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Session 2: Conservation Agriculture: Soil Health/Biology as Key Factors

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Healthy Soil is the Foundation for Food

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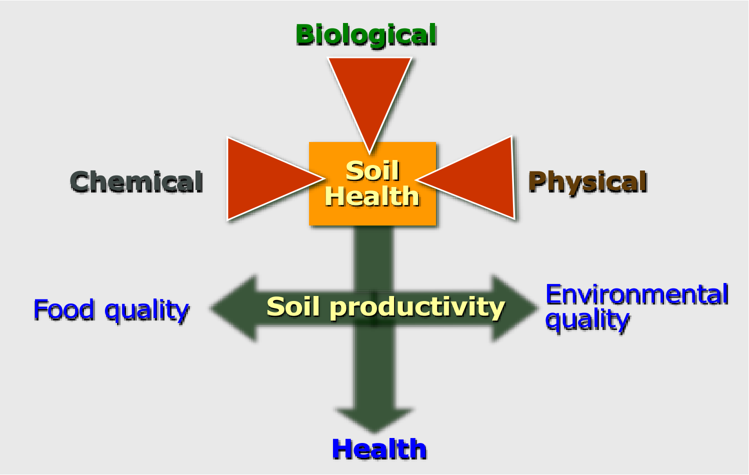
Why do we treat soil like dirt? Why do we support practices that allow our soil to wash away in rainstorms or with irrigation, blow away in the wind, and burn up with tillage. How much soil can we lose before we say enough? When is it too late to start creating healthy productive soil? We have choices.

This is a conceptual paper that discusses and demonstrates the value of soil conservation practices to create healthy productive soils.



The essential practices of Conservation Agriculture teach us to minimize soil disturbance, keep the soil covered as much as possible, and rotate our crops. These practices allow farmers to influence the ability of the soil ecosystem to provide essential services such as decomposition, nutrient cycling, and pest management (depending on our practices we can either help or hinder soil ecosystem functions). This in turn, can affect the nutrient quality of the food and forages we produce, and ultimately human and animal health.

In agriculture, we modify the soil habitat with tillage, forage crops and crop rotation practices. Annual tillage collapses the soil lattice structure with its maze of soil pores, and recycles all the soil biological activity, cuts up the carbon and micronutrient trading network of the mycorrhizal fungi, selecting for the organisms that can function in a dysfunctional system.

Soil biota require belowground infrastructure or a suitable soil habitat, with a stable soil pore network so they can move easily from one resource to another, just like people need roads, running water, electricity, and communication networks to work effectively and efficiently. Earthworms and some insect larvae for example, have the ability to burrow. However, most of the other organisms that live in the soil need good soil structure in order to do their job.

Stable soil aggregates and a continuous soil pore super highway network are essential infrastructure to facilitate predator/prey relationships. These relationships are the command center for nutrient cycling. Microorganisms are the primary producers in soil, and they can out compete the plant for nutrients every time. Predators like protozoa and nematodes keep the populations of bacteria in check, and concentrate the nitrogen from eating the bacteria in an organic form that plants can use- in the rhizosphere! The predators need to use the soil pore network to reach their prey. Most of the organisms (including plant roots) that live in the rhizosphere are trying to modify the soil structure so they have a unique advantage over the competition.   Reduced tillage, cover/forage crops, retained plant material (e.g. stubble, chaff, corn stover) and crop rotation can be used together to create really awesome, well structured soils.

Soil fertility is largely dependent on the processing of organic substrates – root exudates, and residues or soil organic matter (SOM)- through the soil food-web. There are three primary carbon (C) sources: root exudates, litter or residues, and soil organic matter. These C sources vary in their availability and accessibility to soil organisms, and thus, increase the C flow and biodiversity within the food web. The bacteria can immediately use the C that leaks from the roots, protozoa and nematodes eat the bacteria that are attracted to the roots, and the mites and collembola chew on the dead and dying roots and shoots.

The diversity of root architecture and exudates added the agroecosystems by growing mixed forage and/or cover crop can accelerate rhizosphere processes. In the rotation they can enhance soil structural stability, increase the amount and quality of soil organic matter - to depth (providing a diverse source of root exudates) and increase the number, diversity and activity of most soil organisms. The advantages of these practices have been documented for over 100 years.

The take home message is that for healthy productive soils we need lots of biological activity to transform or mineralize the organic nutrients into the inorganic nutrients that the plant can use, predator- prey relationships have an important role to play in feeding and protecting crops, and we can speed-up the rate at which the soil biota create well structured soils by reducing soil tillage and using mixed species forage/ cover crops or soil health primers in rotation.

Conservation agriculture promotes a winning synergy between plants and soils. Better soil structure means more roots, healthier plants, more roots again, and more root exudates from more root surface area (are you starting to see the cyclical pattern?). Together this means more biological activity in the rooting zone (rhizosphere), more predator/prey activity recycling nutrients near the root, less disease (healthier plant) and the cycle keeps spiraling in a beneficial way. Rhizosphere processes are also the key to moving more C belowground, and growing nutrient dense food.

Soil is the foundation of agriculture so allowing it to erode will have a direct impact on the productivity of the soil, that means more inputs, a higher cost of production, and less net return. The scenario is the same for both the upstream and downstream farmer. There are no good reasons for allowing our soil resources to degrade and erode.

Healthy soil means healthy food, and better nutrition for us all, including our livestock. Feed your soil so it can feed the plants. That means looking at the quality of organic matter not just the quantity, and understanding more about how you can actively build organic matter in your soil type and climate. It would always be a good idea to study soil health, not in isolation, but in the context of agroecosystem health, knowing that one size fits no one. The good news is that the processes behind creating healthy soils are universal and can be adapted to where ever you live. There will be different players in the soil health “theatre” for every different agroecosystem, but they will all be working towards the same goal- creating a better habitat.

When you have soil health, you have a functioning agroecosystem, and a better bottom line. So remember that when you are standing on the ground you are standing on the rooftop of another world.

Technological Interventions for Strategic Management of Water for Conserving Natural Resources

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Key words: Conservation agriculture, Resource Conservation Technologies, Technological interventions, Water management strategies

Abstract

Conservation agriculture (CA) has put forth management of water strategically so as to conserve and preserve our natural resources against soil deterioration and its environmental repercussions. Appropriate major technological interventions in today's agriculture are those which are strategically adopted so as to fit in the ecosystem or agricultural production system for its overall improvement over space and time. Here comes the role of resource conservation with appropriate conservation tillage that characterizes the development of new crop production technologies that are normally associated with some degree of tillage reductions, minimum mechanical operations, and more crop residue retention on the soil surface. Conserving natural resources, however removes the emphasis from the tillage component and addresses an enhanced concept of the complete agricultural system as CA refers to the gamut of practice or technological interventions (RCT) with three basic principles of minimum disturbance of soil through practices like zero or no tillage, keeping soil surfaces covered by leaving crop residues on it, and adopting diversified crop rotation measures, and growing crops that have a symbolic correlation to each other. Thus, CA with its roots in universal principles of providing permanent soil cover, minimum soil disturbance and crop rotations is now considered the *EXPRESS WAY* to sustainable agriculture.

In India efforts to adapt and promote RCT have been underway for nearly a decade but it is only in the past 4-5 years that the technologies are finding rapid acceptance by the farmers although these are more or less confined to irrigated agro-ecosystems. Water being the critical input for productivity enhancement, there is a need for its optimum and judicious use (through supplementary irrigation) for realizing higher input use efficiency through various technological options available. These should be in synchrony with the above basic principles of resource conservation. In this paper, an attempt is made to discuss the novel strategies for an effective water management mediated through RCT. An implication of this is to bring together all the stake holders to share information/experiences and to encourage interaction for future research and development efforts in fulfilling our Millennium Developmental Goals (MDG) for realizing production sustainability through conservation agriculture. The key technological interventions (KTIs) include some of the following strategically important components of CA.

KTIs for water management: Need is arisen for evaluating existing CA technologies for developing the efficient water management strategies for their farm level impact in India. KTIs such as *precision land leveling, no-till systems, furrow irrigated raised bed (FIRB) planting systems, crop diversification and its residue management* have shown tremendous potential for efficient water use and its use efficiency (WUE) for sustainable farming systems (Praharaj et al. 2011, Mishra et al. 2012a,b). Unevenness of the soil surface influences the farming operations, drudgery involved, energy use, aeration, crop stand and productivity mainly through nutrient-water interactions. The general practices of land leveling used by the farmers in India is either through use of plankers drawn by draft animals and small tractors or by iron scrappers/ leveling boards drawn by 4-wheel tractors (as in Indo-Gangatic Plains of India known as IGP) are not so perfect (less input use efficiencies and low yield at the cost of more water). Here laser land leveling is useful especially in intensively cultivated irrigated farming through achieving a better crop stand while saving irrigation water with improved input use efficiencies. As a result, zero-till seed drill performed better on a well leveled field compared

to unleveled or fairly leveled field due to better seed placement, germination and uniform distribution of irrigation water and plant nutrients (Sankaranarayanan 2008). Zero tillage allows timely sowing of wheat, enables uniform drilling of seed, improves fertilizers use efficiency, saves water and increases yield up to 20 percent. Similarly, the importance of no till system in India is quite evident in terms of greenhouse gas emission and carbon sequestration (Venkatesh et al. 2013). It is estimated that for each litre of diesel fuel consumed, 2.6 kg of CO_2 is released to the atmosphere. Assuming that 150 litres of fuel is used per hectare per annum for use of tractor and irrigation in conventional system, it would amount to nearly 400 kg CO_2 being emitted per annum per hectare. Thus, the role of no tillage/conservation agriculture in economic growth can't be undermined.

In "*Furrow Irrigated Raised Bed (FIRB) planting systems",* the crop is sown on ridges or beds of 15-20 cm height and 40-70 cm width depending on the crops to enhance crop productivity and save the irrigation water (as in wheat growing area of NW Mexico). Potential agronomic advantages of beds include improved soil structure due to reduced compaction through controlled trafficking, and reduced water logging and timelier machinery operations due to better surface drainage. Typical irrigation savings range from 18% to 30-50% (Hobbs and Gupta 2003, Jat *et al* 2005a,b). Trials by Farmer/researcher in IGP suggest irrigation water savings of 12 to 60% was accrued for direct seeded (DSRB) and transplanted (TRB) rice on beds, with similar or lower yields for TRB compared with puddled flooded transplanted (PTR) rice (Balasubramanian *et al*. 2003). Similarly, raised bed planting out yielded flat planting by 18.8% and also enhanced both water use and WUE in chickpea (Masood Ali 2009).

In the case of crop residue management, drop in soil organic matter (SOM) due to limited/reduced return of organic biomass has been identified as one of the key factors for unsustainability of the system (Singh *et al.* 2011). Improper crop residues Management (burning) due to inadequate *in-situ* recycling (Jat *et al.* 2004) not only leads to loss of considerable amount of N, P, K and S but also contributes to the global NO_2 and CO_2 budget (Grace *et al.* 2002) and destruction of beneficial micro-flora of the soil as a substantial quantum (80.12 m t per annum) of crop residues is available (Pal *et al*. 2002) for recycling in rice-wheat system. Similarly, growing a *cover crop/crop diversification* improves the stability of CA system and agro- ecosystem biodiversity. Legume intercropping in cereals grown with wider row spacing reduces nitrate leaching. *This is why CA systems will be the most thrust of the future farming.*

In *micro-irrigation techniques,* precision technologies are used for efficient management of both water and nutrient precisely near the root zone of crop plant with proven advantages of enhanced conveyance and water use efficiency. In the era of supplementary irrigation, there is a greater need to apply both fertilizer and water through drip especially at very critical stages to improve input productivity of crop, water & nutrient (Praharaj and Narendra 2012). Study also suggests that a single irrigation (20 mm in 5 splits) by drip- fertigation with half of N+K fertilizers at branching produced significantly higher (20%) seed yields and economic return over rainfed pigeonpea (Praharaj 2013). In chickpea, pre-plant irrigation + one irrigation at pre-podding stage increased seed yield by 77% over no irrigation. In addition, use of antitranspirant (HICO) gave significantly higher seed yield (33%) over control under rainfed conditions although no such improvement was recorded in irrigated condition (Masood Ali 2009). As conservation efforts often concentrate on maximizing the efficiency of the existing system, improved back up practices such as chiselling compacted soils, creating furrow dikes to prevent runoff, and using soil moisture and rainfall sensors to optimize irrigation schedules have their role to play.

Constraints in CA System: Conservation agriculture poses a challenge both for the scientific community and the farmers to overcome the *past mindset* and *explore the opportunities* that CA offers for natural resources improvement. Successful adoption of CA systems will call for greatly accelerated effort in developing, standardizing and promoting quality machinery aimed at a range of crop and cropping sequences, permanent bed and furrow planting systems, harvesting operations to manage crop residues, etc. Managing CA systems will be highly demanding in terms of knowledge base as it calls for enhanced capacity building and partnerships with concerned stakeholders. CA also determines the whole system performance. For example surface maintained crop residues act as mulch and therefore reduce soil water losses through evaporation and maintain a moderate soil temperature regime. However, at the same time crop residues offer an easily decomposable source of organic matter and could harbour undesirable pest populations or alter the system ecology in some other way. *Adaptive strategies for CA systems will also be highly site specific* yet learning across the sites will be a powerful way in understanding why certain technologies or practices are effective in a set of situation and not effective in another set. This will greatly accelerate our *learning process* for a sustainable resource management.

To conclude CA has emerged as a way for transition to the sustainability of intensive production systems over the past 2–3 decades globally. Since CA permits improved and efficient management of water and soils for agricultural production, it has assumed importance in view of the widespread natural resource degradation. This is attainable through effective and appropriate CA strategies aided RCT technologies. Attempts to promote CA globally are underway as reflected from developments worldwide where the objective of bringing together farmers, scientists, private sector stakeholders and decision makers to share information and experiences and to encourage interaction for future research and development efforts.

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Microbial Community Structure After Long-Term (31 Years) of Conservation Tillage under Continuous Cotton in West Tennessee

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Background

Microbial abundance and activity of microbial communities are key factors attributed to soil quality improvements in conservation agricultural (CA) practices due to their critical role in biogeochemical cycling. To gain insight on the importance of these shifts, it would be necessary to know the structure and composition of the microbial community after long-term (CA) practices and how this may have impacted soil biochemical properties. The objective of this project was to conduct a comparative analysis of the microbial community structure and activity of soils under a long term CA practices under continuous cotton production (31 years) in West Tennessee.

Experimental Approach

The experimental design of the research plots enables the assessment of the interactions of tillage and cover cropping under varying N application rates. The experimental design was set up in a randomized complete block design (RCBD) with a split-split plot. The main treatment factor is nitrogen fertilizer application rates at four levels (0 Kg Nha^{-1}, 34 kg Nha^{-1}, 67 kg N ha^{-1}and 101 Kg Nha^{-1}), the split plot factor being cover crop (winter wheat -*Triticum aestivum.* L; hairy vetch-*Vicia villosa*; and no cover), and the split-split plot being two tillage practices NoTill and Till. The soils at the site are classified as Lexington silt loam (fine-silty, mixed, thermic, Ultic Hapludalf), well-drained with a 0 to 2 percent slope.

We evaluated the microbial structure as affected by the different practices based on microbial biomass C and N (MBC/N), and microbial community structure via fatty acid methyl ester (FAME) analysis (Schutter and Dick 2000). As an indicator of changes in soil quality, select soil physicochemical properties were assessed that included total carbon (C) and nitrogen (N), bulk density (BD), soil pH, and the availability of select extractable plant nutrients phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Data were analyzed by a Mixed Model Analysis of Variance (ANOVA) and means separated using Fisher's protected LSD using SAS (SAS Institute, Cary, NJ, 2012). Exploratory principal component analysis (PCA) was performed on the correlation matrix using the Vegan package (ver. 2.0-2) in R (Oksanen et al., 2011) to distinguish treatment separation of the microbial FAME biomarkers for fungi and bacteria as influenced by tillage, cover crop and N-rate.

Results, Discussion and Implications for Conservation Agriculture

After 31 years of CA practices, our results demonstrate the value of cover crops and increased crop residue in enhancing soil organic C and N in reduced tillage practices especially under the production of low biomass crops like cotton. Total C and N levels were greater in treatments under NoTill (approximately 19% and 10% higher for TC and TN respectively) which was particularly significantly higher for NoTill treatments having cover crops within the lower N-rates (0, 34 and 67 N kg/ha). The highest levels of total C and N were also recorded in treatments under the highest rate of N-fertilizer application (101 N kg/ha) regardless of tillage or cover crop. We also observed a positive response of total C and N to increasing N-rate fertilizer application for treatments under the wheat and NoCover. However, in treatments under the vetch cover crop, total C and N did not show a response to increasing N-rate. It is apparent that after a continuous period of using a legume cover crop like vetch, crop productivity and soil C can be maintained without the need for additional N-fertilizer. The increased levels of total C and N under NoTill is in agreement with what several other studies have reported under reduced tillage systems especially where cover crops or crop rotations are included (Wrights and Hons, 2004; Halvorson et al., 2002; Al-Kaisi et al., 2005). Mehlich 1 soil extractable nutrients (P, K, and Ca) were also greater in treatments under NoTill while increasing N-rates led to a decrease in the availability of exch. P, K, Ca and soil pH which showed a negative correlation with increasing N rate. These results show an improvement in soil quality and fertility under CA practices.

Regarding the microbial community, the differences in microbial biomass C and N (MBC/N) were mainly only influenced by cover crops with greater amounts of MBN in Hairy vetch treatments. On the other hand tillage and N-rate did not result in any significant changes on the MBC/N. Although our results did not show significant differences in the levels of MBC based on tillage, the microbial community structure revealed higher relative abundance of the *arbuscular mycorrhiza fungi* (AMF) biomarker (16:1ω5c), the gram + bacteria (i15:0, a15:0, i16:0, a17:0), and actinomycetes (10Me17:0, 10Me18:0) under NoTill. In contrast, the saprophytic fungi biomarkers (18:3ω6c, 18:2ω6c) were relatively greater under Till with the fungi to bacteria (F: B) ratio being surprisingly higher in Till treatments than the NoTill. Cover crops had an influence on the relative abundance of gram + and gram – bacteria with the gram + bacteria being relatively greater under Hairy vetch, while gram – bacterial (cy17:0, cy19:0) were relatively less under Hairy vetch. N-rate had a negative correlation on the relative abundance of the AMF biomarker (16:1ω5c) which decreased with increasing N-rate.

The higher F: B ratio under Till treatments compared to NoTill in our study is contrary to what is generally expected upon shifting to reduced tillage practices (Six and Jastrow, 2002; Jastrow et al., 2006; Waring et al., 2013). It is expected that the F:B ratio would correspond to increases in microbial biomass C and organic carbon content observed in this systems (Six et al., 2006; Jastrow et al., 2006; Waring et al., 2013). Several other studies have also reported the lack of fungal dominance under reduced tillage practices (Feng et al., 2003; Helgason et al., 2009; Mathew et al., 2012). Total C in our soils were higher in our study despite the lower abundance of fungi. It is possible that the lower F: B ratio under NoTill was only a seasonal effect; however, the lack of fungal dominance in our study and others mentioned above indicates that there are several other driving factors of fungal populations under reduced tillage systems which may include substrate quality, a response to stress and/or seasonal environmental changes. This therefore calls for further studies to determine the main controlling factors on fungal abundance under reduced tillage systems and what ecological significance this may have. The AMF biomarker on the other hand showed a different response from the other fungal biomarkers indicating that mycorrhiza are more sensitive to tillage as has been demonstrated in other studies (Drijber et al., 2000). The higher abundance of AMF in reduced tillage systems could improve nutrient acquisition especially in developing countries where fertilizer applications are not as affordable and soils are prone to P-fixation.

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No-Tillage Improves Earthworm Species Richness in Southern Brazil(1)

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Background, Results, Application and Implications for Conservation Agriculture

No-tillage (NT) is the most widely adopted conservation farming practice in Brazil, where it currently covers more than 30 million hectares (Febrapdp, 2012). According to Brazilian farmers and researchers (Bartz, 2010), this soil management system is based on three principles: 1) minimal soil movement, sufficient only for the placement of seeds and fertilizers in the soil; 2) maintenance of a permanent organic soil cover (usually crop residues), and 3) the adoption of crop rotations and green manures. The use of NT results in an ecosystem with a lower degree of disturbance or disorder when compared to other management practices that include intense soil mobilization. In particular there is a significant recovery of soil biodiversity, and improvement of the soil as a biotic environment, as a result of lower human impacts on the system (Derpsch, 1991). Among the organisms most promoted by the adoption of NT are the earthworms (Brown et al., 2003). The diversity, density and biomass of earthworms are strongly influenced by soil cultivation (Lavelle et al., 1989) and the earthworm populations can be used as soil quality indicators in agroecosystems (Paoletti, 1999). Several studies and surveys on earthworm populations have been conducted in Brazil, but very few of them identified the species collected. So the aim of this work was to evaluate the earthworm species richness in no-till, integrated crop-livestock and native forest in the State of Santa Catarina, Brazil.

Experimental Approach

A total of 72 sites in 23 counties were sampled. At each site, earthworms were sampled following two complementary approaches: qualitative and quantitative sampling.

Quantitative sampling was carried out on a square grid with 9 points or a transect with 5 points 30m away from each other. The grid was centered in a 1ha plot so that sampling points were at least 20m away from the plot boundaries. At each point earthworms were sampled using the TSBF (Tropical Soil Biology and Fertility) method (Anderson and Ingram, 1993), i.e., hand sorting of a 25x25 cm x 20 cm deep soil monolith. The qualitative sampling consisted in digging at least 10 randomly selected holes in each site. Usually, the holes were dug randomly within the 1 ha area, but in some cases, especially in NF, selected microhabitats (in bromeliads, in and under decaying trunks, under stones, and in wet areas) were also sampled.

Sampling was carried out Jul., Aug. and Dec. 2011, Jan., Jun. and Nov. 2012). Earthworms were fixed and preserved in 92.8% ethanol, counted and identified at family, genus or species level using keys and original descriptions found in Michaelsen (1900), Righi (1990, 1995) and Blakemore (2002).

Results and Discussion

A total of 46 species of earthworms was identified (table 1) in the three land use systems. The fragments of native forest had the lowest richness (24 species), while the agricultural sites (NT and ICL) showed similar species richness (29 and 31 species, respectively). Many juvenile specimens were only identified to one of the four families: Glossoscolecidae, Megascolecidae, Ocnerodrilidae and Acanthodrilidae. There were six species newly recorded for the State of Santa Catarina in this study: *Andiorrhinus duseni*, *Amythas corticis*, *Amynthas morrisi*, *Octolasion tyrtaeum*, *Bimastos parvus* and *Dichogaster gracilis*. The first is a native species and the others are exotic (introduced). Of the 46 identified species, 70% are native and 30% are exotic species (table 1). Considering the sampled sites the percentage of native/exotic was: 83/17, 61/39 and 62/38 respectively in the NF, ICL and NT sites. The results show that, despite the lower total species richness in the forest sites, these areas are important for conserving native populations. However, while the higher richness in the agricultural sites is mainly due to the presence of exotic earthworms (table 1), they are also maintaining an important number of native species. Nevertheless, the quantitative data must still be analysed to verify the abundance of each species (native and exotic) in the sampled sites. Both natural and agricultural sites may be dominated by one or a few species, either exotic and/or native. It is noteworthy that almost all the encountered species of the native genera *Glossoscolex* and *Fimoscolex* are new species that must still be described and named (≅ 24 species).

Table 1. Earthworm species in forest (FN), integrated crop-livestock (ICL) and no-till (NT) sites in the State of Santa Catarina, Brazil. (e = exotic, n = native species).

Family, genus and specie	**Origin**	**FN**	**ICL**	**NT**
Rhinodrilidae				
Pontoscolex corethrurus	e	+	+	+
Urobenus brasiliensis	n	+	+	+
Glossoscolecidae				
Glossoscolex sp.1	n	+	+	+
Glossoscolex sp.2	n	+	-	-
Glossoscolex sp.3	n	+	+	-
Glossoscolex sp.4	n	-	-	+
Glossoscolex sp.6	n	+	-	-
Glossoscolex sp.7	n	+	-	-
Glossoscolex sp.8	n	+	-	-
Glossoscolex sp.9	n	+	-	-
Glossoscolex sp.10	n	-	-	+
Glossoscolex sp.11	n	-	-	+
Glossoscolex sp.12	n	+	-	-
Glossoscolex subadult sp.1	n	-	-	+
Fimoscolex sp.1	n	-	+	-
Fimoscolex sp.2	n	-	-	+
Fimoscolex sp.3	n	+	+	+
Fimoscolex sp.4	n	-	-	-
Fimoscolex sp.5	n	+	+	-
Fimoscolex sp.6	n	+	+	+
Fimoscolex sp.7	n	+	+	+
Fimoscolex sp.8	n	+	+	-
Fimoscolex sp.9	n	-	+	+
Andiorrhinus duseni	n	+	-	-
Ocnerodrilidae				
Ocnerodrilidae sp.1	n	+	+	+
Ocnerodrilidae *contination...*				
Ocnerodrilidae sp.2	n	+	+	+
Ocnerodrilidae sp.3	n	+	+	+
Ocnerodrilidae sp.4	n	-	+	+
Ocnerodrilidae sp.5	n	+	+	+
Ocnerodrilidae sp.6	n	-	+	+
Ocnerodrilidae sp.7	n	-	+	-
Megascolecidae				
Amynthas gracilis	e	+	+	+
Amynthas corticis	e	-	+	+
Amyntahas morrisi	e	-	+	+
Metaphire californica	e	-	+	+
Metaphire sp.1	e	-	-	+
Megascolecidae sp.2	e	-	+	-
Lumbricidae				
Octolasion tyrtaeum	e	-	+	+
Bimastus parvus	e	-	+	+
Lumbricidade sp.1	e	+	+	+
Lumbricidade sp.2	e	+	+	-
Acanthodrilidae				
Dichogaster gracilis	e	-	+	-
Dichogaster bolaui	e	-	+	+
Dichogaster saliens	e	-	-	+
Microscolex sp.1	n?	-	+	+
NI* sp.1	n?	+	+	-
Species richenss		24	31	29
Total of native species		20	19	18
Total of exotic species		4	12	11

* Not identified specie.

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Influence of Tillage and Residue Management Practices on Weeds in Rice-Wheat Cropping Systems

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No till seeding and residue retention, the main components of conservation agriculture are being promoted to address the issue of increasing cost of cultivation, deteriorating soil health and changing climate. The changing tillage and crop residue management practices influence the weeds infestation. The tillage operation stimulates the weed germination and emergence of many weeds through exposure to sunlight as well as through reduced soil strength. No-till system in wheat under rice-wheat system reduced the *Phalaris minor* (littleseed canarygrass) infestation (*Chhokar et al. 2007*) due to higher soil strength but favoured the infestation of broad-leaved weeds like *Rumex dentatus* (toothed dock), *Malva parviflora* (little mallow) and *Medicago denticulata* (burclover).

In the long term experiment on tillage requirement in systems perspective, nine tillage combinations are being tried. There were three tillage options in transplanted rice namely zero tillage, dry rotary and wet rotary in main plots superimposed on which were three tillage options in wheat namely zero tillage, conventional tillage and rotary tillage in subplots, replicated thrice. It has been observed that zero tillage in both rice and wheat crops increases the infestation of *Polypogon monsplensis* among grassy weeds (Figure 1).

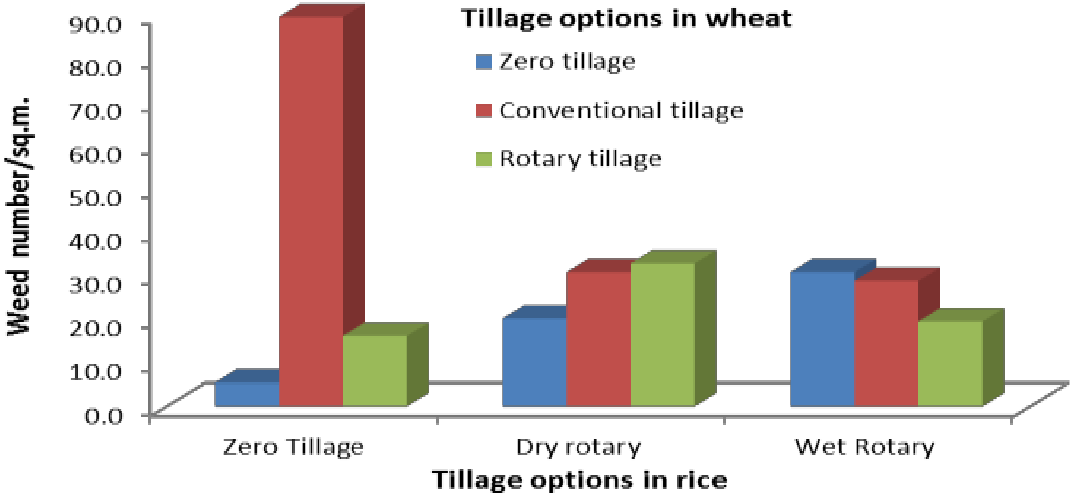

Figure 1. Effect of various tillage options in rice-wheat system on *Polypogon monsplensis* density

It has been observed that rice-wheat system, management of residues, especially rice, is a problem and majority of the farmers resort to residue burning leading to environmental pollution in addition to loss of valuable organic source. The burning of residue also reduces the efficacy of soil-applied herbicides like isoproturon, pendimethalin and pyroxasulfone (Chhokar et al 2009; Moss, 1979), besides affecting the germination of weeds. The factor responsible for reducing the herbicide efficacy is strong adsorptive power of the ash formed after residue burning. Instead of burning, the surface retention of residue is a better option as it besides conserving moisture and moderating soil temperature also helps in suppressing weeds. The surface retention of rice residue of more than 4 t/ha in combination with no-till system reduced the weed abundance in wheat. However, in rice, compared to conventional puddling, no till rice had more diverse and severe weed infestation due to absence of water stagnation. It has been observed that infestation of *Eragrostis japonica* (Pond Lovegrass) was higher under no till without residue retention compared to residue retention and burning treatments (Figure 2). Earlier research workers (Crutchfield *et al.*, 1986; Wicks *et al.*, 1994) have also reported that the retention of crop residue on the soil surface is more beneficial than incorporation and burning, as it helps in moisture conservation and weed control through mulching.

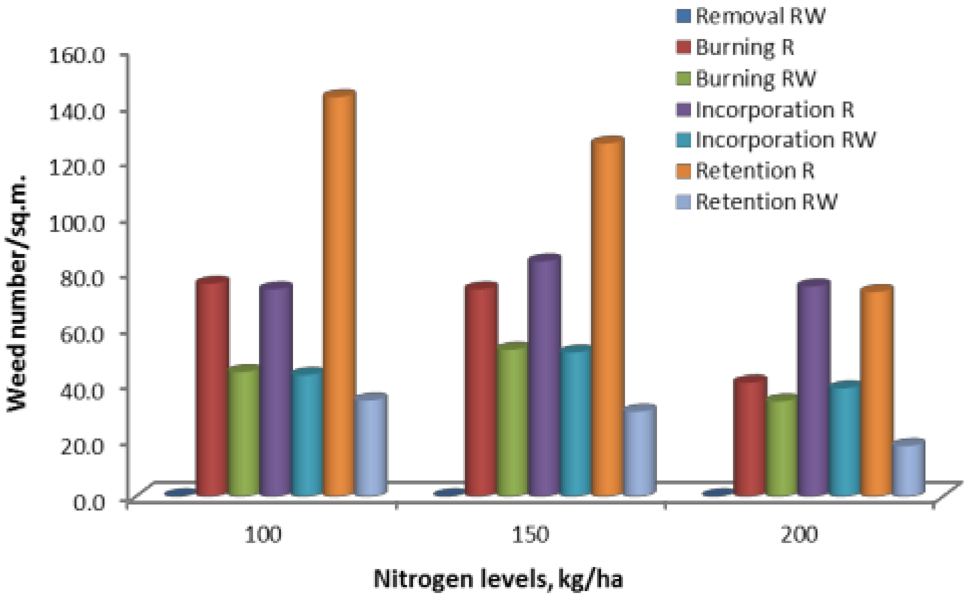

Figure 2. Effect of nitrogen and residue management options on *Eragrostis japonica* density

No till seeding can also be usefully employed for the management of herbicide resistant weeds as there is possibility of using some of the non-selective herbicide like glyphosate and paraquat as pre-plant application. However with adoption of conservation agriculture, the residue retention can reduce the efficacy of pre-emergence herbicides. Considering the advantage of conservation agriculture, efficient weed management strategies need to be evolved under residue retention practices.

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The Role of Conservation Agriculture Practices in Production Risks, Crop Income and Agro-chemical Use

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Extended Abstract

The core pillars of the agricultural Green Revolution relied on improved varieties and fertilizers, as well as public sector support for irrigation and fertilizer subsidies. In Sub-Saharan Africa (SSA), a more balanced approach to agricultural intensification must focus on better natural resource management practices and agro-ecosystem health. Without these supportive pillars, it is unlikely that SSA's rain-fed, capital-deficient production systems which also face serious resource degradation challenges can truly enter a sustained intensification pathway.

In recent years, conservation agriculture (CA) is increasingly advocated as an essential component for making agricultural systems more sustainable and remunerative (long-term yield increase, yield stability, reduce costs and resource degradation) in many SSA countries (FAO, 2011). However, the economic-environmental benefit of CA for smallholders has not been rigorously examined. In principle, conservation agriculture involves minimum tillage, soil surface cover, and crop rotations/intercropping.

The first objective of this paper is to estimate the adoption of CA components (maize-legume rotations (MLR) and minimum tillage (MT) with residue retention) together with complementary inputs such as improved maize varieties (IMV) on net maize income and input use (pesticide and Nitrogen(N) fertilizer) in maize growing areas of Ethiopia. The second objective is to examine the implications of adopting CA components combination (legume-maize rotations & intercropping (here after cop diversification-CD), and MT with residue retention) for cost of risk, measured by risk premium, in sample of Malawi maize growers. These objectives are achieved by applying a multinomial endogenous switching regression (MESR) in a counterfactual framework. This method allows correcting potential endogeneity issue associated with farmers' adoption decision emanated both from differences in observed and unobserved characteristics of framers.

Results show adopting CA practices either in combination or individually significantly reduces cost of risk, increases net maize income and also affects inputs use. The highest impacts achieved when CA practices are adopted jointly rather than individually. In dealing with non –sustainable production intensification in the face of low adoption of external inputs and changing climatic conditions, adopting CA could serve as a better strategy for the sustainable intensification of agricultural production, while promoting a healthy agro-ecosystem and improving farmers' resilience to economic and climatic shocks.

The empirical analysis is based on household and plot level data gathered in 2010/2011. The data collected by the International Maize and Wheat Improvement Center (CIMMYT) under the Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) program in collaboration with the respective countries' national agricultural research institutes.

The surveys covered 9(16) districts in Ethiopia (Malawi). A multi-stage random sampling procedure was employed to select villages from each district and households from each village. A total of 900 (1, 925) farm households operating on 1, 644 (2, 937) maize plots were randomly selected from Ethiopia (Malawi).

Examining three (MLR, MT and IMV) and two practices (crop diversification (CD and MT) in Ethiopia and Malawi respectively lead to eight and four potential practice/technology combinations that a farmer could choose. That is we estimate eight and four sets of adoption equations and associated outcome variables. Farmers technology adoption decisions are likely to be influenced systematically both by

observed and unobservable characteristics that also explain income, input use and cost of risk (outcome variables). To address this problem, we model farmers' choice of combinations of CA practices and impacts of adoption using a MESR in a counterfactual framework where a multinomial logit model used as to correct for unobserved factors(for theoretical & practical application of MESR see Teklewold et al. 2013 & Bourguignon, et al. 2007, respectively). The analysis considers adoption of CA practices as a treatment, and the adoption effects for adopters are estimated comparing the outcomes currently the adopters obtain with the outcome that they could have obtained if they had not adopted. Cost of risk was measured by the risk premium considering farmers' risk preferences and estimated using a quantile moments based approach (Kim et al. 2014).

About 25, 5, 25, and 12% of plots in Ethiopia treated with no CA practices, MRL, IMV and MT, respectively. While 8, 4.5, 14.5 and 5% treated with MLR & IMV, MLR & MT, and jointly with the three practices, respectively. In Malawi about 28, 14, 37, and 21% of plots treated with no CA practices, MT, CD and jointly with the two practices, respectively. The empirical results confirm adopting a set of CA practices with IMV significantly raise the net maize income by 47 to 67%.(Net maize income computed by deducting cost of fertilizer, hired labor, seed and pesticide). Highest impact obtained when the two practices jointly adopted with IMV (Fig 1). On input use, promoting CA practices either jointly or individually reduces N fertilizer use or at least keeps it constant. MT increased pesticide application perhaps to compensate for reduced tillage. However, when it is used jointly with rotation, it did not have significant impact on pesticide use.

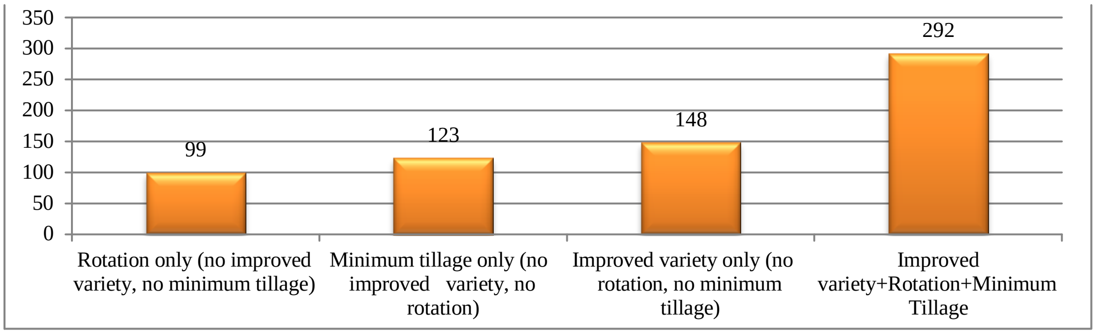

Fig 1. Impact of CA practices combined with IMV on net maize income ($/ha), Ethiopia

The cost of risk is higher for non-adopters compared with adopters. Higher cost of risk reduction achieved when CA practices jointly adopted (Fig 2). Joint adoption reduces the cost of risk by 4% of the maize yield compared with non-adoption under moderate risk aversion (risk aversion coefficient =2).

Lower cost of risk reduction is achieved from adoption of MT. Findings show on average 64% (78%) of the cost of risk for adopters (non-adopters) comes from exposure of downside risk (crop failure).

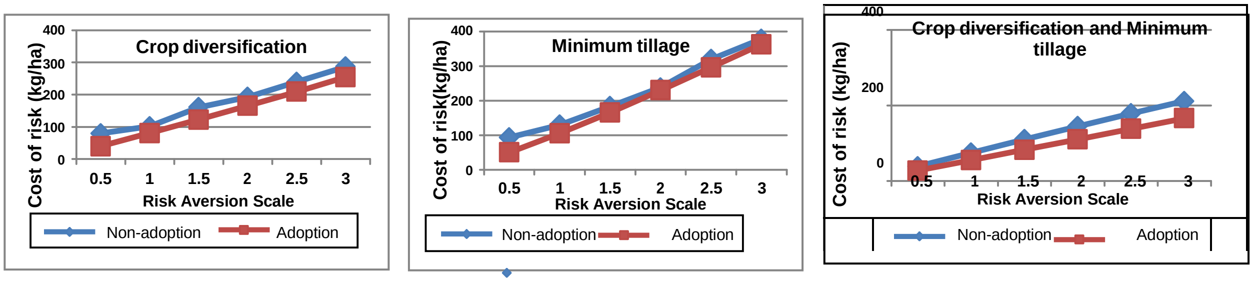

Fig 2. Cost of risk under CA practices combination, Malawi

Overall, results showed policy makers focusing on improving food security and managing Overall, results showed policy makers focusing on improving food security and managing production risk farmers face and reducing resource degradation should promote and consider CA practices in their agricultural policy formulation so that farmers can use resources efficiently.

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