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Session 5: Conservation Agriculture: Climate Change Impacts

ORAL ABSTRACTS

Conservation Impacts on Climate Resilience

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STATE OF CLIMATE CHANGE

Climate change has been occurring through history and agricultural systems have been subjected to variable weather within growing seasons and trends across multiple years. The combination of the within season variability (weather) and the long-term trends (climate) represent the determining factors in what is grown in a particular location and the variation in production levels among years. However, at the present time we are entering into a period of climate change which will subject agriculture to some new challenges because of the degree of change forecast to occur. Changes in the mean values of temperature, precipitation, solar radiation, and carbon dioxide (CO_2), along with changes in the extreme values will add complexity to our ability to manage agricultural systems.

Projected climate change over the next 30 to 50 years varies by region and there is an emerging picture as to the degree of change we can expect to occur. The primary climate change factor affecting agriculture is temperature and precipitation because these critical parameters affect plant growth and induce plant stress either through direct effects of temperature on plant growth, induced plant stress because of the increased water use rates caused by increased evaporation rates, direct effects on evaporation because of the impact of reduced or altered precipitation patterns, or through the indirect effects from altered pest (insect, disease, or weed) pressures (Hatfield et al., 2011; Izaurralde et al., 2011).

Of importance to agriculture are the changes not only to the mean values but also the frequency and severity of meteorological events within the growing season. Mearns et al. (1984) showed that relatively small changes in mean temperature can lead to large increases in the frequency of extreme events. Gutowski et al. (2007) suggested high intensity precipitation events would constitute a larger fraction of total precipitation under scenarios of global warming with these observations evident for all regions and seasons. Rind et al. (1990) proposed both drought and floods would intensify with climate change. The change in drought probability may increase more than expected due a reduction in mean precipitation and conversely, increases in floods or extremely wet portions of the year may be larger than expected from increases in mean precipitation. The probability of drought will increase because the reduction in rainfall linked with an increase in potential evapotranspiration will exaggerate the effect of a reduction in precipitation. This characteristic of climate change has to be considered in evaluation of the potential impacts on agriculture or agroecosystems.

Changes in climate will vary in intensity of the signal, i.e., mean temperatures or precipitation, frequency of events, e.g., temperature or precipitation or general trends (e.g., increasing CO_2 concentrations). All of these changes reveal that the dynamics of seasonal weather patterns and the multiyear climate patterns will impact agriculture and the effectiveness of conservation practices. The objective of this review is to provide an understanding of the potential role of conservation practices to mitigate climate change.

CONSERVATION PRACTICES TO INCREASE CLIMATE RESILIENCE

Conservation practices encompass a range of different systems employed to reduce the offsite impacts of agricultural systems and to ultimately enhance the natural resources. Delgado et al. (2011) listed several examples of potential mitigation strategies including: "increasing soil carbon (C) sequestration to improve soil function; reducing methane (CH_4) emissions from ruminants; using slow release fertilizers to increase N-use efficiencies for cropping systems; capturing nutrients and energy from manure; crop residues and cover crop management; and using more efficient power sources and renewable energy." Specifically for soil and water practices, they identified a range of practices dealing with erosion, irrigation infrastructure, more diverse cropping systems, crop varieties more tolerant to drought and heat stress, synchronizing planting and harvesting with shifts in the hydrologic cycle, managing soil and crops to increase water use efficiency (WUE), evaluating agricultural commodities for their water footprint and environmental traits, increasing soil C sequestration, increasing N-use efficiency, and implementing precision and targeted conservation practices to increase the effectiveness of practices to handle the increased temporal and spatial variation. These practices represent a range of potential ideas and concepts, if implemented, would have a positive impact on the resilience of the production system to climate stresses and a positive feedback in terms of mitigating climate change.

It is critical to understand the feedbacks occurring among all of the components in an agricultural system and their linkages. As an example, evapotranspiration will increase with warming temperatures and cause crop water use rates to increase leading to a faster depletion of the soil water reserves. In soils with limited soil water holding capacity, this will create variation in total crop water use and ultimately crop yield since yield is a function of crop water use. Hatfield and Prueger (2011) found variation among soils within the same field. There was a corresponding difference in yield between these two soils caused by the difference in soil water use throughout the growing season. The role of soil management on WUE was reviewed by Hatfield et al. (2001) in which they proposed that practices which increased water availability would lead to improved WUE. In a simple exercise using the WUE relationship developed for corn (*Zea mays* L.) in the central United States we observed the additional amount of required soil water to increase the current level of yields of 10,000 kg ha^{-1} to 18,000 kg ha^{-1} will require an additional 120 mm of soil water to be transpired through the plant during the growing season. If we follow the relationship developed by Hudson (1994) between soil water holding capacity and soil organic matter achieving sufficient change in the soil profile to result in this amount of extra water in the soil profile, will require very aggressive soil management to increase the soil organic matter levels to the extent needed to increase the soil water availability. Egli and Hatfield (2014) showed that average county soybean (*Glycine max* (L.) Merr.) yields were directly related to the quality of the soil across counties and as the quality of the soil decreased there was an increased chance of crop failure. Soil water availability is critical to crop production and any practice which increases the available soil water supply will have a positive impact on crop production.

IMPLICATIONS FOR PRODUCERS

Climate resilience is directly linked to conservation agriculture because of the short-term and long-term impact on crop water balance. In the short-term we modify the water balance by increasing infiltration and reducing soil water evaporation due to the presence of the crop residue. In the long-term, we modify the infiltration rate, increase infiltration, increase soil biological activity, increase soil biological activity, increase soil organic matter, and water holding capacity. Any method to increase water availability will have a positive impact on increasing climate resilience of agricultural systems since water availability and water use rates are directly related to soil water availability. With the likelihood of more variable precipitation and increased atmosphere demand through rising temperatures, any soil management practice which increases water availability will pay large dividends to producers and decrease the variation among years. Increasing water availability in the soil will increase the efficiency of nutrient utilization by the crop because of the reduced stress levels on the plant. Since much of the water stress occurs during the grain-filling period of growth, additional water availability will help ensure more efficient use of nutrients. Extreme events of temperature occurring during the growth cycle of plants will be offset by reducing the likelihood of water stress and especially during the pollination phase of plant development. Conservation agriculture provides a valuable tool for producers to use to increase climate resilience.

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Adaptation to and Mitigation of Climate Change Effects for Future Food Security in South Asia: Is Precision-Conservation Agriculture a Way Forward?

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Background

Food insecurity and poverty for the large population of the world's hungry and poor, exacerbated by the soaring food and energy prices, global economic downturn, volatile markets and climate change–induced vulnerability, have surfaced as major research for development (R4D) concerns in the South Asia. Since late 1960's, the Green Revolution (GR) in South Asia have contributed to food security and demonstrated that agricultural development supports an effective means for accelerated economic growth and poverty reduction. These notable achievements of GR were largely due to both vertical and horizontal increase in food production owing to use of external inputs such as high-yielding varieties, chemical fertilizer and irrigation. However, recently (at the dawn of 21st century), the problem of food security with added challenges of natural resource degradation has further been surfaced and intensified with indiscriminate use of resources, sharp rise in the cost of production inputs, diversion of human capital from agriculture and shrinking farm size. In South Asia, the ever increasing population growth is interlinked with these challenges and the natural resources in the region are 3-5 times more stressed due to population, economic and political pressures compared to the rest of the world. In the region, the inefficient use and mismanagement of production resources, especially land, water, energy and agro-chemicals, has vastly impacted the health of the natural resource base and contributing to global warning led climatic variability. Studies (Sivakumar and Stefanski, 2011) show that there would be at least 10% increase in irrigation water demand in arid and semi-arid region of Asia with a 1° C rise in temperature. Thus, climate change could result in the increased demand for irrigation water, further aggravating resource scarcity.

This will also increase the price of water for irrigation, making small-holder agriculture more risky venture. Moreover, while maintaining a steady pace of development, the region will also have to reduce its environmental footprint from agriculture. Considering these multiple challenges, agricultural technologies that promote sustainable intensification and adapting to emerging climatic variability yet mitigating GHG emissions (climate smart agricultural practices) are scientific research and development priorities in the region. There are a wide range of agricultural practices that have the potential to increase adaptive capacity of production system, reduce emissions or enhance carbon storage yet increasing food production. Integration of conservation agriculture (CA), a set of management practices involving minimum soil disturbance, residue retention and diversified crop rotation; and precision agriculture (PA), farm management system to identify, analyze and manage variability within and between fields for optimum profitability, sustainability and conservation of the resources; are such innovative management systems that have demonstrated as the potential strategies to boost farm profitability, making crop production resilient to changing climate and to reduce environmental footprint of agricultural production system for sustainable food security. This paper present synthesis of evidence base on precision- conservation agriculture (PCA) based management systems, based on our large number of strategic research as well as farmers' participatory field experiments in wheat, maize and rice based cropping systems of South Asia.

Experimental Approach

International Maize and Wheat Improvement Centre (CIMMYT) under CRPs on CCAFS, WHEAT and MAIZE and in close collaboration with range of stakeholders (public, private, NGOs, farmer organizations, service providers etc) is conducting large number of on-station as well as on-farm participatory trials in various aspects of precision-conservation agriculture in diverse cropping systems in South Asia. The results presented here come from many rice, wheat and maize based systems research conducted in the region. Agronomic productivity of the system was determined following standard agronomic measurements. Cost of production was determined by using variable costs from the respective market rate. GHG emission presented here come from both measurement (by using static chamber method) and model simulation (by using Cool Farm Tool) (Hillier et al., 2011). Weather data were obtained from the observatories closest to the experimental sites.

Results and Discussion:

Analysis of results of large number of experiments reveals that CA based management systems reduces production cost and increase yields and economic benefits. From farmers' participatory trials on forty farmers' fields in Haryana for three consecutive years, we found that the total cost of wheat production in zero tillage with (ZT+R) and without residue retention (ZT) was, on an average, 23% less than that of conventional tillage (CT) system which was mainly due to reduction in the cost of preparatory tillage and irrigation. Due to lower cost of production, net return was significantly higher in ZT-based wheat production than in CT-based wheat production as the yield was at par under both systems. Similarly, through seven years of long-term trial on crop establishment methods in rice-wheat system of eastern IGP, we found that the productivity of rice-wheat was higher under CA-based system (ZTR-ZTW) with and without residue retention as compared to CT systems. Our results also show that CA based system can also moderate the effect of extreme temperatures at grain filling (terminal heat). Adoption of ZT in cereal cropping system in IGP has been reported to advance the planting time thereby increasing the thermal window for wheat and thus escaping from terminal heat effect. Our studies onCA in rice-wheat system in western IGP, showed that retention of rice residue on soil surface lowered the canopy temperature in wheat by 1-4 ° C at grain filling period (between 138-153 days after showing). Similarly, surface retention of crop residues are strategically located at soil-atmosphere interface and offers profound water conserving effect by reducing run-off and evaporative losses. Water savings in CA based management systems also possible because with zero tillage, one crop can be sown by utilizing the residual moisture of preceding crop potentially saving pre-sowing irrigation. Reduced power and energy requirements due to non-requirement of tillage in CA translates into less fuel consumption, lower working time and slower depreciation rates of equipment, all leading to mitigation from farm operations as well as from the machinery manufacturing processes. On an average, by adopting of ZT for land preparation in rice-wheat system of IGP, farmers could save 36 liter diesel ha^{-1} equivalent to a reduction in 93 kg CO_2 emission ha^{-1} yr^{-1}. Through our continuous monitoring of GHGs by using static chamber method in a rice- wheat production system of northwest India, we found much higher emission of CH_4 from rice production in puddled transplanted field with continuous flooding compared to direct seeded rice (DSR) production system (50-250 mg CH_4 m^{-2} day^{-1} in puddle transplanted vs <50 mg CH_4 m^{-2} day^{-1} in DSR). In this study, total cumulative GHGs emission (soil flux of CO_2, N_2O and CH_4) in terms of CO_2-equivalent was about 27% higher in the conventional tillage-based rice-wheat system than in CA-based systems. Through life- cycle analysis of wheat production in northwest India by using Cool Farm Tool, we found that global warming potential of conventional till wheat with ad-hoc nutrient management was significantly higher than in ZT- with precision nutrient management (Precision-Conservation Agriculture) (Sapkota et al, 2014). With increased efficiency of the production system, precision-conservation agriculture (PCA) can act as one of the strategies for adaptation to uncertain climatic conditions as well as reducing environmental foot prints while improving food production on sustainable basis.

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Seasonal Climate Variability Dependent Effects of Conservation Agriculture Practices Across Different Agroecologies in Ethiopia

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Background

Sub-Saharan Africa is particularly vulnerable to effects of seasonal climate variability and the idea that Conservation Agriculture (CA) should be recommended for sustainable intensification in such rainfed dependent agricultural systems is nothing new. Despite considerable effort, adoption of Conservation Agriculture (CA) in Eastern Africa remains very limited (Giller et al., 2009). The seasonal climate variability makes difficult to select with reliability the most adapted technologies in terms of sustainable productivity and economic benefits in a given agroecological zone. In Ethiopia, smallholder farmers rely mainly on rainfed agriculture, and land degradation due to soil erosion and declining soil fertility represent a major challenge to sustainable intensification (Rockstrom et al., 2003). Such degradation is generally attributed to exploitative farming practices that include plowing, removal of crop residues, mono-cropping which have detrimental effects on soil structure and soil organic matter content. Climate change with higher rainfall variability is believed to worsen this trend leading to serious consequences on crop yield. Coupled with poverty and growing population, land degradation poses a serious threat to household food security. CA practices might provide long-term alternatives to reduce the detrimental effects of soil erosion and water stress (Aikins et al., 2012).

Applications and Implications for Conservation Agriculture

Different maize-legume cropping systems under CA practices were evaluated on-farm conditions in three representative agroecologies of Ethiopia (Bako, Melkassa and Hawassa) during several seasons. The objectives of this study were to evaluate the performance of maize-bean cropping systems under CA and conventional farming practices across several seasons, and to identify which cropping systems under CA can reduce adverse effects due to the high seasonal climate variability in each agroecology.

Experimental Approach

Field experiments under rainfed conditions were conducted in three different agroecologies between 2011 and 2013 main cropping seasons. In research managed on-station experiments, four different maize-bean cropping systems (i.e., sole maize, sole bean, rotation and intercropping) were evaluated both under CA and conventional agricultural practices (CP) using a randomized complete block design with three replicates (6 rows of 5.1 meter long plot). Maize was planted at a spacing of 75 cm inter-row and 30 cm intra raw while bean was planted at 40 cm between rows and 10 cm inter-plant density. In on-farm trials, the different maize-bean cropping systems under CA were compared to the CP (e.g., sole maize). The most commonly used maize and bean varieties used were for each location. In the CA practices, narrow rows were opened with a hand-hoe to a depth of about 10 cm to plant seeds and for fertilizer application without any prior tillage and all crop residues were retained in the field. The CP plots were managed similar to the common farmers' practice, and crop residues were cut and carried to the farmers' house for feed and fuel immediately after harvesting. Crop phenology and the major agronomic data including yield and biomass were collected during the cropping season. In case of on-station trials, soil moisture content was measured at harvest for each plot.

Results & Discussion

-*High seasonal climate variability.* In Ethiopia, there was a very low rainfall (severe drought) every three to four years (e.g., 2000, 2003, 2009 and 2012) during the past decade (Fig. 1a). Meanwhile, even within the same district, the variability in rainfall amount and distribution can be very high during the same cropping season (up to two fold) with early or late drought periods (Fig. 1b).

-*Effect on yield.* Rainfall variability had the highest impact on maize yield, whereas CA practices did not have yet a significant effect on yield stability. Over the last three years, maize yield for both CA and CP varied up to four times from one season to the next, while bean yield was relatively stable (Fig. 2).

Monoculture, rotation and intercropping system performances were highly dependent on the amount and distribution of rainfall resulting in two to three-fold variation in grain yield. In addition to the early impact on soil, the phenology and agronomic traits were analyzed in detail in order to identify the most relevant technology or propose other alternatives for each environment.

Effect of CA on soil moisture. Although the effect on overall yield was not significant, the impact of CA practices on soil moisture content at harvest during an above average rainfall season (2011) was significant in case of maize sole and maize-bean rotation cropping systems (Fig. 3). In such context, it appears that maize-bean intercropping under CA can be more advantageous in locations with higher average rainfall, but also why relaying cropping or double cropping systems can be other alternatives to use the residual moisture left under CA.

-*Agroecology dependent CA recommendation.* To benefit of the residual moisture at the end of the season under CA practices, maize-bean intercropping might be a better option in locations where there are sufficient rainfall. Rotation might be a better option in locations with higher frequency of drought; however, smallholder farmers should be able to make higher benefits from legumes. Higher adoption of CA technologies requires better characterization of the best options in each agroecology. Besides, the socio-economic context including market for cash crops and livestock components must be considered in addition to agronomic practices which can limit the risks of seasonal climate variability

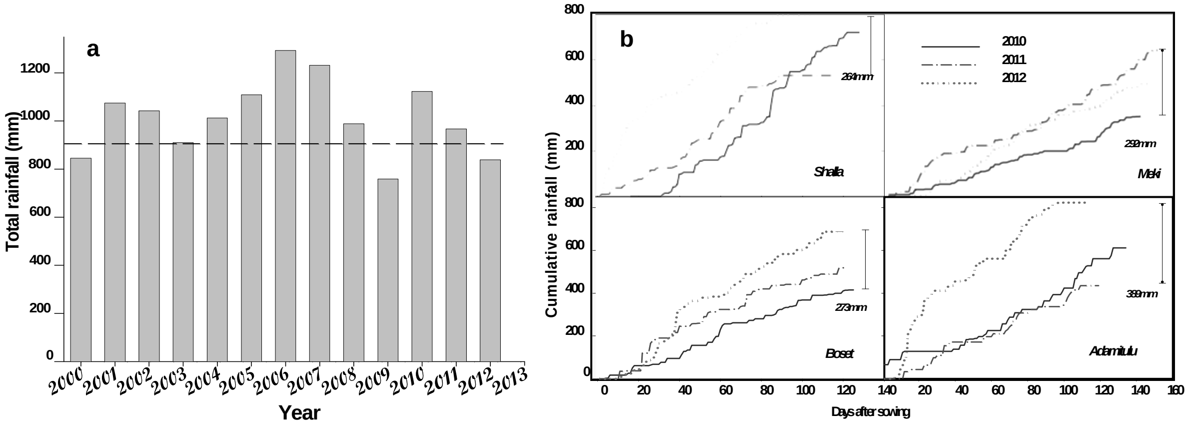

Fig. 1a: Rainfall variability in the Rift Valley (Hawassa research station) between 2000 and 2012 (dashed line representing average rainfall); **b:** Cumulated rainfall from sowing to harvest in 4 different locations of the Central Rift Valley between 2010 and 2012 (vertical line representing the maximum rainfall difference across the different seasons).

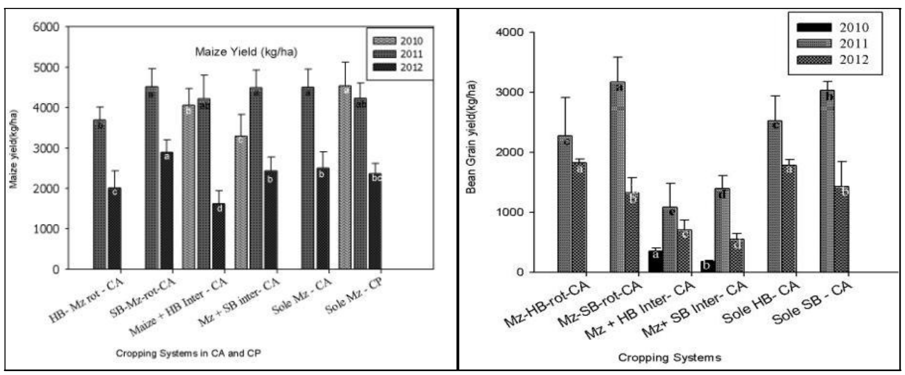

Fig. 2 Effect of seasonal climate variability on maize and common bean grain yield grown under different cropping systems and tillage practices in Bako

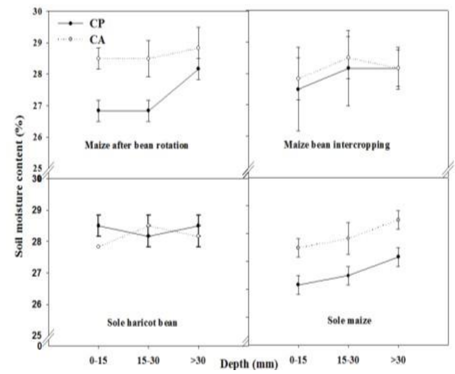

Fig. 3 Pairwise comparison of CA or CP tillage effect on soil moisture content at harvest in 2011 between the different cropping systems

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Climate Change Mitigation and Adaptation Potential of Conservation Agriculture: Effects on Rainwater Use Efficiency, Runoff, Soil Moisture, Soil Organic Carbon and Energy Use

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As climate change will likely have adverse effects on agricultural productivity and food security in much of the semi-arid tropics ((SAT, IPCC, 2007), there is need to develop and disseminate production technologies that provide a layer of resilience against such climate change effects on food security. A long-term experiment was initiated at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) farm in Patancheru, India in 2009 rainy season to assess the potential of conservation agriculture (CA) as an alternative and resilient production technology for sustainable crop intensification under rainfed situations in the SAT of southern India. Two tillage treatments -- , normal tillage (NT) minimum tillage (MT), and residue management practices -- residue removal (RR) and residue retention (RT) were tested in maize-chickpea sequence and maize/pigeonpea intercropping systems with four replications. The soil of experimental field was Vertic Inceptisol, which according to USDA is classified as a member of the fine, montmorillonite, isohyperthermic family of paralithic Vertic Ustopepts (Vertic cambisol as per FAO classification); slightly alkaline (pH 7.91) with EC 0.22, medium in organic C (0.42 %) and available P (10.61 $kgha^{-1}$). Here we present effects of tillage and residue management practices on rainwater use efficiency (RWUE), runoff, soil moisture content and soil organic carbon (SOC) during 2010-11 and 2011-12 seasons. Data from integrated digital runoff and soil loss monitoring unit (IDRSMU, Pathak et al., 2011) were analyzed to estimate runoff in different treatment plots in maize-chickpea system. Soil moisture content was measured using the neutron probe (Troxler model 4302) calibrated under same soil.

Improving RWUE is vital to increase agricultural production and productivity under rainfed conditions in SAT. MT-RT had RWUE at par with NT-RR during 2010-11 but during 2011-12 as weeds could not be controlled timely in MT-RT due to incessant rainfall, which made herbicide applications ineffective, RWUE was lower in MT-RT compared to that in NT-RR in both the maize-based cropping systems. However, effective weeding was possible in NT-RR with tropicultor mounted hoe drawn by bullocks. Therefore, to improve RWUE under CA timely and effective weed control along with proper nutrient management is must. MT-RT reduced total seasonal runoff by 28.62 and 80.22% compared to NT-RR during 2010-11 and 2011-12, respectively. These results imply that higher rainwater infiltrated into the soil to add to the green water. Similarly, peak rate of runoff, which indicates erosive capacity of runoff water was decreased by 25.13 and 72.72% under MT-RT compared to NT-RR during 2010-11 and 2011- 12, respectively. Only 17.41 and 1.11% of total rainwater was lost as runoff under MT-RT compared to 24.40 and 5.62% under NT-RR during 2010-11 and 2011-12, respectively. During 2010-11, MT-RT had
2.25 and 5.49% higher total soil moisture (v/v) in 0-90 cm soil depth in sole maize (in maize-chickpea sequence) and intercropped maize respectively, compared to NT-RR (Fig. 1). During 2011-12, MT-RT had 1.95% higher total soil moisture (v/v) in 0-90 cm depth in sole maize, but in intercropped maize it had 1.31% less total soil moisture compared to NT-RR. MT-RT had higher SOC in 0-15 cm soil depth compared to NT-RR in both the maize-legume cropping systems but SOC was only slightly higher or equal in 15-30 cm soil depth compared to NT-RR. This indicates MT-RT is capable of sequestering more carbon in soil compared to NT-RR. As in MT tillage operations like chisel plowing, mould board plowing, cultivator and blade harrowing and

mechanical interculturing were not done it saved energy equivalent to 41.49 liters of diesel per hectare. As one liter of diesel emits 2.67 kg CO_2 (Environmental Protection Agency, 2009) MT emitted 110.79 kg less CO_2 annually on per hectare basis compared to NT. Besides, with gradual improvement in soil fertility under CA fertilizer requirement is expected to come down in medium to long-term which would help to reduce emission of green house gases (GHGs) both at the level of fertilizer production and post field application stage.

With positive effects on RWUE, runoff, soil moisture content, SOC and energy use which are expected to be more clear in medium to long-term and lesser emission of GHGs CA could be one of the potential climate change mitigation and adaptation production technologies in the SAT.

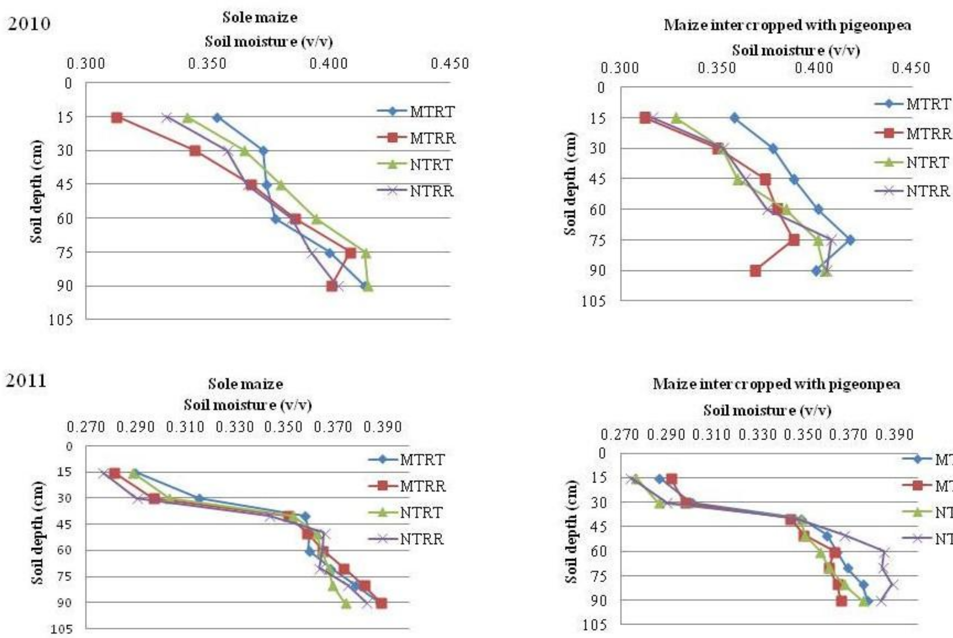

Fig. 1 Effect of tillage and residue management practices on total soil moisture (v/v) averaged over different dates during maize growing period in 0-90 cm depth.

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Environmental Outcomes of Conservation Agriculture in North Italy

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Background

Cropland covers about 4.5 million hectares in North Italy, whose 4.5% are managed through reduced tillage practices according to official statistics. These practices draw however an increasing interest by farmers; moreover incentives are provided in the frame of Rural Development Plans (e.g. Regions of Lombardy and Veneto) to farmers shifting from conventional to conservation agriculture (CA), as a part of a strategy aimed at supporting the development of an agriculture durable and capable to produce larger ecosystem services. Cultivated soils in North Italy show low levels of organic carbon content (SOC), ranging from 34 to 60 t/ha. Therefore cropland soils have a potential to re-gain carbon, if they are managed adopting suitable practices. Moreover carbon sequestration into soils should be considered as a challenge to increase the sustainability of cropping systems as well as a relevant opportunity for agriculture to see rewarded the supply of public goods rendered to society. Nevertheless, often outcomes are still strongly influenced by a relatively poor application of the CA principles (minimal or no soil disturbance, permanent land cover and crop diversity).

Experimental Approach

A study was carried out in Lombardy to evaluate the effect of CA on SOC storage and Soil Biological Fertility. To this purpose, two research sites characterized by different pedoclimatic conditions and cropping systems were used to compare long-term CA managed soils with conventional ploughed soils. The first site was located on fine textured soils (Vertisols or Vertic Cambisols) and was characterized by a crop rotation with winter and summer cereals, soybean, alfa alfa and a wide use of cover crops; instead the second site was located on coarse textured soils (Luvisols) with a crop rotation mainly based on cereals and forage crops without use of cover crops. Six test plots, ~ 5 ha per plot, were selected at both the research sites, managed either using CA (no-till) or conventional practices (plough). Each plot was sampled (six replications) for soil bulk density (BD), SOC concentration (Dumas, Walkley-Black, TOC/Springer-Klee methods), carbon of the microbic biomass, basal and cumulative respiration determinations. These last analysis, together with TOC, metabolic and mineralization quotient, need for the computation of the IBF index (Index of Biological Fertility). Such a index was developed for Mediterranean soils by CRA (Experimental Institute for Plant Nutrition, Rome); a score (from 1 to 5) is assigned to each parameter considered and the algebraic sum of the scores gives the IBF index, as a scale of five classes (higher it is the class, greater is soil fertility).

The carbon balance of CA and conventional practices was also analyzed using the simulation model ARMOSA. ARMOSA is a daily time step model that simulates crops growth, agro-meteorological variables, balance of water, carbon and nitrogen in the soil-plant-atmosphere continuum, nitrogen losses through leaching and volatilization and the CO_2 emissions from the soil.

Results and Discussion

Results from the study (Table 1) showed that fine textured soils managed under CA practices since 10 years had a higher SOC stock than the same soils traditionally ploughed, suggesting CA has a potential to increase SOC up to 2 t ha^{-1} $year^{-1}$. On the contrary, no significant differences ($p<0.05$) in SOC stocks were found on coarser soils: however CA had a higher total carbon stock, as the sum of carbon of soil and that of crop residues, and a more positive carbon balance between carbon sequestration and loss, as a result of the input of cattle manure to ploughed fields (corresponding to about 2-4 t ha^{-1} $year^{-1}$ of organic carbon).

Table 1. *SOC stock under conservation and conventional tillage (Dumas)*

Soil	Management	Organic Carbon Stock (t/ha)	
		Mineral Soil (30 cm)	**Crop residues**
Vertisol or Vertic Cambisol, fine	CA practices	63,70 ± 7,75	2,84 ± 1,56
	Conventional tillage	45,34 ± 6,22	
Luvisol, coarse loamy	CA practices	46,20 ± 7,99	4,79 ± 2,56
	Conventional tillage	47,44 ± 7,91	

These assumptions were confirmed yet by the simulation model analysis. Simulations showed that, shifting from conventional to conservation technique, a significant accrual of organic carbon sequestered into the soils ($p<0.01$) could be achieved together with a significant decrease (from 4% to 9%, $p< 0.01$) of carbon released into the atmosphere by respiration processes of organic substances. Statistical analysis did not report a significant effect of soil characteristics, indicating that CA can lead to a SOC increase in any type of soil. However model suggests SOC accrual can be more pronounced in fine textured soils.With respect to IBF index (Table 2), a higher soil biological fertility was found on both the research sites

Table 2. *IBF index under conservation and conventional tillage*

Soil	Management	IBF index (class)
Vertisol or Vertic Cambisol, fine	CA practices	4
	Conventional tillage	3
Luvisol, coarse loamy	CA practices	3
	Conventional tillage	2

Results achieved in this study should be confirmed by further tests. However they point out CA can actually provide ecosystem services, regardless in particular to the ability to capture or preserve carbon in the soil. Results confirm also a great variation in the potential to sequester carbon and improve biological fertility in soil depending on the climatic conditions and cropping systems and the crucial importance in these processes of crop rotations and management of crop residues.

Applications and Implications for Conservation Agriculture

Results of the experience gained so far in North Italy demonstrate CA plays a potential key role for a higher resilience and adaptation to the impact of climate change in the Po Valley; future projects will be addressed to support strategies for soil protection adapted to the different pedoclimatic conditions and farm types in order to identify viable alternative solutions and optimize environmental outcomes in each specific local situation. Those projects are also expected to contribute to the dissemination of CA practices and convince farmers they are applicable, suitable, able to sustain profitability and create new perspective, such as the generation of carbon and, maybe in the future, environmental credits. To these purposes, a Life+ project named “HelpSoil” (LIFE12 ENV/IT/000578) has started in July, 2013: the project is aimed at monitoring indicators of soil ecosystem functions and assessing the capacity of CA practices to restore agro-ecosystems to a more sustainable and productive state, comparing the environmental and agronomic performance of CA and conventional management practices in 20 demonstrative farms throughout the whole North Italy. Moreover testing a carbon emission offset scheme to bring together opportunity for reduction in GHGs emissions and carbon trading by farmers able to generate carbon credits is the goal of a second project, developed in the frame of the initiatives planned for EXPO 2015.

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