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Postboks 5003
NO-1432 Ås
67 23 00 00
www.nmbu.no

DECLARATION

I hereby declare that the dissertation entitled "**Soil carbon and nitrogen stocks and the management issues for enhancing soil carbon sequestration potential in rangelands of Gairo, Tanzania"** submitted in the partial fulfilment of the Degree of Master of Science (**MSc**) in Environmental Science (**IMV**) is a genuine work based on the research investigations carried out by me except where due acknowledgement is made, under the guidance and supervision of**Prof. Bal Ram Singh(NMBU)** and co-supervision of**Associate Prof.ErnestSemu**and **Prof. Ephraim J. Mtengeti**,Department of Soil Science (**SUA)**. The dissertation there of has not been submitted for any academic award of any university or institution.

Mahesh Adhikari

Signature…………........

Date………………..……

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor **Prof. Bal Ram Singh** for his support, guidance, valuable suggestions and comments in the completion of my thesis work. My special thanks go to **Prof. ErnestSemu** for all kinds of helps and arrangements while conducting the fieldwork and providing valuable suggestions whenever needed.

I would like to thank **CCAIM** project for giving me the opportunity to conduct this research, and **NORAGRIC (NMBU)** for providing the financial aid during my stay at **SUA, Morogoro**.

I would like to thank **Prof. Lars Olav Eik** for all the arrangements he made for my visit to Tanzania.

I am very grateful to **Prof. Ephraim J. Mtengeti**, for all the help and support he provided me during my stay at **SUA**.

My special thanks go to **Dr.Anthony Z. Sangeda**and **Mr.David Maleko** (SUA,Morogoro) for their all possible support in the field for helping me to deal with stakeholders and most importantly conducting the fieldwork.

I would like to thank SUA, especially the soil science/chemistry lab members who helped and supported me during my analysis.

My special thanks go to my friend **Mr.Amoür Suleiman**for helping me with the lab work, and also all kinds of help and support he provided.

Finally, I would like to thank all those stakeholders of Gairo district who helped me directly or indirectly in my sample collection.

Mahesh Adhikari

ABBREVIATIONS

SOM:	Soil Organic Matter
SOC:	Soil Organic Carbon
TN:	Total Nitrogen
GHG:	Green House Gases
Ha:	Hectare
CH4	Methane
NPP	Net Primary Productivity
Pg	Peta gram
Gt	Giga tonnes
CCAIM	Climate change impact adaptation and mitigation
MAP	Mean Annual Precipitation
MAT	Mean Annual Temperature
RMPs	Recommended management practices
ANOVA	Analysis of Variance
SUA	Sokoine University of Agriculture
USDA	United States Department of Agriculture

ABSTRACT

Rangelands are the unutilized lands which constitute 47% of the world land area containing very low SOC. Though they have very low tendency to store carbon, it can be enhanced by few management practices as these holds considerably large area. The study was conducted in soils of two villages of Gairo district, Tanzania, where Leshata was degraded and Mkalama was highly degraded. They showed very low concentration of SOC (<1%). The nutrients like N, P, and K were found to be very low in both of the villages though the concentration of them was found greater in Mkalama in comparison to Leshata. The soil texture based on USDA system of classification showed that the soil in Leshatawas a sandy clay loam, whereas in Mkalamait was sandy clay. The bulk density was found to be 1.51 g/cm3 and 1.37 g/cm3 in Leshata and Mkalama respectively, while corresponding values for pH were 5.13 and 5.36. High density and low pH as the characteristics of degraded soil is shown in both villages. Carbon showed strong correlation with nitrogen in both of the villages (r=0.87, P=0.00) in Leshata and (r=0.75, P=0.00) in Mkalama.Leshata showed decrease in concentration of carbon and nitrogen with the increase in depth, whereas Mkalama did not show any proper depth wise distribution.Water is the limiting factor in context to both of the villages as the loss of water occurs through surface runoff due to lower infiltration in Mkalama, whereas lower water retention capacity due to bigger pores in Leshata.The C: N ratio in these two villages is greater than (10:1) making them useful in storing carbon from future perspectives. But the compact nature of soil with sloppy landscape in Mkalama is prone to erosion during rainfall leading to soil degradation as it erodes away the valuable nutrients required for the growth of plants. So, management practises like developing contours, plantation of Xerophytic plants, control livestock and liming with calcite for regulating soil pH in these acidic soils might be helpful in preventing erosion and restoring carbon. These practices not only help to prevent soil degradation, but also restoresoil carbon stock leading to enhanced soil carbon sequestration potential.

Keywords: Carbon Sequestration, Rangelands, Limiting factors, Infiltration, Xerophytic

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INTRODUCTION

1.1 Background

The terrestrial soil carbon pool contains three times the amount of carbon in the atmosphere including 1500Pg in the surface meter (Eswaran et al., 1995; Batjes, 1996) and 600Pg in the vegetation (Houghton, 1995; Schimel, 1995; Schuman et al., 2002). Out of various efforts being done to minimize the atmospheric CO_2 concentration, a certain portion of it is sequestered in plant biomass and soil called terrestrial carbon sequestration. It provides benefits to the soil by improving soil quality, water holding capacity, nutrient cycling, control soil erosion etc. Carbon sequestration is an emerging issue, and the carbon stock depends on the various land management practices and cropping systems (Derner& Schuman, 2007). We currently have a basic knowledge on carbon dynamics as these involve interaction between climate, soil, plant communities and their management (Schuman et al., 2001).

The rise in concentration of carbon dioxide in the atmosphere is a result of human activities caused by the burning of fossil fuel like oil, coal and natural gas. The increase in concentration of CO_2 from 280 to 380 ppm over the last 280 years is a result of industrial revolution causing proportionate global warming (Sundquist et al., 2008). This Global warming, which can be summarized as the increase in average surface temperature of the earth, is an on-going problem and for which CO_2 is the major constituent. Among the various effects of global warming, some of them include sea level rise, floods, drought, increased frequency of wildfires etc. So, in order to minimize the consequences caused by the increased level of CO2 in the atmosphere, various strategies are required.

Soil is the largest pool of Soil Organic Carbon (SOC) in the biosphere, in comparison to plants and atmosphere combined (Schlesinger, 1997; Jobbágy& Jackson, 2000). Out of many factors that affect carbon in the soil, plant production is one of them, which is known to control soil fertility and agricultural production and is recognised for centuries (Dokuchaev, 1883; Hilgard, 1906; Jenny, 1941; Tiessen et al., 1994). Soil is composed of 45% minerals, 5% organic matter, 20-30% of water, 20-30% of air and micro-organisms (Hoyle et al., 2011). Micro-organisms turn up the soil more rapidly and are essential in the process of decomposition and nutrient cycling, degradation of chemicals and soil stabilization.

1.2 Rangelands and their importance

Rangelands are the unutilized land, with high abundance of grasses, about 250-750 mm of rainfall, and tree canopy is less than 25% of the land area (Schlesinger, 1997). Since, these lands are not barren like deserts, not currently farmed, and huge in area; a proper management of them is going to be beneficial in every possible way. In terms of area, the rangelands constitute 47 % of the world's land area, which is about two-third of the land administered by the forest service. According to Schlesinger 1997, Scurlock and Hall 1998, "Rangelands have a large potential to sequester C because they occupy about half of the world's land area and store greater than 10% of terrestrial biomass C and 10 to 30% of global SOC". It has also been said that the carbon sequestration through rangeland is lower than improved pastures and cropland in terrestrial landscape, and management of these helps to enhance terrestrial carbon sequestration potential as these occupy larger area. So, slight increase or decrease in carbon storage in rangeland ecosystem has the potential to modify global carbon cycle that influence global climate change (Schimel et al., 1990; Ojima et al., 1993; Conant et al., 2001).

Rangelands provides significant source of natural resources and energy as well. They can be used in the mining of hard rock such as gold, copper, silver, zinc, which benefits by strengthening the economy. Also the extraction of coal, natural gas, oil is an important source of energy which can be obtained from rangelands. Woody plants can be used for fuel while grasses and other plants can be used for bio-diesel production. Rangelands are located in areas with dry climate and lower precipitation, the presence of streams, lakes and reservoirs scattered within the rangeland acts as a source of water for irrigation and urban areas, meeting the needs of growing population. Grazing is important to rangelands, as this facilitates physical breakdown, soil incorporation and rate of decomposition of residual plant material, eventually helping in the storage of carbon (Fuhlendorf& Engle, 2001). The management of rangeland should be done from an ecological perspective which involves soil health, vegetation, wildlife, invasive plants and water quality. So, understanding and managing these rangelands involves combined knowledge of both science and art.

1.3 Soil Organic Carbon (SOC)

Soil organic carbon is the complex and heterogeneous mixture of materials, which may vary with their chemical interaction, physical size, degree of interaction with soil minerals and extent of decomposition. Small changes of SOM may influence long-term ecosystem sustainability, the global carbon budget and the atmospheric CO_2 concentration (Amundson, 2001). Although determining the impact of management practices on soil organic carbon contents is important, it does not tell us anything about the type of organic carbon present. Therefore it is important to determine the composition of soil organic carbon which can be categorized as:

• Crop residues—shoot and root residues > 2 mm residing on and in soil.

• Particulate organic carbon—individual pieces of plant debris that are smaller than 2 mm but are larger than 0.053 mm.

• Humus—decomposed materials less than 0.053 mm that are dominated by molecules stuck to soil minerals.

• Recalcitrant organic carbon—dominated by pieces of charcoal.

1.3.1 Benefits of Soil Organic Carbon

There are many important production and environmental benefits associated with increasing carbon in soils including: improved soil structure, increased soil fertility, increased water holding capacity, increased infiltration capacity, reduced runoff, buffering soil pH, decomposition of organic matter, higher nutrient cycling and availability etc. (Bationo et al., 2007). These factors result in increased nutrient growth, increased economic value, reduce fertilizer (N, P) use, reduced erosion risk (reduced soil disturbances / erodability) etc.

1.3.2 Factors affecting Soil Organic Carbon

Soil organic carbon is said to be lower in soils having higher salinity due to poor plant growth which leads to lower carbon input. Salinity affected soils occur mainly in arid or semiarid areas where the rate of evaporation is higher than precipitation and salt dissolved in the groundwater gets accumulated at the surface by capillary action (Yuan et al., 2007). SOC is independent of climatic variation such as temperature, precipitation and dry season period, but rely on clay and silt contents, irrespective of the amount of rainfall. Changes in soil organic carbon reflects the balance between input and output, which includes carbon-dioxide loss from microbial decomposition and any direct loss from erosion.

1.4 Soil Carbon Sequestration

Soil carbon sequestration is the process of capturing and storing atmospheric CO_2 to the soil through crop residues and organic solids in a form that is not ephemeral (Izaurralde et al. 2001). Increasing the concentration of carbon in soil by natural means might provide benefit to soil by reducing the impact that is caused as a result of increasing carbon emissions. All living organisms contain carbon, and if they absorb more carbon from the atmosphere then they emit, then they are called carbon sink, and if they emit more carbon then they absorb, they are called carbon source. Carbon can be sequestered into the earth surface through various processes, i.e. oceanic, terrestrial and geologic.

1.4.1 Terrestrial carbon sequestration

Terrestrial carbon sequestration is the process of storing CO_2 from atmosphere by the trees and plants through the process of photosynthesis. Terrestrial carbon sequestration constitutes about 2500Pg of the global carbon cycle up to 2m depth (Batjes, 1999). It has been depleted by processes such as erosion, salinization, nutrient depletion, extensive tillage, land conversion etc., whereas it can be enhanced through afforestation, reforestation and conservation practices such as building contours on a sloppy landscape. There are various benefits associated with increasing soil organic carbon such as providing ancillary benefits to the plants, increasing crop yield, restoration of degraded ecosystem, improving water quality, water holding capacity, high nutrient retention etc. (Lal, 2003).

Table 1: Technical potential of carbon sequestration in world soils for about 50 to 100 years

Ecosystem	**Technical potential (Gt^aC/yr)**	**References**
1. Croplands	0.6–1.2	Lal (*2004*)
2. Grazing lands (Grasslands and Rangelands)	0.5–1.7	Conant et al. (*2001*); DOE (*1999*)
3. Restoration of salt affected soils	0.4–1.0	Lal (*2010*)
4. Desertification control	0.3–0.5	Lal et al. (*1999*)
Total	1.8–4.4	

[a]Gt (Gigatonne = 10^9 tonnes) (Source: Lal, 2010)

1.5 Carbon sequestration through Rangeland

Carbon sequestration through rangeland is solely dependent on soil type, plant species, regional climate, topography, and management practice (Adams et al., 1990). Among the various benefits that have been outlined in sequestering carbon, its ecological benefit constitutes better soil quality, better water infiltration and higher water holding capacity, which all leads to better plant productivity and higher forage quality. This factor not only makes rangeland less susceptible to drought, but also helps to feed livestock and wildlife during dry periods.

1.6 Soil Degradation and Soil Erosion

Soil degradation denotes decline in soil quality or reduction in attributes of soil which is triggered by three principal factors i.e. physical, chemical and biological. Soil degradation increases bulk density, increases runoff, decrease in macro-porosity, decreases in infiltration and thus leading to intensive soil erosion by water and wind. The intensity of soil erosion is controlled by various natural and anthropogenic factors, where natural constitutes soil, vegetation, climate and other eco-regions, whereas anthropogenic includes land use, management practices, land tenure, farming, cropping etc. (Lal, 2001a).

The detachment of individual soil particles, especially it's weakening and their transport through three phase processes i.e. detachment, transport and deposition constitutes the erosion. Erosion accounts more than 80% of the degraded vegetated land, making it as a major factor in the soil degradation (Oldeman, 1994). Raindrop is an important eroding agent along with running water and wind, and continuous exposure to raindrops on a bare soil weakens the soil making it more vulnerable to erosion. Also, the various processes which includes slaking or dispersion, compaction and crusting reduces structural stability, decreases soil strength, exacerbates erodibility and makes more susceptible to interflow, overland flow, wind or gravity. Soil degradation along with accelerated erosion leads ultimately to desertification.

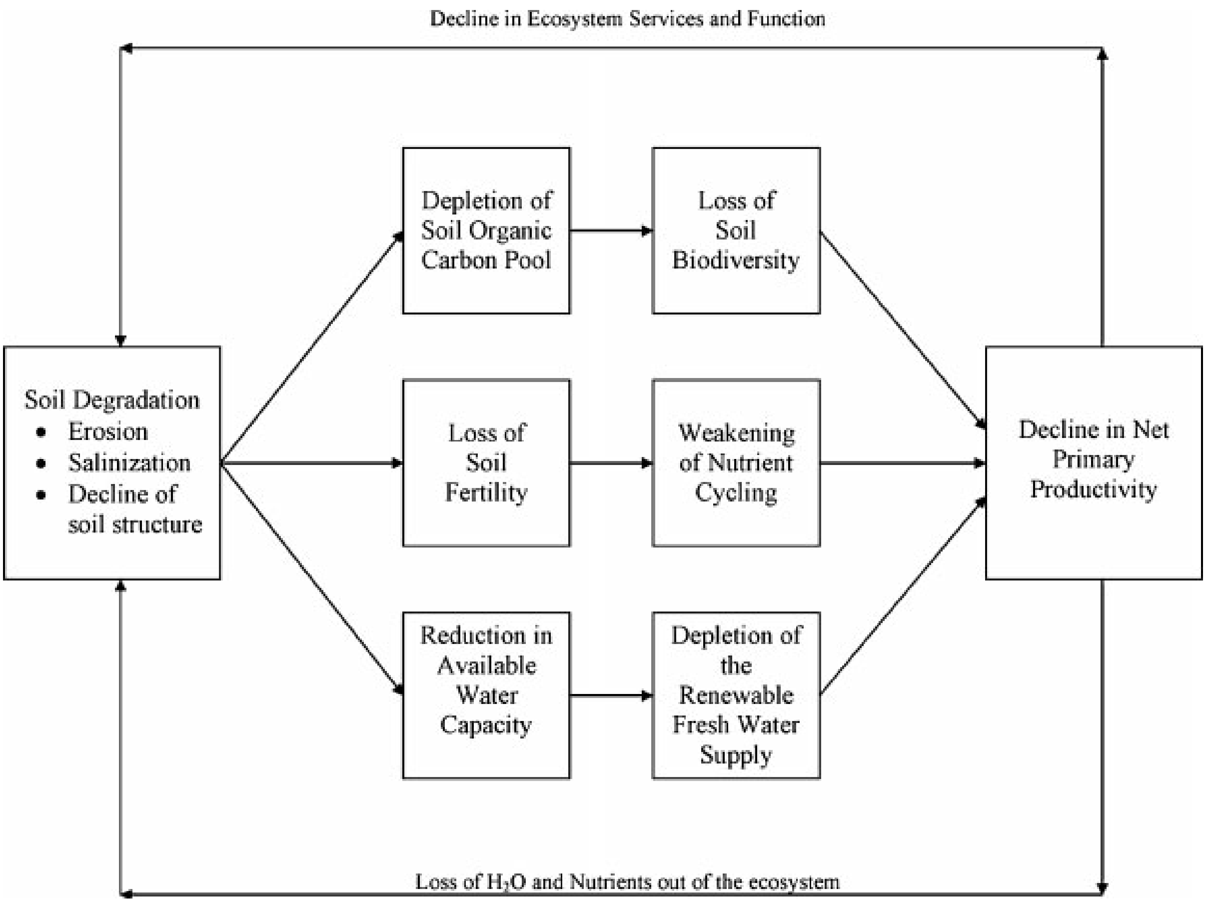


Figure 1: Soil degradation impacts on ecosystem services and functions (Source: Lal, 2009)

1.7 Nutrient cycling

Organic compounds are discussed in terms of 'C/N ratio', since this influences nitrogen supply and potential storage of carbon in the soil. The release of nutrients depends on decomposition rate, C/N ratio of organic residues, and the interaction with decomposer communities and environmental conditions. In plants, wheat have higher C/N ratio that breaks more slowly than legumes having low C/N ratio, which contributes by increasing soil C (Hoyle et al., 2011). The C: N ratio in the soil influences the rate of decomposition of organic matter, which results in the mineralization and immobilization of soil Nitrogen. The presence of more nitrogen in proportion to the carbon causes the nitrogen to get released into the soil, whereas, less nitrogen in proportion to carbon causes the microorganisms to utilize the nitrogen for further decomposition by which the soil nitrogen immobilizes, and becomes unavailable. C and N not only plays a major role in the concentration of greenhouse gases in the atmosphere such as CH4 and N_2O, but also is critical in determining soil quality, like fertility, water holding capacity, ecosystem productivity. Carbon is used by organisms as a source of energy during decomposition process and nitrogen in the building of soil structure. Too much of carbon slows down the decomposition, which might lead to the death of the organisms, whereas others form new cell material using the stored energy. Thus, this causes amount of carbon to reduce and nitrogen to recycle.

1.8 OBJECTIVES

The objective of the thesis is to compare the carbon sequestration potential of two rangelands, degraded to varying degree (degraded and highly degraded) with the help of various physical and chemical parameters, and finally developing a hypothesis on the basis of these parameters by which we can figure out the differences in carbon sequestration potential.

The objectives are:

I. Analyse the Physical parameters like Bulk density and Soil texture
II. Analyse the chemical parameters like PH and Nutients-N,P,K
III. Test the hypothesis for the difference in the soil carbon sequestration potential of two differently degraded rangelands depending upon their properties
IV. Management options to enhance soil carbon sequestration potential in these differently degraded rangelands

1.9 Limitations

There were some limitations observed at the time of collecting the samples and some even in the lab as well based on the protocols that has been followed. First of all, the distance taken while doing the transect method was reduced in Mkalama, as the study area was comparatively smaller. Secondly, it was raining in the very first day of sample collection by which the rain might have tampered the physical and chemical constituents of the soil and thirdly, the methodologies that were followed in the lab, especially while dealing with the properties like texture and density were old ones.

LITERATURE REVIEW

The global soil carbon (C) pool of 2500 gigatons (Gt) includes about 1550 Gt of SOC and 950 Gt of soil inorganic carbon (SIC). The soil C pool is 3.3 times the size of the atmospheric pool (760 Gt) and 4.5 times the size of the biotic pool (560 Gt). The SOC pool to 1-m depth ranges from 30 tons/ha in arid climates to 800 tons/ha in organic soils in cold regions, and a predominant range of 50 to 150 tons ha^{-1} (Lal, 2004). Soil combined with the vegetation is the viable sink of atmospheric carbon, which might mitigate the global climate change (Bajracharya et al., 1998; Lal, 2004).

Soil contain third biggest reservoir of C after ocean and fossil fuel which ranges from 1500-2000 Pg C. The major factors that controls the storage of SOC is controlled by input of primary production and organic matter evolution. Land use change affects the amount of carbon stored in the soils and vegetation, hence the flux of carbon between land and atmosphere (R. A. Houghton, 2003). C storage can be increased by increase in primary productivity; whereas increases in decomposition time will have an opposite effect, i.e. reducing C turnover time (Y. Wang and Y.P. Hilesh, 2002).

The soil rich in organic matter have the tendency to sequester C released by human activities (Tian et al., 1998). Land use and soil management practices can influence the flux of the carbon in the soil (Batjes, 1996; Post and Kwon, 2000), provided the mechanism and processes of C sequestration in the soil not fully understood (Lal et al., 1995; Bajracharya et al., 1998).

The increase in the concentration of CO_2 in the atmosphere is linked to the soil degradation. The degradation of soil through erosion and mineralization depletes almost 4-6 Pg C yr^{-1}, with mineralization constituting 20% of the emission (Lal, 2003). In terms of potential of C sequestration, the semi-arid and sub-humid regions of Africa are known for the greater carbon sequestration potential. The soil in west Africa stores about 4.2–4.5 kg C m^{-2} (Batjes, 2001), which was found to emit more than 50% of the net emission in 1980 (Houghton et al., 1987). The major factors behind the emission were the deforestation, land use changes, agricultural expansion, logging, over-cultivation etc.

C resides in soil in both organic and inorganic form. The organic carbon is found commonly humid and sub-humid regions, whereas inorganic form is found in in arid and semi-arid regions in the form of carbonates and bicarbonates. The loss of C in degraded soil is a matter of erosion, mineralization and leaching (Izaurralde et al., 2000). Temperature acts as catalyst to the mineralization rate, as the increase in temperature speeds up the process. However, the restoration of SOC can be achieved through conversion to an appropriate land use and adoption of Recommended Management Practices (RMPs) (Lal, 2003, 2004a).

The status of soil can be determined on the basis of temperature, soil moisture, plant lignin content, textural class, and nitrogen in the soil of Great Plains (Parton et al., 1987). In such soils SOC can be found related to precipitation, clay content, air temperature (Bruke et al., 1989), while elevation and water regime is given importance by others (Sims and Nielsen, 1986).

The potential of the annual carbon sequestration is estimated to be 15% (1.2 pg C yr^{-1}) of the total annual fossil fuel emission with sequestration rate depending upon climate and topographic variables (Lal, 2004). The sequestration rate varies with 1000 Kg ha^{-1} yr^{-1} in humid climate to neutral and negative in arid hot climate (Lal, 2007). In areas dominated by more humid and tall grass prairie, sequestration rate can reach 500 kg ha^{-1} yr^{-1} by the implementation of management practices that enhances biomass production. In arid extreme, carbon sequestration in rangeland may be <10kg/ha, although management practices are similar.

Terrestrial ecosystem is the cause for the increase in concentration of CO_2 during both the industrial and preindustrial era. The total emission from terrestrial ecosystem was (320 Gt or 0.04 Gt C yr^{-1} for 7800 years) which is supposedly twice the industrial era (160 Gt or 0.8 Gt C yr^{-1} for 200 years). Between 1850 and 1998, the emission from fossil-fuel combustion (270

± 30 Gt) was about twice that from the terrestrial ecosystems (136 ± 55 Gt). The latter includes 78 ±12 Gt from soil, of which about one-third is attributed to soil degradation and accelerated erosion and two-third to mineralization (Lal, 2004b).

The input and output of SOC is determined by the balance of production via plants and decomposition through soil (Schlesinger, 1977).The production and decomposition of SOC increases with the increase in temperature in humid areas, but comparatively the rate of decomposition is greater than the rate of production (Nakane, 1975; Schlesinger, 1977). Estimates of the total potential of C sequestration in world soils vary wildly from lower of 0.4 - 0.6 Gt C yr^{-1} to higher of 0.6 - 1.2 Gt C yr^{-1}. The rate of carbon sequestration varies from negative or zero under arid and hot climate to about 1000 Kg C $ha^{-1}yr^{-1}$ (Lal, 2005).

SOC is associated with the temperature and water content in such a way that it decreases and increases along with the increase in temperature and soil water content respectively. Among various studies that have been done, it has been found that 30^0C increase in temperature is estimated to decrease SOC concentration by about 11% in the upper 30 cm soil depth and increase CO_2 emission by 8% (Sharma et al., 2012).

The loss of the SOC pool is primarily due to three factors : i) Plant root and residue return ii) Increase in biological activity due to soil aeration, which is influenced by cultivation and soil temperature, and iii) Increase in soil erosion which removes carbon rich material (Franzluebers at al., 2001). The SOC is specifically removed by wind and water-borne sediments through erosional processes. Even though a part of carbon buried by erosion may be buried and redistributed, the remaining is emitted into the atmosphere either by mineralization or as CH4 by methanogenesis. Erosion-induced deposition and burial may be 0.4 to 0.6 Gt C yr^{-1} compared with perhaps 0.8 to 1.2 Gt C yr^{-1} emitted into the atmosphere.

SOC shows strong relationship with precipitation and temperature, where precipitation is positively correlated and temperature is negatively correlated (Jones, 2007). Cool, wet conditions favour the accumulation of SOC, unlike the deserts (Schlesinger, 1997). The variation of SOC in rangelands soils is from below 1% to over 10%, which can be seen in many drylands as well (Janzen, 2001). The presence of clay and iron is in favour of SOC, unlike the bulk density of the soil.

Among various factors that control SOM turnover, climate is one of them which include especially temperature and precipitation, along with which vegetation type affecting production, quality of organic matter input influencing decomposition as well as rate of water and nutrients uptake. Distribution and management practices also influences SOM turnover through direct effects on input and output and through indirect effects on factors controlling these fluxes (Six, J., &Jasrow, J.D., 2002).

Jenny (1941) stated that the factors controlling production and decomposition of soil organic matter (SOM) are temperature and precipitation (climate), parent material (often represented by soil texture), relief (landscape position), organisms (particularly the plant community) and management. Precisely, the four influencing factors responsible for the formation of SOM are parent material, time, climate and biota (Jenny, 1980). The control over soil organic matter properties may have complex interactions, and the separate analysis of such controls may limit useful predictions.

Rangeland in semi-arid areas has lower plant cover every year, making it more vulnerable to erosion (Scotney& McPhee, 1991). The sparse plant cover in degraded land allows the sun rays to heat up the soil surface, and if it reaches up to 8°C, then it leads to the rapid breakdown and insufficient utilization of limited organic material (Du Preez&Snyman, 1993). The soil layers with low and variable rainfall restricts the mineralization process both spatially and temporally in semi-arid areas (Wiltshire, 1990) with evaporation ranging from (20 - 70) % of the infiltrated rain.

There are various causes of degraded soils with a depleted SOC pool, and the important ones include erosion, nutrient depletion, mineralization, acidification and leaching, Pollution, contamination etc. Restoring degraded lands includes benefits such as improving water quality, biomass productivity, and for reducing net CO_2 emission. SOC sequestration potential of 0.4-0.7 Pg C yr^{-1} can be achieved through desertification control in soils of arid and semi-arid regions (Lal, 2001).

The sequestration of C from atmosphere to soil reduces greenhouse effect and also restores the soil functions in a sustainable way. Water is the limiting factor for the storage of carbon as dry soils are less likely to lose carbon than wet soils (Glenn et al., 1992) limiting soil mineralization and flux of C to the atmosphere. Despite the major challenge behind the sequestration of soil organic carbon in warm and arid areas for the poor farmers, it is still a win-win strategy. It not only improves ecological approaches and ensures sustainable development, but also enhances SOC sequestration by mitigating global warming, improving water quality and reducing pollution (Lal et al., 2007).

Desertification leads to the depletion of the soil carbon pool. Soil erosion in drylands leads to emission of 0.21–0.26 Pg C yr^{-1}, with an additional 0.02–0.03 Pg C yr^{-1} due to exposure of carbonaceous material to climatic elements caused by surface soil erosion. The total annual emission of C due to erosion-induced land degradation in dryland ecosystem may be 0.23-0.29 Pg C yr^{-1} (Lal et al., 1999). In semi-arid areas, both net primary productivity (NPP) and decomposition rate of plant residues increases with water availability (Scholes & Hall, 1996).

C depletion is worsened when output exceeds the input, which may reach up to 20 to 80 tons C ha^{-1} into the atmosphere. Severe depletion of SOC pool degrades soil quality, reduces biomass productivity, and adversely impacts water quality, and the depletion may be exacerbated by projected global warming. There are several ways of increasing SOC stocks and biomass C out of which afforestation, reforestation and Silvopastoral system are the major ones. These techniques generate increase in biomass carbon and SOC stocks (Lal, 2004).

Soil texture is important to mitigate global climate change in a way that increase in clay content reduces the carbon output through stabilizing effects on SOC (Paul, 1984), leaving the relationship unclear. Soil texture has major influence on form, stability, resiliency, biological structure, weather and management (B.D. Kay, 1997).

SOC in a regional pattern are positively correlated to mean annual precipitation and negatively correlated with mean annual temperature depending on soil and vegetation types (Spain et al., 1983). SOC generally increases with the increase in precipitation and SOC density increases with the decrease in temperature depending upon the intensity of precipitation (Batjes, 1996).

The net balance between input and output determines the carbon sequestration. The processes behind the management of carbon are influenced by management methods and two biotic processes, i.e. production and decomposition of organic matter by microorganisms in soil. The biotic processes are strongly affected by physical, chemical, and biological factors including biome, climate, soil moisture, nutrient availability, plant growth, and erosion

(Derner and Schuman, 2007; Jones, 2007; Post et al., 2001; Svejcar et al., 2008; Ingram et al., 2008).

Conversion of rangeland to cropland might not be a proper solution to the terrestrial pool of carbon as 90% of the C is lost through aboveground and 50% through belowground (Reid et al., 2004). Out of huge area of rangelands in Africa, 53% of them is moderately or severely degraded (Dregne, 1991). The global potential of soil carbon sequestration on rangelands and grasslands through adoption of RMPs ranges from 0.01 to 0.3 Gt C yr^{-1}(Lal, 2007).The adoption of inappropriate and cessation of beneficial rangeland management practice is the key cause of rangeland degradation (IPCC, 2000).

Among the various mechanisms behind erosion, the primary causes are the liberation and transportation of SOM by wind or water leading to faster mineralization, which results in the decrease in physical, chemical and biological quality of the soil, ultimately decreasing the carbon sequestration potential. The occurrence of SOM in the soil determines the quality of soil in such a way that higher the recurrence, higher is the quality of the soil. The distribution of SOM occurs through erosion, whereas mineralisation is considered irreversible in a landscape (Lal, 2001).

Soil bulk density determines the compaction in a soil. It reduces the volume of the pore space by affecting the infiltration rate, i.e. increases in runoff with the soil erosion (Abdel-Magid et al., 1987). Also, the soil compact nature of soil affects the growth of the root due to poor aeration and lower water holding capacity and thus affecting infiltration.

Silt and clay plays an important role in the stabilization of organic compounds and slight variation in the topsoil texture could have large effects on SOC (Bationo and Buerkert, 2001). As clay content increases, the characteristics of soil matrix (including both structure and stability) are increasingly dominated by the characteristics of clay (including mineralogy and exchangeable ions) (B.D. Kay, 1997). Fine silt and coarse clay particles contain the highest SOC per unit mass compared to fine clay fraction (Anderson et al., 1981; Zhang et al., 1988).

Clay helps in the protection of SOM from decomposition by adsorption and aggregation, slowing turnover and thus effectively increasing SOM (Jenkinson, 1977; Paul, 1984). Increasing silt content also increases water holding capacity, so that soil texture interacts with climate in a controlled ecosystem processes (Schimel and Parton, 1986). Fine textured soil with higher clay is good for the growth of plants as they contain greater water holding capacity with low decomposition and oxidation rate. The increase in mineralization was found relatively greater in loamy and clayey than sandy soil, and much lesser for C than N (Hassink, 1992). Sandy soils contain higher mineralized organic N percentage than in loams and clays unlike carbon.

Texture helps in the plant productivity by enhancing water holding capacity, eventually helping in the SOM formation. Soil sink capacity and permanence are related to clay content and mineralogy, structural stability, landscape position, moisture and temperature regimes, and ability to form and retain stable microaggregates (Lal, 2004). Soil microaggregates help in the long term sequestration of carbon by protecting carbon against decomposition providing longer residence time. An agent which binds soil particles together includes root exudates, soil microbes, and fauna by excreting agents (Glinski and Lipiece, 1990).

The presence of SOC can be felt with the combination of silt and clay, whereas SOC is predicted to be lower in sandy soils than with fine or medium textured soils (Patron et al., 1987). The loss of organic matter was found highest in medium textured soil (Tiessen et al., 1982; Schimel et al., 1985a). The loss of SOC stock was attributed to decreased litter input, shifts in abundance of woody and herbaceous vegetation, changes in depth distribution of plant roots, altered soil water and temperature regimes which accelerate decomposition, and a decrease in NPP (Covington, 1981; Johnson et al., 1995; Jackson et al., 2000). The release of carbon from trees, grasses, shrubs occurs at a different rate back to the atmosphere, with turnover time ranging from months to hundreds of years (Davidson and Janssens, 2006).

There are various examples of degraded soils with a depleted SOC pool, and the important ones include erosion, nutrient depletion, mineralization, acidification and leaching, Pollution and contamination etc. Soils with sloppy landscape are more susceptible to erosion, particularly in areas with erratic rainfall. Erosion generally removes low density particles including clay and SOC, which are the two of the bonding agents in aggregation. Also, erosion on other hand might lead to mineralization (Jaycinthe et al., 2002a)

Restoring degraded lands includes benefits such as improving water quality, biomass productivity, and for reducing net CO_2 emission. SOC sequestration potential of 0.4-0.7 Pg C yr^{-1} can be achieved through desertification control in soils of arid and semi-arid regions (Lal, 2001). If the decomposition of soil is prevented in the long run, then SOC can be increased

(Batjes, 1998). Additionally, the residence time of SOC in dylands is larger than in the humid environments due to slow decomposition rate (Gifford, 1992).

Restoration of degraded soils could be a major factor in enhancing carbon sequestration having intact resiliency capacity. Due to low biogenic processes of the rate of SIC sequestration (5-150 kg C ha^{-1} yr^{-1}), it can be accentuated by biogenic processes and leaching of carbonates into soil irrigated with water containing low carbonates (Lal, 2004). Improving soil carbon sequestration through dryland increases as annual precipitation increases and mean temperature decreases (Rasmussen and oartob, 1994; Grace et al., 1998).

Fluxes of CH4 and N_2O might alter the CO_2 mitigation potential of soil management practices and so must be taken into consideration along with SOC sequestration. Mining along with fossil fuel combustion causes increase in concentration of carbon dioxide in the atmosphere due to the decomposition of SOM. An optimum level of SOC stock is needed to hold water and nutrients, decrease risks of erosion and degradation, improve soil structure and tilth, and provide energy to soil microorganisms (Lal, 2004).

Soil organic C and soil organic N are related in such a way that the presence of C can help to predict the presence of N. Clay was the only variable needed in addition to organic C to describe organic N to 20 cm. The regression equation shows the variation of C/N ratio from 10 in rangelands to 9 in cultivated soils (Burke et al., 1989).The balance between C and N is required for enhancing the efficiency of soil C sequestration (Paustian et al., 1997). Xie and Steinberger (2001) have found high concentration of organic carbon and nitrogen between soils under shrubs, below shrub canopies where the level of nitrogen has been governed mainly by the soil moisture.

Higher the C: N ratio, lower is the rate of decomposition in roots and other biomass (Silver and Miya, 2001). In terms of thickness, root thickness >5 mm in diameter compared to fine roots (2-5 mm) is resistant to decomposition, possibly due to resistant organic substances. Reducing deforestation in tropical biomass can help to sequester carbon in trees. Trees harvested and left to decay thus releases 1 to 4 Pg C to the atmosphere annually in tropical latitudes (Iverson et al., 1993).

MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in Gairo district of Morogoro region in Tanzanaia, which lies in the eastern part of Africa. Gairo, is a hill in Morogoro region which is located at an altitude of 1200 m above the sea level and lies in the coordinates 6°10'0" N and 36°54'0" E in DMS (Degree Minutes Second). It has an area of 1,974 km^2 with a population of 193, 011 and population density of 98 km^2, where vast area of it is covered by rangeland.

Figure 2: Satellite view of map of Leshata village of Gairo division showing sampling locations

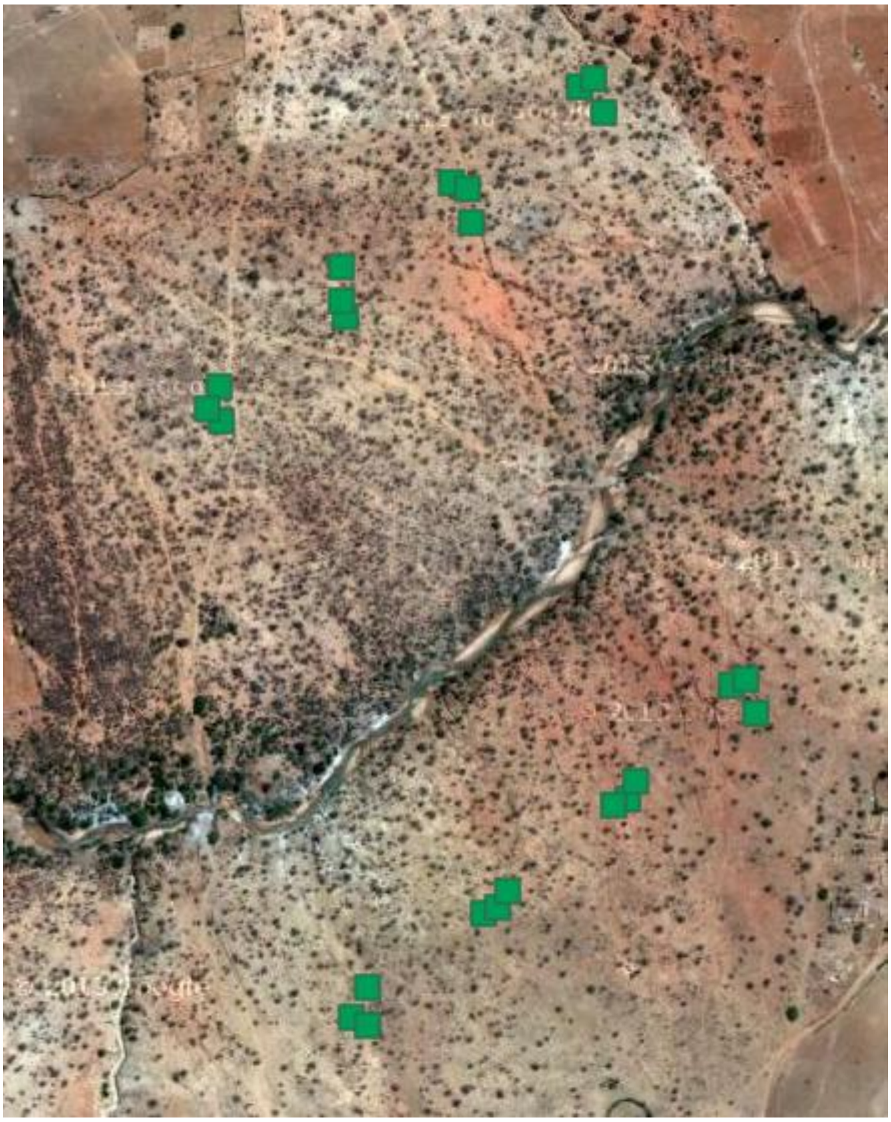


Figure 3: Satellite view of map of Mkalama village of Gairo division showing sampling points

The study was conducted in two villages called Lashata and Mkalama of Gairo district. These two villages which lie in rangelands consisted of sandy loam soil with scattered trees and shrubs in case of Leshata, and sandy clay with few shrubs in case of Mkalama. The study area in Leshata is bigger in comparison to Mkalama, and even the visual observation of the soil showed the difference in soil texture, first being sandy and soft soil and second being reddish in colour and hard soil. There were agricultural activities being observed in between and very close to the sampling site in village first, where as in village second, the soil being highly degraded, the agricultural activities were seen miles away from the sampling area. The soil in both of the villages seemed dry, and most particularly in village second where there were presence of plants suitable for desert kind of habitat, where the tree roots went deep into the soil to absorb water and minerals.

The rainfall in this region ranges from 400-500mm per year between December and April, and short dry spell in the middle from mid-January to mid-February. The erratic rainfall causes intensive soil erosion in cultivated and over-grazed area. The area is inhabited by the agro-pastoralist Kaguru tribe, which uses the land based on subsistence farming and livestock's breeds such as cattle, goats and sheep. The area is comprised of vegetation like *Urochloa*, *Dactoctylenum*, *Aristida*, *Chloris* and *Rhynchelytrum*which are short lived grass species. Also, the perennial grasses such as *Hyperhenia*, *Themeda*, *Heteropogon*, *Cynodon* and *Cenchrus* are found in isolated habitat.

3.2 SOIL SAMPLING

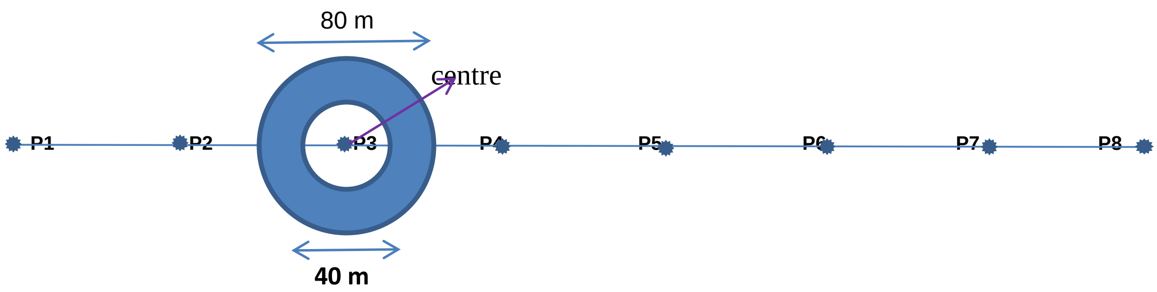


Figure 4: Schematic transect method based on sampling protocol (Transect first)

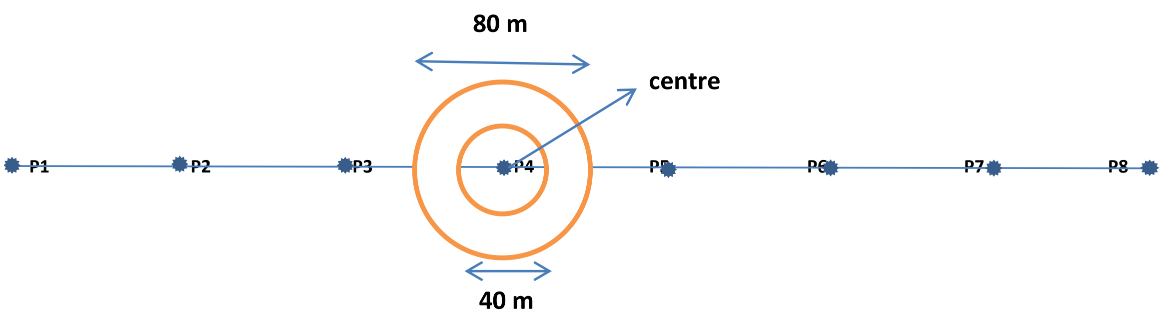


Figure 5: Schematic transect method based on sampling protocol (Transect second)

The soil sampling was done in the first week of March in which the soil samples were collected from two different depth, (0-15) cm and (15-30) cm. The protocol thus followed in the collection of samples were based on transect method. According to this method, each village was composed of two transects i.e. transect 1 and transect 2 and each transect was divided into eight points (which were numbered from 1 to 8), whereas the distance varied based on the available area. In Leshata Due to larger area, the distance between each point was four hundred meters unlike in Mkalala where the distance between each point was just hundred meters due to smaller area. In transect 1,only odd points were taken indicating a distance of eight hundred meters between two points, i.e. 1, 3, 5, and 7 whereas from transect 2, the even points were taken, i.e. 2, 4 6 and 8 maintaining the same distance between two point. The same procedure was followed for Mkalama, where the distance between each alternate point was just two hundred meters. Then, from every point considered, three sub-points were taken, the first taken from the center, whereas the remaining two ones were taken at a radius of twenty and forty meters, and each sub-point was divided at a depth of (0-15) cm and (15-30) cm. So, altogether there were twenty-four samples in transect 1 and twenty-four in transect 2, giving a total of ninety-six samples from both of the villages combined.

For bulksamples, 100-200 gram of soil samples was collected very close to the core samples. Three such samples were collected and transferred carefully into plastic bagfor the determination of chemical parameters i.e. C, PH, N, P and K. Plastic bags were used to avoid the tampering caused by the possible rainfall. The average of these samples will be used later to represent chemical nature of soil at certain point.

Figure 6: Soil sampling for bulk density analysis based on core method

For the determination of bulk density, three identical cores were hammered into the soil and the soil cores were excavated gently. The excess of the soil was removed with the help of knife making sure that it remained parallel with the opposite side. The soil within the core was carefully put into the plastic bag making sure that all of the soil fell inside the bag. Then the sampling bags were tied tightly and were taken to the lab for the analysis.

3.3 SOIL PARAMETERS ANALYZED

Different types of soil parameters were analysed in the laboratory for this study. These basically include various physiochemical properties. The parameters were:

3.3.1 Physical Parameters

3.3.1.1Bulk Density

Bulk Density is the mass of a unit volume of dry soil in its natural structure. The bulk density of the soil is a reflection of the level of compaction and amount of pore space in the soil (Brady, 1995).

Bulk density was determined by core method (Blake and Hartge, 1986). The sample from the core ring was pushed into a plastic bag and oven dried at 105^0C for 24 hours. The weight of the sample was noted, and finally bulk density was calculated by dividing oven dried soil weight by total core volume.

The total core volume in this case was 114.6 cm^3.

Bulk Density, $\rho bd= M_s/V_t$

Where, M_s is the mass of the oven dried soil

$V_t$is the volume of the core

3.3.1.2 Soil Texture

Texture is the distribution of different size fractions of particles. In other word, texture is how the soil feels when rubbed between the fingers as influenced by the range of different sizes of particles. It is an expression that characterizes the relative amounts of sand, silt and clay in the soil (Blake and Hartge, 1986).

Soil texture was determined from ground and sieved sample. Soil texture was determined by soil hydrometer method (Gee and Bauder, 1986).

Sand, silt and clay can be calculated by the formula:

Sand% = 100%- Silt%- Clay%

Silt% = 100%- Clay%-Sand% and

Clay% = 100%- Sand%- Silt%

3.3.2 Chemical Parameters

3.3.2.1 *Soil pH*

Soil pH was determined from ground and finely sieved sample. Soil pH was determined using pH probe along with glass calomel electrode and 1:1 soil: water ratio (McLean, 1982) at Sokoine University of Agriculture (SUA).

3.3.2.2 Available Phosphorus (ppm)

Phosphorous is also one of the most important macro nutrients essential for plant growth. Available Phosphorous was determined in the lab of SUA. It was analysed with a modified version for most of the samples whose PH was less than 7 (Bray's method). Only two of the samples had PH more than 7, and were analyzed by using Olsen's method (Olsen and Sommer, 1982).

3.3.2.3 Potassium (ppm)

Potassium is one of the most important macro nutrients. Major function in the plant is the regulation of water use. Potassium affects water transport in the plant, maintains cell pressure and regulates the opening and closing of stomata (small openings found on the leaf responsible for cooling and taking in carbon dioxide for photosynthesis (Ball, 1998).

Potassium content was determined in SUA lab by the NH_4OAc extraction and flame photometer emission method (Thomas, 1982).

3.3.2.4 Total Carbon

Analysis of the total carbon was performed by "dry combustion" method proposed by Allison, and described in Nelson &Sommer (1982) at Plant and Environmental Science (IPM) lab in Norwegian University of Life Sciences (UMB).

The samples were finely crushed by v.h.a. a mortar and pestle until weigh. Approx. 200 mg of each sample was weighed into a tin foil (100 to 150 mg at much org. Matr.). The samples were analysed using analyser Leco CHN 1000. The results were corrected for dry matter (water content).

3.3.2.5 Total Nitrogen

Determination of total nitrogen was performed by Dumas method at IPM in UMB. The method was described in Bremmer&Mulvaney (1982).

The concentration of nitrogen gas was measured by thermal conductivity (TC cell) at the same analysis instrument, Leco CHN 1000 .The results was corrected for dry matter (water content).

3.3.2.6 C:N Ratio

The C:N ratio was calculated from the values of organic matter and nitrogen%. C:N ratio = organic matter(%)/1.7× nitrogen(%). (Trivedi and Goel, 1986).

3.4 DATA ANALYSIS

Datawas tabulated and statistically analyzed using MINITAB 16. Significant differences in soil physical and chemical properties were determined using One Way ANOVA and Basic Statistics, with the level of Significance placed at 0.05. The obtained data were analysed statistically also using correlation and regression.

Data was also tabulated and calculated using Microsoft Excel. The calculated data were graphically represented using both Excel and Minitab 16.

RESULTS

4.1 PHYSICAL PARAMETERS

4.1.1 BULK DENSITY

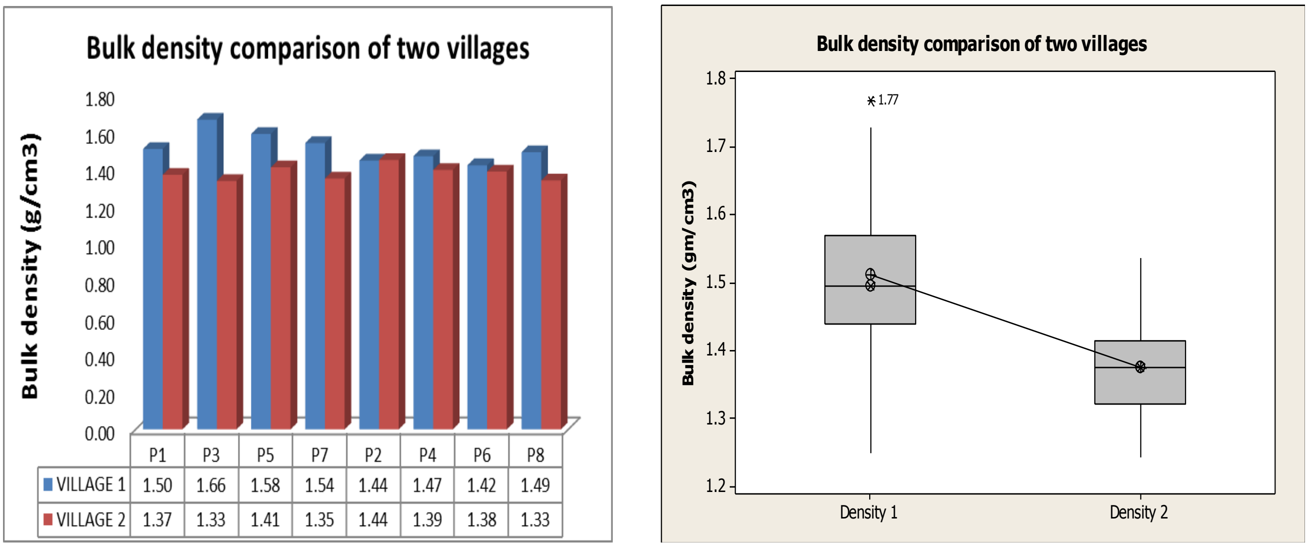


Figure 7: Schematic diagrammatic representation of bulk density indicating the mean point variation of two villages

In Village Leshata, the mean maximum densities of 1.66 g/cm3 lied at the point P3 in transect1; whereas the mean minimum density of 1.42g/cm^3 lied at the point P6 in transect 2. In village Mkalama, the mean maximum density of 1.44g/cm^3 lied the point P2 of transect 1, whereas the mean minimum density of 1.33g/cm^3 lied at the point P3 and P8 of transect 1 and 2 respectively. So, by comparing the overall data in both villages, it can be seen that the density in village Leshata is higher than the density in village Mkalama in every point with minor exceptions.

The above boxplot diagram represents that the mean density of 1.51g/cm^3 in Leshata is found greater than the mean density of 1.37g/cm^{3}in Mkalama. On the other hand, the interquartile range box plot in Leshata is slightly greater than the interquartile range in village Mkalama, which indicated slight more variation of data in Leshata in comparison to Mkalama. The mean in Leshata is slightly greater than median, whereas in Mkalama the mean and median coincided representing the proper distribution of data. This is further explained by the presence of long whiskers and outliers in Leshata which represented high variation in data, whereas in Mkalama, short whiskers can be seen without any outliers.

Based on descriptive statistics, the maximum density of 1.76g/cm^{3}was observed in case of Leshata and 1.54g/cm^{3}in case of Mkalama. While comparing the hypothesis, the Two-sample T-test result showed that (P<0.05) rejected the null hypothesis. The rejection of null hypothesis supported the alternative hypothesis, indicating that the density of two villages was not equal.

4.1.2 SOIL TEXTURE

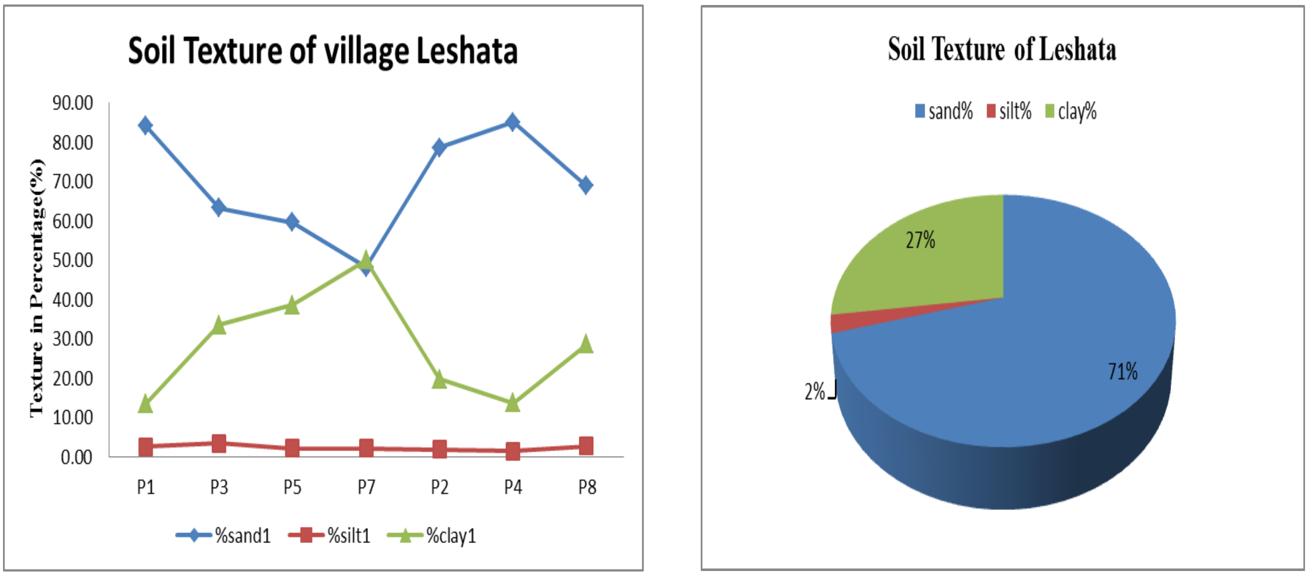


Figure 8: Soil texture comparison in Leshata differentiated on the basis of sand, silt and clay percentage where the point P1, P3 P5, P7 represents transect 1 and the point P2, P4, P6 and P8 represents transect 2

The graph above shows the soil texture differed at different points and transects. In Leshata, sand is seen as a dominant soil texture except at the point P7, followed by clay and silt, where the percentage of silt is seen negligible and less affected. In transect1, the percentage of sand is seen decreasing and at same time the percentage of clay is seen increasing with the increase in distance until they coincide at the point P7 at the end of transect 1. In case of transect 2, sand is seen increasing at the point P2 and P4 and seen decreasing at the point P6 and P8, whereas, in case of clay, the exact opposite case is seen.

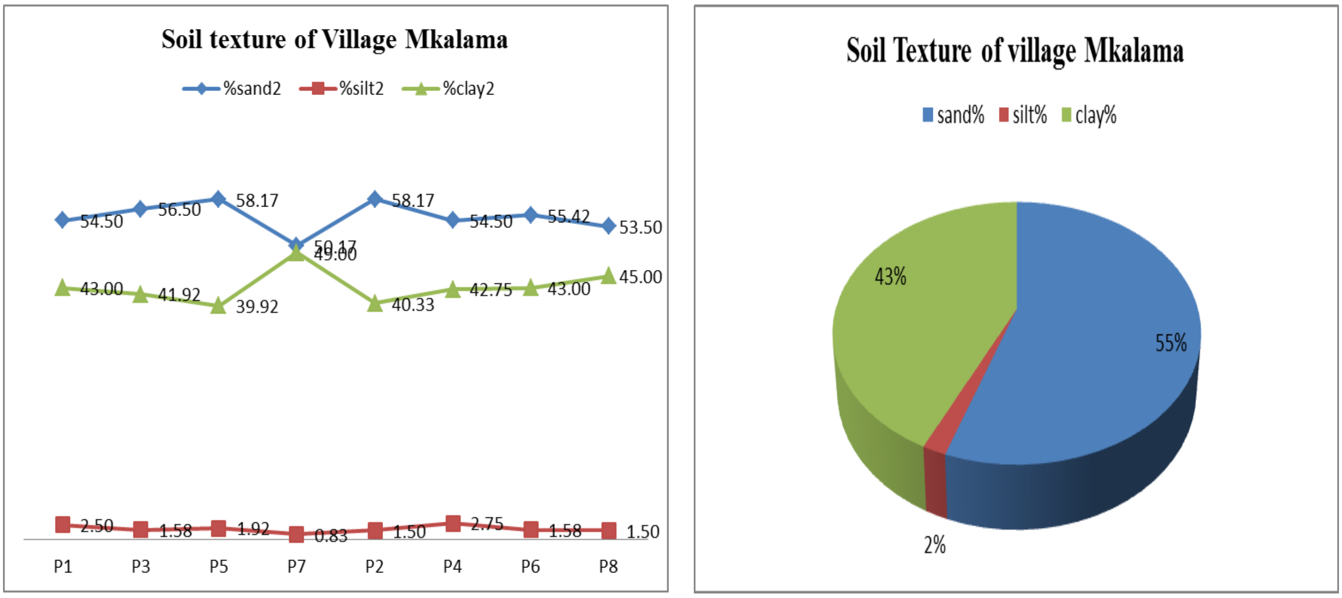


Figure 9: Soil texture differentiated on the basis of sand, silt and clay percentage, where the point P1, P3, P5, P7 represents transect 1 and the point P2, P4, P6 and P8 represents transect 2

The graph above does not show much variation in the data except at point P7 at the end of transect 1. At point P7, the percentage of sand and clay is seen similar, whereas the silt remaining unaffected in the entire transect. In this village, though sand is seen dominant, the ratio of sand is to clay is seen nearly equal to 1, which represented slight variation between sand and clay. Looking at the trend of the line in transect1, sand is seen slightly increasing at the point P1, P3 and P5 and decreasing at the point P7, whereas, the trend can be seen slightly decreasing in case of transect 2. The exact opposite can be seen in case of clay as the percentage of silt is seen relatively low. Point P7 is seen important and interesting as it is the point having highest clay content; on the other hand, it is the only point where the clay percentage is seen similar to the sand percentage.

4.1.2.1 Comparing Soil Texture of Two Villages

By comparing the mean value of different soil texture from two villages, it can be said that the mean value for sand 70.53% in Leshata was greater than the mean value of sand 55.11% in Mkalama. For silt, the mean value of 2.3% was found out to be greater in Leshata than the mean value of 1.77% in Mkalama. Finally, for clay the mean value of 27.15% in Leshata was found out to be less than the mean value of 43.11% in Mkalama. So, overall we can say that Leshata was found out to be greater in sand and silt content but lesser in clay content in comparison to Mkalama.

By comparing the Two- sample T-test for sand, silt and clay content in both of the villages, some results was observed on the basis of P-values. For the percentage of sand and clay, the P-value was ($P<0.05$) level of significance on the basis of which null hypothesis was rejected, stating that the mean of sand and clay in both villages were not equal. On the other hand, the silt content showed p-value ($P>0.05$) suggesting that the mean of the silt content could have been similar in both of the villages.

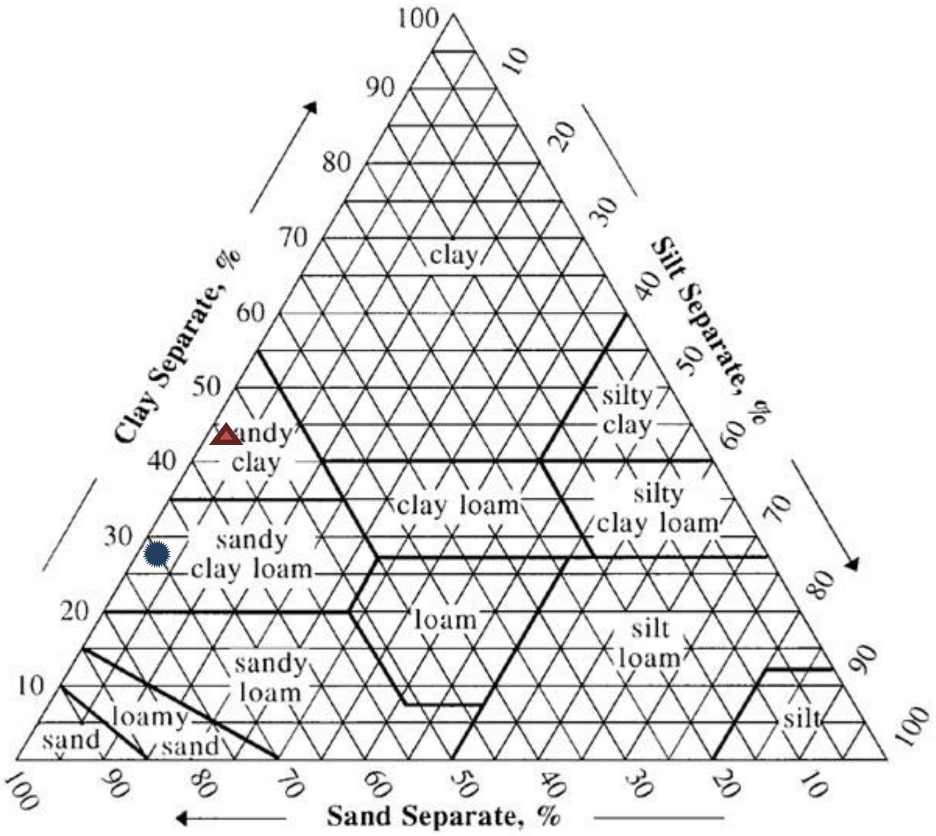
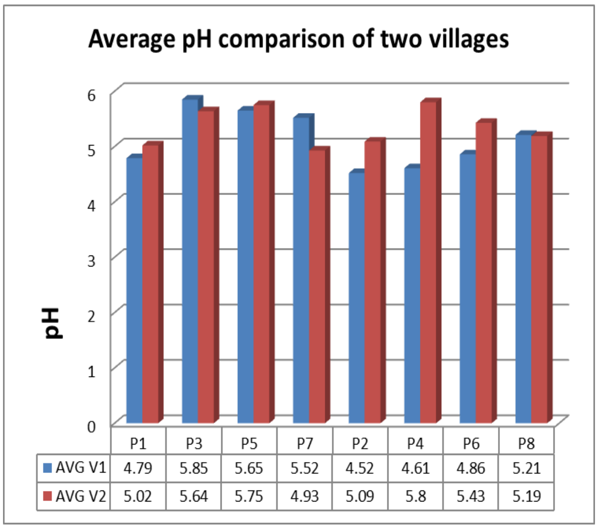


Figure 10: Schematic diagram of soil texture (source: USDA system of classification)

On the basis of the percentage of sand, silt and clay in village Leshata and Mkalama shown by the pie chart, the USDA system of classification stated that the soil in Leshata showed properties of sandy clay loam which is represented by the star sign in the diagram, whereas soil in Mkalama showed properties of sandy clay which is represented by the triangle in the diagram.

4.2 CHEMICAL PARAMETERS

4.2.1 pH



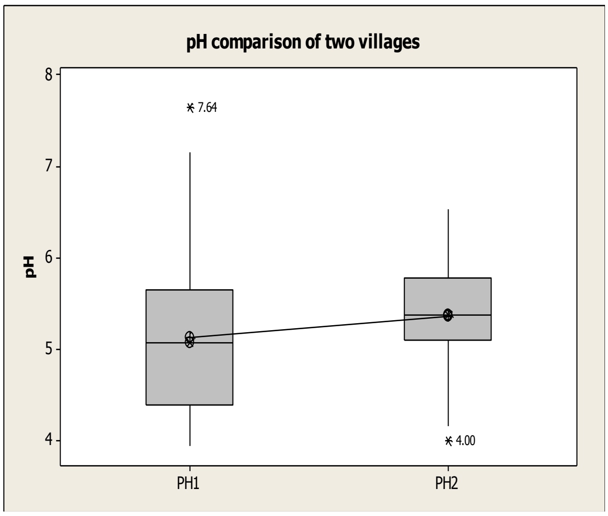


Figure 11: Schematic diagrammatic representation of pH indicating the mean point variation of two villages

From the graph above, not much variation is seen in the average pH of two villages. In village Leshata the average maximum pH of 5.85 is seen at the point P3 of transect 1 and minimum of 4.52 at the point P2 of transect 2. Similarly, in case of Mkalama the average maximum pH of 5.8 is seen at the point P4 of transect 2, whereas minimum pH of 4.93 is seen at the point P7 of transect 1.

From the box-plot above, the mean pH of 5.36 in Mkalama is slightly higher than the mean pH of 5.13 in Leshata. On the other hand, the IQ (Inter Quartile) range of 1.25 in Leshata is almost twice the IQ range of 0.68 in Mkalama. Higher the IQ range, higher is the variation in the data. In Leshata, a maximum pH of 7.64 is denoted by an outlier corresponding to the point P7, whereas in Mkalama lowest outlier of pH 4.00 is observed from the same point.

Maximum and minimum pH denoted by outliers was observed from the point P7, in both villages, and these points were rich in clay content. The relation between them was further illustrated by the strong correlation between them ($r=0.52$, $P=0.00$) at ($P<0.05$). Since, ($P>0.05$) level of significance based on Two- sample T-test null hypothesis was not rejected as a result of which mean pH of two villages cannot be significantly different.

4.2.2 POTASSIUM

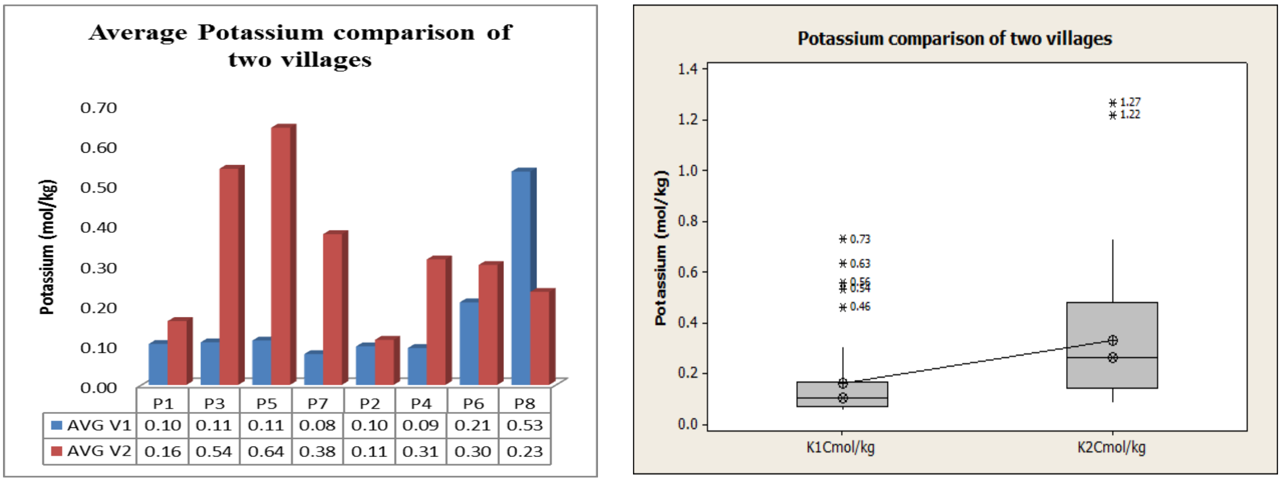


Figure 12: Schematic diagrammatic representation of Potassium indicating the mean point variation of two villages

The above bar diagram showed greater value of Potassium in Mkalama in comparison to Leshata, except at the point P8. The highest value of potassium is found to be 0.64mol/kg at the point P5 of Mkalama, whereas the lowest value of potassium is found to be 0.08mol/kg at the point P7 of Leshata.

According to the above box-plot, the mean in Mkalama 0.33mol/kg is twice the mean in Leshata 0.16mol/kg, where the first lied at Q3, and the second lied slightly above the median. On the other hand, IQ range in Mkalama is 0.33, which is a lot greater than the IQ range than in Leshata 0.09, and this represented the bigger variation of data in Mkalama in comparison to Leshata. Despite, most of the data in Leshata is seen homogeneous; the presence of maximum outliers described the uneven nature of data. The two maximum outliers observed from Mkalama is from the point P5, and sub-points P40 (0-15) and P40 (15-30).

In village Leshata, all the outliers were observed from the same point P8 in transect 2, which could be due to the presence of farm nearby; on the other hand the soil was red in colour with smaller vegetation and taller trees. While comparing the hypothesis, the P values showed ($P<0.05$) which rejected the null hypothesis, as a result of which the alternative hypothesis representing that the mean of the two values were not equal can be verified.

4.2.3 PHOSPHORUS

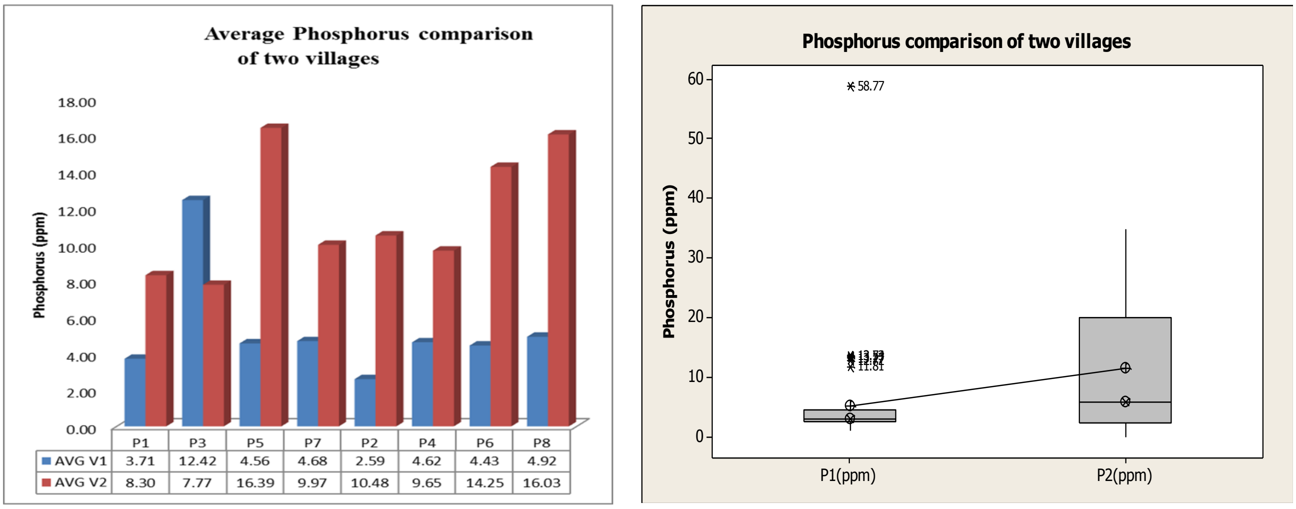


Figure 13: Schematic diagrammatic representation of Phosphorus indicating the mean point variation of two villages

From the above bar diagram, the data from Mkalama is found to be greater than data from Leshata at all points except at the point P3 of transect first. The highest value of P is observed from the point P5 of Mkalama, whereas the lowest is observed from the point P2 of Leshata.

From the above boxplot, the mean value 11.6ppm in Mkalama is greater than twice the mean value 5.24ppm, in Leshata. On the other hand, the size of the box which is determined by IQ range is almost nine times the size of IQ range in Leshata. Although, Leshata showed quite homogeneous data denoted by lesser IQ range in comparison to heterogeneous data in Mkalama, the presence of outliers is seen slightly above, and even high above the boxplot, unlike in Mkalama. Though Mkalama did not show outliers, it showed longer whiskers representing greater variability in the data.

Two- sample T-test showed that ($P<0.01$), which rejected the null hypothesis by supporting the alternative hypothesis that the difference in mean phosphorus value of two villages was not significantly equal.

4.2.4 TOTAL CARBON

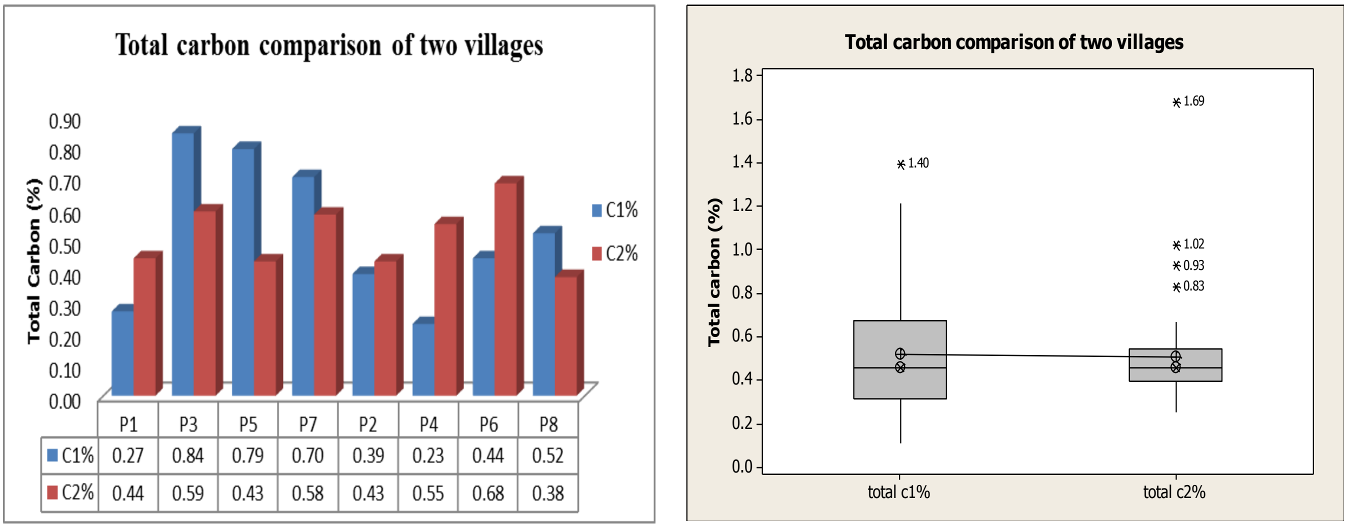


Figure 14: Schematic diagrammatic representation of total carbon indicating the mean point variation of two villages

From the bar diagram above, it can be seen that the average carbon in transect1 of Leshata is found to be higher than Mkalama at points P3, P5 and P7 whereas, it is found smaller at point P1. In case of transect2, the average carbon in Mkalama is higher than Leshata at points P2, P4 and P6, whereas, it is found lower at point P8. In case of Leshata, the average maximum carbon observed at point P3 is 0.84% which lied at transect 1, whereas, the average maximum carbon observed in Mkalama at point P6 is 0.68% which lied at transect 2.

From the above boxplot, the mean carbon in Leshata is found 0.52%, whereas; mean carbon in Mkalama is found 0.50%, which indicates carbon in Leshata slightly greater than carbon in Mkalama. On the other hand, the thick box plot in Leshata showed high variability, whereas the thin box plot in Mkalama showed low variability based on the width of IQ range. In case of Leshata, single outlier is observed followed by longer whiskers, whereas, in case of Mkalama, despite shorter whisker is seen, high outliers are observed.

The reason behind total organic carbon being slightly greater in Leshata in comparison to Mkalama could be due to higher trees and vegetation cover as a result of which, the shades of trees and vegetation created a microclimate condition, eventually affecting the SOM pools.

By testing the hypothesis based on Two- sample T-test, it can be seen that P value was 0.85 at (P>0.05) level of significance, indicating that there was no difference in the mean carbon content of the two villages.

4.2.5 TOTAL NITROGEN

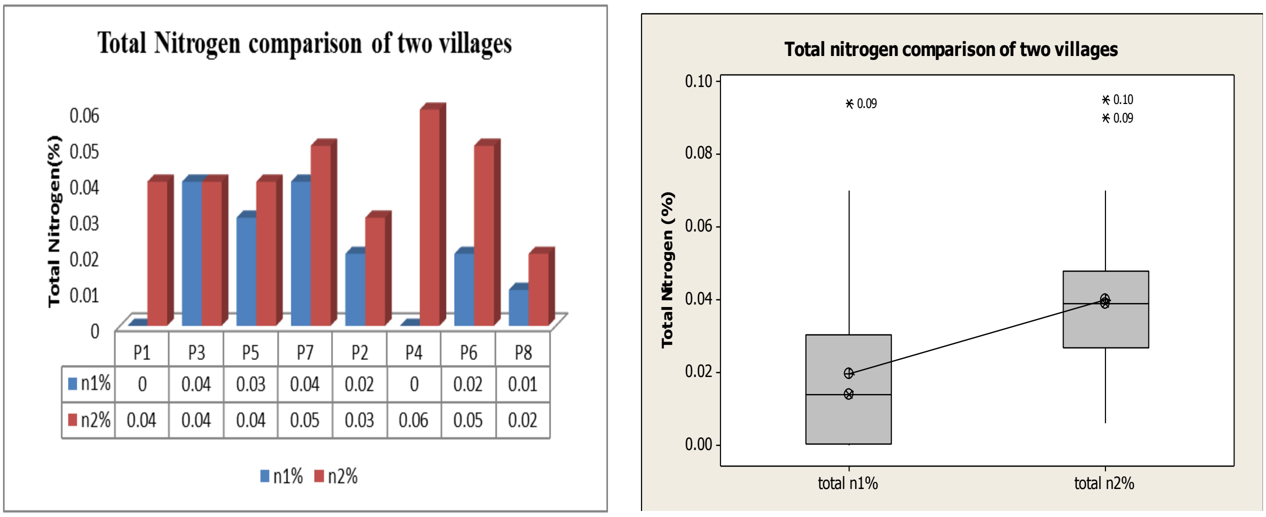


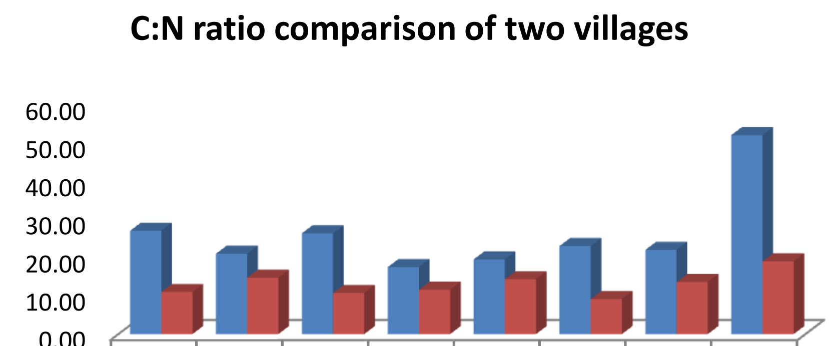
Figure 15: Schematic diagrammatic representation of total nitrogen indicating the mean point variation of two villages

From the bar diagram above, the total nitrogen in Mkalama is seen higher in comparison to the Leshata, except at the P3, where they are found equal. In case of Leshata, the total nitrogen from two point P1 and P4 is seen absent, and out of the remaining ones the maximum observed from the points P3 and P7 is 0.04%. In case of Mkalama, the maximum observed from the point P4 is 0.06%.

According to the above box plot, Mkalamashowed nitrogen content of 0.04% which is greater than twice the nitrogen content of 0.019% in Leshata. The IQ range in Leshata 0.03 is quite similar to the IQ range in Mkalama 0.02, which represented the similar distribution of data in both villages. The presence of whiskers and outliers are seen in both of the villages, representing uneven distribution of data. The outliers 0.09% in Leshata represented to the point P3, P0 (0-15) of transect1, whereas in Mkalama it represented to the point P4, P0 (15-30) and P6, P20 (0-15) for 0.10%.

By testing hypothesis based on Two- sample T-test, it can be seen that P value was 0.74 at ($P<0.05$) level of significance. This rejected the null hypothesis supporting the alternative hypothesis that the mean of the total nitrogen in both of the villages is not equal.

4.2.6 C: N RATIO



	P1	P3	P5	P7	P2	P4	P6	P8
C1:N1	27.00	21.00	26.33	17.50	19.50	23.00	22.00	52.00
C2:N2	11.00	14.75	10.75	11.60	14.33	9.17	13.60	19.00

Figure 16: Schematic diagrammatic representation of C:N ratio comparison of two villages

From the above bar diagram, Leshata showed higher mean C: N ratio at all points in comparison to Mkalama. The point P8 of Leshata showed highest C: N ratio of 52, whereas, the Point P5 of Mkalama showed lowest C: N ratio of 10.75. The increase in C: N ratio caused degradation of SOM, whereas, decrease in C: N ratio caused high degree of humification and easy mineralization of soils.

Higher C: N ratio causes the soil to be more resistant to decomposition, whereas the C: N ratio less than 10:1 increases the rate of decomposition (Brandy NC & Weil RR, 2002). While testing the hypothesis, the null hypothesis got rejected at ($P<0.05$), representing the unequal C: N ratio in two villages.

4.3 REGRESSION ANALYSIS

4.3.1 Regression Analysis for carbon and nitrogen in Leshata

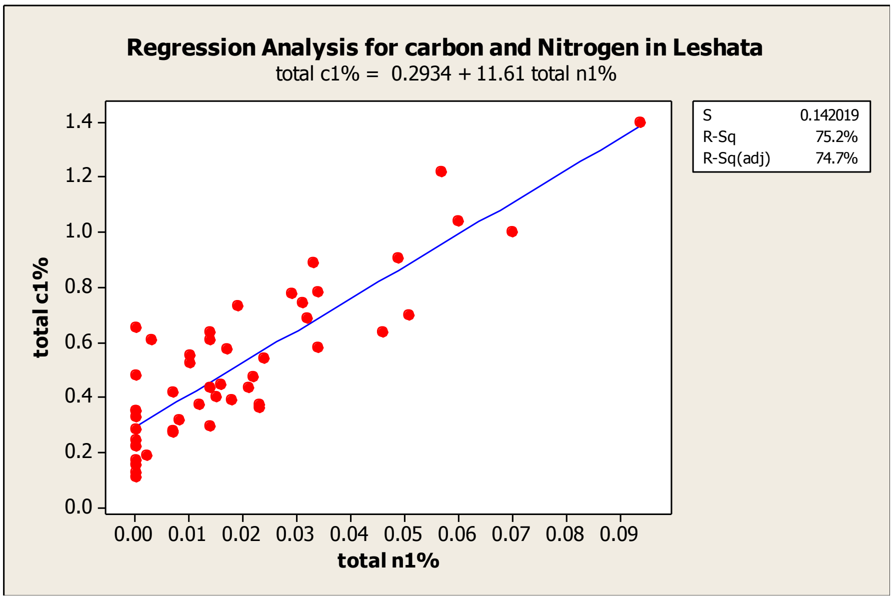


Figure 17: Scatter plot representing the best fitted line for regression analysis between carbon and nitrogen in case of Leshata

From the graph above, it can be seen that the scatter plot indicating the relationship between carbon and nitrogen is represented by the regression line, where (R^2 =75.2%) indicates strong relationship. Also, in above diagram Nitrogen (x) is considered predictor whereas Carbon (Y) is considered response. The P value in which ($P<0.05$) determined the significant relationship between the nitrogen and carbon. Since the P value is 0.00, higher is the probability that the response carbon is explained by the predictor nitrogen.

4.3.2 Regresssion Analysis for carbon and nitrogen in Mkalama

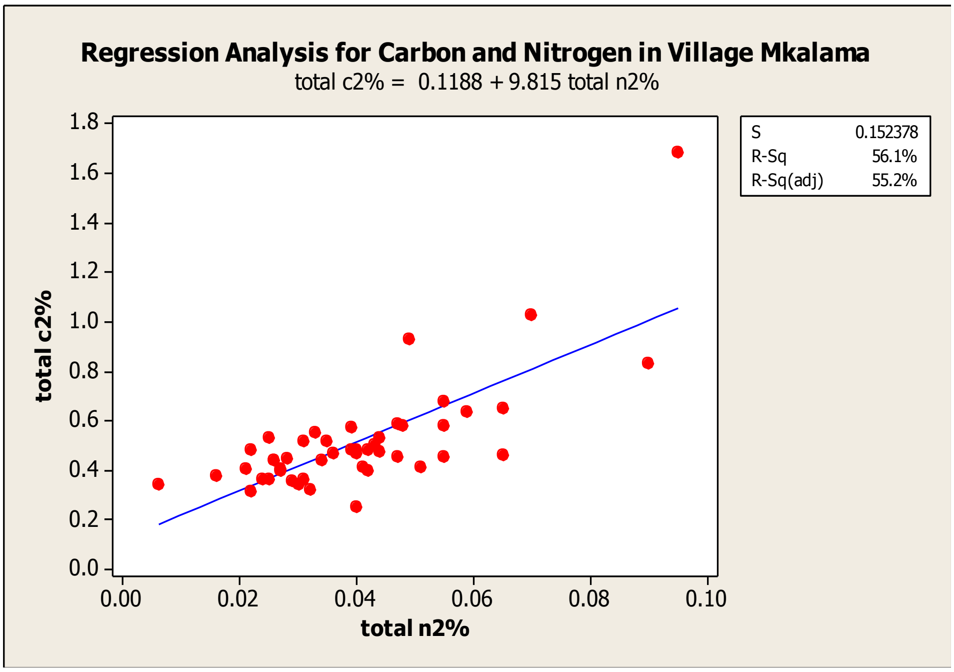


Figure 18: Scatter plot representing the best fitted line for regression analysis between carbon and nitrogen in case of Mkalama

From the graph above, the regression (R^2 =56.1%) indicates strong relationship between carbon and nitrogen as these data fits the line. On the above regression equation, Nitrogen (x) is considered predictor whereas Carbon (Y) is considered response. Also, the P value 0.00 at ($P<0.05$) determined the significant relationship between the nitrogen and carbon. Smaller the P value, greater the probability that these outputs are not explained by chance in the equation.

4.3.3 Regression Analysis of Carbon and Nitrogen with other parameters

Based on the general regression analysis between the response carbon and nitrogen with the predictors in village Leshata, carbon showed significant relationship ($P<0.05$) with the predictor's nitrogen, potassium, phosphorus and sand whereas the other insignificant ones ($P>0.05$) has been eliminated. The regression (R^2 =84.13%) explained strong variability in carbon that changes along with the variation in the predictors. In case of Nitrogen, it showed significant relationship ($P<0.05$) with carbon and potassium as (R^2=78.38%) represented the strong fitted line between the predictors and response. Smaller the P value, greater is the probability that the change in input is followed by the change in output. Surprisingly, the relationship with clay cannot be estimated in both of the villages.

In village Mkalama, the response carbon and nitrogen did not show any significant relationship with the predictors as (P>0.05) except within themselves.

4.4 CORRELATION TABLE FOR CARBON AND NITROGEN WITH OTHER PARAMETERS

4.4.1 Correlation Table for Leshata

Table 2: Pearson correlation table showing relationship between parameters based on level of significance for Leshata

	total c1%	total n1%	PH1	K1Cmol/kg	P1(ppm)	Density 1
total n1%	0.867					
	0.000					
PH1	0.450	0.326				
	0.001	0.024				
K1Cmol/kg	0.044	-0.139	-0.006			
	0.765	0.344	0.968			
P1(ppm)	0.357	0.297	0.067	0.090		
	0.013	0.041	0.651	0.541		
Density 1	0.247	0.225	0.626	-0.188	0.130	
	0.090	0.124	0.000	0.200	0.377	
%sand1	-0.651	-0.529	-0.538	0.002	-0.011	-0.400
	0.000	0.000	0.000	0.988	0.939	0.005
%silt1	0.095	-0.025	0.252	0.046	-0.053	0.155
	0.521	0.866	0.084	0.758	0.723	0.294
%clay1	0.651	0.540	0.518	-0.007	0.018	0.389
	0.000	0.000	0.000	0.960	0.906	0.006

	%sand1	%silt1
%silt1	-0.200	
	0.173	
%clay1	-0.994	0.090
	0.000	0.544

Cell Contents: Pearson correlation
P-Value

A strong relationship (r=0.5-1.0) was seen between carbon and nitrogen, as the correlation coefficient between these parameters was high (r = 0.867) as (P<0.05). It showed significant relationship with pH, phosphorus, sand and clay, whereas it did not show any relationship with potassium, density and silt. Nitrogen also showed significant relationship with pH, potassium, sand and clay whereas it did not show any relationship with potassium, density and silt same like carbon based on Pearson correlation table.

4.4.2 Correlation Table for Mkalama

Table 3: Pearson correlation table showing relationship between parameters based on level of significance for Mkalama

	total c2%	total n2%	PH2	K2Cmol/kg	P2(ppm)	Density 2
total n2%	0.749					
	0.000					
PH2	0.165	0.161				
	0.263	0.275				
K2Cmol/kg	0.148	0.026	0.401			
	0.317	0.860	0.005			
P2(ppm)	-0.095	-0.021	0.121	-0.256		
	0.521	0.887	0.414	0.079		
Density 2	-0.012	0.037	0.019	-0.055	0.232	
	0.934	0.801	0.896	0.709	0.112	
%sand2	0.070	-0.014	-0.121	0.178	0.155	0.158
	0.635	0.925	0.411	0.226	0.292	0.285
%silt2	0.006	0.074	0.048	-0.093	0.131	0.252
	0.969	0.617	0.746	0.527	0.373	0.084
%clay2	-0.069	-0.000	0.109	-0.155	-0.175	-0.200
	0.640	0.998	0.461	0.292	0.234	0.174

	%sand2	%silt2
%silt2	0.067	
	0.652	
%clay2	-0.983	-0.251
	0.000	0.086

Cell Contents: Pearson correlation
P-Value

Mkalama also showed strong relationship (r=0.749, 0.00) between carbon and nitrogen (P<0.00). Surprisingly, carbon and nitrogen did not show any relationship with the other parameters as (P>0.05) in this village.

So, while conducting correlation between different physical and chemical parameters between Leshata and Mkalama, Leshata showed significant relationship with most of the parameters whereas, in Mkalama there seemed to be no such relationship among the parameters except the relationship between Carbon and Nitrogen.

4.5 DEPTH WISE COMPARISON OF PARAMETERS OF TWO VILLAGES

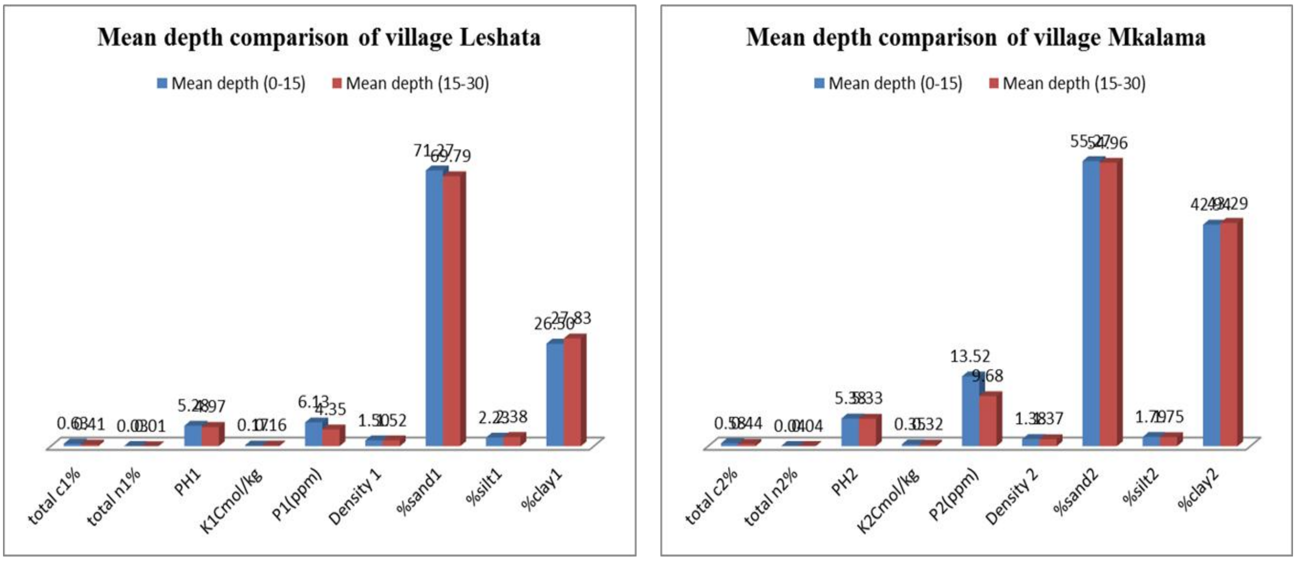


Figure 19: Mean depth wise comparison of physical and chemical parameters of two villages

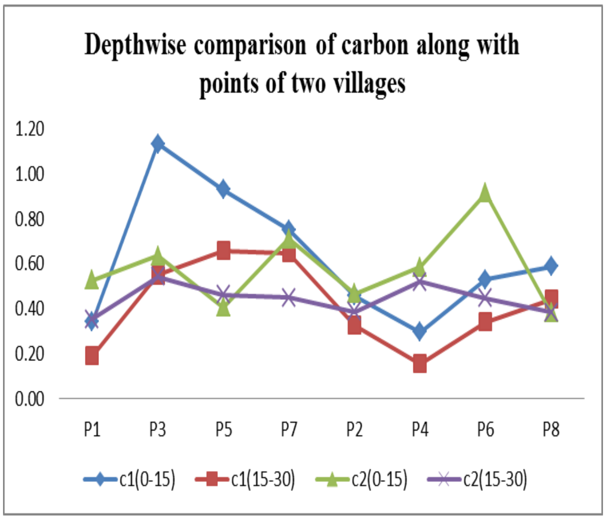
The mean depth wise variation between (0-15) cm and (15-30) cm is compared, on the basis of which no such variation in the physical and chemical parameters of the soil is observed in both of the villages. Taking individual parameter into consideration for Leshata, the mean depth of (0-15) cm is found to be greater for carbon, nitrogen, pH, potassium and phosphorus, whereas, the mean depth of (15-30) cm is found to be greater for density, silt and clay content. In case of Mkalama, the mean depth of (0-15) cm is found to be greater for carbon, nitrogen, pH, potassium, phosphorus, and sand, whereas, nitrogen remained unchanged. On the other hand, the mean depth of (15-30) cm is found greater for density, silt and clay content.

Table 4: The average depth-wise variation comparison of two villages

	LESHATA		MKALAMA	
	Depth (0-15)	Depth (15-30)	Depth (0-15)	Depth (15-30)
Total c1%	0.63	0.41	0.58	0.44
Total n1%	0.03	0.01	0.04	0.04
PH1	5.28	4.97	5.38	5.33
K1	0.17	0.16	0.35	0.32
P1	6.13	4.35	13.52	9.68
Density1	1.5	1.52	1.38	1.37
sand1%	71.27	69.79	55.27	54.96
silt1%	2.23	2.38	1.79	1.75
clay1%	26.5	27.83	42.94	43.29

In the depth-wise comparison of carbon and nitrogen, the top (0-15) cm in both of the villages showed higher concentration of carbon, whereas Nitrogen was found higher in case of Leshata and equal in case of Mkalama. In village Leshata, the P value from both tailed test showed ($P > 0.05$) which did not reject the null hypothesis indicating that the mean of the two depths (0-15) cm and (15-30) cm could have been equal. The same case was observed in Mkalama, illustrating no any depth wise variation.

4.5.1 Depth wise Variation of Carbon and Nitrogen



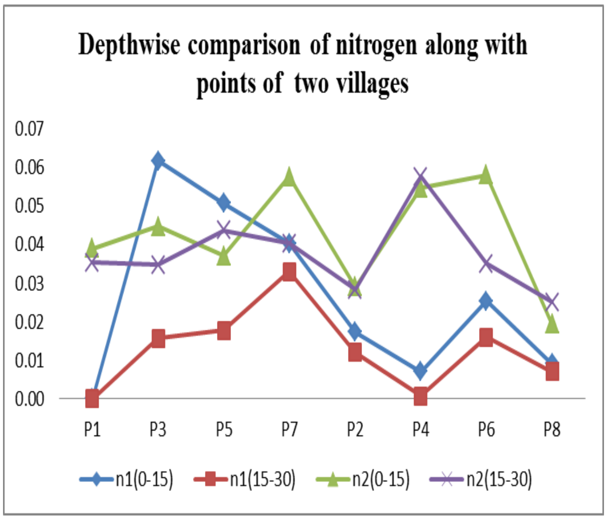


Figure 20: Graphical representation of depth wise variation of carbon and nitrogen along with points for village Leshata and Mkalama

From the graph above, carbon is found greater at a depth of (0-15) cm than the depth (15-30) cm at every point in Leshata. Same case can be seen in Mkalama, except at a point P5, where the concentration of carbon is found slightly greater at (15-30) cm depth. Among two villages, the average total carbon at a depth of (0-15) cm is found to be greatest in Leshata at the point P3, which is 1.13%.

The total nitrogen at a depth (0-15) cm is found greater than at a depth of (15-30) cm in Leshata, except at a point P1, where nitrogen is seen absent. In case of Mkalama, nitrogen is seen to be fluctuating irrespective of the depth. The concentration of nitrogen is seen maximum at point P3, which is 0.06% in Leshata, and the similar concentration can be seen at several points in Mkalama. So, it can be said that the total nitrogen in Mkalama is greater at all depths except at point P3 and P5 than in Leshata.

4.6 List of pictures taken near to the sampling site from both villages


a) Rangeland of village Leshatab) Manures seen in fields close to point P3, P5 and P7


c) Rangeland of villageMkalamad) Grazing of livestocks


e) Soil erosion in Mkalamaf) Gully erosioninMkalama

Figure 21(a,b,c,d,e,f): Picture of rangelands of village Leshata and Mkalama along with various soil processes

DISCUSSIONS

Due to fewer plant vegetation (which are responsible for storing atmospheric carbon dioxide, through photosynthesis), carbon storage in these villages is very less (Lal et al., 1999). On the other hand due to hot climate and less water retention capacity of the soil, the soil in these areas is always disadvantaged in comparison other ecosystem. Soil in Mkalama contained lesser vegetation and harder soil, due to which water could not percolate into the soil creating unfavourable condition for the growth of plants.

When comparing the degree of compaction of the soil in these two villages, the mean bulk density in Leshata and Mkalama were found 1.51g/cm^3 and 1.37g/cm^3 respectively. Not only the mean density of Leshata was greater to Mkalama, but also the individual mean points of transects in Leshata was greater which might be due to trampling by cattle's causing compaction as larger herds were seen in these area. The depth wise variation in density was also compared on the basis of which, the lower depth of (15-30) cm contained slightly higher density than the upper depth of (0-15) cm in Leshata, whereas in case of Mkalama it was seen opposite leading to low infiltration. The reason behind lower density in the surface layer in Leshata could be due to the presence of organic matter. The ideal bulk density for the growth of plant for sandy clam loam is (<1.4) and for sandy clay it is (<1.1). Since density of both villages is more than the ideal requirements, soil is not feasible for the growth of plants in these two villages.

There was strong and inverse relationship seen between sand and clay in both villages as the silt content in both of the villages remained constant. At points P7 of both villages, clay percentage was found higher as both areas contained trees and vegetation. This is supported by the statement that gradual establishment of the vegetation cover can be one of the reasons for the increase in clay formation (Jha and Singh, 1991). Also, soil in Mkalama was well aggregated (finer) than Leshata, which might have developed more tendency to store nutrients (i.e. N, P, and K) due to large surface area (Balanco- canqui, H. 2008).

pH is important to the growth of the plant as the increase or decrease in pH determines the ability of the plants to absorb nutrients and water. If the pH of the soil solution is increased above 5.5; nitrogen is made available to the plants. Phosphorous is made available to the plants if the pH is in between 6.0 to 7.0.Since the mean pH of the soil was 5.12 for Leshata and 5.35 for Mkalama, it might have restricted the supply of nitrogen and phosphorus creating unfavourable condition for the growth and development of plant.

The correlation between pH and sand content in Leshata was seen strong and negative (r=-0.54, P=0.00) at (P<0.05) level of significance. It might be due to the reason that the increase in sand content affect the growth of the plant as larger pores leads to poor water retention. Here the decrease in vegetation, which is proportional to the decrease in carbon, led to the decrease in pH, as carbon is positively correlated to pH (r=0.45, P=0.001), at (P<0.05). This might have caused acidification of soil leading to degradation in both of the villages. In transect 1of Leshata, the point P7 contained highest clay content, and the points P20 (0-15) and P20 (15-30) contained highest pH, as correlation between clay content and pH (r=0.52, P=0.00) at (P<0.05).

High concentration of potassium in Leshata was found at the point P8 of transect 2, as the point contained reddish soil with the scanty vegetation which contained low percentage of sand in comparison to the other points in the transect. The reason behind the other points in Leshata showing low concentration of potassium could be due to the presence of sand, as correlation between potassium and sand showed (r=-0.538, P=0.00) at (P<0.05) in comparison to Mkalama. This is well supported by the statement that sandy soil in high rainfall areas are prone to potassium deficiency, as both native and fertilized held potassium is held poorly and is subjected to leaching.

Phosphorous is the limiting factor for the growth of plants and vegetation, as its concentration ranges from 0.01-1 (Brady and Weil, 2002). The point P3, P20(0-15) in case of Leshata was found to have high content in phosphorous, as the point was really close to the field, piles of manures were seen and the addition of fertilizer would have enhanced the concentration of phosphorous (Fig. 21b). Despite Phosphorous being higher in concentration, plants roots could not use the essential elements, as the enzyme they needed to absorb was dependent on nitrogen availability.

The average carbon in both of the villages showed very less amount of carbon, except the point P3 in Leshata, which showed highest carbon content of 0.84% in comparison. The reason behind this could be that the area is extensively grazed by cattle's, the presence of which has the potential to enhance the total carbon content, as their dung and urine which acts as nutrients to the growth of plant and thus influencing soil carbon. This is in accordance with the statement that the nutrient accumulation through livestock dung in areas settled by pastoralists (Augustine, 2003) and soil enrichment by litter accumulation and subsequent decomposition (Berlinear and Kioka, 2000).

There was strong and positive correlation between soil Carbon and clay content as ($r=0.65$, $P=0.00$) at ($P<0.05$) level of significance observed from Leshata. This might be due to the fact that the increase in clay content caused the soil to retain moisture and nutrients which were good for the growth of the plants, and as the plant grew the roots of the plants helped in the process of decomposition causing increase in the soil carbon. This was in accordance with the statement that SOC increased with the increase in the clay content (Bationo et al., 2007). The correlation between carbon and sand was seen to be strong and negative as ($r=-0.65$, $P=0.00$) at ($P<0.05$) level of significance. The reason behind this could be the nature of sand, that drained down water due to larger pores and which was not in favour to the growth of vegetation reducing the carbon content.

Due to higher total nitrogen in Mkalama (which was more than double the total nitrogen in Leshata) the soil tended to be more acidic in comparison, and at the same time Mkalama contained higher clay content which developed an ability to resist the change in pH, also called the soil buffering capacity. This buffering capacity might have resulted to the rise in pH of soil in Mkalama, making it less acidic in comparison to Leshata. Soil containing lower nitrogen (seen in both of the villages) could reduce the ability of plants to convert carbon dioxide into organic compound such as sugar, through photosynthesis, causing even greater release of CO_2 to the atmosphere.

There was strong and positive relationship observed between soil carbon and nitrogen in Leshata and Mkalama as the correlation in Leshata ($r=0.87$, $P-0.00$) and Mkalama ($r=0.75$, $P=0.00$) at ($P<0.05$). The addition of fertilizer in the field between the points P3, P5 and P7 in Leshata would have enhanced the concentration of nitrogen in Leshata, causing increase in the carbon content (Fig. 21b). This is in accordance with the statement that a strong interaction exists between the availability of nitrogen and the soil carbon pool, and addition of nitrogen may increase the soil carbon pool in N deficient soils (Jaycinthe et al., 2002; Jagadamma et al., 2008) or decrease it while enhancing mineralization in others.

The depth wise variation in both villages showed higher SOC at the top layer (0-15) cm than the depth below (15-30) cm. The reason behind increase in SOC could be due to the presence of leaf litters and higher temperature that speeds the process of decomposition creating more organic carbon at the top layer (Dinakaran and Krishnayya, 2008; Alamgir and Amin, 2008).

The sampling area in Leshata was larger, with greater number of scattered trees and shrubs in comparison to Mkalama (Fig. 21a, c). Despite having larger sampling area, the soil was sandy with large macro pores leading to low water holding capacity. Also, sand being coarsely textured, it could not hold nutrients like N, P, and K which requires large surface area. Additionally, sunlight was found to be the limiting factor for small periphery plant as the tree cover prevented the sun rays to reach the smaller plants affecting their growth and development.

The reason behind Mkalama in more degraded condition could be the composition of soil, where most of them were composed of stones making the soil hard and unsuitable for the growth of the plant. On the other hand, due to rigid soil and sloppy landscape, the rainwater could not percolate inside the soil and as a result it eroded away all the minerals and essential nutrients vital for the growth of the plant (Fig. 21e). Also, due to scanty vegetation in this area, the sun rays heated the surface of the soil increasing the temperature (Fig. 21c). The increase in temperature exacerbated the rate of mineralization, ultimately leading to the decrease in SOC pool. Lower concentration of carbon and nitrogen and more phosphorous, the characteristic of dry soil was shown by Mkalama.

5.1 Rangeland Management options

Rangeland like Leshata and Mkalama are important to the sequestration of carbon from global perspectives as these lands occupy large land area which can be enhanced by few management practices such as developing contours to prevent erosion, planting Xerophytic plants as suitable plant for dry habitat, shrubs which act as windbreak and grasseslike *cynodon*, *Cenchrus* the taproot of which lies directly beneath the surface helping to grasp the soil and making it less susceptible to erosion, control the grazing of livestock, whose dung and urine acts as nutrients to the soil in one hand and also moderate grazing helps in soil treatment by the releasing nitrogen through decomposition in comparison to non-grazed and heavily grazed soils (Fig. 21d). Since, soil in these areas lied in between pH of 4-6; it affected the growth of plants as the nutrients like N, P and K were not made available to the growth of the plants. Acidic soils like these can be managed with the addition of lime (calcite) which increases the soil pH by its buffering capacity. As soon as the pH of the soil increases above 6, it improves the availability of nutrients by enhancing plant nutrition and water use.

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Village Mkalama was found more degraded though it contained slightly lower density and SOC than Village Leshata. On the other hand it contained high Nitrogen, Phosphorus, pH, Potassium, and higher clay content. In Mkalama, carbon and nitrogen did not show any relationship with the other parameters, except within themselves unlike in Leshata (Table 3, Table 4).

Based on USDA system of classification, soil texture of village Leshatacontained sandy clay loam whereas village Mkalamacontained sandy clay. Although soil in Mkalama showed more tendencies to store nutrients than Leshata due to finer soil particles, it was disadvantaged due to compact nature of soil and sloppy landscape leading to erosion.

When comparing the depth wise distribution of carbon and nitrogen in both of the villages, village Leshata showed decrease in concentration of carbon and nitrogen with the increase in depth, whereas village Mkalama did not show any proper depth wise distribution.

Soil in both of these villages showed higher C: N ratio causing slow decomposition of organic matter. Despite having tendency to store carbon in the soil for long run, soils in both of the villages were found more susceptible to processes like degradation, erosion and mineralization releasing carbon into the atmosphere.

Water is the limiting factor to the growth of plant in both of the villages, as the loss of water occurred through surface runoff and lower infiltration rate in Mkalama, whereas the bigger sand pores led water to the deeper layers due to low water retention capacity in Leshata.Also,the lower pH in soils of both of the villages caused the essential nutrients like N, P, and K unavailable to the growth of the plants.

Higher plant biomass in Leshata caused greater SOC due to better plant cover by reducing the soil temperature and increasing its density in comparison to Mkalama (Fig. 21a, c).

The hypothesis stating that the carbon sequestration in differently degraded rangelands was not found to be equal as most of the physical and chemical parameters showed ($P<0.05$) level of significance except silt, pH and carbon.

6.2 RECOMMENDATIONS

There is in need of better understanding for the accumulation and degradation of SOC pool, and also the dynamics of carbon and nitrogen in relation to carbon sequestration.

Information about microbial biomass would have helped in identifying the role of microbial biomass in sequestering carbon. Furthermore, information about leaf litters and root growth would have given better results about the overall carbon stock.

There is need of further research regarding appropriate management alternatives for soil carbon storage with better scientific understanding. It might give a precise picture of global carbon stock of rangelands and how they can be used against the increasing CO_2 concentration in the near future.

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ANNEXES

Table 1: Combined data for soil physical and chemical properties of village Leshata

line no	VILLAGE1	total c1%	total n1%	PH1	K1Cmol/kg	P1(ppm)	Density 1	%sand1	%silt1	%clay1
1	P1P0 (0-15)	0.35	0.00	5.60	0.06	3.52	1.48	85	2	13
2	P0 (15-30)	0.11	0.00	4.17	0.07	1.19	1.53	87	1	12
3	P20 (0-15)	0.35	0.00	5.15	0.14	1.32	1.47	81	4	15
4	P20 (15-30)	0.24	0.00	5.06	0.12	6.08	1.46	83	3	14
5	P40 (0-15)	0.33	0.00	4.44	0.11	4.76	1.55	84	3	13
6	P40 (15-30)	0.22	0.00	4.31	0.11	5.42	1.53	85	2	13
7	P3P0 (015)	1.40	0.09	6.10	0.12	4.00	1.62	61	4	35
8	P0 (15-30)	0.44	0.02	6.88	0.10	1.06	1.71	54	5	41
9	P20 (0-15)	1.22	0.06	5.65	0.21	58.78	1.59	71	2	27
10	P20 (15-30)	0.57	0.02	5.00	0.08	4.88	1.66	65	1	34
11	P40 (0-15)	0.78	0.03	5.67	0.07	3.30	1.66	68	3	29
12	P40 (15-30)	0.63	0.01	5.80	0.06	2.51	1.73	60	5	35
13	P5P0 (0-15)	0.89	0.03	5.36	0.20	3.45	1.5	69.5	0	30.5
14	P0 (15-30)	0.54	0.02	5.00	0.06	3.15	1.56	69.5	0.5	30
15	P20 (0-15)	1.00	0.07	6.24	0.14	3.65	1.57	55.5	2.5	42
16	P20 (15-30)	0.78	0.03	5.63	0.12	2.39	1.57	51.5	2.5	46
17	P40 (0-15)	0.90	0.05	5.91	0.08	12.72	1.61	61.5	2.5	36
18	P40 (15-30)	0.65	0.00	5.74	0.06	1.98	1.69	49.5	4	46.5
19	P7P0 (0-15)	1.04	0.06	4.12	0.11	2.86	1.29	48	1	51
20	P0 (15-30)	0.73	0.02	3.95	0.08	2.58	1.25	43.5	4	52.5
21	P20 (0-15)	0.52	0.01	7.64	0.07	2.04	1.57	50	1	49
22	P20 (15-30)	0.58	0.03	7.15	0.06	1.69	1.77	45.5	4.5	50
23	P40 (0-15)	0.70	0.05	5.10	0.07	5.38	1.67	49.5	0.5	50

24	P40 (15-30)	0.63	0.05	5.17	0.07	13.53	1.66	52	1	47
25	P2P0 (0-15)	0.37	0.01	4.24	0.17	2.50	1.44	83.5	0.5	16
26	P0 (15-30)	0.30	0.01	4.16	0.09	2.31	1.41	81.5	2.5	16
27	P20 (0-15)	0.32	0.01	4.51	0.08	2.35	1.51	81.5	2.5	16
28	P20 (15-30)	0.28	0.01	4.38	0.08	2.55	1.41	80	3	17
29	P40 (0-15)	0.69	0.03	5.24	0.09	3.06	1.42	71.5	0.5	28
30	P40 (15-30)	0.40	0.02	4.60	0.07	2.79	1.46	73.5	1.5	25
31	P4P0 (0-15)	0.28	0.00	5.43	0.10	2.17	1.46	85.5	0.5	14
32	P0 (15-30)	0.19	0.00	4.71	0.06	13.74	1.53	85.5	0	14.5
33	P20 (0-15)	0.17	0.00	4.18	0.12	3.15	1.48	83.5	2.5	14
34	P20 (15-30)	0.13	0.00	4.24	0.07	2.60	1.5	85.5	2	12.5
35	P40 (0-15)	0.43	0.02	4.84	0.13	3.14	1.44	86	1	13
36	P40 (15-30)	0.15	0.00	4.30	0.07	2.89	1.39	84	2	14
37	P6P0 (0-15)	0.74	0.03	5.65	0.31	2.03	1.38	73.5	2	24.5
38	P0 (15-30)	0.39	0.02	4.88	0.31	13.27	1.39	76	5	19
39	P20 (0-15)	0.48	0.02	4.56	0.11	2.58	1.42	79.5	2	18.5
40	P20 (15-30)	0.27	0.01	4.38	0.16	3.03	1.4	77.5	2	20.5
41	P40 (0-15)	0.37	0.02	4.82	0.22	2.65	1.49	77.5	3.5	19
42	P40 (15-30)	0.36	0.02	4.86	0.12	3.05	1.42	77.5	2.5	20
43	P8P0 (0-15)	0.55	0.01	5.36	0.26	2.77	1.45	73.5	5.5	21
44	P0 (15-30)	0.42	0.01	4.34	0.63	5.28	1.47	77.5	1.5	21
45	P20 (0-15)	0.61	0.01	5.13	0.56	11.81	1.49	59.5	3.5	37
46	P20 (15-30)	0.48	0.00	5.07	0.73	3.10	1.49	63.5	1.5	35
47	P40 (0-15)	0.61	0.00	5.85	0.54	3.22	1.5	71.5	4	24.5
48	P40 (15-30)	0.43	0.01	5.50	0.46	3.34	1.52	67.5	0	32.5

Table 2: Combined data for soil physical and chemical properties of village Mkalama

line no	VILLAGE 2	total c2%	total n2%	PH2	K2Cmol/kg	P2(ppm)	Density 2	%sand2	%silt2	%clay2
1	P1P0 (0-15)	0.67	0.06	4.16	0.23	4.09	1.42	62.5	3.5	34
2	P0 (15-30)	0.46	0.04	4.39	0.16	2.12	1.38	56.5	2	41.5
3	P20 (0-15)	0.55	0.03	5.35	0.15	20.48	1.40	52.5	4	43.5
4	P20 (15-30)	0.34	0.03	5.32	0.15	17.56	1.33	56.5	0	43.5
5	P40 (0-15)	0.36	0.03	5.81	0.15	2.51	1.38	40.5	2	57.5
6	P40 (15-30)	0.25	0.04	5.10	0.12	3.04	1.29	58.5	3.5	38
7	P3P0 (015)	0.48	0.04	5.20	0.68	6.08	1.38	60.5	1.5	38
8	P0 (15-30)	0.53	0.03	6.52	0.66	3.96	1.28	46.5	0	53.5
9	P20 (0-15)	0.50	0.04	5.82	0.37	21.29	1.36	58.5	0	41.5
10	P20 (15-30)	0.52	0.03	5.25	0.27	5.02	1.30	50.5	1.5	48
11	P40 (0-15)	0.93	0.05	5.60	0.73	5.42	1.35	64.5	2.5	33
12	P40 (15-30)	0.58	0.05	5.46	0.51	4.88	1.32	58.5	4	37.5
13	P5P0 (0-15)	0.46	0.07	5.65	0.29	34.73	1.45	62.5	2	35.5
14	P0 (15-30)	0.45	0.06	5.21	0.19	18.74	1.42	48.5	2	49.5
15	P20 (0-15)	0.36	0.03	5.46	0.56	18.97	1.41	60.5	3.5	36
16	P20 (15-30)	0.41	0.04	5.83	0.32	21.66	1.34	54.5	1.5	44
17	P40 (0-15)	0.40	0.02	6.35	1.22	2.78	1.40	68.5	0	31.5
18	P40 (15-30)	0.52	0.04	6.01	1.27	1.45	1.41	54.5	2.5	43
19	P7P0 (0-15)	0.64	0.06	5.75	0.36	5.42	1.39	40.5	1.5	58
20	P0 (15-30)	0.45	0.05	4.00	0.12	19.70	1.43	42.5	2.5	55
21	P20 (0-15)	1.03	0.07	5.10	0.66	4.09	1.32	42.5	0	57.5
22	P20 (15-30)	0.46	0.04	4.47	0.49	11.63	1.24	72.5	0	27.5
23	P40 (0-15)	0.47	0.04	5.18	0.27	17.12	1.31	56.5	0.5	43

24	P40 (15-30)	0.44	0.03	5.12	0.36	1.85	1.37	46.5	0.5	53
25	P2P0 (0-15)	0.44	0.03	4.78	0.13	0.04	1.32	56.5	0	43.5
26	P0 (15-30)	0.39	0.04	4.68	0.09	3.17	1.47	64.5	3.5	32
27	P20 (0-15)	0.48	0.04	5.42	0.13	13.98	1.39	48.5	0.5	51
28	P20 (15-30)	0.37	0.02	5.58	0.11	0.00	1.50	50.5	1.5	48
29	P40 (0-15)	0.48	0.02	4.81	0.10	13.83	1.45	58.5	3.5	38
30	P40 (15-30)	0.40	0.03	5.27	0.11	31.87	1.54	70.5	0	29.5
31	P4P0 (0-15)	0.65	0.07	6.20	0.20	28.50	1.34	54.5	4	41.5
32	P0 (15-30)	0.83	0.09	6.34	0.31	1.19	1.34	50.5	1.5	48
33	P20 (0-15)	0.58	0.06	5.39	0.33	5.68	1.35	50.5	1.5	48
34	P20 (15-30)	0.41	0.05	5.43	0.49	1.58	1.50	62.5	2	35.5
35	P40 (0-15)	0.53	0.04	5.06	0.28	0.93	1.38	56.5	1.5	42
36	P40 (15-30)	0.32	0.03	6.39	0.27	20.00	1.43	52.5	6	41.5
37	P6P0 (0-15)	0.57	0.04	5.30	0.49	19.37	1.50	56.5	2.5	41
38	P0 (15-30)	0.59	0.05	5.48	0.46	1.85	1.30	48.5	2	49.5
39	P20 (0-15)	1.69	0.10	5.78	0.18	14.72	1.41	66.5	2	31.5
40	P20 (15-30)	0.40	0.03	5.39	0.23	0.93	1.32	56.5	1.5	42
41	P40 (0-15)	0.48	0.04	5.19	0.32	17.45	1.43	50	0	50
42	P40 (15-30)	0.36	0.03	5.41	0.11	31.17	1.34	54.5	1.5	44
43	P8P0 (0-15)	0.34	0.01	4.53	0.23	20.48	1.32	58.5	3.5	38
44	P0 (15-30)	0.44	0.03	5.82	0.49	25.92	1.35	58.5	2	39.5
45	P20 (0-15)	0.44	0.03	5.94	0.27	20.08	1.39	49.5	2.5	48
46	P20 (15-30)	0.40	0.03	5.24	0.15	2.38	1.30	49.5	0.5	50
47	P40 (0-15)	0.36	0.02	5.28	0.12	26.54	1.35	50.5	0.5	49
48	P40 (15-30)	0.32	0.02	4.33	0.14	0.79	1.30	54.5	0	45.5

Table 3 a): Average physical and chemical properties of village Leshata

	Density 1	%sand1	%silt1	%clay1	PH1	K1	P1	C1	N1
P1	1.50	84.17	2.50	13.33	4.79	0.10	3.71	0.27	0.00
P3	1.66	63.17	3.33	33.50	5.85	0.11	12.42	0.84	0.04
P5	1.58	59.50	2.00	38.50	5.65	0.11	4.56	0.79	0.03
P7	1.54	48.08	2.00	49.92	5.52	0.08	4.68	0.70	0.04
P2	1.44	78.58	1.75	19.67	4.52	0.10	2.59	0.39	0.00
P4	1.47	85.00	1.33	13.67	4.61	0.09	4.62	0.23	0.00
P6	1.42	76.92	2.83	20.25	4.86	0.21	4.43	0.44	0.02
P8	1.49	68.83	2.67	28.50	5.21	0.53	4.92	0.52	0.01

Table 3 b): Average physical and chemical properties of village Mkalama

	Density 2	%sand2	%silt2	%clay2	PH2	K2	P2	C2	N2
P1	1.37	54.50	2.50	43.00	5.02	0.16	8.30	0.44	0.04
P3	1.33	56.50	1.58	41.92	5.64	0.54	7.77	0.59	0.04
P5	1.41	58.17	1.92	39.92	5.75	0.64	16.39	0.43	0.04
P7	1.35	50.17	0.83	49.00	4.93	0.38	9.97	0.58	0.05
P2	1.44	58.17	1.50	40.33	5.09	0.11	10.48	0.43	0.00
P4	1.39	54.50	2.75	42.75	5.8	0.31	9.65	0.55	0.06
P6	1.38	55.42	1.58	43.00	5.43	0.30	14.25	0.68	0.05
P8	1.33	53.50	1.50	45.00	5.19	0.23	16.03	0.38	0.02

Table3c): Depth wise variation of soil Physical and chemical properties for both villages

	VILLAGE LESHATA		VILLAGE MKALAMA	
	depth(0-15)	depth(15-30)	depth(0-15)	depth(15-30)
total c1%	0.63	0.41	0.58	0.44
total n1%	0.03	0.01	0.04	0.04
PH1	5.28	4.97	5.38	5.33
K1	0.17	0.16	0.35	0.32
P1	6.13	4.35	13.52	9.68
Density1	1.5	1.52	1.38	1.37
sand1%	71.27	69.79	55.27	54.96
silt1%	2.23	2.38	1.79	1.75
clay1%	26.5	27.83	42.94	43.29

Table 4: Latitudinal and Longitudinal variation of two villages

	VILLAGE LESHATA		VILLAGE MKALAMA		
Line No.	latitude	longitude	Line No.	latitude	longitude
1	-5.92818	37.03055	25	-6.09944	36.85071
2	-5.928	37.036	26	-6.09816	36.852
3	-5.91895	37.04164	27	-6.09697	36.85336
4	-5.92069	37.04865	28	-6.09579	36.85472
5	-5.92836	37.03055	29	-6.09932	36.85058
6	-5.92334	37.03589	30	-6.09834	36.85205
7	-5.91881	37.04177	31	-6.09691	36.85319
8	-5.92084	37.04872	32	-6.09588	36.85456
9	-5.92837	37.03083	33	-6.09907	36.8507
10	-5.92315	37.03584	34	-6.09781	36.85201
11	-5.91882	37.04129	35	-6.09906	36.85358
12	-5.92067	37.04829	36	-6.09615	36.85482
13	-5.9196	37.03383	37	-6.10581	36.85211
14	-5.9146	37.03903	38	-6.10468	36.85353
15	-5.90867	37.04261	39	-6.10354	36.85493
16	-5.90489	37.04873	40	-6.10225	36.85619
17	-5.91952	37.03366	41	-6.10589	36.85228
18	-5.91452	37.03886	42	-6.10462	36.85369
19	-5.90886	37.04258	43	-6.10347	36.85508
20	-5.90504	37.04884	44	-6.1022	36.85634
21	-5.91924	37.03382	45	-6.10548	36.85229
22	-5.91431	37.03942	46	-6.10446	36.8538
23	-5.90834	37.04251	47	-6.10328	36.85516
24	-5.90467	37.04904	48	-6.10215	36.88805

Table 5: List of data showing calculated soil density of two villages

Line no.	VILLAGE 1	ODW	WTFi	Nodw	Density 1	Line no.	VILLAGE 2	ODW	WTFi	Nodw	Density 2
1	P1P0 (0-15)	491.64	24.85	466.79	1.48	1	P1P0 (0-15)	470.22	23.42	446.8	1.42
2	P0 (15-30)	507.48	25.25	482.23	1.53	2	P0 (15-30)	456.46	23.27	433.19	1.38
3	P20 (0-15)	486.85	24.75	462.1	1.47	3	P20 (0-15)	457.75	17.06	440.69	1.40
4	P20 (15-30)	483.25	25.01	458.24	1.46	4	P20 (15-30)	435.32	17.65	417.67	1.33
5	P40 (0-15)	513.57	24.73	488.84	1.55	5	P40 (0-15)	451.97	17.21	434.76	1.38
6	P40 (15-30)	506.91	25.76	481.15	1.53	6	P40 (15-30)	427.42	22.9	404.52	1.29
7	P3P0 (015)	535.56	25	510.56	1.62	7	P3P0 (015)	457.53	23.58	433.95	1.38
8	P0 (15-30)	561.84	25	536.84	1.71	8	P0 (15-30)	424.48	23.04	401.44	1.28
9	P20 (0-15)	525.7	25.1	500.6	1.59	9	P20 (0-15)	451.68	23.01	428.67	1.36
10	P20 (15-30)	547.36	24.39	522.97	1.66	10	P20 (15-30)	433.74	23.24	410.5	1.30
11	P40 (0-15)	545.64	24.66	520.98	1.66	11	P40 (0-15)	448.42	22.85	425.57	1.35
12	P40 (15-30)	570.17	25.76	544.41	1.73	12	P40 (15-30)	437.99	23.07	414.92	1.32
13	P5P0 (0-15)	498.5	25.1	473.4	1.50	13	P5P0 (0-15)	480.55	22.99	457.56	1.45
14	P0 (15-30)	516.97	25.1	491.87	1.56	14	P0 (15-30)	469	22.95	446.05	1.42
15	P20 (0-15)	518.55	25.1	493.45	1.57	15	P20 (0-15)	466.28	22.95	443.33	1.41
16	P20 (15-30)	519.56	25.1	494.46	1.57	16	P20 (15-30)	443.38	22.79	420.59	1.34
17	P40 (0-15)	532.59	25.1	507.49	1.61	17	P40 (0-15)	459.33	18.07	441.26	1.40
18	P40 (15-30)	555.51	25.1	530.41	1.69	18	P40 (15-30)	462.01	18.25	443.76	1.41
19	P7P0 (0-15)	430.96	25.1	405.86	1.29	19	P7P0 (0-15)	460.67	23.18	437.49	1.39
20	P0 (15-30)	403.11	8.48	394.63	1.25	20	P0 (15-30)	468.45	17.95	450.5	1.43
21	P20 (0-15)	520.47	25.1	495.37	1.57	21	P20 (0-15)	439.04	23.37	415.67	1.32
22	P20 (15-30)	580.37	25.1	555.27	1.77	22	P20 (15-30)	414.83	23.47	391.36	1.24
23	P40 (0-15)	550.13	25.1	525.03	1.67	23	P40 (0-15)	436.32	23.41	412.92	1.31

24	P40 (15-30)	548.38	25.1	523.28	1.66	24	P40 (15-30)	4455.86	23.52	432.34	1.37
25	P2P0 (0-15)	478.96	25.1	453.86	1.44	25	P2P0 (0-15)	439.87	23.03	416.84	1.32
26	P0 (15-30)	467.97	25.1	442.87	1.41	26	P0 (15-30)	484.84	23.29	461.55	1.47
27	P20 (0-15)	498.89	25.1	473.79	1.51	27	P20 (0-15)	461.36	23.31	438.05	1.39
28	P20 (15-30)	494.27	50.2	444.07	1.41	28	P20 (15-30)	495.61	23.1	472.51	1.50
29	P40 (0-15)	455.5	8.28	447.22	1.42	29	P40 (0-15)	477.97	23.36	454.61	1.45
30	P40 (15-30)	485.21	25.1	460.11	1.46	30	P40 (15-30)	507.11	23.56	483.55	1.54
31	P4P0 (0-15)	483.2	25.1	458.1	1.46	31	P4P0 (0-15)	444.59	23.17	421.42	1.34
32	P0 (15-30)	504.99	25.1	479.89	1.53	32	P0 (15-30)	445.49	23.24	422.25	1.34
33	P20 (0-15)	490.9	25.1	465.8	1.48	33	P20 (0-15)	449.28	23.2	426.04	1.35
34	P20 (15-30)	495.78	25.1	470.68	1.50	34	P20 (15-30)	494.31	23.42	470.89	1.50
35	P40 (0-15)	478.16	25.1	453.06	1.44	35	P40 (0-15)	458.17	23.38	434.79	1.38
36	P40 (15-30)	463.11	25.1	438.01	1.39	36	P40 (15-30)	474.28	22.98	451.3	1.43
37	P6P0 (0-15)	459.99	25.1	434.89	1.38	37	P6P0 (0-15)	493.91	22.92	470.99	1.50
38	P0 (15-30)	462.35	25.1	437.25	1.39	38	P0 (15-30)	432.46	22.84	409.62	1.30
39	P20 (0-15)	471.53	25.1	446.43	1.42	39	P20 (0-15)	465.75	22.89	442.86	1.41
40	P20 (15-30)	466.72	25.1	441.62	1.40	40	P20 (15-30)	436.87	23.05	413.82	1.32
41	P40 (0-15)	493.81	25.1	468.71	1.49	41	P40 (0-15)	467.51	17.19	450.32	1.43
42	P40 (15-30)	470.36	25.1	445.26	1.42	42	P40 (15-30)	445.96	23.11	422.85	1.34
43	P8P0 (0-15)	481.36	25.1	456.26	1.45	43	P8P0 (0-15)	438.89	23.05	415.84	1.32
44	P0 (15-30)	488.18	25.1	463.08	1.47	44	P0 (15-30)	447.41	22.9	424.51	1.35
45	P20 (0-15)	494.51	25.1	469.4	1.49	45	P20 (0-15)	461.48	22.89	438.59	1.39
46	P20 (15-30)	493	25.1	467.9	1.49	46	P20 (15-30)	425.5	17.58	407.92	1.30
47	P40 (0-15)	495.66	25.1	470.56	1.50	47	P40 (0-15)	442.78	18.14	424.64	1.35
48	P40 (15-30)	504	25.1	478.9	1.52	48	P40 (15-30)	433.11	25.87	407.85	1.30

Table 6: List of data representing calculated soil texture of village Leshata

Line no.	VILLAGE 1	T1(6MIN)	T2(5HR)	T corr T1	T corr T2	%sand	%silt	%clay
1	P1P0 (0-15)	5	3	7.5	6.5	85	2	13
2	P0 (15-30)	4	2.5	6.5	6	87	1	12
3	P20 (0-15)	7	4	9.5	7.5	81	4	15
4	P20 (15-30)	6	3.5	8.5	7	83	3	14
5	P40 (0-15)	5.5	3	8	6.5	84	3	13
6	P40 (15-30)	5	3	7.5	6.5	85	2	13
7	P3P0 (015)	17	14	19.5	17.5	61	4	35
8	P0 (15-30)	20.5	17	23	20.5	54	5	41
9	P20 (0-15)	12	10	14.5	13.5	71	2	27
10	P20 (15-30)	15	13.5	17.5	17	65	1	34
11	P40 (0-15)	13.5	11	16	14.5	68	3	29
12	P40 (15-30)	17.5	14	20	17.5	60	5	35
13	P5P0 (0-15)	12	11	15.25	15.25	69.5	0	30.5
14	P0 (15-30)	12	10	15.25	15	69.5	0.5	30
15	P20 (0-15)	19	16	22.25	21	55.5	2.5	42
16	P20 (15-30)	21	18	24.25	23	51.5	2.5	46
17	P40 (0-15)	16	13	19.25	18	61.5	2.5	36
18	P40 (15-30)	22	19	25.25	23.25	49.5	4	46.5
19	P7P0 (0-15)	23	22	26	25.5	48	1	51
20	P0 (15-30)	25	22	28.25	26.25	43.5	4	52.5
21	P20 (0-15)	22	21	25	24.5	50	1	49
22	P20 (15-30)	24	20	27.25	25	45.5	4.5	50
23	P40 (0-15)	22	20	25.25	25	49.5	0.5	50

24	P40 (15-30)	21	20	24	23.5	52	1	47
25	P2P0 (0-15)	5	3	8.25	8	83.5	0.5	16
26	P0 (15-30)	6	3	9.25	8	81.5	2.5	16
27	P20 (0-15)	6	3	9.25	8	81.5	2.5	16
28	P20 (15-30)	7	5	10	8.5	80	3	17
29	P40 (0-15)	11	9	14.25	14	71.5	0.5	28
30	P40 (15-30)	10	8	13.25	12.5	73.5	1.5	25
31	P4P0 (0-15)	4	2	7.25	7	85.5	0.5	14
32	P0 (15-30)	4	3	7.25	7.25	85.5	0	14.5
33	P20 (0-15)	5	2	8.25	7	83.5	2.5	14
34	P20 (15-30)	4	2	7.25	6.25	85.5	2	12.5
35	P40 (0-15)	4	3	7	6.5	86	1	13
36	P40 (15-30)	5	3.5	8	7	84	2	14
37	P6P0 (0-15)	10	7	13.25	12.25	73.5	2	24.5
38	P0 (15-30)	9	6	12	9.5	76	5	19
39	P20 (0-15)	7	4	10.25	9.25	79.5	2	18.5
40	P20 (15-30)	8	5	11.25	10.25	77.5	2	20.5
41	P40 (0-15)	8	5	11.25	9.5	77.5	3.5	19
42	P40 (15-30)	8	5	11.25	10	77.5	2.5	20
43	P8P0 (0-15)	10	6	13.25	10.5	73.5	5.5	21
44	P0 (15-30)	8	6	11.25	10.5	77.5	1.5	21
45	P20 (0-15)	17	14	20.25	18.5	59.5	3.5	37
46	P20 (15-30)	15	13	18.25	17.5	63.5	1.5	35
47	P40 (0-15)	11	8	14.25	12.25	71.5	4	24.5
48	P40 (15-30)	13	11	16.25	16.25	67.5	0	32.5

Table 7: List of data representing calculated soil texture of village Mkalama

Line no.	VILLAGE2	T1(6MIN)	T2(5HR)	T corr T1	T corr T2	%sand	%silt	%clay
1	P1P0 (0-15)	16	13	18.75	17	62.5	3.5	34
2	P0 (15-30)	19	17	21.75	20.75	56.5	2	41.5
3	P20 (0-15)	21	18	23.75	21.75	52.5	4	43.5
4	P20 (15-30)	19	18	21.75	21.75	56.5	0	43.5
5	P40 (0-15)	27	25	29.75	28.75	40.5	2	57.5
6	P40 (15-30)	18	15	20.75	19	58.5	3.5	38
7	P3P0 (015)	17	15	19.75	19	60.5	1.5	38
8	P0 (15-30)	24	23	26.75	26.75	46.5	0	53.5
9	P20 (0-15)	18	17	20.75	20.75	58.5	0	41.5
10	P20 (15-30)	22	20	24.75	24	50.5	1.5	48
11	P40 (0-15)	15	13	17.75	16.5	64.5	2.5	33
12	P40 (15-30)	18	15	20.75	18.75	58.5	4	37.5
13	P5P0 (0-15)	16	14	18.75	17.75	62.5	2	35.5
14	P0 (15-30)	23	21	25.75	24.75	48.5	2	49.5
15	P20 (0-15)	17	14	19.75	18	60.5	3.5	36
16	P20 (15-30)	20	18	22.75	22	54.5	1.5	44
17	P40 (0-15)	13	12	15.75	15.75	68.5	0	31.5
18	P40 (15-30)	20	18	22.75	21.5	54.5	2.5	43
19	P7P0 (0-15)	27	25	29.75	29	40.5	1.5	58
20	P0 (15-30)	26	23.5	28.75	27.5	42.5	2.5	55
21	P20 (0-15)	26	25	28.75	28.75	42.5	0	57.5
22	P20 (15-30)	11	10	13.75	13.75	72.5	0	27.5
23	P40 (0-15)	19	17.5	21.75	21.5	56.5	0.5	43

24	P40 (15-30)	24	23	26.75	26.5	46.5	0.5	53
25	P2P0 (0-15)	19	18	21.75	21.75	56.5	0	43.5
26	P0 (15-30)	15	12	17.75	16	64.5	3.5	32
27	P20 (0-15)	23	21.5	25.75	25.5	48.5	0.5	51
28	P20 (15-30)	22	20	24.75	24	50.5	1.5	48
29	P40 (0-15)	18	15	20.75	19	58.5	3.5	38
30	P40 (15-30)	12	11	14.75	14.75	70.5	0	29.5
31	P4P0 (0-15)	20	17	22.75	20.75	54.5	4	41.5
32	P0 (15-30)	22	20	24.75	24	50.5	1.5	48
33	P20 (0-15)	22	20	24.75	24	50.5	1.5	48
34	P20 (15-30)	16	14	18.75	17.75	62.5	2	35.5
35	P40 (0-15)	19	17	21.75	21	56.5	1.5	42
36	P40 (15-30)	21	17	23.75	20.75	52.5	6	41.5
37	P6P0 (0-15)	19	17	21.75	20.5	56.5	2.5	41
38	P0 (15-30)	23	21	25.75	24.75	48.5	2	49.5
39	P20 (0-15)	14	12	16.75	15.75	66.5	2	31.5
40	P20 (15-30)	19	17	21.75	21	56.5	1.5	42
41	P40 (0-15)	22	21	25	25	50	0	50
42	P40 (15-30)	20	18	22.75	22	54.5	1.5	44
43	P8P0 (0-15)	18	15	20.75	19	58.5	3.5	38
44	P0 (15-30)	18	16	20.75	19.75	58.5	2	39.5
45	P20 (0-15)	22.5	20	25.25	24	49.5	2.5	48
46	P20 (15-30)	22.5	21	25.25	25	49.5	0.5	50
47	P40 (0-15)	22	20.5	24.75	24.5	50.5	0.5	49
48	P40 (15-30)	20	19	22.75	22.75	54.5	0	45.5

Table 8: Table showing PH of two villages along with temperatures

Line no.	VILLAGE1	PH1	TEMP1	VILLAGE2	PH2	TEMP2
1	P1P0 (0-15)	5.60	27.5	P1P0 (0-15)	4.16	26.3
2	P0 (15-30)	4.17	27.4	P0 (15-30)	4.39	28.3
3	P20 (0-15)	5.15	27.3	P20 (0-15)	5.35	27.7
4	P20 (15-30)	5.06	26.9	P20 (15-30)	5.32	27.6
5	P40 (0-15)	4.44	27.3	P40 (0-15)	5.81	27
6	P40 (15-30)	4.31	27.3	P40 (15-30)	5.10	26.9
7	P3P0 (015)	6.10	26.7	P3P0 (015)	5.20	27.5
8	P0 (15-30)	6.88	26.7	P0 (15-30)	6.52	27.5
9	P20 (0-15)	5.65	27.8	P20 (0-15)	5.82	28.2
10	P20 (15-30)	5.00	26.8	P20 (15-30)	5.25	28.3
11	P40 (0-15)	5.67	27.5	P40 (0-15)	5.60	27.6
12	P40 (15-30)	5.80	27.4	P40 (15-30)	5.46	26.5
13	P5P0 (0-15)	5.36	27.4	P5P0 (0-15)	5.65	27.6
14	P0 (15-30)	5.00	27.8	P0 (15-30)	5.21	27.5
15	P20 (0-15)	6.24	28.3	P20 (0-15)	5.46	28.3
16	P20 (15-30)	5.63	27.9	P20 (15-30)	5.83	27.7
17	P40 (0-15)	5.91	28.3	P40 (0-15)	6.35	27.7
18	P40 (15-30)	5.74	27.1	P40 (15-30)	6.01	27.1
19	P7P0 (0-15)	4.12	27	P7P0 (0-15)	5.75	27.6
20	P0 (15-30)	3.95	27	P0 (15-30)	4.00	27.2
21	P20 (0-15)	7.64	27.1	P20 (0-15)	5.10	28.1
22	P20 (15-30)	7.15	27	P20 (15-30)	4.47	27.4
23	P40 (0-15)	5.10	27.8	P40 (0-15)	5.18	26.7
24	P40	5.17	27.8	P40	5.12	27

	(15-30)			(15-30)		
25	P2P0 (0-15)	4.24	27	P2P0 (0-15)	4.78	27
26	P0 (15-30)	4.16	27	P0 (15-30)	4.68	27
27	P20 (0-15)	4.51	27	P20 (0-15)	5.42	27.5
28	P20 (15-30)	4.38	27	P20 (15-30)	5.58	27.7
29	P40 (0-15)	5.24	27	P40 (0-15)	4.81	27.1
30	P40 (15-30)	4.60	27	P40 (15-30)	5.27	27.6
31	P4P0 (0-15)	5.43	27	P4P0 (0-15)	6.20	27.1
32	P0 (15-30)	4.71	27	P0 (15-30)	6.34	27.2
33	P20 (0-15)	4.18	27	P20 (0-15)	5.39	27.3
34	P20 (15-30)	4.24	27	P20 (15-30)	5.43	27.5
35	P40 (0-15)	4.84	27	P40 (0-15)	5.06	27.6
36	P40 (15-30)	4.30	27	P40 (15-30)	6.39	28.3
37	P6P0 (0-15)	5.65	27	P6P0 (0-15)	5.30	28.5
38	P0 (15-30)	4.88	27	P0 (15-30)	5.48	27
39	P20 (0-15)	4.56	27	P20 (0-15)	5.78	27.4
40	P20 (15-30)	4.38	27	P20 (15-30)	5.39	26.7
41	P40 (0-15)	4.82	27	P40 (0-15)	5.19	27.4
42	P40 (15-30)	4.86	27	P40 (15-30)	5.41	26.8
43	P8P0 (0-15)	5.36	27	P8P0 (0-15)	4.53	27.6
44	P0 (15-30)	4.34	27	P0 (15-30)	5.82	26.8
45	P20 (0-15)	5.13	27	P20 (0-15)	5.94	28.4
46	P20 (15-30)	5.07	27	P20 (15-30)	5.24	28.1
47	P40 (0-15)	5.85	27	P40 (0-15)	5.28	26.9
48	P40 (15-30)	5.50	27	P40 (15-30)	4.33	28.3

Table 9: Table showing the concentration of Phosphorus of two villages

Line no.	VILLAGE 1	ABSRB	CONC	volpptd	wt of sam	P (ppm)	VILLAGE 2	ABSRB	CONC	volpptd	wt of sam	P (ppm)
1	P1P0 (0-15)	0.04	0.08	10.00	3.00	3.52	P1P0 (0-15)	0.03	0.05	5.00	3.00	4.09
2	P0 (15-30)	0.01	0.01	5.00	3.00	1.19	P0 (15-30)	0.02	0.03	5.00	3.00	2.12
3	P20 (0-15)	0.01	0.02	5.00	3.00	1.32	P20 (0-15)	0.55	0.25	5.00	3.00	20.48
4	P20 (15-30)	0.05	0.07	5.00	3.00	6.08	P20 (15-30)	0.48	0.21	5.00	3.00	17.56
5	P40 (0-15)	0.04	0.06	5.00	3.00	4.76	P40 (0-15)	0.02	0.03	5.00	3.00	2.51
6	P40 (15-30)	0.04	0.07	5.00	3.00	5.42	P40 (15-30)	0.02	0.04	5.00	3.00	3.04
7	P3P0 (015)	0.03	0.05	5.00	3.00	4.00	P3P0 (015)	0.05	0.07	5.00	3.00	6.08
8	P0 (15-30)	0.01	0.01	5.00	3.00	1.06	P0 (15-30)	0.03	0.05	5.00	3.00	3.96
9	P20 (0-15)	0.45	0.71	5.00	3.00	58.78	P20 (0-15)	0.58	0.26	5.00	3.00	21.29
10	P20 (15-30)	0.04	0.06	5.00	3.00	4.88	P20 (15-30)	0.04	0.06	5.00	3.00	5.02
11	P40 (0-15)	0.03	0.04	5.00	3.00	3.30	P40 (0-15)	0.04	0.07	5.00	3.00	5.42
12	P40 (15-30)	0.02	0.03	5.00	3.00	2.51	P40 (15-30)	0.04	0.06	5.00	3.00	4.88
13	P5P0 (0-15)	0.03	0.08	10.00	3.00	3.45	P5P0 (0-15)	0.26	0.42	5.00	3.00	34.73
14	P0 (15-30)	0.03	0.08	10.00	3.00	3.15	P0 (15-30)	0.51	0.22	5.00	3.00	18.74
15	P20 (0-15)	0.04	0.09	10.00	3.00	3.65	P20 (0-15)	0.51	0.23	5.00	3.00	18.97
16	P20 (15-30)	0.01	0.06	10.00	3.00	2.39	P20 (15-30)	0.16	0.26	5.00	3.00	21.66
17	P40 (0-15)	0.25	0.31	10.00	3.00	12.72	P40 (0-15)	0.02	0.03	5.00	3.00	2.78
18	P40 (15-30)	0.00	0.05	10.00	3.00	1.98	P40 (15-30)	0.01	0.02	5.00	3.00	1.45
19	P7P0 (0-15)	0.20	0.07	10.00	3.00	2.86	P7P0 (0-15)	0.04	0.07	5.00	3.00	5.42
20	P0 (15-30)	0.01	0.06	10.00	3.00	2.58	P0 (15-30)	0.53	0.24	5.00	3.00	19.70
21	P20 (0-15)	**-0.18**	**0.04**	10.00	2.50	2.04	P20 (0-15)	0.03	0.05	5.00	3.00	4.09
22	P20 (15-30)	**-0.02**	**0.03**	10.00	2.50	1.69	P20 (15-30)	0.09	0.14	5.00	3.00	11.63
23	P40 (0-15)	0.02	0.06	5.00	3.00	5.38	P40 (0-15)	0.46	0.21	5.00	3.00	17.12

24	P40 (15-30)	0.03	0.32	10.00	3.00	13.53	P40 (15-30)	0.01	0.02	5.00	3.00	1.85
25	P2P0 (0-15)	0.01	0.06	10.00	3.00	2.50	P2P0 (0-15)	0.00	0.00	15.00	3.00	0.04
26	P0 (15-30)	0.01	0.06	10.00	3.00	2.31	P0 (15-30)	0.02	0.04	5.00	3.00	3.17
27	P20 (0-15)	0.01	0.06	10.00	3.00	2.35	P20 (0-15)	0.38	0.17	5.00	3.00	13.98
28	P20 (15-30)	0.01	0.06	10.00	3.00	2.55	P20 (15-30)	0.00	0.00	5.00	3.00	0.00
29	P40 (0-15)	0.02	0.07	10.00	3.00	3.06	P40 (0-15)	0.37	0.17	5.00	3.00	13.83
30	P40 (15-30)	0.02	0.07	10.00	3.00	2.79	P40 (15-30)	0.86	0.38	5.00	3.00	31.87
31	P4P0 (0-15)	0.00	0.05	10.00	3.00	2.17	P4P0 (0-15)	0.77	0.34	5.00	3.00	28.50
32	P0 (15-30)	0.27	0.33	10.00	3.00	13.74	P0 (15-30)	0.01	0.01	5.00	3.00	1.19
33	P20 (0-15)	0.03	0.08	10.00	3.00	3.15	P20 (0-15)	0.04	0.07	5.00	3.00	5.68
34	P20 (15-30)	0.01	0.06	10.00	3.00	2.60	P20 (15-30)	0.01	0.02	5.00	3.00	1.58
35	P40 (0-15)	0.03	0.08	10.00	3.00	3.14	P40 (0-15)	0.01	0.01	5.00	3.00	0.93
36	P40 (15-30)	0.02	0.07	10.00	3.00	2.89	P40 (15-30)	0.54	0.24	5.00	3.00	20.00
37	P6P0 (0-15)	0.00	0.05	10.00	3.00	2.03	P6P0 (0-15)	0.52	0.23	5.00	3.00	19.37
38	P0 (15-30)	0.26	0.32	10.00	3.00	13.27	P0 (15-30)	0.01	0.02	5.00	3.00	1.85
39	P20 (0-15)	0.01	0.06	10.00	3.00	2.58	P20 (0-15)	0.40	0.18	5.00	3.00	14.72
40	P20 (15-30)	0.02	0.07	10.00	3.00	3.03	P20 (15-30)	0.01	0.01	5.00	3.00	0.93
41	P40 (0-15)	0.02	0.06	10.00	3.00	2.65	P40 (0-15)	0.47	0.21	5.00	3.00	17.45
42	P40 (15-30)	0.02	0.07	10.00	3.00	3.05	P40 (15-30)	0.84	0.37	5.00	3.00	31.17
43	P8P0 (0-15)	0.02	0.07	10.00	3.00	2.77	P8P0 (0-15)	0.55	0.25	5.00	3.00	20.48
44	P0 (15-30)	0.02	0.06	5.00	3.00	5.28	P0 (15-30)	0.70	0.31	5.00	3.00	25.92
45	P20 (0-15)	0.02	0.28	10.00	3.00	11.81	P20 (0-15)	0.54	0.24	5.00	3.00	20.08
46	P20 (15-30)	0.03	0.07	10.00	3.00	3.10	P20 (15-30)	0.02	0.03	5.00	3.00	2.38
47	P40 (0-15)	0.03	0.08	10.00	3.00	3.22	P40 (0-15)	0.72	0.32	5.00	3.00	26.54
48	P40 (15-30)	0.03	0.08	10.00	3.00	3.34	P40 (15-30)	0.01	0.01	5.00	3.00	0.79

Table 10: Table showing the concentration of Potassium of two villages

Line no.	VILLAGE 1	abs	G.R (mg/l)	K (mol/k)	VILLAGE 2	abs	G.R (mg/l)	K (mol/kg)
1	P1P0 (0-15)	2.5	2.47619	0.06	P1P0 (0-15)	9.3	8.952381	0.23
2	P0 (15-30)	2.7	2.666667	0.07	P0 (15-30)	6.5	6.285714	0.16
3	P20 (0-15)	5.6	5.428571	0.14	P20 (0-15)	6.2	6	0.15
4	P20 (15-30)	4.9	4.761905	0.12	P20 (15-30)	5.9	5.714286	0.15
5	P40 (0-15)	4.5	4.380952	0.11	P40 (0-15)	5.9	5.714286	0.15
6	P40 (15-30)	4.3	4.190476	0.11	P40 (15-30)	4.7	4.571429	0.12
7	P3P0 (015)	4.9	4.761905	0.12	P3P0 (015)	2.7	2.666667	0.68
8	P0 (15-30)	4	3.904762	0.10	P0 (15-30)	2.6	2.571429	0.66
9	P20 (0-15)	8.5	8.190476	0.21	P20 (0-15)	15.2	14.57143	0.37
10	P20 (15-30)	3	2.952381	0.08	P20 (15-30)	11.1	10.66667	0.27
11	P40 (0-15)	2.8	2.761905	0.07	P40 (0-15)	2.9	2.857143	0.73
12	P40 (15-30)	2.3	2.285714	0.06	P40 (15-30)	2	2	0.51
13	P5P0 (0-15)	7.9	7.619048	0.20	P5P0 (0-15)	11.6	11.14286	0.29
14	P0 (15-30)	2.5	2.47619	0.06	P0 (15-30)	7.6	7.333333	0.19
15	P20 (0-15)	5.6	5.428571	0.14	P20 (0-15)	2.2	2.190476	0.56
16	P20 (15-30)	5	4.857143	0.12	P20 (15-30)	13.2	12.66667	0.32
17	P40 (0-15)	3.1	3.047619	0.08	P40 (0-15)	4.9	4.761905	1.22
18	P40 (15-30)	2.5	2.47619	0.06	P40 (15-30)	5.1	4.952381	1.27
19	P7P0 (0-15)	4.3	4.190476	0.11	P7P0 (0-15)	14.7	14.09524	0.36
20	P0 (15-30)	3.3	3.238095	0.08	P0 (15-30)	4.9	4.761905	0.12
21	P20 (0-15)	2.7	2.666667	0.07	P20 (0-15)	2.6	2.571429	0.66
22	P20 (15-30)	2.5	2.47619	0.06	P20 (15-30)	1.9	1.904762	0.49
23	P40 (0-15)	2.7	2.666667	0.07	P40 (0-15)	10.8	10.38095	0.27

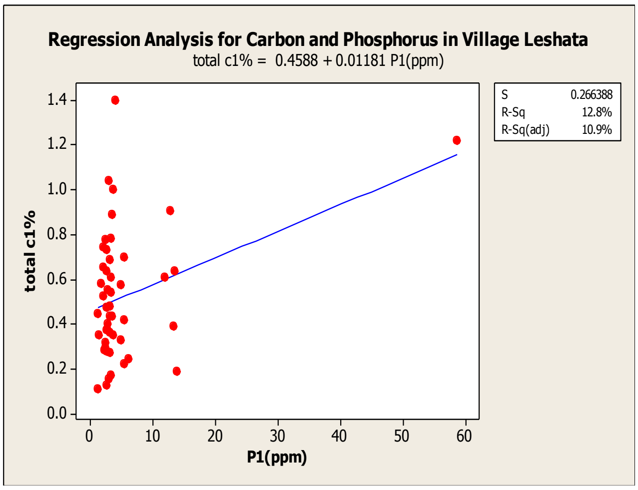
24	P40 (15-30)	2.8	2.761905	0.07	P40 (15-30)	14.6	14	0.36
25	P2P0 (0-15)	6.9	6.666667	0.17	P2P0 (0-15)	5.2	5.047619	0.13
26	P0 (15-30)	3.7	3.619048	0.09	P0 (15-30)	3.5	3.428571	0.09
27	P20 (0-15)	3.1	3.047619	0.08	P20 (0-15)	5.4	5.238095	0.13
28	P20 (15-30)	3.2	3.142857	0.08	P20 (15-30)	4.6	4.47619	0.11
29	P40 (0-15)	3.5	3.428571	0.09	P40 (0-15)	4.1	4	0.10
30	P40 (15-30)	2.6	2.571429	0.07	P40 (15-30)	4.2	4.095238	0.11
31	P4P0 (0-15)	3.8	3.714286	0.10	P4P0 (0-15)	7.9	7.619048	0.20
32	P0 (15-30)	2.5	2.47619	0.06	P0 (15-30)	12.7	12.19048	0.31
33	P20 (0-15)	4.8	4.666667	0.12	P20 (0-15)	13.6	13.04762	0.33
34	P20 (15-30)	2.8	2.761905	0.07	P20 (15-30)	1.9	1.904762	0.49
35	P40 (0-15)	5.3	5.142857	0.13	P40 (0-15)	11.3	10.85714	0.28
36	P40 (15-30)	2.8	2.761905	0.07	P40 (15-30)	10.9	10.47619	0.27
37	P6P0 (0-15)	12.5	12	0.31	P6P0 (0-15)	1.9	1.904762	0.49
38	P0 (15-30)	12.5	12	0.31	P0 (15-30)	1.8	1.809524	0.46
39	P20 (0-15)	4.5	4.380952	0.11	P20 (0-15)	7.4	7.142857	0.18
40	P20 (15-30)	6.5	6.285714	0.16	P20 (15-30)	9.5	9.142857	0.23
41	P40 (0-15)	9.1	8.761905	0.22	P40 (0-15)	12.9	12.38095	0.32
42	P40 (15-30)	4.9	4.761905	0.12	P40 (15-30)	4.3	4.190476	0.11
43	P8P0 (0-15)	10.7	10.28571	0.26	P8P0 (0-15)	9.5	9.142857	0.23
44	P0 (15-30)	2.5	2.47619	0.63	P0 (15-30)	1.9	1.904762	0.49
45	P20 (0-15)	2.2	2.190476	0.56	P20 (0-15)	10.8	10.38095	0.27
46	P20 (15-30)	2.9	2.857143	0.73	P20 (15-30)	6	5.809524	0.15
47	P40 (0-15)	2.1	2.095238	0.54	P40 (0-15)	4.7	4.571429	0.12
48	P40 (15-30)	1.8	1.809524	0.46	P40 (15-30)	5.5	5.333333	0.14

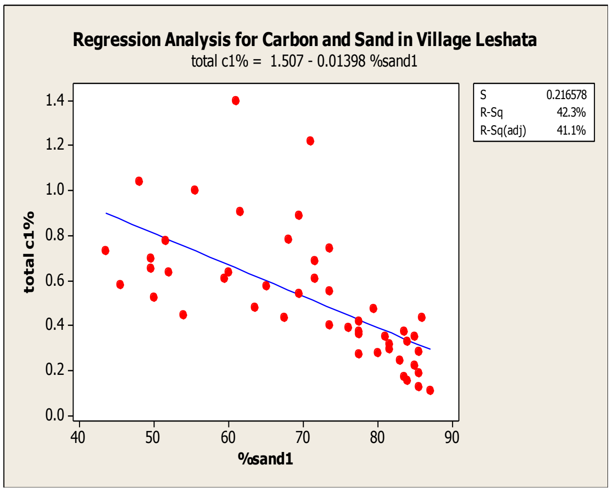
Table 11: Table representing total carbon and nitrogen content of two villages

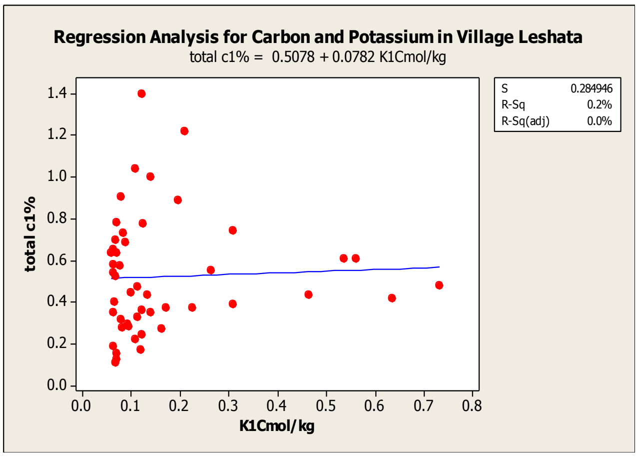
line no	VILLAGE 1	total c1%	total n1%	VILLAGE 2	total c2%	total n2%
1	P1P0 (0-15)	0.35	0.00	P1P0 (0-15)	0.67	0.06
2	P0 (15-30)	0.11	0.00	P0 (15-30)	0.46	0.04
3	P20 (0-15)	0.35	0.00	P20 (0-15)	0.55	0.03
4	P20 (15-30)	0.24	0.00	P20 (15-30)	0.34	0.03
5	P40 (0-15)	0.33	0.00	P40 (0-15)	0.36	0.03
6	P40 (15-30)	0.22	0.00	P40 (15-30)	0.25	0.04
7	P3P0 (015)	1.40	0.09	P3P0 (015)	0.48	0.04
8	P0 (15-30)	0.44	0.02	P0 (15-30)	0.53	0.03
9	P20 (0-15)	1.22	0.06	P20 (0-15)	0.50	0.04
10	P20 (15-30)	0.57	0.02	P20 (15-30)	0.52	0.03
11	P40 (0-15)	0.78	0.03	P40 (0-15)	0.93	0.05
12	P40 (15-30)	0.63	0.01	P40 (15-30)	0.58	0.05
13	P5P0 (0-15)	0.89	0.03	P5P0 (0-15)	0.46	0.07
14	P0 (15-30)	0.54	0.02	P0 (15-30)	0.45	0.06
15	P20 (0-15)	1.00	0.07	P20 (0-15)	0.36	0.03
16	P20 (15-30)	0.78	0.03	P20 (15-30)	0.41	0.04
17	P40 (0-15)	0.90	0.05	P40 (0-15)	0.40	0.02
18	P40 (15-30)	0.65	0.00	P40 (15-30)	0.52	0.04
19	P7P0 (0-15)	1.04	0.06	P7P0 (0-15)	0.64	0.06
20	P0 (15-30)	0.73	0.02	P0 (15-30)	0.45	0.05
21	P20 (0-15)	0.52	0.01	P20 (0-15)	1.03	0.07
22	P20 (15-30)	0.58	0.03	P20 (15-30)	0.46	0.04
23	P40 (0-15)	0.70	0.05	P40 (0-15)	0.47	0.04

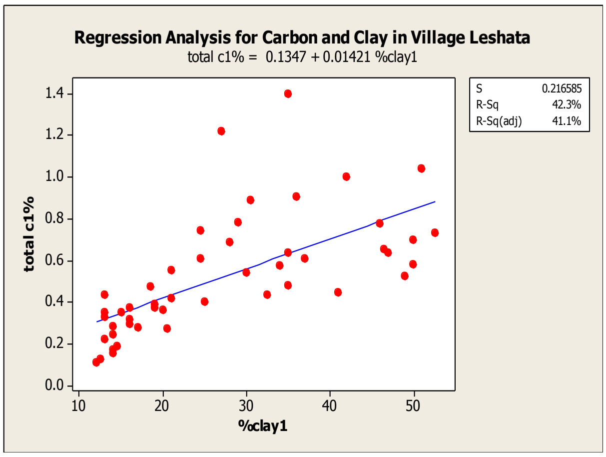
24	P40 (15-30)	0.63	0.05	P40 (15-30)	0.44	0.03
25	P2P0 (0-15)	0.37	0.01	P2P0 (0-15)	0.44	0.03
26	P0 (15-30)	0.30	0.01	P0 (15-30)	0.39	0.04
27	P20 (0-15)	0.32	0.01	P20 (0-15)	0.48	0.04
28	P20 (15-30)	0.28	0.01	P20 (15-30)	0.37	0.02
29	P40 (0-15)	0.69	0.03	P40 (0-15)	0.48	0.02
30	P40 (15-30)	0.40	0.02	P40 (15-30)	0.40	0.03
31	P4P0 (0-15)	0.28	0.00	P4P0 (0-15)	0.65	0.07
32	P0 (15-30)	0.19	0.00	P0 (15-30)	0.83	0.09
33	P20 (0-15)	0.17	0.00	P20 (0-15)	0.58	0.06
34	P20 (15-30)	0.13	0.00	P20 (15-30)	0.41	0.05
35	P40 (0-15)	0.43	0.02	P40 (0-15)	0.53	0.04
36	P40 (15-30)	0.15	0.00	P40 (15-30)	0.32	0.03
37	P6P0 (0-15)	0.74	0.03	P6P0 (0-15)	0.57	0.04
38	P0 (15-30)	0.39	0.02	P0 (15-30)	0.59	0.05
39	P20 (0-15)	0.48	0.02	P20 (0-15)	1.69	0.10
40	P20 (15-30)	0.27	0.01	P20 (15-30)	0.40	0.03
41	P40 (0-15)	0.37	0.02	P40 (0-15)	0.48	0.04
42	P40 (15-30)	0.36	0.02	P40 (15-30)	0.36	0.03
43	P8P0 (0-15)	0.55	0.01	P8P0 (0-15)	0.34	0.01
44	P0 (15-30)	0.42	0.01	P0 (15-30)	0.44	0.03
45	P20 (0-15)	0.61	0.01	P20 (0-15)	0.44	0.03
46	P20 (15-30)	0.48	0.00	P20 (15-30)	0.40	0.03
47	P40 (0-15)	0.61	0.00	P40 (0-15)	0.36	0.02
48	P40 (15-30)	0.43	0.01	P40 (15-30)	0.32	0.02

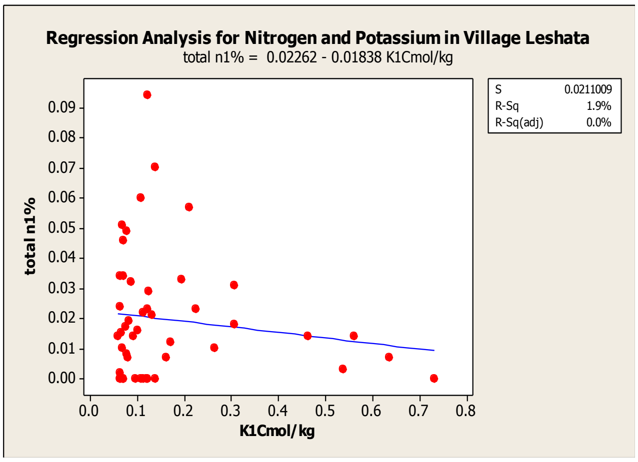
Regression analysis with parameters showing significant relationship with carbon and nitrogen in village Leshata

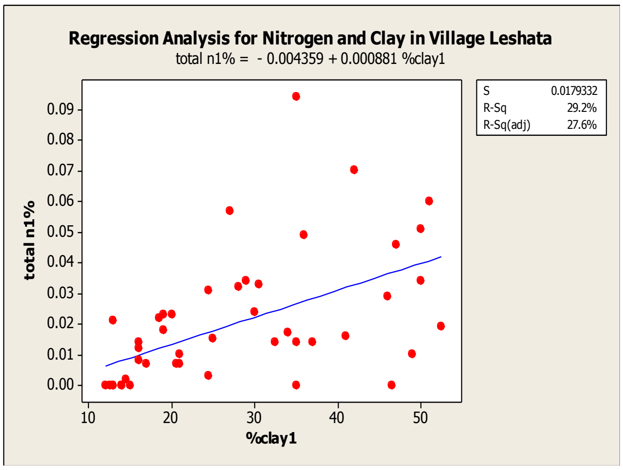












Picture of me along with the soil sampling team and stakeholders from two villages