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POSTER ABSTRACTS

Poster session 6: Response of Conservation Agriculture to Stress

Using Micrometeorology to Compare Carbon Dioxide (CO_2) Flux Between Till and No-till Agriculture Practices in Lesotho

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Background:
Soil organic matter represents the third largest pool of carbon on earth after only the lithosphere and the oceans. With estimates ranging up to 35% of ice-free land devoted to agriculture to feed a growing population of over seven billion people, agriculture can either sequester or emit carbon (C) thereby either contributing to or mitigating greenhouse gas emissions and subsequent impacts on climate. A majority of agricultural land in sub-Saharan Africa is degraded due to erosion (Bai et al., 2010, Henao and Baanante, 1999) with the Kingdom of Lesotho having the greatest rate of soil erosion in both central and southern Africa (Chakela and Stocking, 1988). Pimentel et al., (1995) suggest that tillage is one of the greatest contributors to soil erosion of agricultural land as it leaves soil vulnerable to erosion by both wind and water. In addition to reducing soil erosion, reduced and no- tillage enhances soil structure and infiltration, improves resilience to drought and flooding, increases soil organic matter, and enhances fertility and productivity (Thierfelder et al., 2013, Kurkalova et al., 2004). Changing from tillage to no-tillage also has potential to reduce agricultural CO_2 emissions (West and Post, 2002) but this may depend on climate and soil regime (Baker et al., 2007; Powlson et al., 2005), so more research is needed, especially for developing countries (FAO, 2009). Finally, the lack of carbon dioxide (CO_2) flux measurements on African small-holder farms makes it difficult to estimate C sequestration rates on small farmer's fields. This study measured and compared the CO_2 flux between tillage and no-till agricultural management practices in the Senqu valley region of Lesotho in southern Africa.

Results
The present study provided important insights into the applicability of BREB measurement methods to investigate CO_2 sequestration at remote agricultural locations. The results of this study show that the total g CO_2-C sequestered for 7 days during the non-growing season in Aug and Sep 2011 was -0.03 and -0.01 g m^{-2} by the no-till and till plots respectively, and was -29.06 and -5.86 g m^{-2} during 5.5 days in Jan 2012, indicating that no-till management practices in Lesotho sequestered more CO_2 than conventional tillage. A description of the experiment, findings and lessons learned can be found in O'Dell et al. (2013).

Applications and Implications for Conservation Agriculture
Quantifying the ability of agricultural practices to sequester carbon is critical to recommending them as means for mitigating greenhouse gas emissions in carbon trading markets. This technology has the potential to measure the CO_2 emissions or sequestration potential of any agricultural practice in most climates and soil regimes and provides specific comparative values of practices to recommend, reward or penalize practices. This will be increasingly important because few methods simultaneously address food security issues and reduce atmospheric concentrations of CO_2 to mitigate climate change.

Experimental Approach

Carbon dioxide flux measurements comparing tilled and no-till treatments were calculated using Bowen Ratio Energy Balance (BREB) data collected between 2010 and 2012. A BREB system was established on each of two 100-m by 100-m sites that were planted with corn (*Zea mays*), with one site under no-till soil management and the other conventional tillage (plow, disk-disk).

Results and Discussion

This study implemented BREB micrometeorology instrumentation under demanding circumstances in a remote mountainous area. Much was learned in terms of the instrumentation robustness, power requirements and personnel support and processes. Though much of the data was lost or rejected due to these challenges, two periods showed that that there was greater sequestration of CO_2-carbon over no-till practice than the till treatment.

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Grain Yield and Protein Content of Wheat (*Triticum aestivum*) as Influenced by Nitrogen Fertiliser Application and Cropping System Under No-Till in the Swartland Sub-Region of the Western Cape of South Africa

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Background

Wheat is a very important winter cereal grown under dry land conditions in the Swartland sub-region of the Western Cape Province of South Africa. Wheat can be included in crop rotation systems after various crops including wheat, canola, lupin and medic. Information on carry over nitrogen and the rate of N mineralisation in soils that were planted to abovementioned crops (wheat, canola, lupin and medic) is not readily available in the Western Cape and needs to be quantified.

Grain yield and quality is a function of, amongst others, N supply. Adopting conservation agriculture (CA) leads to, amongst others, changes in soil organic matter content and a resultant increase in soil nitrogen mineralisation potential (Doran 1980, Tivet et al. 2013). As a result of this increase, a decrease in nitrogen fertiliser requirement of the wheat crop is expected. The aim of this study was to evaluate the effect of mineral nitrogen as influenced by the previous crop on wheat yield and grain protein content in no-till systems.

Applications and implications for conservation agriculture

Adoption of conservation agricultural practices during the late 1990's in the Western Cape resulted in changes of several important soil characteristics. Changing from monoculture wheat under conventional till to rotating non-related crops with minimum soil disturbance at seeding changed the characteristics of the uppermost layer of the soil. Amongst others, crop residue cover and soil organic C content increased. It is therefore necessary to revisit N fertilisation norms as it is expected that, as the positive influence of conservation agriculture develops, nitrogen fertiliser requirements will decrease.

Experimental approach

A trial was laid out at the Langgewens Research Farm near Moorreesburg (33^0 16'42.33" S; 18^0 42'11.62" E; 191m) to evaluate the effect of previous crop and nitrogen (N) application rate on wheat production and grain protein content grown under no-till conditions during the 2008-2010 seasons. The trial was laid out as a factorial arranged in a split plot design with previous crops (wheat in WWWW-, canola in WWCW- or medic in McWMcW system) allocated to main plots and N treatments to sub-plots. Nitrogen fertiliser rate treatments were either 0 or 30 kg N ha^{-1} at planting followed by various combinations of 0, 30 or 60 kg N ha^{-1}, 30 and/or 60 days after emergence. Fertiliser application rate was calculated as the sum of nitrogen applied during the growing season. Data were pooled as 0, 30, 60, 90 and 120 kg N ha^{-1}.

Results and discussion

A gradual increase in mean grain production in the McWMcW system was recorded as N fertiliser application rate was increased from 0 kg N ha^{-1} to 90 kg N ha^{-1} followed by a decrease in grain yield as N rate was increased to 120 kg N ha^{-1} (Fig 1). Grain protein content followed a linear increased response (R^2=0.9824) as N application rate was increased from 0 – 120 kg N ha^{-1}.

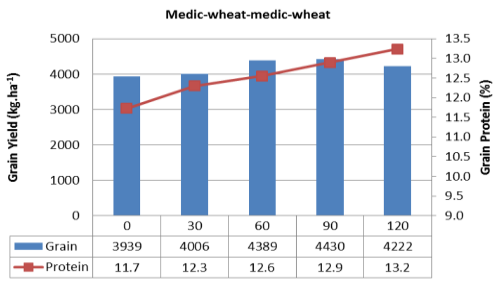

Figure 1 Influence of fertiliser N application rate (0, 30, 60, 90 and 120 kg ha^{-1}) on wheat grain yield and grain protein content (%) in a wheat-medic-wheat-medic system at Langgewens.

An increase in N fertiliser application rate resulted in a gradual increase in grain yield in the WWCW system. Although increased N fertiliser application rate resulted in a linear increased response (R^2=0.8405) in grain protein content, a definite decline in grain protein content was observed at 30 kg N ha^{-1}, a definite indication of N shortages during grain filling (Fig 2).

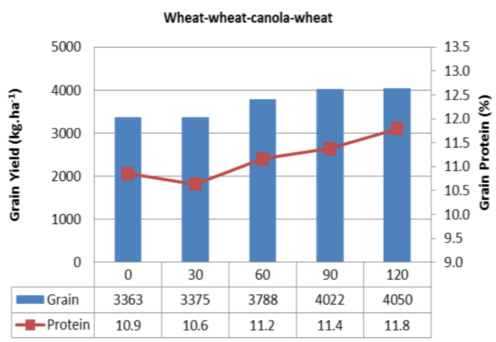

Figure 2: Influence of fertiliser N application rate (0, 30, 60, 90 and 120 kg ha^{-1}) on wheat grain yield and grain protein content (%) in a wheat-canola-wheat-lupin system at Langgewens.

The response to fertiliser N in the WWWW was similar to the WWCW, however at lower grain yield and grain protein levels.

Conclusions

Wheat that followed medic in a cropping system produced higher grain yields of higher grain protein content compared to the WWWCW and WWWW systems.

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Keywords: grain quality, nitrogen, wheat

Soil Properties and Carbon Sequestration in Conservation Agriculture in a MOLLISOL and INCEPTISOL of México

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Background
Conservation agriculture (CA) can improve physical and chemical properties of the soil, at the same time as it can mitigate global warming (Lal, 2010) by organic carbon and nitrogen sequestration in the soil, moderating greenhouse gas emission, such as CO_2 and N_2O. We hypothesized that, after thirteen years of treatment, no tillage (NT) and minimum tillage systems (MT) would increase organic carbon and nitrogen content at the soil surface compared with the effects of conventional tillage system (CT), additionally this would reflect in higher SOC and STN under NT, and MT than CT. Reduction of losses by erosion and addition biomass through retention of residues from previous crops in rotation can increase storage of SOC and STN under conservation agriculture, especially in the surface layer (Sainju *et al.*, 2008). The objective of this work was to evaluate the effect of three tillage systems on soil properties, emphasizing on soil organic carbon (SOC) and soil total nitrogen (STN) sequestration in a MOLLISOL and INCEPTISOL in the Central Valley of Mexico.

Experimental Approach
The study was conducted in an irrigated MOLLISOL and rain INCEPTISOL at Agricultural Experiment Station of Chapingo University (19° 29'N, 98° 53'W, 2240m altitude). Three treatments were evaluated, no till (NT), minimum till (MT) and conventional till (CT) in a Latin square design. Data were collected in spring/ summer bean crop 2011, thirteen years after experiment was set up. Soil physical properties studied were bulk density (Mg m^{-3}) and gravimetric water content (%) by undisturbed soil core random samples. Soil chemical properties studied were pH, organic Carbon content (OC) (%), total Nitrogen content (N) (%), availability of Potassium (K) (mg kg^{-1}) and extractable Phosphorus (P) (mg kg^{-1}) by random composite samples. Soil samples were collected at 0-3cm, 15-18cm, and 30-33cm of soil depth. SOC (Mg C ha^{-1}) and STN (Mg N ha^{-1}) sequestration were calculated by multiplying their concentrations (%) by bulk density for each treatment and depth, for 0-10cm, 11-21cm, and 22-33cm soil layers.

Results and Discussion
Physical and chemical properties were better in NT and MT compared with CT in both soil studied, mainly at 0-3 cm soil depth, but only some chemical properties showed statistically significant differences ($P \leq 0.05$). Soil OC and K showed differences statistically significant ($P \leq 0.05$) in INCEPTISOL and MOLLISOL, respectively, at 0-3 cm soil depth. Soil P showed differences statistically significant ($P \leq 0.05$) in both soils studied, at the same soil depth. SOC was mostly influenced ($P \leq 0.05$) by soil tillage treatments in the soil layers evaluated, emphasizing significantly greater value ($P \leq 0.05$) of SOC in NT than MT, and CT at 0-10 cm soil layer. Similarly, STN concentration varied mostly with treatments at the surface soil layer, but it was not significantly different (Figure 1). This indicates that retained residues of previous crops on the soil under CA increases SOC and STN at the surface soil (Sainju *et al.*, 2008), moderating greenhouse gas emission.

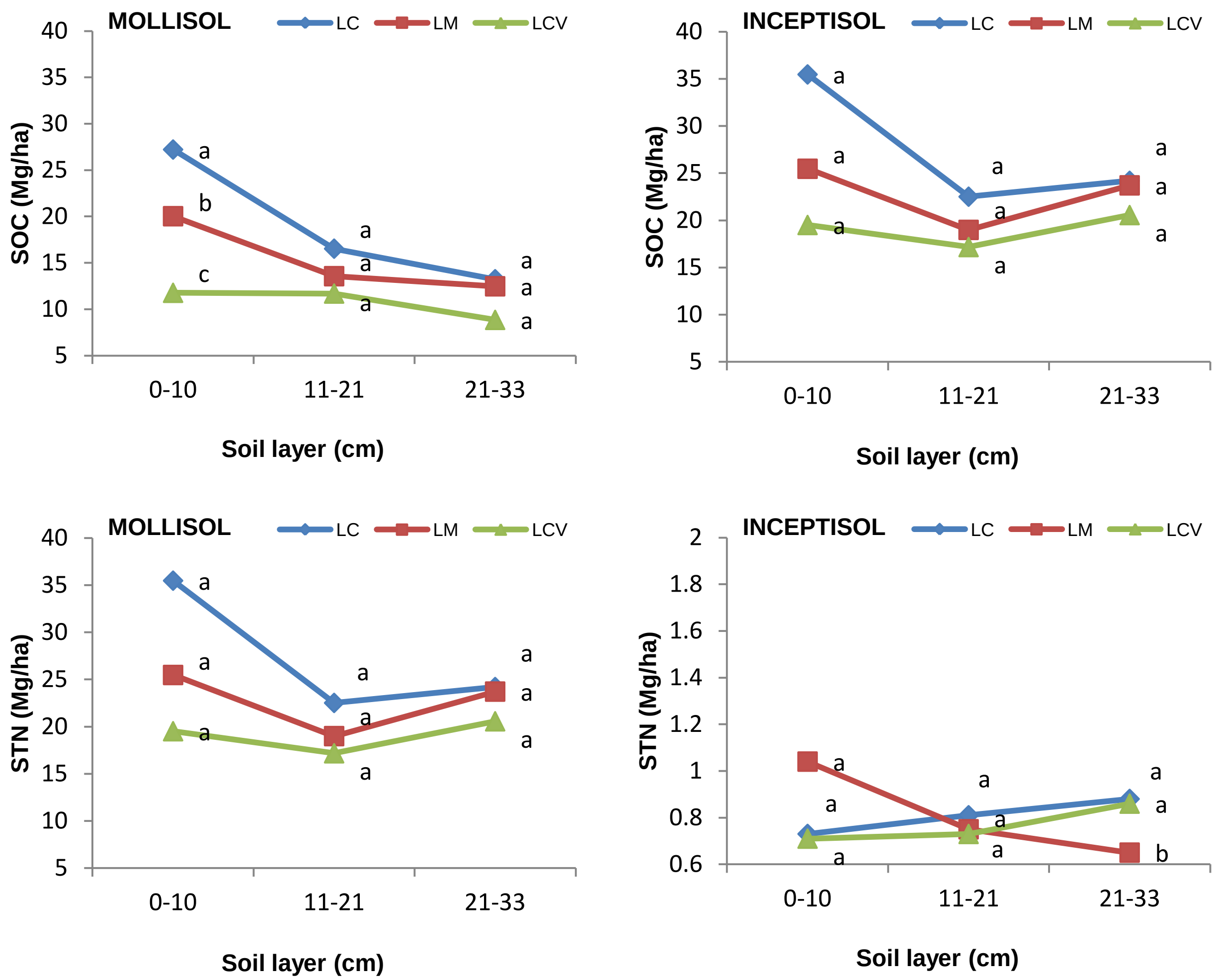

Figure 1. Soil organic carbon (SOC) and soil total nitrogen (STN) sequestration under three tillage systems (NT=no tillage, MT= minimum tillage, and CT= conventional tillage) after thirteen years of conservation agriculture in a MOLLISOL and INCEPTISOL of México.

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Dynamics of Soil Organic Matter, Organic Carbon and Organic Nitrogen under No-Tillage.

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Introduction

In Tunisia; cereals annually occupy each year an area which exceeds 1.2 million ha. Among these areas, 350,000 ha are affected by water erosion and the third is severely affected. Land productivity remains low and the causes are multiple. These lands are often on rough terrain with more than 30% on low to moderate slopes. Soils formed on tender rocks and poor in humus are sensitive to erosion and fragile. Irregular and torrential rainfalls promotes their erosion .Thus conservation agriculture has emerged as an alternative to conventional agriculture which is a new approach to the reversal of the process of land degradation, the improvement of the production and the preservation of the environment (Abdellaoui et al., 2006).

Cultivated areas according to this technique covers 12,000 hectares in Tunisia, operated by 78 farmers distributed as follows: 41% in the sub-humid, 30% in the lower semi-arid and 28% in the upper semi arid. The objective of this study is to determine the dynamics of soil organic matter, organic carbon and organic nitrogen under no-tillage.

Materials and Methods.

The study has been realized during the growing season 2012-2013 on the experimental site Kodia belonging to the National Institute of Field Crops (INGC). The climate is the higher semi-arid. The annual average of rainfall recorded during this cropping season is about 527 mm with a good distribution during the crop cycle. The soil is characterized by a sandy clay-loam texture: 46.74% sand; 27.66% clay and 25.6% loam. They contain low proportions of limestone and with a slightly basic pH. The total dosage of carbon is determined by oxidative pyrolysis at 950 °C by means of mapper purposes of fine ground samples previously decarbonated. Total nitrogen was determined by the Kjeldahl method on samples of fine ground purposes.

Results and Discussion

Results shows that (table.1), Organic matter is higher under no tillage than under conventional tillage in the depths of (0-10) and (10-20) (1.25 vs 1.15) and (1.20 vs 1.05), contrariwise conventional tillage is more enriched by OM than the no tillage in the layer 20-40 cm (1.40 vs 1.10). These results are in agreement with those of Benito and Sombrero (2006) who found the same trend for 0-10 and 10-20 cm after 10 years of trying. Also, according to Recous and Lawrence (2001), the plowing influences the dynamics of organic matter in the soil through changes in climatic conditions (temperature, water content, etc.) and the regular mechanical action exerted on the structure thereof. The plowing destroys soil structure and exposes organic matter previously protected to mineralization. However, these differences were not observed at a depth of 20-30 cm (Benito and Sombrero, 2006). Furthermore, after eleven years of testing, Müller et al. (2008) found that the distribution of humus in the soil profile varies greatly. Indeed, up to 10 cm deep in the soil under no tillage almost always contains more humus than under conventional tillage. Between 10 and 20 cm, the results are similar. Beyond 20 cm, plowed plots contain more humus.

We also recorded the same trend for organic carbon which is higher under no tillage for depths (0-10) and (10-20). Against under conventional tillage carbon is highest in the 20-40 layer. Saber and

Mrabet (2001) explain this trend by the fact that not distributing the soil under no tillage is responsible for the accumulation of organic carbon in the soil surface, while the low carbon content of the soil under conventional tillage may be due to high mineralization. Similarly Scopel et al. (2005) found a significant increase in the carbon content of the soil over time conducted under no till: the average growth rate is about 0.75 t / ha / year, while confirming the capacity of these systems to store carbon is largely related to their production capacity and restoration of biomass.

Table 1. Dynamics of soil organic matter (OM), Carbon (C) and Organic Nitrogen (Norg) of soil under no tillage and conventional tillage

	0-10		10-20		20-40	
Treatment	SD	SC	SD	SC	SD	SC
% OM	1.25	1.15	1.20	1.05	1.10	1.40
% C	0.72	0.66	0.69	0.60	0.64	0.80
% N org	0.168	0.184	0.137	0.182	0.124	0.228

Organic nitrogen is higher for all depths in conventional till. In the no till system, the rate of organic nitrogen is higher at the surface. on the other side, Oorts (2006) showed that after 32 years, the stock of organic nitrogen in the soil to a depth of 28 cm is more important in no till (4.4 TN / ha) compared to conventional till (4.1 TN / ha).

Conclusion

The results showed that the proportion of organic matter, organic carbon is higher at the 0-20 cm layer in no till compared to conventional till. On the other side, in the 20-40 cm layer, the Conventional till allows more enriching soil by organic matter and organic carbon. Organic nitrogen is higher for all depths in conventional tillage.

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Suitability of Maize-Based Conservation Agriculture Systems in Southern Africa– An on-Farm Study

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Background

Low levels of agricultural productivity, mainly caused by soil fertility depletion [1], are a key cause of food insecurity and hunger in tropical Africa, where over 260 million people are affected by constant or recurrent food shortages [2]. In addition climate change scenarios are forecasted to negatively affect agricultural production, particularly in Southern Africa [3]. Conservation agriculture (CA) has been proposed as a crop management system to reverse declining soil fertility while increasing the productivity of current farming systems [4, 5]. This study assessed the potential of CA to improve maize yields, and soil physical and chemical properties across different agro-ecologies in Southern Africa.

Experimental Approach

The study was carried out in 16 target communities of Mozambique, Zambia and Zimbabwe on 84 on-farm validation trials. The trials were clustered in groups of 3-10 per target community. The treatments tested were a conventional control practice (CP) compared to a conservation agriculture (CA) treatment. The trials were preexisting at time of sampling and they had been hosted by farmers and managed by farmers with the support of extension officers and CIMMYT technicians and scientists for up to seven years. The study measured maize grain yield; time to pond (a proxy for infiltration); soil physical and chemical parameters.

Results and Discussion

The present study confirms that CA has the potential to increase productivity per unit area for smallholder farmers (Table 1). Increases in maize grain yield under CA in southern Africa have previously been confirmed in on-station long-term trials [6-8] and more recently also from validation trials in Malawi and Zambia [9, 10].

Table 1: Effect of cropping system on Maize grain yield (t ha^{-1}); time to pond (s); soil carbon stock in the top 30cm of the soil profile (Mg ha^{-1}); and aggregate distribution of topsoil (0-10cm).

	Maize grain yield (t ha^{-1})	Time to Pond (s)	Carbon 0-30cm (Mg ha^{-1})	Aggregate Distribution[1] (MWD)
CA	3.62 a	8.74 a	37.96 a	1.28 a
CP	3.00 b	6.72 b	35.09 b	1.28 a
	**	**	.	
SED	0.0978	0.2039	1.1464	0.0337

Signif. codes: 0.001 ‘**’ 0.01 ‘*’ 0.05 ’.’

[1]Mean Weight Diameter determined through dry sieving by rotary sieve. MWD was calculated as the sum of the soil on each sieve multiplied by the mean sieve size of that particular sieve.

Several studies in southern Africa have shown increases in water infiltration and soil moisture [7, 11-14]. Time to Pond data from validation trials in Malawi [9] shows similar results as the present study. Given the climate change projections for the region [15] increased water infiltration will likely play a significant role in adaptation to seasonal dry-spells [12]. Results from existing case studies on the influence of tillage on C-stocks are not consistent and information on C storage in tropical and sub-tropical areas is also lacking [16]. The results presented here will contribute to our understanding of soil carbon and carbon sequestration.

Applications and Implications for Conservation Agriculture

The study confirms that CA can be a viable option for smallholder farmer in Southern Africa. Results show that it improves yield, increases water infiltration and C-stocks gradually. It may therefore help smallholder farmer adaptation to climate change.

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Lessons Learned in Creating Awareness of Scale-Appropriate Machinery for Strip Tillage and Bed Planting Through Video in Bangladesh

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Background

Southern Bangladesh is among the country's most impoverished regions, with over 3 million households subsisting primarily on cereals based agriculture (MOA and FAO, 2012). Since 2010, the CSISA project has worked in this region to encourage the uptake of resource-conserving and cost-reducing agricultural practices, with an emphasis on conservation agriculture (CA). However, the sheer number of farmers in the region presents great challenges to extension and training efforts. Public video screenings and the distribution of DVDs can provide an alternative way to share information with farmers and raise awareness. But in order to be communicate effectively, videos must have local relevance and should resonate with farmers. This is best accomplished when farmers themselves help to identify the information to be shared. A clear strategy for video dissemination is also necessary (Van Mele, 2006).

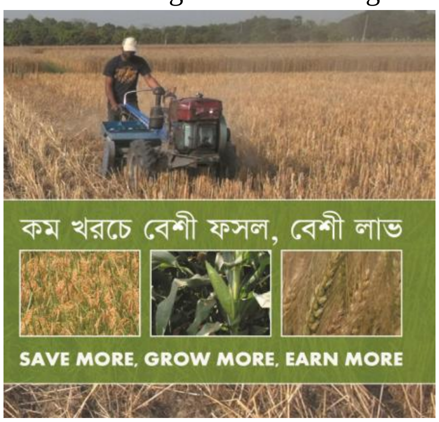

***Figure 1*. DVD cover showing an LSP preparing a field.**

In 2012, the International Maize and Wheat Improvement Cente(CIMMYT) and Agro-Insight produced a 20-minute film, entitled "Save more, Grow More, Earn More" (Figure 1; see also: http://www.accessagriculture.org/category/156/Mechanisation), focusing on scale- appropriate farm machinery for strip tillage and bed planting in Bangladesh. Much of the film's subject matter was identified through pre-filming focus group discussions and interviews with innovative and articulate farmers, many of whom also spoke in the video itself. We also focused on local service providers (LSPs), who are rural entrepreneurs familiar with CA. Most LSPs own their machinery, and sell CA land preparation and planting services to farmer-clients. Though full tillage is still the most common tillage service, CA is increasing in Bangladesh, with >300,000 two-wheel hand tractors (2WTs) that can be made compatible with direct seeding and bed planter attachments (Biggs et al., 2011). "Save more, Grow More, Earn More" showed machinery that LSPs can attach to 2WTs for strip tillage and bed planting.

After filming the videos, CIMMYT worked with the Agricultural Advisory Society to organize public video showings and distribute DVDs in southwestern Bangladesh. Using both qualitative methods and a phone survey (Bentley et al. 2013), this poster reviews some of the lessons learned in our efforts to use video to boost awareness of CA machinery and practices.

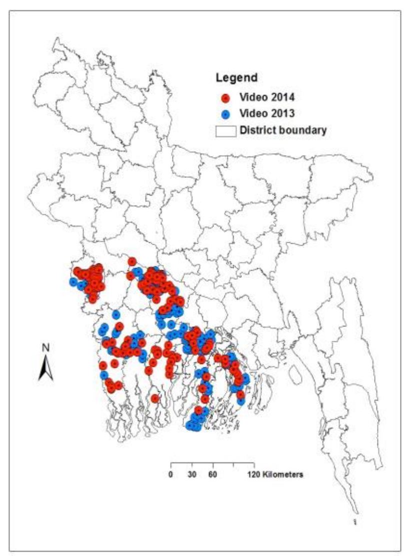

***Figure 2.* Locations of the 482 video shows in Bangladesh.**

Results

"Save More, Grow More, Earn More" was shown to 112,029 farmers in 482 screenings between 2012-14 (Figure 2), with active viewer engagement (Figure 3). Several of the shows included demonstrations of strip-tillage and bed planting machines, with demo plots where crops were grown to maturity in 51 villages. 1,439 copies of the "Save More" DVD and 6,350 leaflets describing CA and telling farmers where they could purchase 2WT-attachable machinery were also distributed machinery dealers, shop owners, lead-farmers, and 2WT owners.

***Figure 3.* Audience watching video in a village in Barisal,**

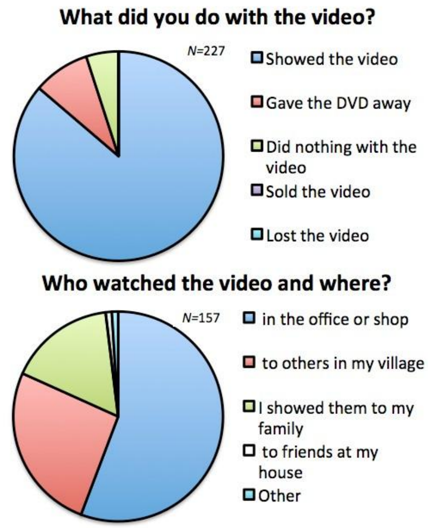

***Figure 4.* Results of mini-survey of machinery dealers, shop owners, lead-farmers, and 2WT owners who received additional DVDs.**

Applications and Implications for Conservation Agriculture

- *Distribute copies of DVDs wherever possible*. Of 227 people surveyed who received DVDs, 69% showed the video. 58% were agro- dealers, extension agents, NGOs or shop owners who showed the video to clients and customers (Figure 4). Some watched the video many times to study the content. Thoughtful distribution plans can help get DVDs to as many end-users as possible.
- *Make posters, not leaflets.* The leaflets were often forgotten or lost. Few people followed up by contacting machinery dealers. Posters may be more effective because they can be left in public places in villages, with extension agents, or in community centers.
- *Videos screenings open the door for LSPs and farmers to adopt CA practices*, but farmers and LSPs will also need hands-on training and technical backstopping to experiment with CA. Video screenings can be combined with practical planting and machinery demonstrations. Farmers and LSPs are more interested in seeing the performance of a crop grown by machinery than in seeing the machinery itself.
- *Video shows are prime media for linking potential CA service providers with machinery dealers.* Private firms should be involved from the start to plan showings, rather than as an add-on after film screening schedules are set by development projects.
- *Public video shows attract hundreds of people and raise many questions*. Showings are more effective when followed by a question and answer session led by a skilled facilitator with sufficient technical knowledge, using microphones and speakers so that farmers can ask more about what they have seen.

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Water management for cucumber: Greenhouse experiment in Saudi Arabia and modeling study using SALTMED model

SOIL CONSERVATION COUNCIL OF CANADA
CONSEIL CANADIEN DE CONSERVATION DES SOLS

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Introduction

Agricultural land expansion throughout the world with limited and misuse of natural resources causes significant losses and degradation in biodiversity and ecosystem function (Qadir et al. 2013). In Saudi Arabia, both farmers and governmental agencies started changing irrigation strategies since 1995 by using surface and subsurface drip irrigation. This could save irrigation water while maintaining satisfactory crop production (Al-Omran et al. 2013). To save irrigation water and increase crop water productivity (CWP), moderate deficit irrigation (DI) has to be applied (Kirda et al. 2004; Cheng et al. 2012); this means crops are deliberately exposed to some degree of deficit irrigation through all, or certain, growth stages (Kirda et al. 2004).

Deficit Irrigation System, DI

DI is defined as an optimization strategy in which irrigation is applied during non-drought-sensitive growth stages of a crop (English 1990). No major change was observed when water was applied above 100% ETc. Mao et al. (2003) studied the effect of water deficit on the yield and water use of cucumber planted in a greenhouse in China and concluded that the CWP decreased when increasing the irrigation water applied from stem fruiting to the end of the growth stages. On the other hand, the CWP improved with an increase of applied water from fruit setting to the first fruit repining of cucumber.

SALTMED model

The study of successive salinity and wetting patterns and root water uptake under DI needs detailed water soil monitoring and measurements. Numerical modeling is considered as a cheap, rapid, and labor saving tool for simulating water and solute dynamics under different irrigation methods and techniques (Selim 2012). The SALTMED model (Ragab 2012) has been developed for such generic applications. The model employs established evapotranspiration, solute and water transport and crop water uptake equations (Ragab 2002). Because the Saltmed model was successful under different climatic conditions, irrigation water qualities and irrigation types in different places throughout the world, there is substantial benefit in testing the latest version of the model for its suitability in Saudi Arabia's arid conditions. This model could help not only in irrigation scheduling, estimating crop water requirements and irrigation water conservation but can also be used to predict yields and soil salinization.

Purpose

The main objectives of this study are to investigate:

1. Effect of deficit irrigation under greenhouse conditions on cucumber yield and crop water productivity (CWP).
2. calibrate and validate the SALTMED model using the obtained experimental data.

Methods

Experimental design

Field experiments were conducted in April 2013 at the greenhouse complex of Almohous Farm, 120 km northwest of Riyadh, Saudi Arabia (altitude: 722 m above mean sea level, latitude: 25° 17' 40" N and longitude: 45° 52' 55" E). Hundred and ninety-two soil samples were collected from each treatment and its replicate during different growth stages representing the soil near emitter at 0-15, 15-30, 30-45 and 45-75 cm depths.

Chemical properties of irrigation water.

EC (dS/m)	pH	Cation and anion concentration (meq/L)								SAR	Trace elements (mg/L)		
		Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		Fe	B	NO_3
1.43	7.1	4.2	2.4	7.3	0.13	0.0	2.0	7.2	5.0	4.1	0.20	0.81	7.0

Irrigation scheduling methods was based on pan evaporation because they are easy to use, and were available in the greenhouse (Mahajan and Singh 2006; Zhang et al. 2003). Crop evapotranspiration (ETc) was calculated using the following equation:

$$ETc = Eo \times Kp \times Kc \qquad (1)$$

Where: ETc is the maximum daily crop ET in mm; Eo is the evaporation from class A pan in mm; Kp is the pan coefficient (ranges between 0.70 and 0.88); Kc is the crop coefficient (ranges between 0.57 and 1.26 depending on growth stages). The Kp and Kc were calculated according to the equations of Allen et al. (1998). The gross water requirement (GWR) was calculated by the following equation (Cuenca 1989):

$$GWR = \frac{ETc}{(1-LR)\times Ea} \qquad (2)$$

$$GWR = \frac{Kc \times Eo \times Kp}{(1-LR)\times Ea} \qquad (3)$$

Where: GWR is the gross water requirement in mmday[-1], Ea is the irrigation efficiency and LR is the percentage of leaching requirement. The Ea was calculated according to Savva and Frenken (2002) as follows:

$$Ea = Ks \times EU \qquad (4)$$

Where: Ea = Irrigation efficiency, EU = emission uniformity (%) and Ks = the water storage efficiency of soil

Then the EU was calculated using the following equation:

The EU for our experiment was 0.964 (preferred); however, the Ks was assumed 0.95 according to Savva and Frenken (2002). The Ea was calculated and equal 0.92.

The LR was calculated according to Ayers and Westcot (1985) as follow:

$$LR = \frac{ECw}{(2 \times max\,ECe)} \qquad (5)$$

Where: ECw is salinity of irrigation water (1.43 dSm[-1]), and max ECe is the electrical conductivity of the saturated soil extract

$$CWP = \frac{Yield}{Water\ Applied} \qquad (6)$$

The quadratic polynomial function of Helweg (1991) was expressed as follows:

$$Y_a = b_0 + b_1 W + b_2 W^2 \qquad (7)$$

Where:

Y_a is crop production or yield, Mg ha[-1], W is applied irrigation water, m³ ha[-1] and b_0, b_1 and b_2 are fitting coefficients.

The maximum predicted yield (Y_{max}) can be calculated by substituting the W_{max} in the Eq. (7):

$$\frac{\partial Y}{\partial W} = +b_1 + 2b_2 W = 0 \qquad (8)$$

$$W_{max} = \frac{-b_1}{2b_2} \qquad (9)$$

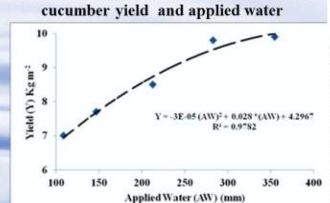
$$Y_{max} = b_0 + b_1 W_{max} + b_2 W^2_{max} \qquad (10)$$

Model data requirements

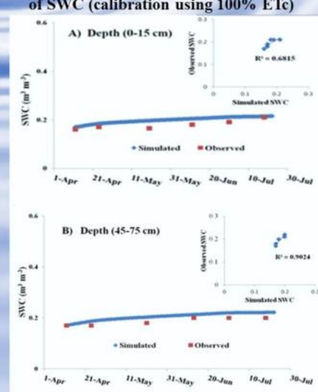
1. Plant characteristics include crop coefficient, Kc, Kcb (Allen et al. 1998), depth of root and lateral extension, height of the crop, and final yield observed in the region under optimum conditions.
2. Soil characteristics include soil horizon depth, hydraulic conductivity, saturated soil water content, diffusion coefficient of salt, coefficient of longitudinal and transversal dispersion, initial soil water and salinity profiles, and tabulated data of soil water versus soil water potential and soil water versus hydraulic conductivity. Soil parameters such as water retention curves were obtained from laboratory measurements. Initial soil water content, depth and salinity of shallow groundwater, and soil salinity were obtained also from field measurements.
3. Meteorological data include daily values of maximum temperature, minimum temperature, relative humidity, global and net radiation, wind speed, and daily rainfall. Those data were collected from our meteorological station which was located inside the greenhouse near the experiment.

Results

The Relationship between marketable total cucumber yield and applied water



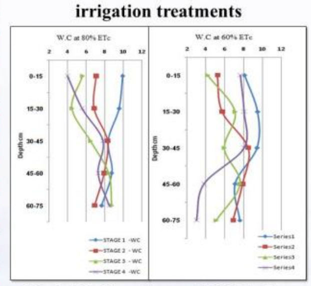
Measured versus simulated, and correlation of SWC (calibration using 100% ETc)



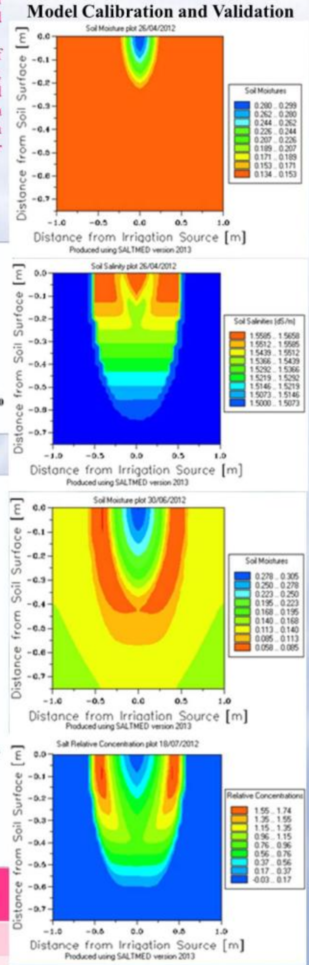
ETc%	Observed yield (Mg ha[-1])	Simulated yield (Mg ha[-1])	
100%	99.3	94.0	
80%	98.0	91.0	
60%	85.0	88.0	
40%	77.0	80.0	
30%	70.0	77.0	
RMSE			0.313
CRM			-0.002

Differences between simulated and observed cucumber yield for the five irrigation treatments for the 2013 growing season.

water content throughout deficit irrigation treatments



Model Calibration and Validation



soil moisture, salinity and salt relative concentration plots and soil, salt distribution vertical and horizontal and crop yield during stage one predicated by SALTMMED program.

Greenhouse Gas Offsets – Alberta's Market Experience

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Background

The global population is projected to grow by another two billion to a total of nine billion by 2050 however the global economy is expected to quadruple in the same period, putting enormous pressure upon energy sources and human impacts on natural resources (OECD, 2012). Global climate change is expected due to the continuing increase in greenhouse gas (GHG) emissions, so substantial decreases in emissions are needed to limit the predicted climate changes and associated strains on society (IPCC, 2013). Innovative policies are needed to constrain the growth in GHG emissions.

One policy tool is that of carbon or GHG markets to encourage emission reduction trading. The World Bank (2012) valued global carbon markets at US$176 billion with the largest portion (84%) from the European Trading Scheme of emission allowances. The secondary Certified Emission Reduction (CER) offset market was valued at US$22 billion (12% of total). Continued global interest in carbon markets saw five new economy-wide cap and trade systems announced as of 2012 although the Australian system has since been stalled with changes in government (World Bank, 2012).

The province of Alberta has the largest proportion of GHG emissions in Canada (39%) due to its large energy production profile (Environment Canada, 2014). The Alberta government realized that policies to reduce emissions were needed early on and became the first province with a climate change strategy in 2002, followed by amendments in 2007 to create a compliance offset system for large emitters of GHGs.

Results

The current compliance system requires all industrial facilities with annual GHG emissions more than 100,000 tonnes CO_2e to file annual inventory of emissions of all GHGs and reduce emissions by 12% below their 2003-2005 baseline. Currently there are about 100 facilities that are under compliance. In order to meet their reduction targets, facilities conduct internal modifications and improvements to reduce emissions and have three options available to enable them to comply with the annual reduction targets.

They may purchase:

1. Emission Performance Credits. Obtain performance credits (buy, trade, etc) from other regulated companies that have reduced their emissions beyond their reduction target.
2. Technology Fund Credits. Pay into the Climate Change and Emissions Management Fund at a set price of C$15/tonne CO_2e. Funds collected are to be used to develop or invest in Alberta based technologies, programs, and other priority areas.
3. Emission Offsets. Companies may offset their emissions by purchasing emission reduction offsets from unregulated companies who voluntarily undertake projects to reduce emissions.

Emission offsets are obtained from project developers using government approved protocols and securing credits from within Alberta. Currently there are over 30 protocols available to developers. Alberta was the first jurisdiction to recognize agricultural offsets. Alberta offsets are developed following the ISO 14064-2 process, are internationally compatible, and standardized. They are based on best possible science with rigorous technical review and use emission factors and calculations which require tracking of practice changes rather than the prohibitive costs of monitoring and measuring all GHG changes. Valid projects must use government approved protocols, be third party verified and be serialized on the Carbon Offset Registry.

Applications and Implications for Conservation Agriculture

Alberta's offsets, especially the Tillage System Management Protocol recognize the scientific basis for NoTill increases in sequestration of carbon, addresses additionality by allocating only newly sequestered carbon and permanency using a discounting approach. This illustrates the legitimacy of CA mitigate GHG emissions. Swallow and Goddard (2013) contrasted Alberta and two bio-carbon schemes in Africa and provide an analytic framework to evaluate the institutional characteristics and actors that benefit and impede market schemes.

Result and Discussion

Between 2007 and 2012, Alberta's entire GHG reduction program lowered emission intensities by 34 million tonnes (Mt) of carbon dioxide equivalents (CO2e), which is similar to taking over 6 million cars off the road. Close to 58% of the reductions were from GHG offsets, with 39% from applying the Tillage protocol. Aggregator companies assembled 72 projects with farmers from across Alberta, had them verified by a third party and listed them on the Registry. Although price disclosure is not required, the $15 alternative price for the Technology Fund option effectively caps the price. Offset sales are somewhat less but still represent about $175 million of revenue for the agriculture sector.

The important role of aggregators is recognized as essential to assemble projects. The shifting policy to accommodate evolving expectations and scheme requirements in Alberta has increased transaction costs (Tarnoczi, 2011). Without a change in the carbon price, diminishing margins do not forecast a vibrant market.

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Real-time Carbon Sequestration Rates on Smallholder Fields in Southern Africa

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Background

Soil carbon gains and losses generally determine soil quality and sustainability. Soil degradation continues to jeopardize food security throughout Africa. Farmers often respond to these low yields by farming more land in an effort to achieve household food sufficiency and security. However, good agronomic practices can significantly improve overall household wellbeing through managed intensification. Improving soil fertility and crop yield through conservation agriculture can reduce pressure to convert forests or marginal land into farmland as is the conventional response to declining agricultural productivity. Conservation agriculture practices thus have multiple benefits by increasing food security, soil fertility and sustainability, and soil carbon sequestration, while forestalling the conversion of higher carbon-content forests and grassland soils to cropland (Grieg-Gran, 2010). With these multiple benefits, the overall GHG mitigation potential of these practices is probably underestimated. While it is common knowledge that tillage results in soil C loss it is less clear at what rate C is either lost or gained in agricultural settings especially in remote smallholder farming areas in Africa. Our soil fertility/agronomic research has improved maize (*Zea mays*) yields roughly 20-fold from less than 0.5 Mg/ha to greater than 10 ton/ha in many areas of Zimbabwe and Lesotho (Bruns, 2012). The objectives of this research were to quantify real-time C sequestration rates on four different 0.64 ha fields. Each treatment had either a wheat (*Triticum aestivum*), blue lupin (*Lupinus angustifolios* L.) or no cover crop with residue incorporated (tilled) or left on the surface (untilled).

Results

From June 14 through October 31, 2013 (140 days), approximately 258 g CO_2-C were sequestered per m^2 in the wheat cover crop, while 73 g CO_2-C were emitted per m^2 under the blue lupin, and 144 and 215 g CO_2-C were emitted for the tilled and untilled respectively. These results suggest that cover crops can not only significantly reduce emissions but can sequester a substantial amount of C compared to tilled soils or soils left fallow.

Applications and Implications for Conservation Agriculture

This research provides evidence that cover crops—a suggested but not mandated tenet of conservation agriculture—reduce CO_2 emissions and sequester C compared to tilled soils or soils untilled or left fallow. Although agriculture has long been known to contribute to CO_2 emissions, as evidenced by declining soil C following plowing, this research demonstrates that with proper soil management practices soils can sequester a substantial amount of carbon thereby providing agriculture a unique opportunity to offset greenhouse gas production from fossil fuel emissions as well as errant agricultural practices. Slash and burn agriculture, widespread deforestation, and intensive tillage practices are major contributors to the climate change problem whereas farmers—even small farmers—that embrace CA can have a major impact locally as well as mitigate the global problem. This is an important outcome because this is one of the few means to effect this problem and a means that ALL farmers could and should embrace.

Experimental Approach

The Bowen ratio energy balance (BREB) system was used to measure CO_2 flux in real time over agricultural treatments. This flux-gradient micrometeorology approach measures larger areas addressing the spatial variability of CO_2 flux from soil. CO_2 concentration, air temperature and vapor pressure are measured and recorded every 5 minutes from sensors housed in rotating arms at two heights. There are at least 15 other measurements including net radiation, soil heat flux and temperature. Energy and CO_2 fluxes are calculated for each of four instruments and compared.

Results and Discussion

Wheat cover crop sequesters C, while fallow tilled and untilled emits CO_2. Other more sparse cover, such as the blue lupin may not sequester C but emits less than fallow. We have developed an approach that is robust and can be used in developing countries to measure and quantify the emissions and mitigation potential of agricultural practices. Our first study in Lesotho comparing till and no-till was a field test of this approach and conducted in demanding circumstances in a very mountainous area. We refined the instrumentation and approach and in our second study we lost about 9% of data for one of the treatments, which is still much less than the average of 35% of data missing or rejected reported by FluxNet sites (Gilmanov, et al., 2010).

By measuring conservation agriculture practices over the short term for different climates and soil regimes, we can make climate smart recommendations to CA practitioners and policy recommendations for carbon market compensation.

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