JUNE 22-25, 2014

WINNIPEG CONVENTION CENTRE
WINNIPEG, MANITOBA

WCCA6.ORG

WORLD CONGRESS6 on CONSERVATION AGRICULTURE

Poster Session #2 - Soil Health and Biology as a Foundation of Conservation Agriculture

POSTER ABSTRACTS

Soil Carbon Stocks in an Experimental Area Cultivated with Mangabeira (*Hancornia speciosa* Gomez) in an Quartzipsamment with Duripan in João Pessoa, Paraíba , Brazil

Authors and affiliations: Alexandre Fonseca D'ANDREA[1], Eugênio Pacelli Fernandes LEITE[1], Edivaldo Galdino FERREIRA[2], Glaydson Gonçalves da SILVA[1], Gabrielle Cavalcanti RODRIGUES[1].
[1]Federal Institute of Education, Science and Technology of Paraíba (IFPB). Avenida 1 de Maio, 720, João Pessoa, Paraíba, Brazil. CEP 58.015-430;
[2]Paraíba State Enterprise for Agricultural Research SA (EMEPA). Rodovia PB 008, Km 7. João Pessoa, Paraíba, Brazil. CEP: 58000-000
Corresponding authors contact information: Alexandre Fonseca D'Andrea. Email: alexandre.dandrea@ifpb.edu.br; Phone nº: +55 83 8831 0075; Fax nº: +55 83 3612 1200.

Introduction

In tropical region, proper management of agricultural areas is an alternative to increase the levels of soil organic carbon (SOC), an important issue in the current context of global climate change. Changes in land use due to deforestation, biomass burning and conversion of natural to agricultural ecosystems can contribute to the increase of CO_2 emissions from soil and to enhance the transfer of soil carbon to the atmospheric compartment (Lal, 2004). The depletion of soil organic matter is one of the factors leading to the decline of yield and crop productivity, especially in soils with coarse texture. Under these conditions, high temperatures in most of the year and lower physical protection of organic matter leads to a rapid depletion of soil carbon, especially in conditions of intensive use and management, with high soil disturbance, condition generally related to annual crops under conventional tillage (Six et al., 2000). In Brazil, in Oxisols with sand content ranging from 0.564 kg kg^{-1} and 0.692 kg kg^{-1}, Wendling et al. (2005) found negative effects of conventional tillage on the water stable aggregates indexes, closely correlated with the levels of SOC. Moreover, the cultivation of perennial crops have been one of the alternatives to short cycle crops to increase the SOC because of the sink capacity of soil organic matter for atmospheric carbon (Lal, 2004). This study aimed to calculate the stock of soil organic carbon in a mature "mangabeira" orchard in the coastal region of João Pessoa, Paraíba, Brazil.

Materials and Methods

The study area is located at the Experimental Station of the Paraíba State Enterprise for Agricultural Research (EMEPA), coordinates 7°11'54"S and 34°48'44"W, average altitude of 28m. The climate is As' according to Köppen Climate Classification (tropical climate with rain season on fall-winter), with average annual rainfall of 2,000 mm yr^{-1} and an average annual temperature between 26 and 27°C. The studied orchard is located on a Entisol (Neossolo Quartzarênico órtico, Brazilian soil classification equivalent to Quartzipsamment, Soil Taxonomy) cultivated with mangabeira (*Hancornia speciosa* Gomez) since 1991. For sampling we selected five trees located between 10 and 20 meters apart. On each tree, two transects were delimited in a perpendicular way, and the points were marked according to the distances of 1m, 2 m and 3 m from the stem of trees. At each point, we collected soil samples with deformed and undisturbed structure in five depths (0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm and 40-50 cm). Soil fertility attributes were determined, such as pH, P, K, Na, Ca, Mg and Al (Table 1).

Table 1. Fertility attributes and soil density (BD) in an Quartzipsamment with duripan cultivated with mangabeira orchard in João Pessoa, PB, Brazil.

Depth (cm)	P (mg dm^{-3})	pH	Ca^{2+} ($^{-3}$)	Mg^{2+} ($^{-3}$)	Al^{3+} ($^{-3}$)	BD (g cm^{-3})
0-10	93	5.3	0.5	0.3	1.4	1.3
10-20	77	5.4	0.4	0.2	1.4	1.4
20-30	57	5.6	0.4	0.2	1.1	1.3
30-40	52	5.6	0.4	0.2	0.9	1.3
40-50	76	5.6	0,4	0.2	1.1	1.3

The soil organic carbon stock was determined considering each sample depth range, from the results of soil organic carbon (SOC) and bulk density (BD), according to the expression: Carbon stock = SOC x BD x e/10, in which "e " is the thickness of the layer considered.

Results

The analysis of variance demonstrated a highly significant effect of sampling depth on soil carbon stocks ($p < 0.000$), with greater average storage of organic carbon in the two surface layers (up to 20cm) compared to the deeper layers (from 20 to 50 cm). The average carbon stocks in soil depths (layers of 10 cm thick) ranged between 12.05 and 22.01 Mg ha^{-1}. The average cumulative carbon stock within 50 cm depth was 82.95 Mg ha^{-1}, of which 42.17 Mg ha^{-1} are included in the first two layers (0-20cm), which corresponds to 50.8 % of total soil organic carbon stored up to 50 cm (Table 2).

Table 2. Soil organic carbon stocks in an Quartzipsamment with duripan cultivated with mangabeira orchard in João Pessoa, PB, Brazil.

Depth (cm)	OC stocks (Mg ha^{-1})	% of total	ative SOC stocks (Mg ha^{-1})	Cumulative %
0-10	22.01 a	26.5	22.01	26.5
10-20	20.16 a	24.3	42.17	50.8
20-30	14.55 b	17.5	56.72	68.4
30-40	12.05 b	14.5	68.77	82.9
40-50	14.18 b	17.1	82.95	100.0
0-50	82.95	100.0	-	-

Same letters in column indicate means that do not differ significantly by the Tukey test at 5% probability.

Discussion

The frequent additions of mangabeira orchard fresh residues on the soil surface and soil water regimes favored by the presence of duripan layer made possible the maintenance of relatively high levels of soil organic carbon. Carbon stocks in this Quartzipsamment are consistent with values found even in soils with higher clay contents, as in the case of Oxisols from the Central Plateau of Brazil. In this situation, D'Andrea et al. (2004) evaluated the carbon stocks in an Oxisol of the Cerrado region under native vegetation, conventional tillage and no-till, finding values between 58.70 and 69.86 Mg ha^{-1} (accumulated in the 0-40 cm layer), comparable to the present study (68.77 Mg ha^{-1} accumulated in the 0-40 cm layer, Table 2). The results indicate that it is possible to maintain a reasonable storage of soil organic carbon in tropical environment, even in sandy soils, as in the case of areas cultivated with perennial crops, contributing to the settlement of soil carbon and reducing its loss in the form of carbon dioxide resulting from the decomposition of soil organic matter.

References

D'ANDREA. A.F.; SILVA, M.L.N.; CURI, N.; GUILHERME, L.R.G. Carbon and nitrogen storage, and inorganic nitrogen forms in a soil under different management systems. **Pesquisa Agropecuária Brasileira**, v. 39, n. 2, p. 179- 186, 2004.

LAL, R. Soil carbon sequestration to mitigate climate change. **Geoderma** 123, p. 1- 22, 2004.

SIX, J.; ELLIOT, E.T.; PAUSTIAN, K. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. **Soil Biology & Biochemistry** 32, P. 2099-2103, 2000.

WENDLING, B.; JUCKSCH, I.; MENDONÇA, E. S.; NEVES, J. C. L. Carbono orgânico e estabilidade de agregados de um Latossolo Vermelho sob diferentes manejos. **Pesquisa Agropecuária Brasileira**, v.40, n.5, p.487- 494, 2005.

Residue Management in Pulse Intercropping -A Precursor for Soil Quality Improvement in Rainfed Regions

Ummed Singh*, Narendra Kumar, C.S. Praharaj, K.K. Hazra and M. Senthil Kumar
Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India-208 024
singhummed@yahoo.co.in

Key words: Intercrop, Pulse Residue, SMBC, Soil Quality

Crop residues added through growing food crops accrues substantial benefits in terms of SOC and conservation of resources including recycling of nutrients (Venkatesh at al. 2013). Besides their diverse uses through food for human, feed and fodder for ruminants, wastes for composting and burying *in-situ* and mulches as soil cover; addition of crop residues and/or minimum tillage sustains crop productivity and restores soil fertility. An analysis suggests that India generates around 500 million tonnes of crop residues every year retaining substantial amount of mineral nutrients as a component for crop uptake. For example, in cereals alone around 25% of N & P, 50% of S and 75% of K uptake are retained back in residues, and are subjected to further recycling as a valuable source of nutrients in soil. In pulses however, its residue add more nutrients in soil compared with cereals due to low C: N ratio. Pulses, like pigeonpea and chickpea also add substantial biomass through leaf fall and plant residues resulting in long-term improvement in soil quality and productivity of crops. This is further enhanced through conservation of soil moisture through incorporation of above ground biomass and mulching (Wilhelm et al. 2004).

Therefore, soil organic matter is important in relation to soil fertility, sustainable agricultural systems, and crop productivity, and there is concern about the level of organic matter in many soils, particularly with respect to global warming (Venkatesh at al. 2013). Long-term experiments since 1843 at Rothamsted provide the longest data sets on the effect of soil, crop, manuring, and management on changes in soil organic matter especially under temperate climatic conditions. Trends in long-term crop yields also show that as yield potential has increased, yields are often larger on soils with more organic matter compared to those on soils with less.

Under arid and semi-arid conditions of India, declined soil quality as a result of deteriorated soil fertility associated with low soil organic carbon (SOC) and limiting soil moisture (LSM) is thus, the major constraint in realizing higher productivity of crops (Praharaj 2013). In rainfed agro-ecology, monsoon crops are dependent on rainfall water while the succeeding *fall* planted crops are dependent on residual soil moisture, reinforced sometimes with one or two supplementary irrigations. Under the above situation, short duration crops, like sorghum, pearlmillet, mungbean, cowpea and cluster bean followed by chickpea, lentil, mustard and barley during *fall* are preferred due to their satisfactorily yield levels. In addition growing of a pulse intercrop like, cowpea, green gram and black gram in a cereal system could supplement the sole crop yield besides acting as an insurance against aberrant weather situations (Johnston et al. 2009).

A recent study carried out during 2012-13 at Indian Institute of pulses Research, Kanpur under Indo-Gangetic plains of India suggests that higher pearl millet equivalent yield (PEY) was recorded when the cereal component is intercropped with green gram (PEY of 3612 kg/ha) and cowpea (3227 kg/ha) over the sole cereal (2635 kg/ha) crop. Improved moisture conservation practices also results in higher relative leaf water content (RWC, 62.2%) at 90 days in *fall* planted chickpea under the combined practice of mulching and one supplemental irrigation (similar to the combined effect of mulching + two irrigations). Similar benefits are also observed under adequate crop nutrition (recommended crop nutrition). Improvement in soil physico-chemical (decrease in bulk density and soil penetration resistance, and increase in water holding capacity) and biological properties (soil microbial biomass carbon up to 450 µg/g soil and dehydrogenase activity up to 21 µg TPF/24 hr/g soil) inclusive of higher residual nutrient status (available N, P, K, S, Zn and Fe and organic carbon for chickpea) are also evident under incorporation of green gram and cowpea crop residues. Among intercropping system highest SMBC was observed when bajra intercropped with cowpea followed by bajra+greengram and least under bajra sole (Fig. 1). Study also suggests that addition of organic manure has a greater impact on the biomass C and activity, compared to mineral fertilizers. Increased dehydrogenase activity by mineral N fertilizer was also reported in several other studies (Wilhelm et al. 2004).

The above study substantiates the role of pulse intercropping as a *Good Agricultural Practices* (GAP) in improvement in soil quality and crop productivity. Evidence from farmers' filed those who have been incorporating straw for some years invariably suggests that there has been a benefit in terms of ease of ploughing. Possibly incorporation of crop residues by inversion or noninversion tillage prevents the soil becoming seriously compacted (Wilhelm et al. 2004).

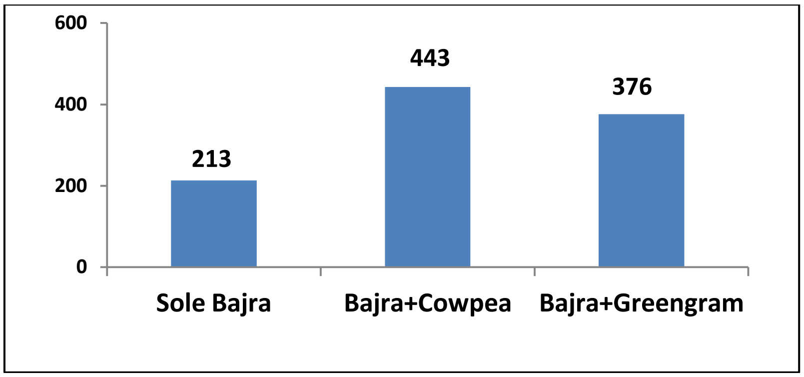

Fig. 1. Influence of pulse intercrop on soil microbial biomass C (mg/kg soil)

References

Johnston A. Edward, Paul R. Poulton and Kevin Coleman 2009. Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes. Adv. Agron. 10:2-45.

Praharaj C.S. 2013.Managing precious water through need based micro-irrigation in a long duration pigeonpea under Indian Plains. In *Intern. Conf*. for water and food security held at Cairo, Egypt during June 24-26, 2013 organised by ICARDA,FAO, IFAD,IDRC,CRDI and ARC.P.4.

Venkatesh, M.S., K.K. Hazra, P.K. Ghosh, C.S.Praharaj, and Narendra Kumar. 2013. Long-term effect of pulses and nutrient management on soil carbon sequestration in Indo-Gangetic Plains of India. Can. J. Soil Sci. 93:127-136.

Wilhelm, W.W., J.M.F. Johnson, J.L. Hatfield, W.B. Vorhees, and D.R. Linden. 2004. Crop and soil productivity response to corn residue removal: a literature review. Agron. J. 78: 184-189.

Crop Rotations with Annual and Perennial Forages under No-Till Soil Management: Soil Attributes, Soybean Mineral Nutrition, and Yield

Walter E. Riedell and Shannon L. Osborne
USDA-ARS, North Central Agricultural Research Laboratory 2923 Medary Avenue
Brookings, South Dakota 57006 USA walter.riedell@ars.usda.gov

Background

Row crops grown in extended rotations that contain multiple years of perennial forages often produce greater yield than row crops grown in monoculture or short 2-yr rotations (Riedell et al., 2009). There is little information in the literature that details how soybean yield and seed composition respond to diverse crop rotations that include forages under no-till soil management. Study objectives were to measure responses of soil chemical and physical properties as well as soybean yield and seed components to four rotations of increasing crop diversity [soybean-maize 2-yr rotation (S-C); soybean-spring wheat-maize 3-yr rotation (S-W-C); soybean-oat/pea hay-maize 3-yr rotation (S-H-C); and soybean-oat/pea hay companion seeded with alfalfa-alfalfa-alfalfa-maize 5-yr rotation (S-H/A-A-A-C)].

Results

Soils under the 5-yr S-H/A-A-A-C rotation had 129 kg ha^{-1} preseason residual NO_3-N concentration while the other rotations averaged about 65 (Table 1). The 5-yr rotation also had lower bulk density than the 3-yr S-H-C with the 3-yr S-W-C and 2-yr S-C intermediate. Soybean seed yield was about 10% greater in the 5-yr rotation than in the other treatments. Kernel protein was 3% greater under the 5-yr rotation than under the 2-yr S-C rotation while the others were intermediate (Table 2).

Applications and Implications for Conservation Agriculture

Changes in soil chemical and physical properties under rotations that include perennial forages may play an important role in increasing soybean seed yield and enhancing seed protein. Because of high preseason soil NO_3-N levels, however, these soils may also be susceptible to NO_3-N leaching.

Experimental Approach

Four crop rotation treatments, initiated in 1997, were arranged in a randomized complete block experimental design with four replications. Data were collected from soybean phase in 2009 and 2010. Inoculated soybean seeds were planted (407,000 seeds ha^{-1} in 51 cm rows) on 20 May 2009 and 24 May 2010. Soil samples were taken to a depth of 60 cm during late fall of the preceding year. Residual soil NO_3-N was measured on 0- to 60-cm core segments while soil bulk density was measured on the 0- to 15-cm core segments and. Soybean seed yields (100 g kg^{-1} moisture content basis) were measured with a research plot combine. Seed protein was estimated with near infrared reflectance spectrometry and seed Zn measured with a ICP-AES. Soil and seed data were analyzed with PROC GLIMMIX in SAS. Results and Discussion

Soils under the 5-yr S-H/A-A-A-C rotation had significantly greater residual NO_3-N concentration in the top 60 cm than the other rotations (Table 1). This observation confirms that N mineralization from alfalfa residue can carry over into the second year following alfalfa (Vanotti and Bundy. 1995). Soil bulk density in the 0 to 15 cm depth was lower in the 5-yr S-H/A-A-A-C rotation than the 3-yr S-H-C rotation, while those for the 3-yr S-W-C and 2-yr S-C rotations were intermediate (Table 1). For rotations that contain alfalfa, soil macropores that form after alfalfa root decomposition often extend deep into the soil profile and could provide pathways for NO_3-N leaching below the root zone (Robbins and Carter, 1980).

Table 1. Residual soil NO_3-N and bulk density (BD) under different crop rotation treatments. Values represent data combined across both years of the study.

Rotation	NO_3-N	BD
	kg ha^{-1}	g cm^{-3}
S-C	60 b‡	1.38 ab
S-W-C	69 b	1.39 ab
S-H-C	65 b	1.46 a
S-H/A-A-A-C	129 a	1.35 b

‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

Soybean seed yield was about 10% greater in the 5-yr S-H/A-A-A-C rotation than in the other treatments. Kernel protein was 3% greater and kernel Zn was 11% greater under the 5-yr rotation than under the2-yr S-C rotation while the others were intermediate. In comparing the 5-yr and the 2-yr rotations, increased seed yield in the 5-yr rotation was accompanied by increased seed protein. Soybean seed yield and seed protein have also been observed to increase in response to N fertilizer application to soybeans (Adeli et al., 2005). Thus, increased soil NO_3-N in the 5-yr rotation likely increased soybean seed yield and protein concentration. Because there is no literature available that examines soybean seed Zn concentration in response to N fertilizer or increased soil NO_3-N under no-till field conditions, further research would be needed to understand the physiological mechanisms for crop rotation effects on Zn.

Table 2. Soybean yield and seed concentrations of protein, oil, and Zn from plots managed under different crop rotation treatments. Values represent data combined across both years of the study.

Rotation	Yield	Protein	Zn
	kg ha^{-1}	g kg^{-1}	mg kg^{-1}
S-C†	2761 b‡	358 b	26.6 b
S-W-C	2859 b	361 ab	27.7 ab
S-H-C	2720 b	364 ab	27.3 ab
S-H/A-A-A-C	3044 a	368 a	29.8 a

‡ Means followed by the same letter within columns are not significantly different (Tukey-Kramer grouping for least square means, α=0.05).

References

Adeli, A., K.R. Sistani, D.E. Rowe, and H. Tewolde. 2005. Effects of broiler litter and soybean production and soil nitrogen and phosphorus concentrations. Agron. J. 97:314-321.

Riedell, W.E., J.L. Pikul, Jr., A.A. Jaradat, and T.E. Schumacher. 2009. Crop rotation and nitrogen input effects on soil fertility, maize mineral nutrition, yield, and seed composition. Agron. J. 101:870-879.

Robbins, C.W., and D.L. Carter. 1980. Nitrate-nitrogen leached below the root zone during and following alfalfa. J. Environ. Qual. 9:447-450.

Vanotti, M.B., and L.G. Bundy. 1995. Soybean effects on soil nitrogen availability in crop rotations. Agron. J. 87:676-680.

Conservation Agriculture as Alternative to Reduce Impact of Climate Change for Smallholder in North Africa: Tunisian Case

*Hatem CHEIKH M'HAMED, Houcine ANGAR, Mohamed ANNABI

* Corresponding author: hatemcheikh@yahoo.fr / National Institute of Agronomic Research of Tunisia (INRAT), Laboratory of agronomy, Hedi Karray street, 2049 Ariana, Tunisia
Phone: +216 98 579 788 / fax: + 216 71 752 897

Background

Tunisia is located in North Africa, on the border of the Mediterranean. A big part of Tunisia have semiarid and arid climates, which are marked by extremes in daily high and low temperatures, with hot summers and cold winters, and little rainfall approximately 200 to 400 mm per year for semiarid regions and less than 100 mm per year for desert regions (Radhouene, 2013). Tunisia is vulnerable to climate change impacts (Vicente-Serrano, 2006) and has been qualified as the « hot spot for climate change» (Giorgi, 2006). Water scarcity, even in the absence of climate change, will be one of the most critical problems facing North African countries and especially in Tunisia in the next few decades (Ashton, 2002). Water is at the heart of the main expected impacts of climate change on the natural environment in the Mediterranean (El-Quosy, 2009). According to the simulations made by climate specialists on the basis of the IPCC scenarios (GTZ, 2007), the dramatic effects of climate change will be observed in Tunisia. However, they show that: **i)** the annual average temperature will increase by 1.1°C by 2030 and that at the 2100 horizon, a potential increase of the temperature from 1.3 to 2.5 °C, and an elevation of the sea levels from 38 cm to 55 cm will occur , **ii)** the number and intensity of droughts will increase, **iii)** 28% of water resources will decrease by 2030, **iv)** The loss of groundwater reserves in particular will become a problem, **v)** 20% loss in arable cropland by 2030, and **vi)** substantial increase in the vulnerability of ecosystems. The decrease in annual precipitation that is predicted for Northern Africa in the 21st century will exacerbate these effects, particularly in semiarid and arid regions that rely on irrigation for crop growth (Hulme *et al*., 2001). Conservation Agriculture (CA) practices has been proposed as an adapted set of management principles that assures a more sustainable agricultural production (Verhulst *et al*., 2012), and can also contribute to making agricultural systems more resilient to climate change. In many cases, conservation agriculture has been proven to reduce farming systems' greenhouse gas emissions and enhance their role as carbon sinks in order to improve soil health and structure holds the key to improving water use efficiency (WUE) which leads to improved farm profits and benefits the farm environment. Also, CA is as an approach to farming that seeks to increase food security, alleviate poverty, conserve biodiversity and safeguard ecosystem services.

Results

Results showed that for the three cropping season, the grain yield, Total Dry Matter (TDM), grain Water Use Efficiency (WUE-g) and biological Water Use Efficiency (WUE-b) of durum wheat under CA system were increased compared to conventional tillage. However, under CA system and for the second crop rotation (Durum wheat/Faba bean), Durum wheat had the highest WUE-g (8,24 kg/ha/mm) and WUE-b (19,69 kg/ha/mm) than for the first crop rotation (Durum wheat/Durum wheat) tested, with respectively 7,74 kg/ha/mm and 18,28 kg/ha/mm for WUE-g and WUE-b.

Applications and Implications for Conservation Agriculture

Conservation agriculture (CA) has been proposed as an adapted set of management principles that assures a more sustainable agricultural production. It combines the following basic principles: **i)** reduction in tillage, **ii)** retention of adequate levels of crop residues and permanent soil surface cover, **iii)** Crop diversification and use of adequate crop sequences. These CA principles allow to increase water infiltration and to reduce in water evaporation and erosion (Ma *et al.* 2006). CA based on no tillage system and crop residue retention gives positive control of surface water (Bachmann and Friedrich 2003) and increase plant available water in arid and semi-arid rainfed agriculture, and may lead to enhanced water use efficiency (WUE) by crops. Also, CA based on no tillage system alters the partitioning of the water balance, decreasing soil evaporation and increasing transpiration, infiltration and deep percolation, leading to increased yields and WUE (Wang *et al.* 2004).

Experimental Approach

The experiment was carried out on farm located 30 km from Tunis, Tunisia (36° 36' 37,3" N Lat, 10° 0,8' 30,7" E Long, 65 m asl), during three cropping seasons (2007/2008, 2008/2009 and 2009/2010). The climate is semi-arid and the annual rainfall average is about 400 mm. The soil had a clay texture with 180 mm m^{-1} total available water. The biennial rotation was tested [Durum wheat/ Durum wheat (W/W), Durum wheat/ Faba bean (W/F)]. Soil water balance and crop water uptake was determined (soil moisture was measured under different soil depth using gravimetrically method each month). At the harvest, the TDM and yields compound of durum wheat were determined.

- Biological Water Use Efficiency (WUE-b) = Total dry matter/ETR (kg/ha/mm)
- Grain Water Use Efficiency (WUE-g) = Grain yield/ETR (kg/ha/mm)

An analysis of variance for all measured parameters was made, using Statistical Analysis System software (SAS, 1985).

Results and Discussion

Results of this study were given in the table below (table 1).

Cropping season	Treatment	Grain yield (kg/ha)		TDM (kg/ha)		WUE-g (kg/ha/mm)		WUE-b (kg/ha/mm)	
		W/W	W/F	W/W	W/F	W/W	W/F	W/W	W/F
2007-2008	CA	2800[a]	3100[a]	6900[a]	7500[a]	7.36[a]	8.15[a]	18.15[a]	19.73[a]
	CoA	2600[b]	3300[b]	6300[b]	7950[b]	6.19[b]	7.85[b]	15.00[b]	8.92[b]
	$LSD_{(0.05)}$	175	193	266	320	0.15	0.28	1.13	1.41
2008-2009	CA	3200[a]	3420[a]	7600[a]	8050[a]	8.08[a]	8.50[a]	19.00[a]	20.12[a]
	CoA	3000[b]	3460[a]	7250[b]	8100[b]	6.66[b]	7.55[b]	16.15[b]	18.00[b]
	$LSD_{(0.05)}$	192	210	320	460	0.36	0.42	1.32	1.18
2009-2010	CA	3050[a]	3430[a]	7300[a]	8080[a]	7.14[a]	8.09[a]	17.38[a]	19.23[a]
	CoA	2980[a]	3640[a]	7280[a]	8250[a]	6.52[b]	7.82[a]	15.82[b]	7.93[b]
	$LSD_{(0.05)}$	160	202	380	500	0.41	0.38	0.95	1.22

CA: Conservation agriculture; CoA: Conservation Agriculture; W: Durum wheat; F: Faba bean; TDM: Total Dry Matter; LSD: Least Significant Difference

Results of three years of experimentation showed that under CA system, the average grain yield (3000 kg / ha) and TDM (7266 kg/ha) of Durum wheat were better than conventional agriculture (2800 kg /ha and 6940 kg/ha), respectively for grain yield and TDM for the first crop rotation (W/W). However, for the second crop rotation (W/F) , the average grain yield and TDM were higher under conventional agriculture compared to CA system, with respectively (3500 kg/ha , 8100 kg/ha) and (3300 kg / ha , 7870 kg/ha) . In fact, grain yield and TDM of Durum wheat conducted under conventional agriculture were improved compared to those under CA system, which is probably because the biomass yield of the previous crop (Faba bean) was more important under conventional agriculture than CA. Grain Water Use Efficiency (WUE -g) and biological Water Use Efficiency (WUE -b) under CA system increased compared to conventional agriculture for both crop rotations tested. Improvement of WUE - g under CA compared to conventional agriculture are 15%, 18% and 10%, respectively for the years 2007/2008, 2008/2009 and 2009/2010 for the first rotation tested (W/W). However, a smaller improvement is recorded when the durum wheat is grown in succession of faba beans under CA compared to conventional agriculture. This improvement was 4%, 12% and 5%, respectively for the years 2007/2008, 2008/2009 and 2009/2010. Also, same results were recorded for the case of WUE -b.

This finding confirms that CA practices improves WUE and proposed as set adapted that contribute to making agricultural systems more resilient to climate change in semiarid and arid regions, especially as water scarcity , in the odd lack of climate change, will be one of the most critical problems of Tunisia.

References

- Ashton, P. J. 2002. Avoiding conflicts over Africa's water resources, Ambio, 31: 236-239.

- El-Quosy, D. 2009. Impact of Climate Change: Vulnerability and Adaptation. Fresh Water pp 75-86 Report of the Arab forum for Environment and Development. Mostafa K.Tolba and Najib W.Saab Eds.

- Giorgi, F. 2006. Climate change hot-spots. geophysical Resources Letters, 33: 707-715.

- GTZ. 2007. Adaptation to climate change: development of a national strategy for agriculture, ecosystems and water resources in Tunisia 2005 to December 2007. 3p

- Hulme, M., Doherty, R., Ngara, T., New, M. and D. Lister, D. 2001. African Climate Change: 1900-2100. Climate Research, 17(2): 145-68.

- Ma Z, Boa X, Shu Q, Liu S, Sun J, and R. Yang. 2006. Studies on yield and benefit of CT for wheat–corn intercropping. In Proceedings China-Canada CA Forum on CA Technology & Application. Bachmann T, Freidrich, T. 2003. Conservation Agriculture in Mongolia. In proceedings of the II World Congress on CA. Parana, Brazil.

- Radhouene, L. 2009. Climate change impacts on North African countries and on some Tunisian economic sectors. Journal of Agriculture and Environment for International Development - JAEID, 107 (1): 101 – 113.

- Verhulst, N., Govaerts, B., Sayre, K.D., Sonder, K., Romero-Perezgrovas, R., Mezzalama, M., Dendooven, L., 2012. Conservation agriculture as a means to mitigate and adapt to climate change, a case study from Mexico. In: Wollenberg, E., Nihart, A., Tapio-Biström, M.-L., Grieg-Gran, M. (Eds.), Climate Change Mitigation and Agriculture. Earthscan, Oxon, ISBN: 9781849713924, pp. 287-300.

- Vicente-Serrano, S. M. 2006. Spatial and temporal analysis of droughts in the Iberian Peninsula (1910-2000). Hydrol. Sci. J., 51(1): 83-97.

- Wang FH, Wang XQ, Ren DC. 2004. Study on ridge culture technology in irrigated winter wheat. *Journal of triticeae crops* 24, 68-72.

Residue Cover Provision Challenges for Conservation Agriculture (CA) Associated with Termite (*Isoptera)* Infestations in Southern Africa

Isaiah Nyagumbo[1], Eleanor Mutsamba[1], Eduardo Mulima[2], Custódio José[2], and Domingos Dias[2]
[1] CIMMYT, Box MP163, Mt. Pleasant, Harare, Zimbabwe, i.nyagumbo@cgiar.org; [2]IIAM, Centro Zonal Centro, Estação Agrária de Sussundenga, Manica, Moçambique

Introduction

Provision of permanent soil cover is a key requirement for conservation agriculture (CA) and at least 30% residue cover is recommended at the time of seeding (Kassam and Friedrich, 2012) . Smallholder farms of Southern Africa face serious constraints in implementing this principle due to competition for residues as mulch and as livestock feed (Valbuena *et al.*, 2012), and removal of surface applied crop residues through termite consumption. Termites (*Isoptera*) are soil borne macro-fauna known to cause both beneficial and harmful effects on crop production (Sileshi *et al.*, 2005). This paper reports on studies carried out to evaluate the effects of different residue application rates in Zimbabwe and the effectiveness of different termite management/control strategies in CA systems in Manica province of Mozambique.

Materials and Methods

To better understand the effects of residue application in CA on termite prevalence, experiments were established in 2008 in Kadoma, Zimbabwe. Different maize residue application rates of 0, 2, 4 and 6 t ha^{-1} in CA were compared against conventional mouldboard ploughing(CMP) planted to maize and monitored over two cropping seasons on 3 farms. The experiment was laid out in a completely randomized block design with 3 replications per farmer. Later, two further studies were established in Manica province of Mozambique in 2012. The first of these involved a rainfed experiment in which 11 different termite management strategies were tested from 2011 to 2013 while the second experiment tested the same management methods under different irrigation watering regimes mimicking different rainfall seasons at Sussundenga research station, Mozambique. The treatments included conventional ploughing, CA with and without residue application, CA plus residues together with various natural control chemicals as well as one commercial product Fipronil. These were set up in completely randomized blocks with 4 replicates per treatment. Main measurements included termite activity, crop lodging and maize grain yields.

Results and discussions

The major termite species observed at the Mozambican locations were the *Odontotermes* spp while in Kadoma, Zimbabwe, it was mainly the *Macrotermes spp* and *Odontotermes spp*. Results from Kadoma generally showed lower termite numbers per m^2 in the conventional mouldboard ploughing treatments compared to CA. In addition, significantly higher crop lodging was observed in CA systems (42-48%) compared to CMP (30-34%) in both seasons. Within CA systems, termite abundance also increased with increasing residue application rates, giving a significant ($p=0.01$) linear regression relationship (Figure 1). Significantly higher maize yields were also observed under CA ($p<0.05$) compared to CMP. Similarly, results from Sussundenga (Figure 2) and Chimoio showed that reduced soil disturbance and provision of residues as surface soil cover, contributed to increased termite activity in CA systems ($p<0.05$). In addition, at Chimoio reduced termite activity was also observed from plots treated with a commercial insecticide Fipronil Thus, of all the control methods tested, only the commercial product Fipronil proved to be effective in reducing termite activity and resulted in at least 1.5 tha^{-1} of residues remaining in the system by the start of the 2013/14 season at Chimoio (Figure 3). However the termite management methods had no significant effect on maize yields at both Mozambican locations.

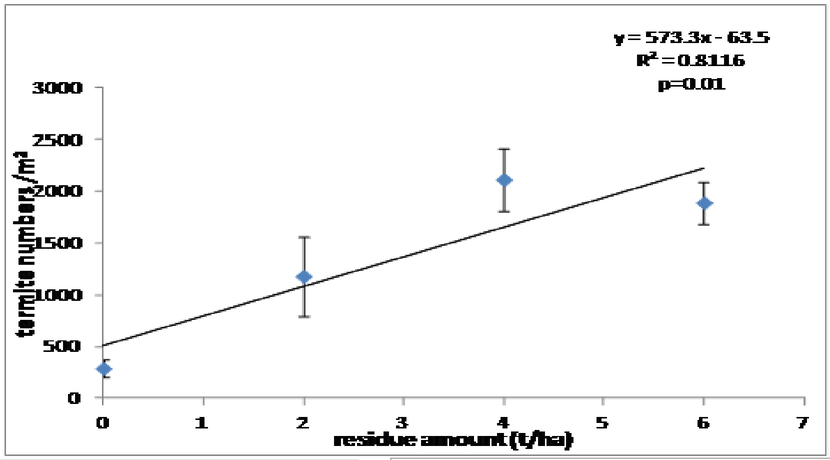

Figure 1. Effects of residue application rates on termite numbers per m2 in Kadoma over two seasons (2008/9 and 2009/10) under CA. **Note: Error bars denote +/- SE of Mean.**

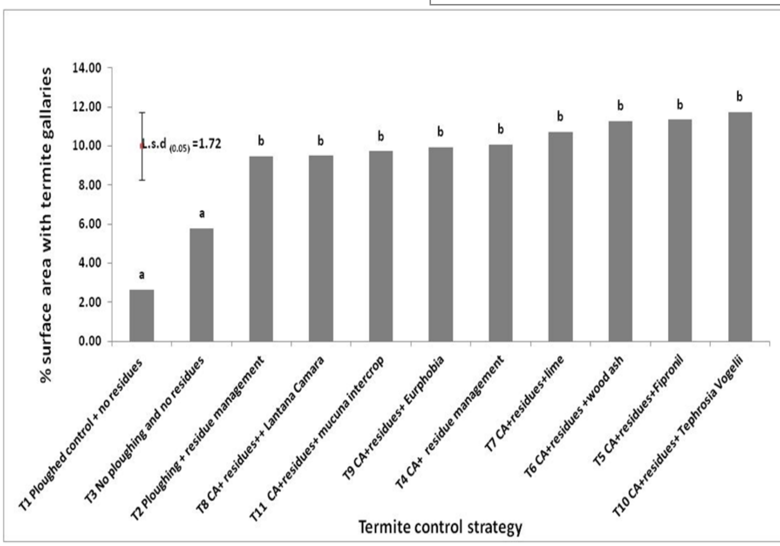

Figure 2. Overall effects of different termite control strategies over 3 irrigation watering regimes on % surface area with termite galleries at Sussundenga experiment station in 2012. Note: Treatments in the graph followed by the same letter above each bar are not significantly different at p<0.05 using Duncan's Multiple Range Test.

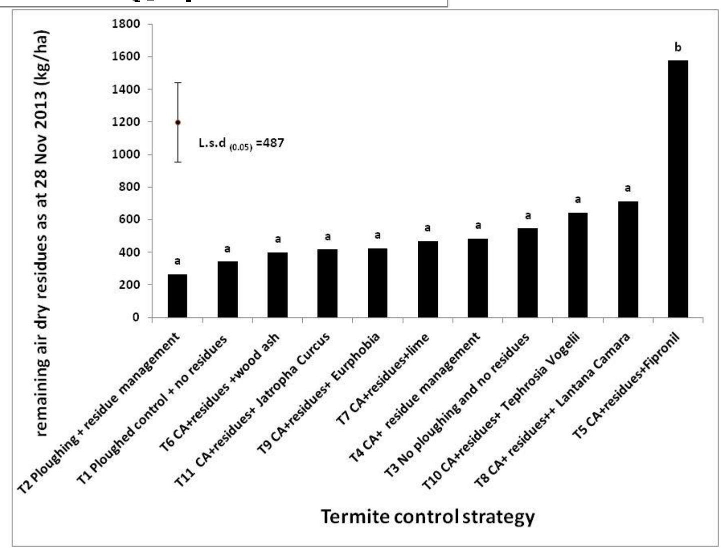

Figure 3. Effects of different termite control strategies on residues remaining at the start of the season at Chimoio as at 28 November 2013. Note: Treatments in the graph followed by the same letter above each bar are not significantly different at p<0.05 using Duncan's Multiple Range Test.

Conclusion

We concluded that application of crop residues and reduced soil disturbance in CA were major contributors towards termite infestation challenges experienced in CA systems. On the other hand all the tested termite management strategies applied in Mozambique had no significant effect on crop lodging while in Zimbabwe crop lodging due to termite attack increased on switching from conventional ploughing to CA. All the tested control methods failed to work except for a commercial product Fipronil, that enabled retention of at least 1.5t/ha of maize residues by November 2013 in Mozambique and thus offered a potential solution to termite control in such environments. The need to develop alternative strategies for managing termites in order to retain surface residues in termite prone/infested environments under CA is apparent.

Literature

Kassam, A., and Friedrich, T. (2012). An ecologically sustainable approach to agricultural production intensification: Global perspectives and developments. *Field Actions Science Reports* **6**, 1-6.

Sileshi, G., Mafongoya, P. L., Kwesiga, F., and Nkunika, P. (2005). Termite damage to maize grown in agroforestry systems, traditional fallows and monoculture on nitrogen-limited soils in eastern Zambia. *Agricultura and. Forest Entomology* **7**, 1, 61-69.

Valbuena, D., Erenstein, O., Tui, S. H.-K., Abdoulaye, T., Claessens, L., Duncan, A. J., Gerard, B., Rufino, M. C., Teufel, N., van Rooyen, A. A., and van Wijk, M. T. (2012). Conservation Agriculture in mixed crop–livestock systems: Scoping crop residue trade-offs in Sub-Saharan Africa and South Asia. *Field Crops Research* **132**, 14, 175-184.

Soil Management Extension: Going Back to the Basics to Build Healthy Soils

Marla Riekman[1] and Curtis Cavers[2]
[1]Manitoba Agriculture, Food and Rural Development
Box 1149, 65-3rd Ave NE
Carman, Manitoba, Canada R0G 0J0
Marla.Riekman@gov.mb.ca
[2]Agriculture and Agri-Food Canada, Portage la Prairie, Manitoba, Canada

In 2013, Manitoba Agriculture, Food and Rural Development (MAFRD) and Agriculture and Agri-Food Canada (AAFC) held a number of in-field and classroom workshops on soil and water management. The workshop hinged on three main principles: water and nutrient movement through the soil and landscape, improving soil physical properties, and how to build and maintain soil health. A variety of extension tools were used to help demonstration how to address common soil management issues to maintain or enhance the health of our soils. The following is a list of successful demonstrations that have since become a key part of our soil management extension program.

Soil Aggregate Stability

Aggregate stability was demonstrated using a “dip test” where aggregates from three similar soils of different cropping histories were placed in small sieves and dipped in water repeatedly. For these demonstrations, we typically used three soil types, a heavy clay, a clay loam, and a sandy loam soil. Each one of these soil types had aggregates taken from a conventionally tilled, zero tilled and native prairie or long term perennial cropped soil for comparison. In each case, the impact of the perennial in the cropping system did more for aggregate stability than just the zero tillage alone. Creating good aggregate stability is an important part managing for healthy soils as they are better able to withstand negative forces such as wind, water and tillage.

Soil Slaking

Soil slaking was observed by subjecting air-dried clods of soil to a rapid wetting process. Again, clods were collected from varying management systems for the slaking comparison. The clods were placed at the top of a glass cylinder filled with water, held in place by a piece of wire mesh so that the clods were fully submerged but not allowed to drop to the bottom of the cylinder. As water rushed into the soil pores, the more stable soil was able to withstand the pressure, while the particles of the less stable soil “slaked” off into the water.

Surface Crusting

Surface crusting (especially with canola) was an issue for many producers in the spring of 2013 as we experience some heavy rains after seeding followed by hot sunny days. To demonstrate the impact of crusting, soils with low organic matter and poor aggregate stability were placed in aluminum pans, seeded with small rows of wheat, canola, corn and soybeans, heavily wetted and then left to bake in the sun. A comparison soil with a low potential for crusting was also subjected to the same process. The impact of crusting was easily seen when very few seedlings emerged compared to the non-crusting soil.

Water Infiltration

Following the USDA Soil Quality Test Kit Guide (2001) protocol, PVC rings approximately six inches in diameter were inserted into soils of two different management systems. The management systems begin compared depended on the location of the field workshop; however, for the most part, we were able to compare between perennial and annual cropping systems. The inside of the ring was lined with plastic wrap and approximately one inch of water was poured on top. The plastic wrap was removed and a timer used to compare how long it took for the water to fully infiltrate for each of the management systems.

Infiltration rates were generally higher in the perennially cropped soils, except for areas with heavy wheel traffic.

Rooting Viewing Boxes

Root viewing boxes (Trent, 2009) were constructed so producers and agronomists could visually inspect how roots move through the soil as the plant develops. The most common comment that we received during the early stages of crop growth was "I can't believe the roots are actually deeper than the plant is tall!" These root viewing boxes have been an excellent addition to our extension products and we plan to use them in the future to demonstrate the impact of soil compaction and other problematic growing conditions on root growth.

References:

Trent, Keith. 2009. Root Viewing Box Fabrication Instructions. Available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_018716.pdf

United States Department of Agriculture – Natural Resources Conservation Service. 2001. Soil Quality Test Kit Guide. Available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050956.pdf

The Importance of Crop Residue on Soil Aggregation and Soil Organic Matter Components

Shannon L. Osborne*, Amber L. Hammerbeck, Tom E. Schumacher and Joe L. Pikul, Jr.
*USDA-ARService-North Central Agricultural Research Laboratory,
2923 Medary Ave.,
Brookings, South Dakota 57006 USA
shannon.osborne@ars.usda.gov

Background

The soil's main source of organic matter is above- and below-ground plant residue. This plant residue, following the decomposition process, serves as a binding agent to hold soil particles together forming aggregates and increase soil C storage (Jastrow et al., 1997). Soil organic matter serves in stabilizing soil particles (aggregation), assists in supplying plant available nutrients, increasing water holding capacity, and helping reduce soil erosion. Particulate organic matter (POM) is the microbially active and labile fraction of SOM consisting of fine particles of partially decomposed plant tissue (Cambardella et al., 2001) and is what soil aggregates have been found to form around (Gale et al., 2000). Golchin et al. (1994 and 1995) found POM has a greater effect on stability of soil aggregates than total SOM (tSOM), because these plant and root materials have a cohesive effect on soil particles. Six et al., 1998 found that coarse intraaggregate POM (cPOM) is tied to the amount of aggregation occurring whereas fine intraaggregate POM (fPOM) increases with decreasing rate of aggregate turnover.

Applications and Implications for Conservation Agriculture

Cropping system, residue and tillage management impact POM, thus are anticipated to also impact aggregation. The proportion of wind EF of aggregates (<1 mm) was larger under residue removal and no-tillage (Singh and Malhi, 2006) than under tillage and all residue removed. Practicing no-tillage without removing crop residues allows for greater increases in soil aggregation compared to no-tillage with residue removed (Branco-Canqui and Lal, 2009). Soil aggregation can serve as indicator of soil quality or soil health. Healthy productive soils are necessary to meet the multiple demands placed on soil resources. The objective of this paper is to evaluate the impact of removing corn residue on specific soil physical properties including soil DASD, EF, SOM and POM.

Experimental Approach

In the spring of 2000, a corn-soybean rotation experiment was established at the North Central Agricultural Research Laboratory near Brookings, SD. Treatments initially included removal of corn residue at three levels: low, medium and high residue removal (LRR, MRR and HRR respectively. In the fall of 2005 the residue removal treatments were split and a cover crop treatment (with or without cover crop) was integrated into the overall design, thus adjusting the experimental design from a randomized complete block design to a split-plot design, with residue removal remaining as the whole-plot treatment and cover crops representing the split-plot treatment. Additional experiment details are reported in Hammerbeck et al. (2012). Soil samples were collected July, 2012 from all plots. Using methods outlined by Chepil (1962), DASD was determined using a rotary sieve to separate the soil into six aggregate size classes representing <0.42, 0.42-0.84, 0.84-2.0, 2.0-6.4, 6.4-19.2, >19.2 mm respectively and the mass of soil in each class was determined relative to its original sample weight. From each aggregate size class, two representative subsamples were collected and further processed in preparation for POM, and SOM. Data for all soil parameters was evaluated utilizing SAS version 9.3 with residue removal and cover crops considered as fixed effects and replications considered a random effect. Mean separation and multiple comparisons were obtained with a LSMEANS statement within PROC MIXED. Significance for all data is reported at $P \leq 0.05$.

Results and Discussion

Particulate organic matter and organic C are indicative of SOM. The importance of organic matter on the chemical, biological and physical properties have been well documented. Above ground biomass serves as a significant contribution to SOM therefore, it is not surprising that we found a decrease in measured soil physical properties when residue was removed from the soil surface. The distribution of soil aggregates was less favorable when residue was removed without the addition of other sources of organic matter such as cover crops. The EF was more than twice as large in the HRR (16.1%) treatment as in the LRR (7.5%), with the presence of a cover crops and even higher when there was no cover crop present (30.7% for the HRR compared to 8.5% for the LRR). The presence of a cover crop within the HRR treatment found a 50% reduction in the EF compared to no cover crop present (30.7 to 16.1%). We believe that the residue remaining on the soil surface or the presence of a cover crop provided protection from the erosive forces of wind and water, reducing the breakdown of larger aggregates into smaller aggregates that are susceptible for wind erosion.

Amounts of SOM, cPOM, fPOM and tPOM consistently decreased as a greater amounts of residue are removed from the soil surface. These organic matter components are short-term indicators of potential further degradation of the soil structure, as organic matter levels affect soil aggregation, soil water availability, nutrient storage and release, and the cation exchange capacity of the soil, and have a further cause-and-effect relationship with an array of soil health properties (Magdoff and Weil, 2004). This research supports the concepts of the disruption in aggregate formation and the breakdown of larger aggregate when adequate crop residue is removed from the soil surface previously discussed by Hammerbeck et al., 2012 and Blanco-Canqui and Lal, 2009. We believe that the reduction of POM found within this research sites disrupted the formation and continuation of the cycling of aggregation. Six et at., 1998 stated that aggregate formation is of central importance in the stabilization of SOM, management processes that interrupt the formation and stabilization of aggregates (such as residue removal) should be avoided. Without the addition of organic matter, such as incorporating a cover crop, to replace the C removed, soil physical properties measured within this study were negatively impacted.

References

Jastrow J.D., and R.M. Miller. 1997. Soil aggregate stabilization and carbon sequestration: Feedbacks through organomineral associations. In Lal R, Kimble JM, Follet RF, Stewart BA (ed.) Soil Processes and the Carbon Cycle. CRC Press, Boca Raton, FL, 207-223.

Cambardella C.A., A.M. Gajda, J.W. Doran, B.J. Wienhold, and T.A. Kettler. 2001. Estimation of particulate and total organic matter by weight loss-on-ignition. In Lal R, Kimball JM, Follet RF, Stewart BA (ed.) Assessment methods for soil carbon. Lewis Publishers, Boca Raton, FL, 349-359.

Gale W.J., C.A. Cambardella, and T.B. Bailey. 2000. Root-derived carbon and the formation and stabilization of aggregates. Soil Sci. Soc. Am. J. 64:201-207.

Golchin A., J.M. Oades, J.O. Skjemstad, and P. Clarke. 1994. Soil structure and carbon cycling. Aust. J. Soil Res. 32:1043-1068.

Golchin A., J.M. Oades, J.O. Skjemstad, and P. Clarke. 1995. Structural and dynamic properties of soil organic matter as reflected by 13C natural abundance, pyrolysis mass spectrometry and solid-state 13CNMR spectroscopy in density fractions of an Oxisol under forest and pasture. Aust. J. Soil Res. 33:59-76.

Six J., E.T. Elliott, K. Paustian, and J.W. Doran. 1998. Aggregation and soil organic matter accumulation in cultivated and native grassland soils. Soil Sci. Soc. Am. J. 62:1367-1377.

Blanco-Canqui H, and R. Lal. 2009. Corn stover removal for expanded uses reduces soil fertility and structural stability. Soil Sci. Soc. Am. J. 73:418-426.

Hammerbeck A.L., S.J. Stetson, S.L. Osborne, T.E. Schumacher, and J.L. Pikuljr. 2012. Corn residue removal impact on soil aggregates in a no-till corn/soybean rotation. Soil Sci. Soc. Am. J. 76:1390-1398.

Chepil W.S., 1962. A compact rotary sieve and the importance of dry sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4-6.

Magdoff F., R.R. Weil. 2004. Soil organic matter in sustainable agriculture. CRC Press, Boca Raton, FL

"Building Soil Health in North Dakota"

*S.E. Samson-Liebig[1], H. Weiser[1], J. Printz[1], J. Fuhrer[1], W. Bott[1], T. Alme[1], and A. Wick[2]
[1]USDA-NRCS, Bismarck, ND; [2]North Dakota State University, Fargo, ND

Background:
Soil health is vital for sustainable agroecosystem management and ultimate survival on planet earth. In North Dakota, activities to build soil health have intensified across the state. The use of cover crops along with reduced tillage, and crop diversity is being used to build soil health and soil quality and has been effectively promoted and widely adopted throughout North Dakota. Increased intensity of the integration of conservation practices and cover crops in agricultural systems has been driven by concurrent interests to reduce commercial inputs and build soil health in crop, pasture, and grazing lands as well as pollinator habitat. Enhanced soil properties associated with soil health is a benefit from the use of cover crops, crop diversity, and best management practices on rangeland and pastureland, which is critical in addressing resource concerns such as depleted soil fertility, lack of soil biological diversity, increased salinity, and poor water infiltration rates. Several demonstration projects throughout North Dakota have been initiated to evaluate the use of cover crops in cropping and/or grazing systems. These projects involve the testing of new simple soil testing methods and soil biological methods to better assess management effects on soil function resulting from improved conservation practices. Outreach via field tours, workshops, and small around-the-table discussion groups have been a key component in education and implementation. These demonstration projects have also drawn people from all over the world to observe, learn, and exchange ideas about soil health building techniques. This poster provides an overview of key demonstration projects including data generated from some of the projects and ongoing research in North Dakota.

Applications and Implications for Conservation Agriculture:
Improving soil health awareness, educating producers and others about building soil health, and experimenting with various management systems that apply soil health building principles in a non-research environment is a key driver for establishment of demonstration areas. Soil health principles used to improve soil function include keeping the soil covered to minimize soil erosion, minimize soil disturbance, increasing crop diversification, maintaining live plant cover as much as possible, and livestock integration. Demonstration sites employ various combinations of these principles to show techniques to restore soil health and move production agriculture toward sustainability. In addition to the demonstration projects, researchers at the United States Department of Agriculture Agricultural Research Service Northern Great Plains Research Lab (USDA-ARS-NGPRL) and North Dakota State University (NDSU) Extension are quantifying benefits and identifying issues associated with cover crop use in cropping and grazing systems, as well as developing cover crop decision aids. These are on-going efforts.

Experimental Approach:
The demonstration sites were designed to test various techniques to build soil health and soil quality and compliment on-going research by USDA-ARS-NGPRL, NDSU, and the USDA Natural Resources Conservation Service (NRCS) Plant Materials Centers National Cover Crop project initiated in 2012. On all demonstration sites, soil samples are collected and analyzed for select soil chemical, physical, and biological properties such as soil microbial biomass, aggregate stability, soil bulk density, soil organic and inorganic carbon and nitrogen, pH, electrical conductivity (EC), phospholipid fatty acid (PLFA), and soil food web analysis. In-field measurements on select sites include water infiltration rates, soil temperature, soil moisture, and earthworm counts.

Results and Discussion:
A primary objective of the demonstration sites has been to improve the knowledge base of soil health among producers, agricultural professionals, and others. Since 2005, attendance at soil health related workshops and tours has increased significantly throughout North Dakota, yet outcomes in increased awareness have not necessarily translated to a rapid increased adoption of conservation practices on agricultural land.

Preliminary data indicates improved select soil physical, chemical, and biological properties with reduced inputs on several demonstration projects. The application of compost and compost tea in conjunction with cover crop cocktails on one demonstration farm have also been evaluated to determine their effects on soil health and crop yield. Initial data indicate increases in soil biological activity, total soil biological counts, and soil organic carbon on fields where full season cover crops in conjunction with high crop diversity are used versus no cover crops and low crop diversity. When compared, the low crop diversity field had 1,901 ng/g total living microbial biomass and 195 ng/g total fungi, as compared to the high crop diversity field which had 2,180 ng/g total living microbial biomass and 226 ng/g total fungi. Soil organic matter increases ranged from an average of 0.5 percent to 2 percent on select sites where soil health building practices have been applied.

*Susan Samson-Liebig
USDA-NRCS
Soil Quality Specialist
220 E. Rosser Ave
Bismarck, ND 58501
701-530-2018
susan.samsonliebig@nd.usda.gov

Building Soil Resilience and Sustainable Cropping Systems in Eastern African Drylands after Nine Years of Conservation Agriculture-Based Systems

Tesfay Araya[1,*], Jan Nyssen[2], Bram Govaerts[3], Frédéric Baudron[4], Wim M. Cornelis[5]
[1]Mekelle University, Department of Crop and Horticultural Science, P. O. Box 231, Mekelle, Ethiopia.
[2]Ghent University, Department of Geography, Krijgslaan 281 (S8), B-9000 Gent, Belgium
[3]International Maize and Wheat Improvement Centre (CIMMYT), A.P. 6-641, Mexico D.F. 06600, México.
[4]International Maize and Wheat Improvement Centre (CIMMYT), P.O. Box 5689, Addis Ababa, Ethiopia
[5]Ghent University, Department of Soil Management, Coupure Links 653, B-9000 Gent, Belgium
*corresponding author: tesfayaraya@gmail.com, tesfayw2002@yahoo.com

Background:
Long term conservation agriculture (CA)-based experiments are rare in sub-Saharan Africa, particularly in Eastern Africa. CA aims at improving soil quality, soil moisture and thus, improve crop yield whilst reducing runoff and topsoil erosion which raises the soil resilience to combat soil degradation. In Ethiopia, conventional farming practices based on repeated intensive tillage combined with complete crop residue removal at harvest mainly for feed followed by intensive aftermath grazing in croplands, burning of crop residue, use of crop straw and animal dung for fuel and the repeatedly occurrence of drought have reduced the biomass returned to the soil and thus, have aggravated cropland degradation. Hence, a long-term tillage experiment was carried out (2005 to 2013) on a Vertisol to evaluate changes in soil quality, runoff, soil loss, crop and economic productivity due to CA-based field conservation practices in semi-arid northern Ethiopia.

Materials and methods: The experimental layout was implemented in a randomized complete block design with three replications on permanent plots of 5 m by 19 m with a slope gradient of 3%. The soil at the study site is a Calcic Vertisol (FAO 1988), Pellic Calcaric Vertisol (WRB 2007) or Typic Calciustert (Soil Survey Staff 2010). Three tillage practices were applied: *derdero+* (DER+), *terwah+* (TER+) and conventional tillage (CT), all using the local ard plough. 1) *Derdero*+ (DER+) was a newly developed tillage system based on a traditional *in situ* water conservation technique (*derdero*) (Nyssen *et al.* 2011; Tesfay *et al*. 2012). Planting with DER+ system was done using one tillage operation only by refreshing the furrows at planting, while no tillage was performed on the raised beds which were kept permanent for 9 years (2005-2013) with an intended retention of 30% crop straw. 2) The traditional local tillage practice *terwah* was applied without modification from 2005 to 2007. However, starting from 2008, *terwah+* (TER+) was a newly modified tillage system developed from the traditional *in-situ* water conservation method (*terwah*) (Nyssen *et al*. 2011; Tesfay *et al.* 2011). 3) Conventional tillage (CT) which was the control in our experimental setup, where we use it as a reference to the results obtained from the two modified tillage practices. In CT, three tillage operations per year were carried out and crop residues were completely harvested which was similar to the farmers practice in the study.

Local crop rotation practices followed during the nine years sequentially from the first to the ninth year included wheat-teff-wheat-barley-wheat-teff-grass pea-teff-wheat. Glyphosate was sprayed starting from the third year (2007) at 2 l ha^{-1} before planting to control weed before crop emergence in DER+ and TER+. It should be noted that in keeping crop residue, we targeted to have 30% on the beds only. In case of barley and wheat residue, this resulted in more than 60% of the surface area of the plot being covered by 30% residue, whereas after teff cropping about 20% of the plot was covered, while the soil was not covered at all after grass pea cropping.

Results and discussion: Significantly different ($p<0.05$) runoff coefficients (%) averaged over 9 yrs were 14, 22 and 30 for DER+, TER+ and CT, respectively. Mean soil losses of 9 yrs were 3, 11 and 17 t ha^{-1} y^{-1} in DER+, TER+ and CT. Although improvements in crop yield were observed, a period of at least three years of cropping was required before they became significant. On 9 yrs average, yield in DER+ and TER+ increased with 35% and 18% respectively, as compared to CT. Also gross margin increased significantly from 2007 with a similar trend as for crop yield improvement (Table 1).

Among the several assessed physical, chemical and biological soil properties, soil organic matter (SOM), total soil N, available P, total soil organic C and N enrichment ratios, soil microbial biomass carbon (SMBC), time of ponding, aggregate stability index, consistency index, cone index, air capacity and macroporosity were shown to increase significantly in soils subjected to DER+ planting system compared to CT, particularly at 0-10 cm depth. Significantly different ($p < 0.05$) mean SMBC in 2011 at 0-15 cm soil depth was 87, 66 and 36 mg (100 g_{DM})$^{-1}$ with DER+, TER+ and CT, respectively. Three years (2006, 2009 and 2011) mean OM in the topsoil (0-10 cm) was significantly higher with DER+ (25.3 gm/kg) followed by TER+ (23.7 gm/kg) and lowest with CT (22.5 gm/kg). On the other hand, other properties such as *cation-exchange capacity*, texture, pH, field saturated hydraulic conductivity, liquid limit, plasticity index, field capacity, permanent wilting point, plant-available water capacity, matrix porosity and soil physical quality index did not appear to be significantly affected after seven years of CA. Some soil parameters such as PAWC, PWP, FC, K_{fs} and pH have shown a tendency of improvement with DER+ planting system but the difference were not statistically significant between treatments.

Table 1. The last three years (2011-2013) of crop grain and straw yield, runoff coefficient, soil loss and gross margin for the experimental site in Adigudem, northern Ethiopia ($p<0.05$)

Year	**Crop types**	**Treat-ments**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Runoff Coeff. (%)**	**Soil loss (t ha^{-1} yr^{-1})**	**gross margin(USD)**
2011	Grass pea	DER+	1.76a	2.03a	16c	4c	413a
		TER+	1.66a	1.99a	21b	9b	373a
		CT	1.31b	1.59b	33a	17a	197b
2012	Teff	DER+	1.09a	5.33a	23c	1c	3979a
		TER+	1.11a	5.89a	30b	6b	419a
		CT	0.88b	4.33a	41a	15a	213b
2013	Wheat	DER+	4.20a	12.22a	12c	1c	1394a
		TER+	3.50b	10.33b	22b	5b	1011b
		CT	2.80c	6.50c	40a	12a	619c

This study revealed that CA based planting systems DER+ and TER+ are potential land management systems for the farmers in northern Ethiopia on Vertisol with equivalent or higher crop yield in the CA systems than CT during the nine years of study period (except for teff in the second year in 2006). Improvements in crop yield in CA-based treatments required a period of at least three years of cropping before they became significant, whilst on a steeper slope and cooler climate in a nearby sub-humid area with the same treatments at least five years were required (Tesfay *et al.* 2012). The lower teff yield in 2006 was due to application of glyphosate herbicide started in our study as of 2007. Soil degradation is a severe problem due to intensive tillage and limited amount of biomass return to soil, especially in the northern highlands of Ethiopia. Avoiding repeated tillage, retention of crop residues and the capacity of the furrows to retain a large proportion of runoff as depression storage in DER+ contributed to the consistent smaller soil loss and runoff coefficients in DER+, as compared to CT. Farmers in the study area also suggested that the implementation of CA in croplands upstream of a reservoir nearby our experiments can reduce siltation and will extend the lifespan of the reservoirs of irrigation and hydroelectric dams. This beneficial effect which was also modelled at catchment scale in our study area (Lanckriet et al., 2012), extends reservoir lifespan and reduces maintenance costs. Reduction in runoff can also imply the reduction of gully erosion and rural road maintenance costs.

Conclusion:
Adoption of improved local practices of DER+ and TER+ planting systems that employ conservation agriculture principles can reduce runoff, soil loss and improve crop yield and soil quality and thus, sustainability in Vertisols. Adoption of CA-based systems in the study area requires further work to improve smallholder farmers' awareness on benefits, to guarantee high standards during implementation and to design appropriate weed management strategies

References
Tesfay Araya, Cornelis W.M., Nyssen J., Govaerts B., Tewodros Gebregziabher, Tigist Oicha, Fekadu Getnet, Raes D., Mitiku Haile, Deckers J. and K.D. Sayre. 2011. Effects of conservation agriculture on runoff, soil loss and crop yield under rain fed conditions in Tigray, Northern Ethiopia. *Soil Use Manage.* 27, 404-414.

Tesfay Araya, Cornelis W.M., Nyssen J., Govaerts B., Fekadu Getnet, Bauer H., Raes D., Kassa Amare, Mitiku Haile and J Deckers. 2012. Medium-term effects of conservation agriculture for in-situ soil and water management and crop productivity in the northern Ethiopian highlands. Field *Crop* Res.132, 53-62.

Nyssen, J., Govaerts, B., Tesfay Araya, Cornelis, W.M., Bauer H., Mitiku Haile, Sayre, K. and J. Deckers. 2011. The use of the *marasha* ard plough for conservation agriculture in northern Ethiopia. Agron. Sustain. Dev. 31, 287-297.

Lanckriet, S., Tesfay Araya, Cornelis, W.,Verfaillie, E., Poesen, J., Govaerts, B., Bauer, H., Deckers, J., Mitiku Haile, and J. Nyssen. 2012. Impact of conservation agriculture on catchment runoff and soil loss under changing climate conditions in May Zeg-zeg (Ethiopia). J. Hydrol. 475, 336–349.

Evaluation of Soil Cultivation Trials of the Südzucker AG by using the Classification Key of WEYER & BOEDDINGHAUS and the Octet Method of THIELEMANN

Weyer Th, Horsthemke J, Burat R, Nichting I, Oellers H

South Westphalia University of Applied Sciences, Department of Agriculture, Soil Sciences and plant nutrition, Soest, Germany;

weyer@fh-swf.de

Preliminary remarks

The Südzucker AG of Mannheim runs a total of 7 Agricultural Field Trial Operations in Germany. Since 1990 in each trial station a large-scale plot (surface area 10 to 15 ha) is being cultivated using diverse soil cultivation systems (Dieckmann, 2009).

The following soil cultivation methods were conducted by Südzucker-AG on the sample plots:

- **Direct seeding**
- **Mulch seeding**
- **Soil loosening** (intensive usage of the grubber to a depth of maximum 30 cm)
- **Ploughing**

In 2013 in the course of a project work of the University of South Westphalia, soil cultivation systems were examined and compared by the Südzucker AG with regard to the tendency towards soil compaction. This examination was done with the "Classification Key for Detection and Valuation of Soil Compaction in the Field" (Weyer and Boeddinghaus, 2009). In addition to this the earthworm abundances in each of the variants were determined as indicators for biological activity in the soil.

The aim of the examinations was to assess and compare the conventional and conservation cultivation methods in view of a soil compaction threat and biological activity.

Material and Methods

On four of the seven Südzucker Trial sites in the States of Baden-Württemberg and Bavaria the soil cultivation variants were examined using the aforementioned methods. In each field trial station, per cultivation-variant, three spot checks were evenly distributed over the variant plot and determined with the Classification Key and the Octet method. Hence for the result presentation the spot-checks amounted for each variant to 12.

In the course of the assessment the average of all spot-checks of each variant in all sites was determined and compiled according the soil cultivation technique.

Results and discussion

Both soil-conservation tillage methods Mulch-seeding and Direct-seeding scored during the examinations with the classification key an average of 70 to 72 points and showed an undisturbed soil usage and soil fertility. Also the soil-loosening variant scored with an average of 62.5 very well. In comparison, the plough variant shows, with 83.7 points, signs of a beginning soil compaction.

Striking is the appearance of a plough pan by using conventional tillage and a diminishing biological activity. Also the soil surface, a typical indicator for erosion prone by wind and water, showed a sub-optimal condition when the plough was used compared to mulch-seeding or the direct-seeding variant.

Also large differences could be noted regarding the biological activity with the different soil cultivation variants by using the earthworm abundance.

The conservation tillage with an average of 99.4 specimens by direct seeding as well as 61.2 earthworms/m^2 by the mulch seeding-variant showed by far the highest biological activity. The soil loosening variant as intermediate between conservation and conventional tillage showed an abundance of 49.4 earth worms/m^2. With an incidence of only 8.6 earthworms/m^2 the plough-variant showed by far the lowest biological activity.

Transferring the results of the examinations to the general practice, the tillage with the plough shows the highest tendency to soil compaction in the fields.

In view of soil protection and the sustaining of a long lasting intact arable production basis, the establishment and expansion of conservation tillage in many sites is the better alternative.

Within the more profound and higher soil cultivation variants a clear picture emerges. The higher the intensity of the soil tillage, the lower the occurrence of the earthworms. Here the cause for the earthworm-discrepancy could be a mechanical disturbance through the plough or an over- intensive grubber application. A further cause for the lowering biological activity could be the damaging of the eggs of the earthworms through the turning soil tillage.

References

Dieckmann, J. (2009) Zur Bedeutung der Bodenstruktur für den Ertrag von Zuckerrüben- eine pflanzenbauliche und ökonomische Analyse in einer Zuckerrüben- Getreide- Fruchtfolge mit dauerhaft differenzierter Bodenbearbeitung, Cuvilier Verlag Göttingen, S. 24-31

Weyer,Th., Boeddinghaus, R. (2009) Bestimmungsschlüssel zur Erkennung und Bewertung von Bodenschadverdichtungen im Feld / Classification Key for Detection and Valuation of Soil Compactions in the Field. Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

Weyer, Th., Boeddinghaus, R. (2010) Bodenverdichtungen vermeiden, Bodenfruchtbarkeit erhalten und wiederherstellen. Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen