exhibit indigenous knowledge of ancient people on selection of suitable soil types in order to construct stable tank bunds.

This paper aims to assess the composition and the properties of soils which were used to fill the dam of small tanks and compare these properties with soils sampled from tank bed and the command area.

2. Materials and Methods

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 11, Nov 2018
www.ijasrm.com
ISSN 2455-6378

The field experiment was conducted at the archeological excavation site at Rajarata University premises in Mihinthale where an abandoned village tank is located. Laboratory analyses were carried out at the soil science laboratory, Faculty of Agriculture, Pulliyankulama. Soil samples were drawn from three different depths of excavated soil pits on tank bed, bund and the command area with three replicates.

The soil reaction was measured by glass electrode/pH meter system using 1: 2.5 soil water suspension (Rowell, 1994). Electronic digital conductivity meter was used to determine soil Electrical Conductivity (Chapman and Pratt, 1961). The soil texture was measured using pipette method (Gee and Bauder, 1986) and soil bulk density was determined by core sampling method. Samples were analyzed for soil P and organic matter determination using Olsens and Walkley and Black methods respectively (Olsens, 1954, Walkley and Black, 1934). The percentage of the variation of Linear Shrinkage of the soil (LS) was determined by using following calculation (Standard Association of Australia, 1977).

LS (%) = Ls/L *100

Where: L = Length of the mould (mm)

Ls = Longitudinal shrinkage of the specimen (mm)

3. Results and Discussion

3.1. Soil bulk density

Figure 01 shows the variation of bulk density in three different soil depths of the tank bed, bund and the command area. The average bulk density of 0-30 cm depth of the tank bed was 1.34 g/cm^3 indicating deposition of fine soil particles such as silt and clay with organic matter. However, slightly higher bulk density (1.52g/cm^3) was observed at the 30 – 100 cm depth probably due to higher content of sand. The bulk density has slightly decreased below the depth of 100 cm indicating low compaction of decomposing parent material. Soil bulk density of the command area varied from 1.3 to 1.58 g/cm^3 to. Lowest value of 1.3g/cm^3 was observed in the soil depth of 100- 150 cm probably due to presence of partially decomposed materials. The middle layer of soil (30 – 100cm) reported relatively higher value of bulk density (1.58 g/cm^3). The reason could be compacted hardpan in Reddish Brown Earth Soils. Upper most soil (0-30 cm) showed relatively low bulk density as a result of loosening of soil in the land preparation for agricultural activities.

Bulk density of different soil depths in the tank bund increases with the depth due to different soil texture and compaction levels. It varies from 1.5 to 1.74g/cm^3. The top soil showed lowest bulk density of 1.5g/cm^3 and the highest value of 1.74g/cm^3 was observed above 100 cm depth. The bulk density of the middle layer was 1.68g/cm^3. The bulk density in all three depths in the tank bund showed highest values compared to bulk density of other two locations. This clearly indicates highly compacted nature of soils exists in the tank bund.

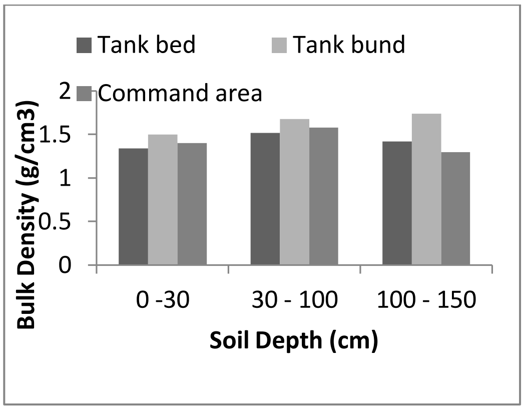

Figure 01. Soil bulk density

3.2. Soil clay percentage

Figure 02 illustrates the variation of clay percentage of different soil depths in three locations. Highest value of clay percentage was observed in tank bed. This may probably due to the process of sedimentation in the tank bed. The clay content of the all three depths of the tank bund also fairly high. The bottom layer (100-150cm) showed highest clay content of 52%. Since clay has high compaction ability it reduces movement of water due to gravitational force. In the command area 30- 100 cm depth reported high clay percentage compared to other two layers. The possible reason could be downward movement of clay and get them accumulate in sub surface soils.

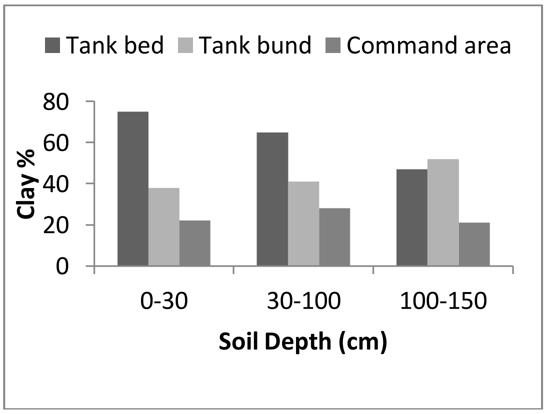

Figure 02. Soil clay percentage

Earth dams have been used since the earliest times to store and provide water for agriculture and other purposes. They are simple compacted structures that resist to seepage of water and are the most common type of dam found worldwide. Soil with high clay content is the widely used material in construction of earth dams in small reservoirs even in modern world. As a core material of earth dams, clay soils show sufficient shear strength and tensile strength to resist against hydraulic pressure generated from reservoir water. Inadequate compaction during construction, the dam will offer weak structural integrity, causing possible pathways for preferential seepage (Richard and Wiltshire, 2002). Therefore, selection of good quality soil with sufficient amount of clay and proper level compaction are vital factors to ensure the safety of earth dams for longer period of time. However, high amount of expandable clay in the filling materials may cause instability of the dams due to swelling and shrinking with the fluctuation of soil moisture content.

3.3. Soil texture

The textural analysis indicates that tank bund soils have sandy clay loam to sandy clay soil texture and it deviate from soil texture of other two locations. Tank bund soils also showed comparatively high amount of sand and clay in all depths (Table 01). This is a clear evidence to show that soils used to build the dam were not originated from the same place. These findings further indicate that a special mixture of sand and clay was used to construct earth dams for strengthening dam stability and cut down seepage losses.
Very high clay content was observed in all depths in the tank bed. This may probably due to siltation of the tank. Most of the small tanks in dry zone Sri Lanka are facing the risk of siltation as a result of poor land management at the upper catchment. Apart from that many nature friendly components associated with village tank ecosystem have been disappeared due to rapid land use changes in the catchment area. (Dharmasena, 1994).

Table 01. Variation of soil texture

Soil depth (cm)	Tank bed	Tank bund	Command area
0-30	Clay	Sandy clay loam	Sandy clay loam
30- 100	Clay	Sandy clay	Clay loam
100-150	Clay loam	Sandy clay	Sandy loam

3.4. Shrinking property of soil

Soils which exhibit high shrinking property on drying are not suitable for earth dams because it will make cracks and open to the passages of water. Linear Shrinkage (LS) is one of the reliable indicators to measure shrinking property of the soil. If LS is greater than 15% is not considered as a good filling material for earth dams. The LS factor of the soils in different depths in tank bed, bund and the command area is given in Table 02. It clearly reveals that soils used for dam construction had low LS factor though it contained high amount of clay. It highlights the knowledge of the ancient people to select proper material for filling earth dams of village tanks.

Table 02. Variation of linear shrinkage (%)

Soil depth (cm)	Tank bed	Tank bund	Command area
0-30	10	10	8
30- 100	8	10	9
100-150	4	13	6

3.5. Soil organic carbon

Soil organic carbon content in three locations is illustrated in figure 03. Tank bed and the command area showed higher organic carbon content especially in 0 – 30 cm soil depth. However, very low organic carbon content was reported in tank bund soils. It varied from 0.3% to 1.1% indicating selection of low organic matter containing soil to construct tank bund. High organic matter content may enhance soil permeability which leads to increase losses of tank water mainly through seepage.

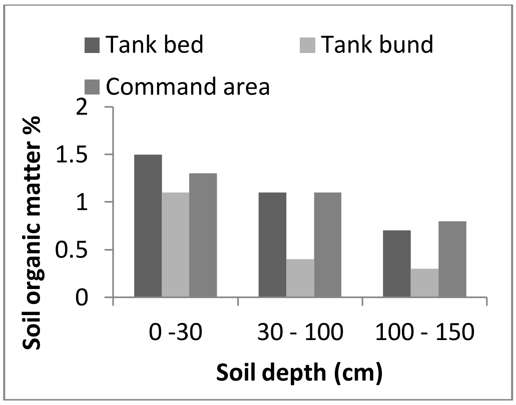

Figure 03. Soil organic carbon content

3.6. Sediment depth of the tank bed

Sand to (silt + clay) ratio of different depths of a tank bed is a good indicator to determine the boundary between original soil and deposited sediments. This is based on the assumption that the sediment contains more silt and clay particles than the original soil layer (Dharmasena, 1992). A sudden increasement of sand to (silt+clay) ratio at the 90 -120 cm depth clearly show the boundary between deposited sediment and original soil in the tank bed (Table 03). It clearly reveals that the depth of the deposited sediment in the tank bed is about 90 cm. Soil erosion is the main causal factor of sedimentation in village tanks. The erosion rate is quite high in Reddish Brown Earth soils due to low water stability of the soil aggregates (Panabokke, 1975). High intensity rainfall and undulating nature of the landscape may

ISSN 2455-6378

aggravate the situation with farming without proper soil conservation measures.

Table 03. Soil texture of the different depths of the tank bed deposit

	Percentage of soil particles			
Depth (cm)	Sand	Silt	Clay	Sand to (Silt+ Clay) ratio
0 -30	12	12	76	0.14
30 - 60	16	14	70	0.19
60 -90	23	19	58	0.29
90- 120	42	09	49	0.73
120-150	43	10	47	0.75

4. Conclusion

The soil profile of command area showed unique characteristics of the great soil group Reddish Brown Earth indicating no alteration has taken place other than farming during past centuries. In contrast, the soil properties of tank bund were completely different from other two locations exhibited layers with different composition indicating artificial filling and compaction. The soil profile of tank bed showed deposition of sediments in large extent and that may be a major reason to abandonment of the tank.

References

[1].Chapman, H. D., and Pratt, P. F. 1961. Methods of Analysis for soils, plants and water. Univ. California, Berkeley, CA, USA.

[2].Dharmasena, P.B. 1992. Magnitude of sedimentation in village tanks. Tropical Agriculture, Department of Agriculture, Peradeniya, Sri Lanka. 148:97:110.

[3].Dharmasena, P.B. 1993. Man – Environment interaction in Tank- Village home gardens: The trends in vegetation. Proc. of the 4th Regional Workshop on Multipurpose Trees, (Ed.) H. P. M. Gunasena, University of Peradeniya, Sri Lanka. Pp 90 – 101.

[4].Dharmasena, P.B. 1994. Conservation farming practices for small reservoir watersheds: A case study from Sri Lanka. Agrofor. Syst. 1994, 28, 203–212.

[5].Gee, G.W. and Bauder, J.W., 1986. Particle size analysis methods of soil analysis part 1 Am. Soc. Agron. Agronomy monograph 9, Madison, Wiscinsin U.S.A. pp383-409.

[6].Olsen S, Cole C, Watanabe F, Dean L 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular Nr 939, US Gov. Print. Office, Washington, D.C.

[7].Panabokke, C.R. 1959. A study of some soils in the dry zone of Ceylon. – Soil Science **87** (2): 67-74.

[8].Panabokke, C.R. 1975. Erosion hazard and farming systems in the humid tropics of South Asia. In Soil Conservation and Management in the Humid Tropics. Eds. D.J.Greenland and R.Lal. pp 213-219. John Wiley and Sons, New York, USA.

[9].Rowell, D.L. 1994. Soil Science: Methods and Applications. Prentice Hall, Harlow.

[10]. Richard, L. and Wiltshire, P.E. 2002. 100 Years of Embankment Dam Design and Construction in the U.S. Bureau of Reclamation. Technical Service Center Bureau of Reclamation. U.S. Department of the Interior, Denver, Colorado.

[11]. Standards Association of Australia, 1977. Methods of testing soils for engineering purposes. North Sydney, N.S.W.

[12]. Walkley, A. and Black, I. A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-37.