Programme

Programme Director: Professor de Wet Gideon

15h30 – 15h35 **Academic Procession:**	Deputy Registrar, Mr Noel Knickelbein
15h35 – 15h40 **Opening Prayer:**	Pastor Mxolisi Ndevu Seventh Day Adventist Church
15h40 - 15h45 **Welcoming:**	Vice Chancellor, Dr Mvuyo Tom
15h45- 15h50 **Introduction of Inaugural Professor:**	Deputy Vice Chancellor Academic Affairs, Prof Larry Obi
15h50– 16h35 **Key note address:**	Professor Pearson Mnkeni
16h35 -16h40 **Induction of Inaugural Professor:**	Vice Chancellor, Dr Mvuyo Tom
16h40 – 16h45 **Handover of gift**	Vice Chancellor, Dr Mvuyo Tom
16h45 – 16h50 **Message from the Dean of the Faculty:**	Professor Farhad Aghdasi
16h50 - 16h55 **Vote of thanks:**	Registrar Professor Michael Somniso
16h55– 17h00: **Closure of event:**	Vice Chancellor, Dr Mvuyo Tom

Singing of the National Anthem

University of Fort Hare
Together in Excellence

Professor Pearson Mnkeni
Inaugural Address

Lecture title

Climate Smart Soil Management: A Win-Win Response to Climate Change and Food Security Challenges

Professor Pearson Mnkeni

Short Biography

Professor Mnkeni was born in Mamba Ndolwa, Same District, in Kilimanjaro region, Tanzania. He obtained his BSc degree in Agriculture (Honours) from the University of Dar es Salaam in Tanzania; and his Masters and PhD degrees from McGill University in Canada.

His academic career began at the University of Dar es Salaam, Agriculture Campus in Morogoro Tanzania which became an autonomous University in 1984 known today as the Sokoine University of Agriculture. His research career began in 1984 soon after obtaining his doctorate degree. His research activities up to 1996 were informed by the productivity challenges faced by resource-poor smallholder farmers in Tanzania. Most smallholder farmers could not afford costly mineral fertilizer inputs so he teamed up with geologists from the University of Guelph, Canada to investigate locally available phosphate rocks that could be used as cost-effective sources of phosphorus. Minjingu phosphate rock was found to be especially suited as a source of phosphorus for acid soils. This work paved the way for the current growing use of Minjingu phosphate rock for direct application in Tanzania and Kenya.

Prof Mnkeni joined the University of Fort Hare in November 1997 and made a significant contribution to the revitalisation of research in the biophysical sciences at Fort Hare through the National Research Foundation (NRF) funded research niche area on "Sustainable Agriculture and Land Use Strategies" he helped develop and lead. This niche area was a channel for NRF funding to several researchers in Science and Agriculture between 2003 and 2012. This RNA is presently funded by the University of Fort Hare and he was appointed to continue leading it in October 2013.

Over the years Prof Mnkeni has led or collaborated in several nationally and internationally funded projects including: (1) Development of Land Use Management Practices for increasing sustainability of Farming systems in Communal areas of Eastern Cape funded by the British Council, (2) Land Use Systems in Communal areas of Central Eastern Cape funded by the Flemish Government, (3) Use of Indigenous nitrogen fixing Cyanobacteria for Sustainable Improvement of Soil Biogeochemical Performance and Physical Fertility In Semiarid Tropics funded by the European Union, (4) Ecological Sanitation, and (5) Best Management Practices in Smallholder irrigation schemes in the Eastern Cape and KwaZulu-Natal funded by the Water Research Commission. Through these projects he has been able to put together state of the art soil science research infrastructure worth more than 4 million rands.

Professor Mnkeni's work at Fort Hare has contributed to: 1. greater understanding of the fertility status of Eastern Cape soils, 2. identification, characterization, and evaluation of farmer-available organic materials that can be used for improving the organic matter content and fertility of EC soils, 3. formulation of organic fertilizers from wastes which could otherwise be disposed in ways that would contribute to green house gas emissions, 4. providing the scientific basis for the development of cyanobacteria as biological fertilizers for improving soil fertility and soil biogeochemical performance, and 5. the evidence that conservation agriculture is an effective soil management system for improving soil productivity and food security in the Eastern Cape.

Professor Mnkeni has authored or co-authored over 60 papers in nated journals including Plant and Soil, Plant Nutrition and Soil Science, Journal of Plant Nutrition, Communication in Soil Science and Plant Analysis, Compost Science and Utilization, South African Journal of Plant and Soil, Waste Management Research, WaterSA, Agriculture Ecosystems and Environment, Soil and Tillage Research, Nutrient Cycling in Agro-ecosystems, Pedosphere, South African Journal of Science, and African Journal of Biotechnology. Professor Mnkeni and his collaborators have also presented over 50 papers in national and international Conferences. He serves as a reviewer for several national and international journals and currently serves as an Associate Editor of the South African Journal of Plant and Soil. He has served as an NRF rating panellist for Earth Sciences.

Prof Mnkeni is a member of the Soil Science Society of South Africa and the International Union for Soil Scientists. He is the recipient of several prestigious fellowships, notably, the International Development Research Centre (IDRC) fellowship for his postgraduate work, the DAAD fellowship for his postdoctoral work and the Fullbright Senior Researcher Award. In 2010, Prof Mnkeni received a C2 rating (established researcher) from the NRF.

Professor Mnkeni is happily married to Dr Astereda Mnkeni. They have three grown up children: Nampombe married to Prof Amos Saurombe; Amani married to Ayanda Mnkeni; and Felicia married to Athi-Ho Mlanjana. The Mnkenis have four grandchildren: Gianna, Joylyn, Agano and Thiyane.

Abstract:

Sub-Saharan Africa faces a major food security challenge as a result of projected fast increases in population growth and continuing declining per capita food availability. This calls for accelerated increases in productivity to meet expected increases in food demand. However, the soils from which the extra production is to come from are highly degraded, especially in South Africa where a large proportion of the land is ranked as having high degradation potential. This is compounded by the increasing climate change challenge which will render more land unfavourable for production. The climate change is mainly caused by global warming believed to be a result of increasing greenhouse gas emissions. The link between soil carbon, food security, and climate change will be explained in this paper. It will be shown that the high degradation status of South African soils is related to their low organic carbon contents. Efforts to restore their productivity must include strategies to minimize further loss of organic matter and encouraging carbon sequestration. Some interventions investigated with the help of my students and collaborators are presented. They include use of farmer available organic materials that can be applied to soils to improve soil carbon sequestration and fertility status; use of cyanobacteria to improve soil carbon sequestration and soil biogeochemical performance; and the adoption of conservation agriculture.

1. Introduction

Soils are the fundamental agricultural resource and their correct management has been fundamental to the survival and growth of human populations since the creation of mankind. When soils become degraded, farmers get caught up in a vicious cycle of poverty and food insecurity that compromises their ability to live healthy and productive lives. Unfortunately, the unprecedented growth in human population globally has increased the pressure on soil and land resources. In many instances this has resulted in soil resources undergoing severe deterioration or become unproductive through, for example, erosion, salinisation, or fertility decline. This is especially true for sub- Saharan Africa where, according to Sanchez *et al*. (1997), soil fertility depletion in smallholder farms is the fundamental biophysical root cause of declining per capita food production.

In South Africa, soil degradation is linked to discriminating policies of past political dispensations that saw most rural people farming mainly marginal lands. In the Eastern Cape (EC) province, poor nutrient supply in arable lands is a critical factor limiting crop yields (Mandiringana *et al*. 2005). In this province, maize is the main food crop and is produced mainly under rain-fed conditions on fields ranging in size from 1 to 4 ha. Harvesting of mature dry cobs is done during early winter but the stover is usually left on the land for village livestock to graze. This practice is estimated to remove up to 60% of the nutrients used by maize during its growth resulting in negative nutrient balances, as most small-scale farmers are risk-averse and rarely spend money on fertilizers to replenish the nutrients (Van Averbeke and De Lange, 1995).

The problem of soil degradation will be exacerbated by climate change which is projected to affect Africa more than other regions of the world (Intergovernmental Panel for Climate Change (IPCC) (2007). The climate change is believed to be anthropogenically forced through increases in atmospheric greenhouse gas (GHGs) concentrations which are believed to be largely responsible for global warming. The GHGs contributions by sector are: energy (26%), transport (13%), residential and commercial buildings (8%), industry (19%), waste and waste water (3%), forestry/land use change (17%) and agriculture (14%). Green house gases produced by the agricultural sector are N_2O (38%), CH_4 from enteric fermentation (32%), biomass burning (12%), rice production (11%), and manure management (7%). It is estimated that since 1750 these anthropogenic perturbations have resulted in gross global temperature increases equivalent to 1.95ºC comprising of 1.6ºC caused by GHGs (CO_2, CH_4, N_2O), 0.3ºC caused by soot particles, and 0.05 ºC caused by urban-heat island effect. The projected increase in global temperature, under business as usual (BAU) scenario is 2ºC to 6ºC by 2011 (IPCC, 2011).

In South Africa, projected changes over the next 50 years show a warming of between 1°C and 3°C; a potential reduction of approximately 5 to 10% of current rainfall**;** increased daily maximum temperatures in summer and autumn in the western half of the country; increased incidents of flood and drought; and enhanced temperature inversions (DEAT, 2004). Slightly more rain for the central and eastern parts of the country, but less for the Western Cape is predicted (DEA (Department of Environmental Affairs), 2013).

The projected increases in temperatures, reduced rainfall and water scarcity will significantly affect agricultural systems in South Africa, including the EC. Major impacts will include reduction in the amount of land suitable for both arable and pastoral agriculture, the reduction in the length of the growing season and a decrease in yields. Climate change is therefore, going to compound the food security challenges caused by biophysical and socioeconomic factors. The main aim of this paper is to highlight soil management approaches which can result in improved crop productivity and food security whilst adapting to and mitigating climate change.

2. Soil degradation

Soil fertility depletion is the fundamental biophysical root cause of declining per capita food production in sub-Saharan Africa (Sanchez *et al*., 1997). The depletion in soil fertility is mainly the result of loss in soil organic matter (SOM) due to degradative processes. The humus fraction of SOM is relatively stable and has a major effect on various soil properties and processes that play a role in the functioning of soils (Stevenson and Cole, 1999). It is a major source of nutrients and microbial energy, holds water and nutrients in available form, usually promotes soil aggregation and root development and improves water infiltration and water-use efficiency. Soil organic matter is therefore a key determinant of soil health and quality.

The equilibrium of organic matter in soils is disturbed by human activities such as crop and stock farming. These activities lead to decreases in soil organic matter content through oxidative processes which convert it to carbon dioxide, a green house gas. Organic matter depletion is therefore the major cause of soil degradation which in turn causes soil compaction or crusting, erosion, and infertility. Loss of SOM, particularly from the pedoderm has been shown to have a disproportionately large effect on water infiltration and nutrient supply (Mills and Fey, 2004). Soil organic matter is, therefore, the kingpin in soil degradation and concomitantly on food security and environmental pollution (Fig. 1).

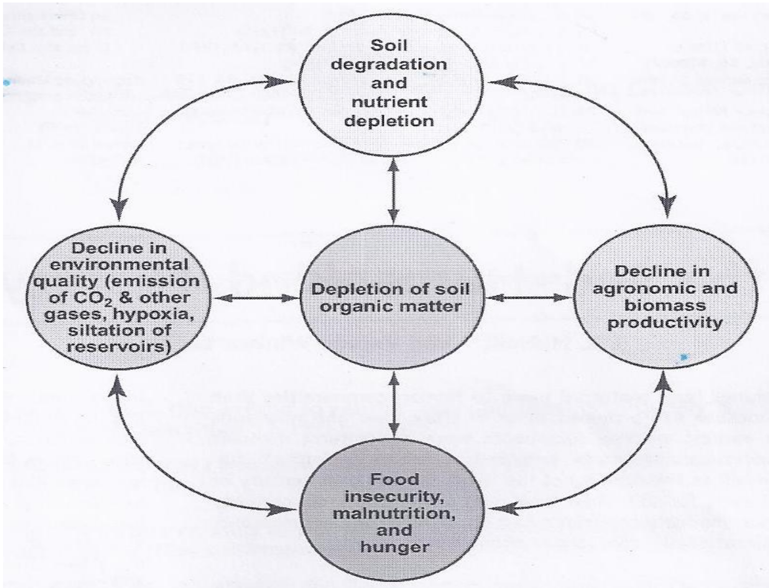


Figure 1: The vicious cycle of depletion in soil organic matter-decline in crop yield-food insecurity-soil and environmental degradation (Lal, 2004)

3.1 The role of soils in adaptation to climate change

The global soil carbon is estimated at 2500 gigatons (Gt) of which 1500 Gt is soil organic carbon (SOC). The soil C pool is 3.3 times the size of the atmospheric pool (750 Gt) (Lal, 2004) and 4.5 times the size of the biotic pool (560Gt) (Brady and Weil, 2008). In agricultural soils, the ultimate organic matter content is governed by the kind of land use and resulting land cover (Arrouays *et al*., 2001). It is estimated that conversion of natural to agricultural ecosystems causes the depletion of soil organic C pool by as much as 60% in temperate regions and by 75% or more in tropical systems.(Lal, 2004). For soils to mitigate climate change requires that atmospheric CO_2 be transferred to long-lived pools through carbon sequestration such that it is not immediately re-emitted.

3.2 Organic matter status of South African Soils

Du Preez *et al*. (2011a, 2011b), based on review of the literature, reported the organic C content to range from less than 0.5% to about 4%. However, only 4% of the soils contained more than 2% organic C, while 58% of the soil contained less than 0.5% organic C. The remainder of the soils contained 0.5 to 2% organic C. The country-wide distribution of organic carbon content shown in Fig. 2 indicate that South Africa is characterized by soils with very low organic matter levels making them very susceptible to degradation.

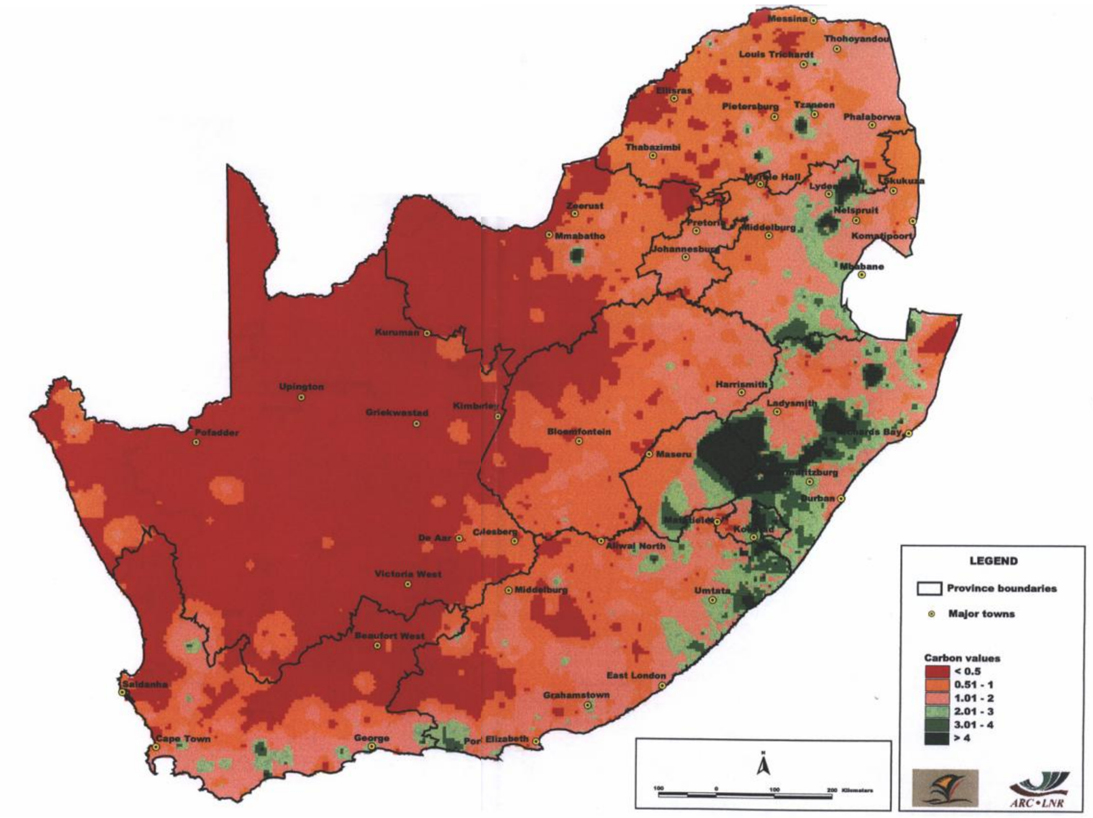


Figure 2: Generalized organic C map for virgin top soils in South Africa (Barnard, 2000).

4. Fertility status of Eastern Cape soils

4.1 Background

A study by Mandiringana *et al*. (2005) revealed that the fertility status of smallholder farms in the EC Province ranged from low to very low. Specifically, 62 – 100% of soils in the Eastern Cape, depending on location, had less than 1% organic carbon (OC). Therefore, a large proportion of the Eastern Cape had less than 1.1% OC considered as the critical carbon concentration for most soils of the tropics and subtropics. A large proportion of smallholder farms in the EC was therefore declared to be degraded and that their restoration required management interventions that can break the vicious cycle of organic matter depletion (Fig. 1). Interventions that can improve soil organic matter include use of manures and composts, no till farming, leguminous cover crops, mulching, nitrogen fixation and integrated farming systems (Lal, 2004). Accordingly, we have carried out several studies over the years to find ways of improving the SOM status of EC soils so as to improve soil health and concomitantly contribute to climate change mitigation. A few of these studies are summarized in the sections that follow.

4.2 Use of kraal manure to improve soil organic matter and arrest soil degradation

Manures contain high organic matter (OM) content and when applied to soils can increase soil OM content, soil aggregate stability, water-holding capacity, water infiltration and hydraulic conductivity and decrease bulk density and evaporation rates (Eck and Stewart, 1995). Kraal manures are the main form of manure in smallholder farms in the Eastern Cape. However, there was no documented information on their types, quantities and quality to guide their optimal application as sources of nutrients and for increasing the carbon content of soils. A study was, therefore conducted to address this need. The results revealed that the nutrient composition of the manures from the Transkei varied with livestock species, geographical location and mineral particle content (Mkile, 2002). Manures from Elliotdale had higher nutrient contents than those from Mthata and Mt. Fletcher, which suggested a possible relationship between altitude-related factors and manure quality. These findings indicated that manure type and quality should be taken into consideration when determining optimum rates of kraal manure application for different locations in the province. The study further revealed that farmers were aware of the fertilizer value of kraal manures but due to a number of constraints they were not applying adequate quantities of manure to their crops. Most homesteads had large quantities of unutilized manure in their kraals which become waterlogged during rainfall seasons resulting in the development of anaerobic conditions favourable for the production of the methane and nitrous oxide (Mosier *et al*., 1998). It is, thus, important that constraints to the full utilization of this underutilized resource be removed so that it is fully utilized for the restoration of degraded soils and avoid its contribution to GHGs emissions.

4.3 Enhancing phosphorus availability in phosphate fixing soils using goat manure

This study sought to establish the extent of phosphate fixation in the Transkei region and evaluated the effectiveness of goat manure in improving fertilizer P utilization efficiency. The results obtained (Gichangi *et al*. (2008), Gichangi and Mnkeni, (2009)) indicated moderate levels of P fixation in the former Transkei but more importantly revealed that co-application of inorganic P fertilizers with goat manure improved the P use efficiency of the added P and thus reduced the need for external P inputs. Gichangi *et al*. (2009, 2010) further demonstrated that kraal manure could be used to manipulate microbial biomass P, improve P cycling and increase the effectiveness of soil and applied fertilizer P.

The net effect is that less fertilizer P will be needed when it is co-applied with kraal manure resulting in cost savings to the farmer and reduced GHGs emissions from the use of less fertilizer P.

4.4 Composting studies involving kraal manure

In urban and peri-urban areas organic wastes generated there can be used for increasing the soil organic matter content and health of the soils and thus improving soil productivity while minimizing their contribution to GHGs emissions and global warming. These include sewage sludge, food processing wastes, town refuse, residential wastes and waste paper (Adediran *et al*., 2002). Organic and paper wastes constitute 21% of waste generated in South African municipalities (Fig. 3). Guidelines for the local beneficial utilization in agriculture of some locally produced and potentially polluting wastes were, however, lacking.

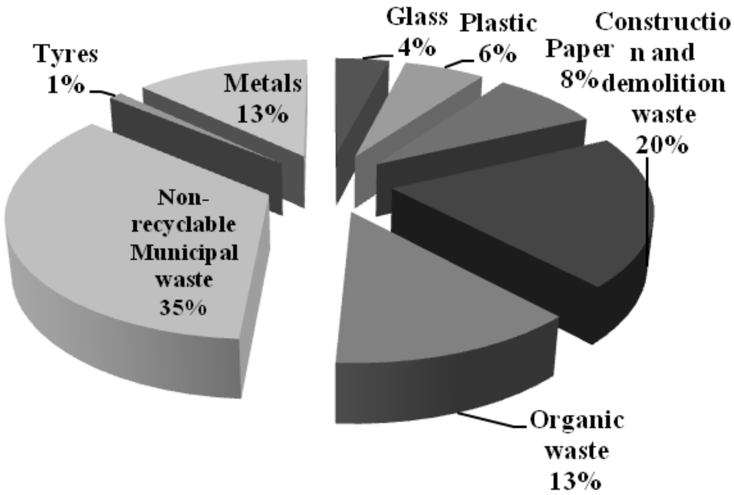


Figure 3: Composition of general waste generated in South African Municipalities

The studies summarized below investigated how composting and vermi-composting could be used to add value to these wastes and enhance their soil amendment and carbon sequestration value.

4.4.1 Co-composting pine bark with kraal manure

A large proportion of pine bark generated from the de-barking of pine trees in Hogsback and other areas in the Eastern Cape is disposed of through incineration thus contributing to GHGs emissions and global warming. This study investigated the composting of pine bark with kraal manure and determined the potential of the resulting composts as growing media substitutes and as soil amendments. The results demonstrated that goat manure composted well with pine bark and the resulting compost had desirable nutritional properties (Mupondi *et al*. 2006a). The pine bark-goat manure co-compost supported better seedling growth than pine bark alone compost consistent with its superior nutritional properties (Mupondi *et al*., 2006b, 2010). This co-compost is, therefore, a promising substitute for pine bark alone compost as a seedling growing medium, especially for smallholder horticultural producers who cannot afford fertilizer supplements but have access to goat manure or other animal manures. The use of seedling transplants is now recommended for green maize production so local production of this growing medium has the potential of stimulating local seedling nurseries not just for vegetables but for green maize as well.

4.4.2 Vermi-composting of waste paper with kraal manure and rock phosphate

This study investigated the safe recycling in agriculture of organic wastes generated at household and institutional level using a combination of thermophillic composting and vermicomposting. Results obtained showed that: (i) a precomposting period of one week followed by vermicomposting for 7 weeks was effective in stabilizing and sanitizing dairy manure-waste paper mixtures (Mupondi *et al*., 2010), (ii) phosphate rock incorporation improved degradation of the waste mixtures and increased the total and available P and N contents of the resultant vermicomposts, and (iii) Dairy manure – waste paper vermicompost mixed with pine bark compost at a ratio of 3:2 was a better growing medium for tomato seedlings than pine bark alone (Mupondi, 2010). Since P seems to be critical for the vermicomposting process, a systematic study is underway to establish critical P levels for phosphate rock and soluble P sources such as TSP in the vermicomposting of different waste mixtures.

5.0 Use of indigenous N_2-fixing cyanobacteria for sustainable improvement of carbon sequestration and soil productivity

Most South African soils are susceptible to surface crusting and erosion due to low organic matter and high silt contents. They are also low in nitrogen due to their low organic matter status. Some cyanobacteria strains are known to have biofertilization and bioconditioning effects in soils and have been tried in Asia with some positive outcomes. Under favourable conditions of light, moisture and pH, the photosynthetic activity of cyanobacteria has been shown to result in increases of soil OM as cyanobacterial biomass of up to 450 kg/ha organic C and 60 kg/ha N(Ghoshi and Saha, 1997). We, therefore, investigated if there could be local strains of cyanobacteria in the Eastern Cape which could be mass produced and used to positively influence soil nutrient dynamics, organic matter turnover, and physical properties of selected degraded soils in the province. Results obtained showed that two out of 97 cyanobacteria strains (3g and 7e) screened for their ability to fix nitrogen and produce exopolymeric substances (EPS) could be used to improve the stability of physically degraded soils and improve the N status and productivity of N-poor soils (Maqubela *et al*., 2009, 2010). These findings have provided the basis for the exploitation of cyanobacteria as biological fertilizers and amendments for increasing carbon sequestration in South African soils with concomitant effects on food security improvement as well as mitigate the effects of climate change.

6. Conservation agriculture

As noted earlier, over 60% of South African soils have low organic matter content and are conducive to degradation and low productivity. Du Toit *et al.*, (1994) found that 5-90 years of cultivation in the Free State resulted in a loss of 10-73% of C and N relative to natural grassland. According to Mills and Fey (2004) the major cause of decline in soil quality is the removal of vegetation cover by ploughing, grazing or burning. Conservation agriculture (CA) involving viable crop rotation, minimal soil disturbances and organic soil cover is increasingly recognised as a way to arrest soil degradation and improve soil productivity (Derpsch and Friedrich, 2009). Njaimwe (2010) investigated the effect of tillage and crop rotation on soil quality parameters and maize yield at Zanyokwe irrigation scheme, Eastern Cape. His results showed that after just two cropping cycles no till (NT) maintained higher organic carbon levels than conventional tillage (CT) (Fig. 4a). The maize-oats-maize (MOM) and maize-wheat-maize (MWM) rotations maintained higher organic carbon levels than the maize-fallow-maize (MFM) rotation at both the 0-5 and 5-20 cm sampling levels (Fig. 4b).

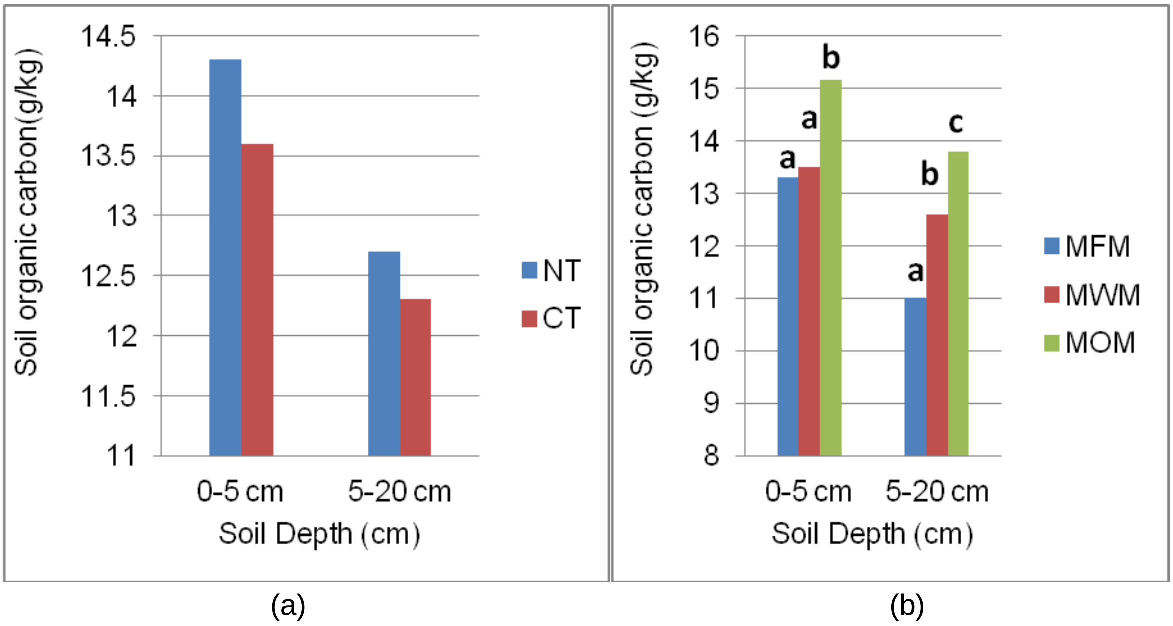
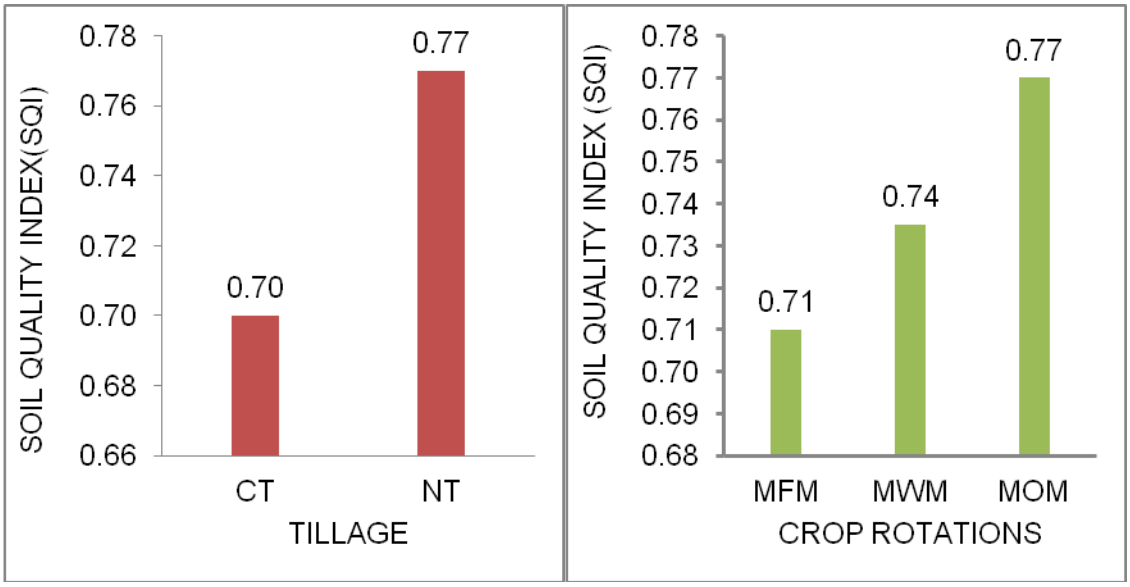


Figure 4: Tillage (a) and crop rotation(b) effects on soil organic carbon at Zanyokwe irrigation scheme.[NT = No Till; CT = Conventional tillage; MFM=maize-fallow-maize; MWM=maize-wheat-maize; and MOM=maize-oat-maize]

Treatments effects on overall soil quality were assessed using the soil management assessment framework (SMAF) (Fig. 5). The SMAF soil quality index (SQI) was much higher under NT than under CT (Fig. 5a) while the maize-wheat-maize and maize-oats-maize rotations resulted in higher SQI values than the maize-fallow-maize rotation (Fig. 5b). These findings conclusively established the superiority of conservation agriculture in improving soil carbon sequestration and overall soil health even under short term conditions.

The worldwide adoption of CA is growing at a rate of 10 million hectares per annum, and stands at 130 million hectares globally (Africa Congress of Conservation Agriculture (ACCA), 2014). However, most of this growth in adoption is largely restricted to North and South America. In Africa, only 0.3% of the total land is under CA, with commercial farmers being the major adopters (FAO, 2010). The EC provincial government tried to use a conditional input scheme under the Massive Food Production (MFP) programme to encourage the adoption of CA in the province but this did not bear the desired results (Lange and Dirk, 2010) and CA adoption in by smallholders in the EC remains minimal (FAO, 2011). We therefore recently conducted a study to investigate causes for the low rate of CA adoption in the EC. The results showed that many farmers in the EC are knowledgeable about CA, have received CA training and some are practicing some aspects of CA (Table 1). Among the farmers practicing CA, 100% practised no till, 33% practised crop rotation and 45%



(a) (b)

Figure 5: Tillage (a) and crop rotation(b) effects on soil quality index (SQI) at Burnshill block, Zanyokwe irrigation scheme.[NT = No Till; CT = Conventional tillage; MFM=maize-fallow-maize; MWM=maize-wheat-maize; and MOM=maize-oat-maize] practiced residue retention.

Therefore, while farmers have no problem with practicing no tillage they find it difficult to implement the CA principles of crop rotation and maintenance of soil cover (Muzangwa *et al*., 2014). This indicated a need to identify key CA entry points compatible with the smallholder environment in the EC. We have since established two long-term on-station CA trials at Fort Hare and Phandulwazi, High School farms and three long term on-farm CA trials at Amathole, OR Tambo, and Alfred Nzo District Municipalities aimed at identifying suitable and sustainable CA entry points in the EC. It is hoped that the identification of these entry points will contribute towards enhanced adoption of CA in the Eastern Cape. This, however, may need to be accompanied by introduction of incentives to encourage farmers to adopt CA. This could be in the form of starter grants from the Green Fund run by the Department of Environmental Affairs (DEA) coupled with incentive payments to farmers who have managed to improve the quality of their soils through adoption of CA and other climate smart soil management approaches.

Table 1: Frequencies (%) of farmers knowledgeable about CA, training and level of CA adoption of interviewed farmers in the Eastern Cape

Variable	District				
	Alfred Nzo	Amathole	Chris Hani	Joe Qabi	OR Tambo
Knowledge about CA	71.0	87.5	51.7	80.8	64.0*
Farmers ever received training on CA	67.7	57.7	48.0	53.8	58.6
Level of CA adoption					
Practising	45.2	33.3	34.5	38.4	40.0
No longer practising	25.8	16.7	10.3	15.4	4.0*
Never practised	29.0	50	55.2	46.2	56.0*

*Denotes significant differences between the districts at $p<0.05$

7. Concluding Remarks

There is a close link between soil carbon depletion, soil degradation, food security and climate change. Crop productivity and hence food security in most African countries, including South Africa, is compromised by the high degree of soil degradation. The high degradability of South African soils is due to their low to very low organic matter contents. Efforts to increase the productivity of these soils must include strategies to arrest the loss of soil organic matter as well as increase it. Promising options include the soil application of kraal manure and other farmer available organic wastes that are readily available and underutilized in most rural and peri-urban areas. The rates of application must be guided by the type and quality of the manures which was found to be very variable. Its use will increase the organic matter content of soils and also minimize its contribution to GHGs during the rainy season when it sits unused in kraals.

Adoption of conservation agriculture is the best option for increasing soil organic matter, overall soil health and productivity based on our results and work done elsewhere. It is a climate smart approach because it encourages carbon sequestration and minimises its emission to the atmosphere. Its adoption is, however, limited by among other things lack of appropriate entry points for different agro-ecologies in the EC province. Work in progress is addressing this need through a long-term study on the interactive effects of the three CA principles of minimum physical soil disturbance, permanent soil cover with live or dead plant material, and crop diversification in space and time. Further work is needed to evaluate suitable cover/rotational crops for different agro-ecologies in the province.

There is need to explore ways of incentivising soil carbon sequestration through the use of Incentive and Market Based Mechanisms (IMBMs). The IMBMs such as Payment for Ecosystems Services (PES) and the Carbon Market can be used to reward farmers who, through adopting climate smart technological packages such as CA, are able to reduce the carbon and water foot prints of their farms. The requisite funding for this programme could come from funding instruments already established by DEA such as the Green Economy and Green Fund.

The first Africa Congress on Conservation Agriculture (1ACCA, 2014) unanimously agreed in March 2014 that CA is the best climate smart option for contributing to the achievement of the Comprehensive African Agriculture Development Programme (CAADP)'s goal of 6% annual growth in the agricultural sector. It called for, among other things, Agricultural training institutions like the University of Fort Hare to make CA an integral part of their training programmes. The re-curriculation exercise in agriculture that is currently under way at UFH should take this into consideration.

The production of biochar from various biomass sources is receiving increasing research attention as one way of sequestering carbon. Biochar is a fine-grained and porous substance produced by the slow pyrolysis of biomass at low to medium temperatures (450 to 650°C) under oxygen limited conditions (Sohi *et al*. 2009). Biochar can be prepared from different types of biomass such as crop residues, logging residues, and various grasses. Biochars have been shown to improve the physical, chemical and biological properties of soils (Laird *et al*. 2010). So far no work has been done with biochars in the EC so future studies will explore the potential of using biochars as a climate smart strategy for sequestering carbon from crop residues and their potential to improve soil health.

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