Sveriges lantbruksuniversitet
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Fakulteten för landskapsplanering,
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Comparison of soil carbon stocks in two cropping systems as affected by nitrogen application levels

Jämförelse av kolförråd i marken mellan två odlingssystem, vid två kvävenivåer

Esmaeil Echreshavi

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Foreword:

Getting used to a daily life, in a fairly small world that surrounds us, has prevented us from thinking ‘out of the box’ and comprehending what lies beneath. Living in a consumer based economy has taught us to just care about supply and demand, and just for today; to produce more, at any cost, to consider the soil as a ‘bed’ for the plants and nothing more, to believe that it is ok to use chemicals as long as we wear a protective mask and to use as much fertilizer as we can afford, because fertilizers are ‘good’.

This is a real story of the facts I came to know when I started studying Agroecology. It started at September 2010, seemed strange and weird on the first days to be honest, but little by little I could see the dots are getting connected and a whole new dimension of thinking is starting to appear in all glory.

We learned that a currency that we should consider in making calculation about today’s world economy is not US$, nor Euro, Yen or Yuan, it is the Solar Dollar and it costs the nature a whole cycle of energy transformations in various physical and chemical forms to provide us with a single Solar Dollar, and yet we sell it very cheap, because our societies are ‘meant’ to consume. We learned what a sustainable production system mean and what to consider when evaluating these systems; that ecosystem services are obtained for free but should not be considered “for granted” cause these services are affected by our activities as much as ecosystems do.

Coming to Sweden and getting accustomed to a totally different environment, socially and academically had its own difficulties, but I have to admit that this decision was the best possible investment I have made in my time and future. Attending this program was a wakeup call for an agronomist who used to focus his attention and studies on possible ways of producing more. Now I can see things I couldn’t see before, I am conceiving ecosystems and their services in a more holistic way and I believe in thousands and thousands of new breakthroughs and bright ideas from Agroecologists in the near future, to make our planet a nice place to stay, even for the coming generations.

Esmaeil Echreshavi, September 17, 2012.

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Thanks to all my classmates in the program for making these two years memorable, to all the awesome teachers during the program, all the officials in the department and the university who generously provided a unique educational experience and environment.

At last but not least, many thanks to the Almighty Allah, my parents and other family members back in Iran who never stopped supporting me by all means and my lovely wife and sweet daughter, who bear with my busy schedule and always provided me with love and support I needed.

Abstract:

This study aimed to trace possible changes in soil organic carbon (SOC) at different soil depths when treated with different levels on nitrogen fertilizer, in both conventional tillage and reduced tillage systems. The experiment was undertaken in Lönnstorp research station at SLU, Alnarp in south west of Sweden, as a part of a long term experiment. The results agreed with the hypothesis that implied there will be no difference in the amount of soil organic carbon in the soil profile between conventional tillage and reduced tillage systems. But results did not certify other hypothesis of higher SOC in top 20 cm of soil in reduced tillage and neither did they comply with hypothesis of higher SOC in 20-50 cm depth in conventional tillage system. Furthermore, higher levels of N fertilization showed no significant effect on the amount of SOC in soil profile in neither of the systems. In order to encourage farmers to include operations to preserve SOC a case study was included in the socio-economic part and discussed. Since the monetary terms and conditions make the idea more acceptable to farmers, the suggested idea in the case study to provide a carbon-exchange system where the total value of the sequestered carbon can be sold and bought like shares seemed to be suitable, but its feasibility in all countries is questionable. In places where providing incentives to the farmers to sequester carbon in the soil is considered, the longevity of this action for many years is required, due to the nature of SOC.

Keywords: Carbon sequestration, reduced tillage, N fertilizer, SOC, soil organic carbon, soil bulk density.

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1. Agroecological perspective:

There is an increasing interest in our future as human race, or better said, our planet’s future, as our home. Among many factors which are prompting this interest are the increasing levels of greenhouse gases (GHGs) of which CO_2 is the focus point (Baker et al., 2006). While the top 1m soil layer on earth contains approximately 1500 Gt of organic carbon (Eswaran et al. 1993), why should it be a source of concern when over 38000 Gt of carbon (Schlesinger, 2000) exists in the oceans? Baker et al. (2006) answered this question based on the idea of response to modification. They suggested that there is a very delicate equilibrium which controls the whole carbon cycle in the soil, and delicate means this cycle is prone to destruction or deformation by human’s activities and so is the carbon content of the soil. Agriculture practices are also responsible for a considerable part of N_2O emission, either by burning the biomass and releasing big amounts of nitrous oxide from the burnt biomass and the soil (Bouwman, 1994; Galbally et al., 1992), fertilization (production of fertilizers and their volatilization) and animal manure as fertilizer (Mosier et al., 1998) or by aerating the soil by plowing it, since aerated soils (depending on the level of aeration) cannot be sinks for nitrous oxide which exists in the atmosphere (Freney, 1997).The emissions caused by N_2O and CH_4 fluxes by agriculture are considered non-CO_2 base, but still converted and evaluated by CO_2 emission units to calculate their GWP (Global Warming Potential) (Robertson and Grace, 2003).

Agriculture, being one of the largest anthropogenic mediated changes on the surface of the earth, is a major contributor to CO_2 emissions, either by increasing the CO_2 flux into the atmosphere by applying conventional methods of tillage (most of the flux happens immediately after changing from natural system to a conventional one), or by the considerable amount of fuel used by agriculture machinery or the industrial processes of producing fertilizers and chemicals. The amount of CO_2 emission caused by agricultural practices equals to 20-25% of the whole CO_2 flux into the atmosphere (Smith et al., 2008; Duxbury, 1994). The CO_2 emission from the soil is accounted as the primary mechanism and reason of losing C in the soil (Parkin and Kaspar, 2003). The CO_2 flux to the atmosphere can be intensified by some agricultural practices such as tillage, which disturbs the soil, aerates and oxidizes soil and plant residues (Jastrow et al., 1996, cited in Sainju et al., 2006).Kucharik et al (2001) suggested that United States lands have lost 30-50% of their carbon compared to pre-cultivation era. Lal et al (1998) calculated the organic carbon loss from United States soils to be as much as 36 t/ha during its history of agriculture. furthermore, production of agricultural commodities and cropping operations in soils which previously have been the origin of some native plant species leads to degradation and reduction of soil organic matter, because of the changes in quality and quantity of soil carbon inputs, which are functions of soil physical properties and their effects of soil carbon decomposition rate (Luo et al., 2010; Haas et al. 1957).Lal (2004) suggested that the conversion of natural to agricultural ecosystems will deplete the soil carbon at various rates, according to the climate; as much as 60% of carbon in temperate soils to more than 75% in the tropics.

This significant footprint of agriculture in this change increases its responsibility to reverse this effect, and agriculture might have the tools to fulfill the expectations. These tools and methods of management are built on a potential of soil to act as a sink (Gifford, 1994). By sequestering atmospheric CO_2 into the soil, or prevent it from reemitting, we can use this potential, even if these lands are already used as croplands (IPCC, 2001). The capacity of this pool equals the total amount of carbon lost during human's history (55-78 Gt) (Lal, 2004). Using soil as carbon sink and increasing carbon sequestration will eventually lead to a carbon saturated soil, which can take and reserve no more soil organic carbon (SOC), but even at this stage applying conventional methods quickly decreases the amount of trapped carbon, due to volatile nature of recently sequestrated carbon (Marland et al., 2001). The speed of losing carbon from soil under these circumstances is much faster than the rate of gaining carbon, in case of applying inappropriate soil management methods, which makes the soil itself a source of emissions (Marland et al., 2001).

2. Introduction:

2.1 Background:

It is estimated that the global top 1m soil carbon is about 2400-3200Gt of which 1500 Gt is in organic form (Eswaran et al. 1993).The carbon in the 1 m depth layer of the soil is two times as much as the total carbon in the atmosphere (Lal, 2007). The consequences of failing to prevent excess flux of carbon into the atmosphere are not environmentally negligible and leads to an important loss in soil quality as well, which threatens agricultural production systems and food security (lal, 2007). Tillage is one of the main agricultural operations contributing to carbon loss from soils, as Davidson and Ackerman (1993) suggest that generally up to 40% of total carbon in the top 30 cm of soil is lost due to tillage compared to uncultivated lands. Most of C loss happens directly after changing land use from natural grassland to cropping farm. Houghton et al. (1991) suggested that 20% of the soil carbon is lost in the first 5 years of changing to cropping farms and another 5% loss happens in the next 20 years before land gets into a steady equilibrium. They also suggested that after this period of time the losses or gains of soil carbon are not as significant as the first 20 years. The total C loss from soil during the whole period of crop production in lands around the world is estimated to be 20-40% (Houghton et al., 1991). Davidson and Ackerman (1993) calculated this amount and suggested 30% of carbon loss.

But the effect of tillage is not that easy to consider and is dependent on the type of the crop and rotation as well. Various researches have shown that diversifying the crops into rotation can result in relatively higher organic carbon content (Gal et al, 2007., Batjes, 1996).Tilling conventionally or choosing no-tillage or minimum tillage methods can make a difference in the way organic carbon gets distributed in soil profile. In studies conducted by Allmaras et al. (2004) and Tresder et al.(2005) it was shown that vertical growth of roots increased with tillage while no-tillage resulted in more horizontal distribution of root and thus higher root density near the surface, which all led to relatively higher organic carbon content near the soil surface.

One of the proposed methods to mitigate the negative changes imposed by cultivation is conservation agricultural practices (CAP) as suggested by Lal (2004). CAPs provide many options and methods but among all of these options changing the tillage system from conventional to no-tillage or minimum tillage is considered an important step. (Paustian et al, 2000).

But all of CAP procedures would turn to be relatively futile if the main drivers of carbon losses (erosion, leaching and fast decomposition of carbon (due to different temperatures and moisture levels) (Lal, 2009)) are not considered and addressed in management practices. Marland et al (2001) argued that it is important to consider the limited capacity of the soil in acting as a carbon sink.

It is important to point out that some of the mentioned procedures to enhance soil carbon content are not agreed upon by all researchers and farmers when considering other factors.

Reicosky (2008) mentions a few cautions to consider with residue management practices which can bring along a lot of discussions and must be included in future research. Problems such as disease outbreak and weed infestation, alternative (sometimes more profitable) uses of residues, the important role of nutrient cycling and plant availability and choosing cultivars with better compatibility with conservation tillage system generally decide whether a certain management method is suitable for a definite situation or not.

2.2 Soil Carbon:

The carbon in the soil is found in three forms:

A) Elemental carbon: this type of carbon is the most publicly known form of carbon. Like in charcoal and graphite. This type of carbon is the result of incomplete combustion of an organic substance (Schumacher, 2002).

B) Mineral carbon: This type of carbon originates from soil originates from soil parental materials. It is generally found in two forms which are Calcite and Dolomite, both carbonate materials.

C) Organic carbon: The result of decomposition process of plants and animals residue and parts. It can be found in different forms like freshly decomposed litter to completely decomposed matter (humus) (Schumacher, 2002). This type of carbon (or generally soil organic matter)is very dynamic and shows a quick respond to the way soil is managed (Reicosky, 2004). Regularly the photosynthesized carbon, which is the only source of soil carbon in lack of other major contributors (Jensen et al. 2012) is added to the soil through root and plant litter and in the final stages this carbon is decomposed back to CO_2 as a result of actions of soil biota (Ellert et al, 2006).

The presence of soil organic matter is an indicator to soil potential and health in agriculture terms and its vital role can be highlighted in various terms, such as a source of nutrients necessary for plant and microbial environments to grow and nurture (e.g. Nitrogen, Phosphates, and Sulfur), as a major contributor to soil structure in suitable form and to provide a valuable source of micronutrients such as Zinc, Copper and Manganese (Reicosky, 2008; Dalal and Mayer, 1986).

The importance of carbon is not just about forming the organic matter of soil. Carbon acts as a source of energy for microbial activities in soil, which is a vital indicator of soil health (Reeves, 1997). Among other indicators of soil health which are greatly affected by the presence of soil organic carbon are plant available water capacity in soil, infiltration ratio, aggregate formation and stability in soil structure, soil bulk density, cation exchange capacity (CEC), presence of adequate soil enzymes and the level of activity of invertebrate soil bio indicators (earthworms) (Reicosky 2004; Reeves 1997).

Using soil as a carbon sink can turn the surplus farmlands into natural ecosystems, which can provide various ecosystem services (Follet, 1993).Carbon changes through various stages and phases in soil ecosystem (Figure 1) and the most concerning parts of the cycle are ones which intensify the concentration of carbon dioxide in atmosphere (seen as upward arrows).

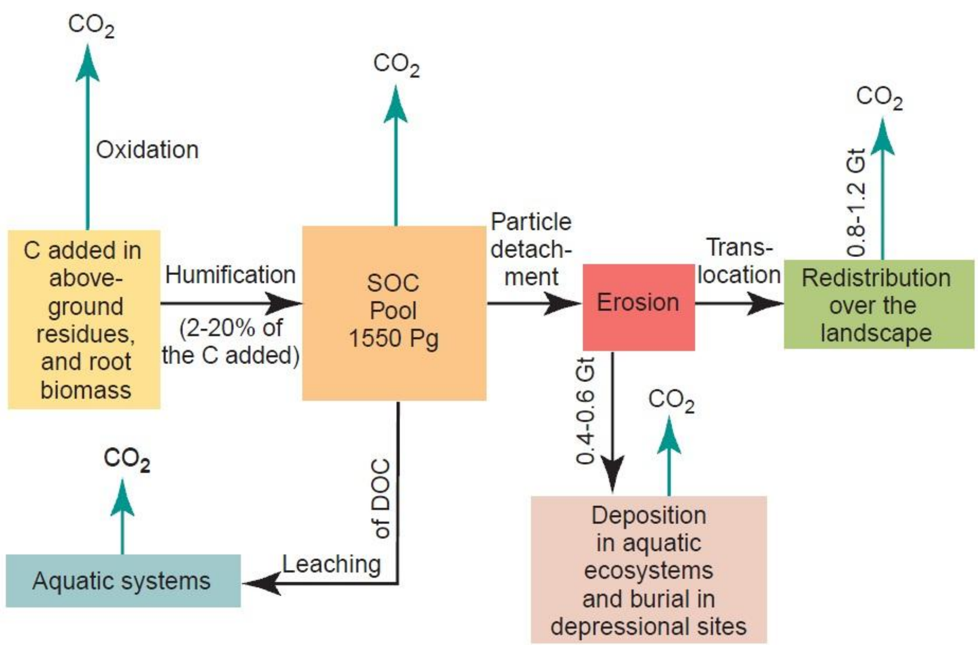

Fig 1: *The dynamics, forms and the amount of carbon inputs and outputs in soil ecosystem on the earth crust. The arrows upward indicate* CO_2 *flux into the atmosphere.SOC: Soil Organic Carbon, DOC: Dissolved Organic Carbon. Adapted from Lal (2004).*

2.3 Carbon sequestration and its importance:

Carbon sequestration is defined as trapping the carbon in the soil, or as IPCC (2001) defines, it is the "*process of increasing the carbon content of a (carbon) reservoir other than the atmosphere"*. Carbon sequestration gains importance over the ever increasing awareness of the growing effects of global warming due to GHGs (Green House Gasses). The main reason behind the unprecedented increases in the volume of these gasses in atmosphere is burning fossil fuels and deforestation (IPCC, 2001) and by the current trend, it is expected to eyewitness an increase in global temperature between 1.4 and 5.8 degrees Celsius over the next 100 years, which means a global disaster by all means. This concerning fact is a driver behind many international treaties such as Kyoto protocol (1997) which demands world countries to help achieving a stabilization of atmospheric concentrations of GHGs to prevent the worrisome interference of human activities and the climate system (UNFCCC, 2003).

Carbon sequestration is attainable through changes in land use methods and recommended management practices, which are both cost effective and environment friendly. (Lal, 2004).These practices work in two possible ways, either to increase carbon input to the soil or reducing the carbon losses (Table 1) (Lal, 2009).

Table 1: *How different techniques lead to increase of soil organic carbon (Lal, 2009).*

Increasing C inputs via:	Recycling of bio solids to the soil growing biomass to be returned to the soil
Decreasing C losses via:	Minimizing erosion Minimizing leaching Decreasing decomposition

As mentioned before, the total capacity of soil to absorb carbon and trap it is equal to the whole carbon lost from soil during the past centuries. But the available capacity which can be attained through proper management is only 50-66% of the potential capacity (Lal, 2004). Thus further procedures are necessary to limit the total emitted carbon to the atmosphere.

Lal (2004) suggests that the rate of increasing carbon sequestration in soil through different management practices follows a sigmoid curve. It reaches the maximum in 5-20 years and will start decreasing as soil reaches the equilibrium and gets close to the saturation limit. Lal et al

(1998) estimated 50 years of proper management to return all of the lost carbon back to the soil could bring it back to equilibrium. Soil absorbs carbon until it reaches equilibrium and enters a steady state. That means that during the process of carbon sequestration the rate of carbon accumulation decreases gradually and finally soil gets saturated by carbon. But even at this point the environmental benefits of this accumulation continue (Reicosky, 2008).

A detailed schematic presentation of effective methods to increase SOC is shown in figure 2:

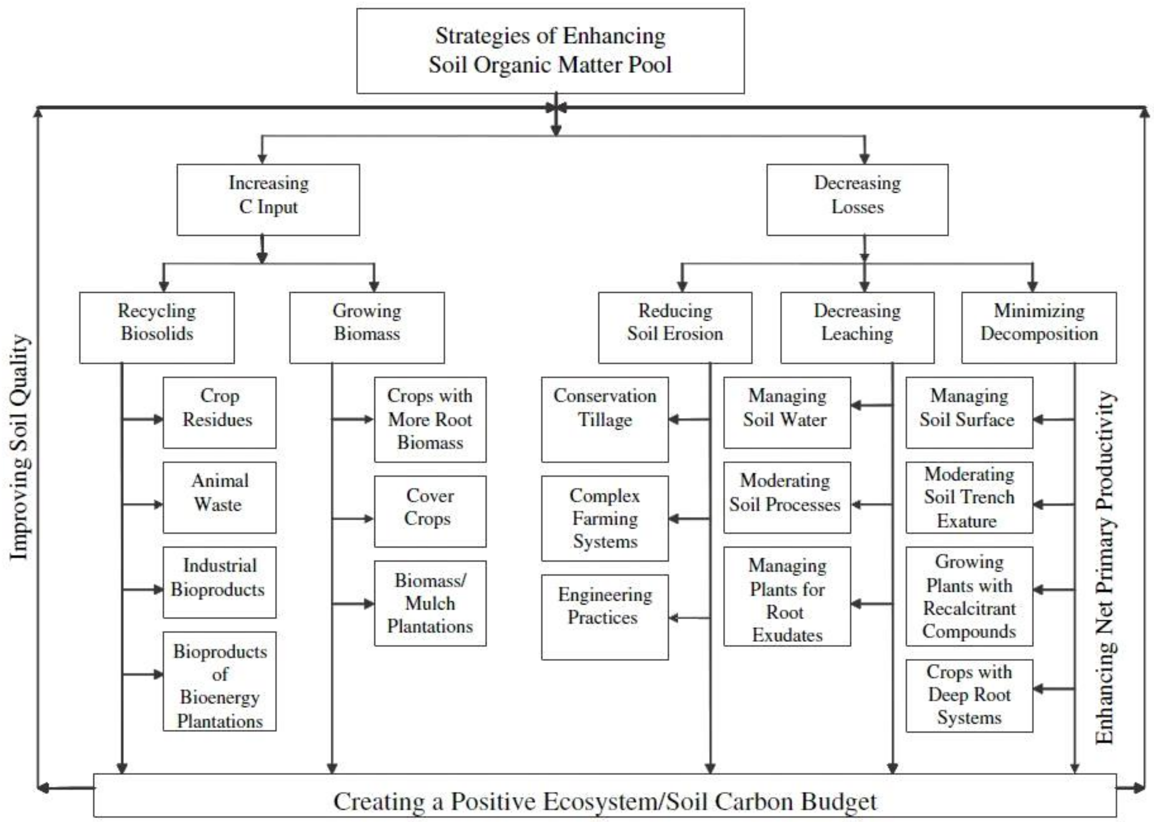

Fig 2: *Collateral benefits of different techniques which lead to more SOC in soil and build up a soil carbon based ecosystem. Adapted from Lal (2009).*

2.4. Possible effects of tillage on carbon cycle:

Studies show a high amount of controversy when tackling tillage and its possible effects on soil carbon. While numerous studies have shown that no tillage can increase the carbon content in the top soil (0-15 cm), other studies suggest the exact opposite results, which meant decrease in carbon content in soil under no tillage systems and other reports even show an increase in soil carbon under conventional tillage systems (Christopher et al., 2009; Baker, 2006). Etana et al., (1999) found no significant difference in SOC content between soils under minimum tillage system vs. soils under long-term conventional tillage system. Angers and Eriksen-Hamel (2008) reviewed 47 experiments and suggested that no tillage system can lead to a significant increase in carbon in top soil, while conventional, full-inversion tillage increases the concentration of carbon at the bottom of the plow layer; in the same research they mentioned more than 20 cases in which full inversion tillage resulted higher SOC in top soil. Hutchinson et al. (2007) suggested that no-tillage leads to higher moisture in the top soil which is very useful in arid areas, while in semi-arid areas higher moisture can lead to faster carbon decomposition and more carbon loss.

To explain this inconsistency, some researchers believe that the methodology of sampling is biased in many cases and simply most of the experiments do not consider going deep enough to extend the available clues to explain this phenomenon. Baker et al (2006) suggest that sampling depth should not be less than 1 meter to prevent the biased results seen in researches with shallow sampling, because the way carbon is being distributed in the soil profile might produce faulty conclusions if sampling depth isn't deep enough. Pe´rie´ &Ouimet (2007) suggested that depth of sampling affects the results because of the possible change in carbon forms and displacement. While Luo et al. (2010a) and Campbell et al. (2005) suggest that many other factors are considered as important when considering the results of no tillage on soil carbon; such as cropping system and frequency, irrigation type and fertilizers application, soil type, clay content and weather conditions. The variety of results could be because of environment, methods of management, sampling bias and methods of analysis, or a combination of some or all of these points.

2.5 Nitrogen application and soil organic carbon:

Applying N fertilizers is a general tradition in agriculture almost everywhere in the world. The nitrogen fertilizer addition to the soil can have complicated effects on the carbon content. Some researchers suggest a strong relationship between adding N fertilizers and increasing (or maintaining) the SOC quantity and its organic carbon content (Dalal et al, 2010; Cusack et al., 2010; Barber 1979), especially when combined with residue management and reincorporating residues to the soil. Kirkby et al. (2011) and Campbell et al. (2001) suggested that SOC cannot be increased in the soil unless the other elements tied up to carbon in humus (which consists 40-60% of SOC) like N,S,C and P are available as well. Analyzing 598 agricultural soil samples from all over the world to consider the possible relationship between soil N and soil total C resulted in almost linear increase (Kirkby et al. 2011) (Figure 3).

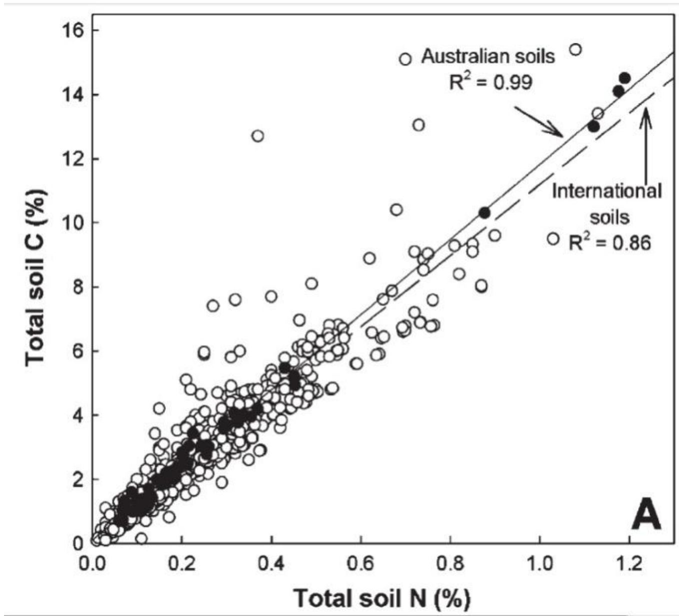

Fig 3: *Linear increase of total soil carbon as N concentration increases. This chart represents 598 soil samples from all over the world. (Adapted from Kirkby et al. 2011).*

On the other hand Khan et al. (2007) reported a tendency of reduction in SOC despite high residue retention and application of NPK fertilizers, probably because of intensification of heterotrophic decomposition of soil organic material in the presence of fertilizers. Their study showed that the higher the rate of fertilizer, the more likely it is to lose more SOC. Waldrop et al (2004) suggest that increased amount of N in the soil stimulates loss of Carbon due to increased microbial activity. Waldrop & Firestone (2004) point out that the reason behind increased microbial activity in presence of N appears when considering the high ration of C/N of the plant residues that get back to soil. Their ratio forces a situation in which N is the limitation of decomposition, and as it added to the soil the process of decomposition accelerates.

West and Post (2002) and Luo et al. (2010b) suggest that the effect of nitrogen application is a result of other decisive factors, such as the frequency of cropping (e.g. double cropping per year). They argue that having more crops use the availability of nitrogen leads to more biomass production and more residues in the soil, which can trigger an increase of soil carbon. Residue management can lead to more carbon in the soil in an indirect way either. While Lal (2009) mentioned both different results of N application on soil carbon and suggested that in both cases making a decision on whether the soil carbon has increased or decreased goes back to how to decide the baseline of soil carbon, which is very critical.

3 Aim and objectives of the study:

3.1: Aim of the study:

This study aims at determining possible gradual changes in soil organic carbon in different depths and relationships between the amount of soil organic carbon and the continued supply of N fertilizers, under different tillage systems (Minimum vs. Conventional). The agroecological perspective of economy of organic carbon, carbon sequestration and agriculture-based emissions will be considered and discussed as well.

3.2: Objectives:

- To quantify the effect of two cropping systems on the amount and distribution of organic carbon in the soil profile, down to a depth of 50 cm.
- To quantify any possible change in soil profile organic carbon content due to application of nitrogen fertilizer, and how this might differ between the two cropping systems
- To discuss possible relationships between soil organic carbon content and socio-economic aspect of farmers' life, due to possible direct and indirect effects of soil organic carbon on farm and yield status and potential changes in socio-economic aspects.

3.3: Hypotheses:

- ✓ In a reduced tillage cropping system, the amount of soil organic carbon in the profile is not different when compared to a conventional tillage cropping system.
- ✓ In a reduced tillage cropping system, the level of stock carbon is higher in the 0-20 cm layer compared to a conventional tillage cropping system
- ✓ In a reduced tillage cropping system, the level of stock carbon is lower in the 20-50 cm layer compared to a conventional tillage cropping system
- ✓ An increased level of soil organic carbon positively influences farmers' life social and economic aspects due to possible sustainable increase in crop yield which means more economic profits.
- ✓ A higher application rate of N fertilizers increases the organic carbon content at all soil depths.

- ✓ The increase in soil organic carbon content, due to a higher N application rate, is larger in the reduced tillage cropping system than in the conventional tillage cropping system, in the 0-20 cm layer.
- ✓ The increase in soil organic carbon content, due to a higher N application rate, is smaller in the reduced tillage cropping system than in the conventional tillage cropping system, in the 20-50 cm layer.

3.4: Limitations:

Due to the limited geographic area of the experiment and specific weather conditions, results from this experiment are not possible to generalize in bigger scale. In addition, because of the existence of carbon in many tools, places and even our bodies, chances are that possible contaminations would reduce the precision of the results and form a significant source of error.

The initial design of this long-term experiment does not permit a conventional statistical comparison between the two cropping systems, since the fields are not replicated. This means that extra care must be taken at the stage of interpretation of data and drawing of conclusions. Due to limitations imposed by the site's soil type (relatively high amount of stones in the soil), current sampling tools failed to sample to the recommended depth (90 cm) and this change of plan might have a negative effect on the overall results of this study. The same limitation reduced the ability to analyze soil bulk density in more areas and due to possible high variation in soil density in different areas; insufficient sampling might have a negative effect on the validity and reliability of results.

4 Materials and methods

4.1: Experimental site:

In order to evaluate the possible changes in soil organic carbon with different levels of N application and tillage procedures, an experiment was planned to get carried out in Lönnstorp research station (55°40'0.29"N,13°6'45.09"E). Soil type is loamy and its pH varies in range of 6.4 to 7.4 with average of 6.9. This experiment was a part of an older – still continuing experiment which started back in 1993 and covering 12 fields of which 6 are operated in conventional way (A1-A6) and the 6 other in integrated way with reduced tillage (B1-B6). All fields have been also benefiting from crop rotation system (Appendix 1).

The amount of N every single field received as NPK each year is kept the same (175 kg/ha).Inside each plot there are 2×6 sub-plots which have been treated annually with one of the six different levels of nitrogen. In this study, the 6 main plots in each cropping system, and two of the nitrogen levels in each plot (N0 = 0 kg/ha and N3 = 160 kg/ha), are used.

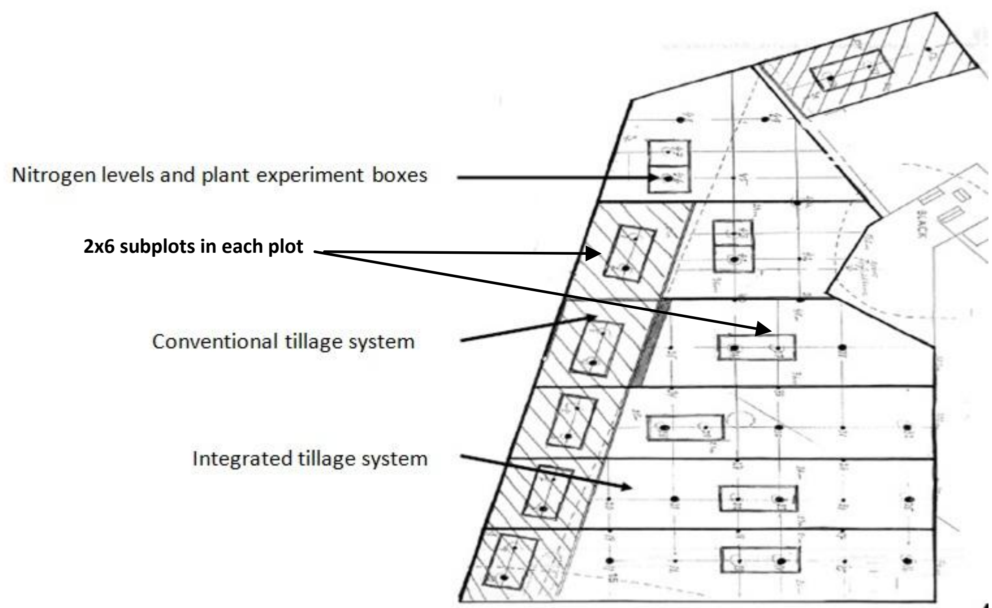

Fig4: *An overview of the experimental site at Lönnstorp. The hashed plots (vertical to the left and one on the top) are the conventional ones, labeled as A1 to A6 (up to down) and fairly bigger ones on the right and middle are integrated ones, labeled as B1 to B6 (up to down).*

4.2: Sampling:

Due to high number of stones in soil profile and the technical difficulties of soil corers to operate properly in this type of soil, the depth of sampling was decided to be 50 cm, which fell into two levels, 0-20 and 20-50. The sampling was carried out in late March and early April 2012 in all the 12 plots, inside experimental subplots (shown in Figure 1) which were treated by N0 level of nitrogen (0 kg N/ha) or N3 (160 kg N/ha). A steel soil corer 0.7 m long with inner diameter of 2 cm was used to take soil samples. The sampling points where randomly chosen in each subplot with at least 0.7 m from subplot's closest border. Inside each subplot the sample was taken twice with the distance of at least 20 cm between the sampling holes, sealed in plastic bags with proper labeling and transferred back to the lab. This process came out with 96 samples (6 plots x 2 systems x 2 levels of N x 2 depth x 2 replicates).

4.3: Preparing samples:

As the first step the samples were dried in the oven. They first got transferred separately into Aluminum trays and kept in the oven at 105 ºC for 24 hours. As the next step the samples were crushed into 2-5 mm crumbles and kept into plastic bags in the desiccator in order to prevent any moisture absorption.

The samples were milled to fine powder using a ball mill model Retsch MM200. Milling was set for 30 seconds at the frequency of 25 beats per second. After mixing the contents to assure homogeneity, a small amount of the milled sample was transferred to Eppendorf tubes, all labeled and transferred back into a desiccator.

4.4: Analyzing:

Since in this experiment the focus point is on soil organic carbon and there was a possibility of presence of carbonates, an extra procedure before analyzing was necessary to get rid of the mineral carbon.

A small amount of each of the soil samples (45 ± 10 mg) was put in a tin capsule and the weight was registered. Then all tin capsules were treated with 0.2 ml of 0.1 Ml HCl and transferred to oven at 80 degrees Celsius for 24 hours then the temperature was increased to 105 for a few hours to get totally dry samples. This method resulted in 96 capsules with dry soil sample, free of inorganic carbon.

These tin capsules were rolled into small balls using tweezers and arranged in a special plastic tray with a matrix-label for every capsule. After preparing proper procedure of tin capsules, they got analyzed by Carlo Erba NA 1500 elemental analyzer at 1021 degrees Celsius for 210 seconds. Pure Helium (99.9995%) was injected into the machine at the rate of 80mL/min as the carrier gas while to perform combustion in the quartz tube, pure Oxygen flow was prepared. The combustion tube was prepared of a column of quartz wool and other chemicals to burn the samples in much higher temperatures (Jensen, 1991). The elemental analyzers was sending data to PC running EAGER 200 software to process data and provide information in numbers and a chart for each sample. The printed results were used to identify the percentage of organic Carbon in each sample.

4.5: Soil Bulk Density:

In order to be able to state the amount of organic carbon in comprehensible units (Kg/m^2 or t/ha) it is necessary to measure soil density in each system and in corresponding layers.

To achieve this, soil samples were taken from one location in each of the tillage systems (conventional and integrated) using stainless steel cylinders 100mm high and 70 mm diameter. Five samples were taken in each site, down to 50 cm deep with 10 cm intervals.

After collecting samples they were transferred back to the department lab in sealed and labeled bags, then were put in the oven at 105 degrees Celsius for 24 hours and finally weighed. Soil bulk density (g/cm^3) was calculated by dividing the dry soil weight (g) by the cylinder volume (cm^3).

4.6: Calculation &Statistical analysis:

By using IBM SPSS 21 running in Microsoft windows 7 the average amount of SOC in each treatment was analyzed using Univariate linear model at confidence level (P) of 95%. Multiple comparison sets of data were prepared to test the concentration of SOC in different depths, treated with both levels of Nitrogen, in both tillage systems. Since SOC calculations take soil bulk density into account, it is important to correct for compaction to avoid biased calculations. Compaction means that the same depth of soil for both farming systems meant different mass of soil in the same volume. The surface of soil in one system might be higher or lower compared to the other after a few years and that means that there is a possibility that the sampling depth has to be different in the systems, to get the same mass of soil; thus causing an error if both calculated without correcting the depth. To address this problem, soil bulk density average down to 50 cm (in two increments, 0-20 and 20-50) was compared in both systems, to find the necessary correction in depth for each sample. Although soil bulk density was actually measured in 5 separate depths with 10 cm increments, the SOC was measured in only 2 depths (0-20 and 20-50) (Table 2).

Table 2: *The actual sampling depths to measure soil organic carbon (SOC) and soil bulk density (SBD)*

Sampling depth increments	
SOC	SBD
0-20	0-10
	10-20
20-50	20-30
	30-40
	40-50

The average soil bulk density in the same depths, 0-20 and 20-50, was used to calculate SOC. Since each of the two systems were sampled for soil bulk density only in one location, an assumption was made that it is possible to generalize the density in each depth to the whole area covered by its related system.

The average value of soil bulk density in 0-50 profile was higher in the conventional system (1.57 g/cm^3 compared to 1.52 g/cm^3 in the integrated system), which meant more soil has been collected in the samples taken from the conventional farms (Figure 5). In order to eliminate the effect of this problem, the SOC in the extra soil had to be subtracted from the total SOC weight of conventional system, so a proper comparison with the integrated system can be performed.

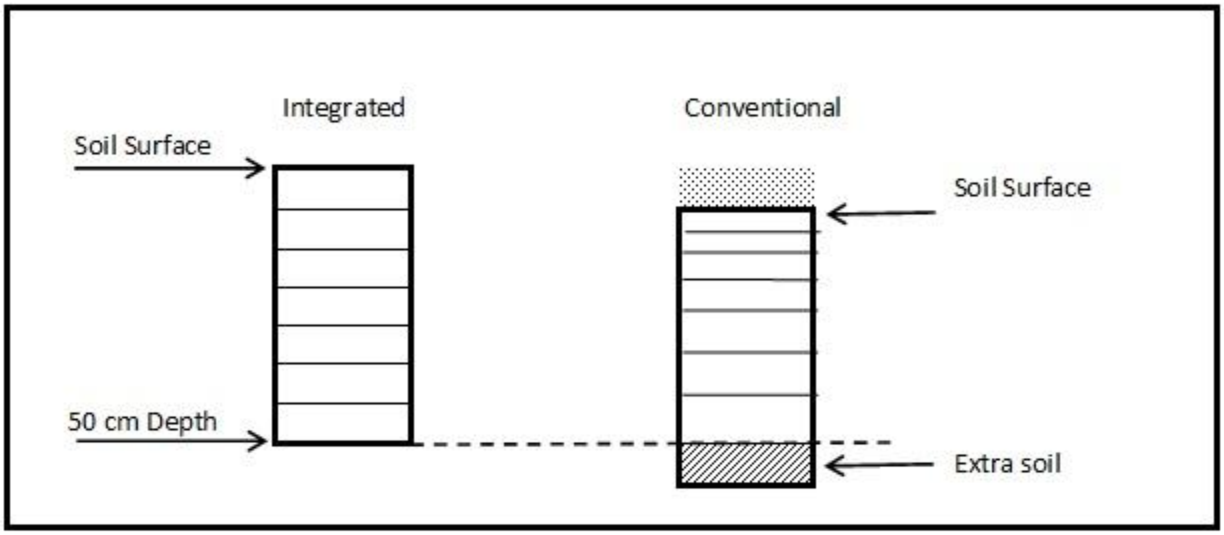

Fig 5: *A schematic illustration on soil bulk density change in two tillage systems. Both columns represent 50 cm sampling depth, but due to more compaction in conventional system (in whole 50 cm profile, as an average), the soil surface is lower, which means sampling depth is actually more compared to the integrated system.*

To correct the actual amount of SOC in the conventional system, these calculations were made:

a. As the first step, the soil weight of the sampled layer per area unit was calculated, for both farming systems:

   Soil weight (kg/m^3) = Sampling depth (m) x Bulk density (kg/m^3) x Surface area (m^2)

b. Then the amount of carbon was calculated in each sampling layer, for both farming systems, using their soil weight calculated in step (a):

   Amount of SOC in samples layer (kg/m^3) = Soil weight of sampled layer (kg) x SOC (%)

c. In order to proceed with the correction, it is necessary to calculate the weight of the extra soil (Figure 5) in conventional system and its SOC amount:

   SOC of extra soil (kg/m^3) = (Soil weight of conventional system – Soil weight of integrated system) x SOC (%) in the 20-50 cm layer of conventional system (this layer contains extra soil, (Figure 5)).

d. Now with the SOC content of the extra soil calculated, it is possible to get the correct value of SOC in conventional system by a simple subtraction:

Corrected SOC of conventional system = total SOC of conventional system – SOC of extra soil (calculated in step c).

5 Results

Soil C content under two tillage systems (minimum tillage and conventional tillage) was analyzed. In both systems samples taken from two subplots treated with different levels of N fertilizers (N0=0 kg/ha and N3=160 kg/ha). The results of analysis obtained in percentage of soil organic carbon down to 50 cm of soil depth were changed to total carbon (kg/m^2) in each treatment.

Table 3: *Soil bulk density of the experimental site. Notice the relatively higher density in top layers of integrated and deep layers of conventional plots.*

		Soil Bulk Density (g/cm^3)	
		conventional	integrated
Sampling Depth (cm)	0-10	1.30	1.41
	10-20	1.56	1.62
	20-30	1.64	1.53
	30-40	1.67	1.64
	40-50	1.67	1.42

As a simple comparison, the total amount of SOC content is presented in different depth of the soil, in both integrated and conventional systems, treated with both levels of nitrogen. The results show a relatively higher amount of carbon in top layer of the soil (Table 4) in this comparison, and all those come afterwards, the difference in soil density in different layers was considered (Table 3). Table 3 shows that the plots under conventional plowing system show relatively higher density in deeper layers, due to the hard pan caused by heavy machinery, while the integrated system caused a relatively higher soil density in top soil, where it was not disturbed for a longer time.

Before any statistical analysis, the data are presented as simple charts here to highlight the general trend of carbon content (Table 4).

Table 4: *A comparison table of percentage of SOC in both tillage systems and both nitrogen levels. Standard Error of each data set is shown on the right. The shaded cells represent 20-50 cm depth.(S/E= Standard Error, avg= Average)*

	Integrated						Conventional					
	0-20	**avg**	**S/E**	**20-50**	**avg**	**S/E**	**0-20**	**avg**	**S/E**	**20-50**	**avg**	**S/E**
N0 (0 kg N/ha)	0.87	0.63	0.06	0.38	0.42	0.04	0.81	0.62	0.05	0.28	0.34	0.04
	0.72			0.59			0.55			0.48		
	0.69			0.41			0.52			0.25		
	0.55			0.46			0.61			0.42		
	0.48			0.32			0.7			0.35		
	0.47			0.35			0.5			0.27		
N3 (160 kg N/ha)	0.81	0.65	0.06	0.31	0.35	0.02	0.8	0.65	0.04	0.31	0.31	0.03
	0.68			0.26			0.68			0.44		
	0.76			0.34			0.59			0.35		
	0.62			0.39			0.65			0.26		
	0.6			0.34			0.66			0.24		
	0.4			0.43			0.54			0.26		

The results from ANOVA have shown no significant differences in total SOC in subplots treated with 160 kg N/ha in both depths in both tillage systems. The average amount of SOC in subplots considered in this test is shown in Figure 6. Notice that the corrected values of SOC are only applied to the 0-50 column in Figure 6, as it is not applicable to 0-20 and 20-50 separately.

When comparison was made in 0-20 cm depth in both tillage systems, no significant change was observed. The test produced the same results when the deeper level of soil (20-50) was considered.

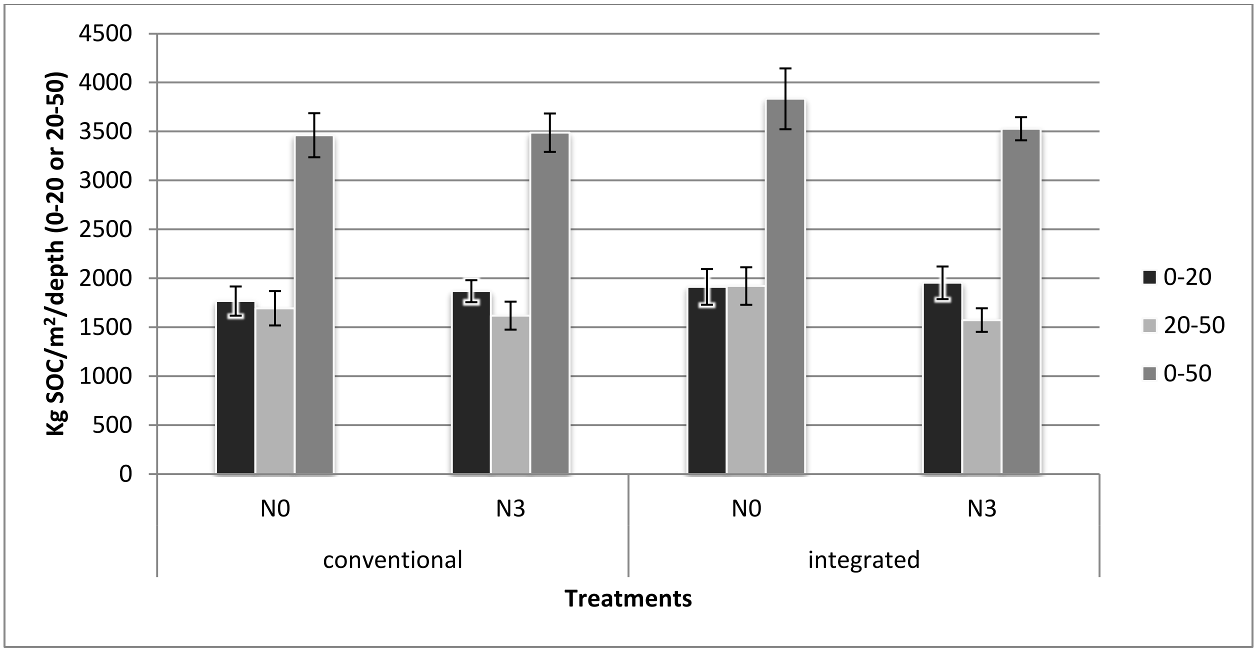

***Fig 6**: Total weight of SOC in each soil layer separately. All values are calculated considering the bulk density and actual depth of sampling. Corrected values are used in 0-50 columns only because correction is not possible for the 0-20 and 20-50 depths separately. (N0= 0 kg/ha N and N3= 160 kg/ha N).*

To analyze the differences between the tillage systems, the total carbon weight of each subplot was considered for each N-fertilizer treatment. The results showed no significant difference between of the treatments. Moreover, the comparison between the nitrogen treatments in each of the tillage systems showed no significant difference either.

6 Discussion:

The results of the current experiment showed no significant difference in SOC between the treatments at the 0-20 cm depth, 20-50 cm depth or the whole 50 cm depth. The same insignificant results were the outcome when considering different levels of N application. This can be due to limited number of samples which can lead to a failure in representing the field correctly, or limited depth of sampling, which according to Lal (2004) and Angers&Eriksen-Hamel (2008) has prevented many researchers to achieve satisfactory results because of the depth in which SOC has been washed down, or accumulated in other forms. Furthermore, Baker et al. (2007) pointed out that in studies where deeper soil samples were considered, no difference in total C in soil profile was found, and all studies which had reported more SOC in minimum or no tillage systems were biased by the sampling depth. According to Baker et al., (2006) considering the rhizosphere layer only in the research is only acceptable when its depth and thickness are the same everywhere, which is not the case and thus all researches report findings only based on the rhizosphere layer are doubtful. Davidson and Ackerman (1993) had conducted series of calculation on data from various studies and found out that most of the carbon loss occurs in the plow layer. They also found out that the total soil carbon loss will be approximately 7-10% lower when the deeper soil is included in analysis. While Pe´rie´ and Ouimet (2007) suggested that when SOC shows no significant increase under conservation tillage systems, it is because of the change in qualitative aspects of soil carbon, which means carbon might have changed its forms or location. This could be one of the reasons of not finding significant difference in SOC in top 50 cm, and draws a possibility that the difference in SOC content among different treatment may be present in different forms in deeper layers of soil.

Results in this experiment have shown no difference in SOC in plots treated by higher level of Nitrogen compared to plots which received no N fertilizer. These results agree with studies which have shown a strong effect of nitrogen fertilizers on carbon decomposition (Khan et al., 2007). Various researchers suggest that this is due to the mineralization of carbon in lower depths (Soon and Arshad, 2002; Mack et al., 2004). Mineralization of carbon can be another aspect of what was mentioned in the previous paragraph, suggested by Pe´rie´ and Ouimet (2007).

6.1: Carbon economy:

All the procedures such as residues management and conservation agricultural practices (CAPs) proposed to increase carbon in the soil must be applied to be effective. Farmers want to be sure that the risks they take for less intensive practices are worth it. Marland et al, (2001) suggest that such changes would not be welcome by farmers who are not willing to take risks when producing crops, especially older farmers who are reluctant to change their system and risk a failure at the end of their career. The same goes with farmers with limited resources. Here is where risk managing insurance would prove to be helpful. Moreover, this type of management is more resource demanding than conventional methods of production; add to that the relatively long time of adopting this type of management before any evident change in carbon is achieved because this process takes years before showing its positive effects. These factors all act as barriers in the way of widespread adoption of conservative methods of crop production.

To add more complexity to the already complex matter of adopting methods to increase carbon sequestration, four points have been highlighted by Marland et al, (2001):

6.1.1: Farms which are already being used for providing food and by-products would enter a negative competition with their previous situation when they change system to sequestrate carbon. This competence originates from decreased productivity, increased final price of the crops and finally decreased income for the farmer due to less sales and exports.

6.1.2: As mentioned before, it is suggested that applying nitrogen fertilizer would increase the amount of biomass return to the soil and help carbon sequestration (Barber, 1979). But if adding nitrogen fertilizers to the soil becomes a trend to achieve higher carbon on the soil, then the whole idea of carbon sequestration would offset from its goal. Because any increase in application of N fertilizers means more GHG production in the industry to produce fertilizers and more nitrous oxide flux from soil to the atmosphere. Depending on the rate of N fertilizer application, the CO_2 released into atmosphere defers. Brentrup et al (2004) estimated this amount to be 70, 80 and 145 kg of CO_2 for applying 144, 192 and 240 kg N fertilizer per hectare, respectively..

6.1.3: The decreased production of crop per area would mean requiring more lands to fulfill the shortage in production and that leads to deforestation and grassland conversion into farms, all leading to higher emissions.

6.1.4: Subsidies and incentives can effectively act as a driver to push the farmers toward changing their management methods to sequester carbon. But as mentioned before, all the trapped carbon can be released into the atmosphere if management methods go back to conventional. This means that subsidies and incentives must be present for long periods of time to keep the farmers interested in new management policies or otherwise the carbon gains will be eliminated or even worse, reversed back to atmosphere.

Furthermore, conservation methods which are recommended to sequester more carbon in the soil may be avoided by poor smallholders who own steep lands and/or of poor soil quality (Govaerts et al. 2009). These farmers risk their already limited production by trying conservation methods in their generally weed infested lands (Binswanger, 1980). Govaerts et al. (2009) connected this tendency to avoid conservation methods to the belief that adopting these methods is riskier than using new herbicide or new varieties of crop. Another factor which influences this aversion from conservation methods is the limited financial capital possessed by the smallholders.

In order to scale out these methods to help increasing soil carbon globally a few steps are necessary:

- A large part of farm workers and owners lack adequate education and are distant from knowledge flow to keep them in touch with the latest findings and researches in agriculture (Goavertset al., 2009).
- Previous experiences on both commercial and non-commercial farming systems proved that any innovation in agricultural science must consider the possibility of the innovation to perform in networks and groups of farmers, developers and producers of machinery, extension services and researchers (Hall et al., 2005).

To address this problem it is necessary to develop a network of "learning hubs" in different agroecological zones and considering different cropping systems. It is important to put more focus on a few representative regions of each system rather than a widespread, less effective network that covers everywhere (Sayre & Goaverts, 2008; Goaverts et al., 2009). In these learning hubs which are supervised and synthesized by international research centers the importance and methods of increasing soil carbon can be spread among the farmers as a prerequisite of applying those methods. There is no single solution to encourage farmers toward having a better carbon economy and possible methods would differ considering the differences in access to the resources in different areas, as well as variables in household dynamics and stakeholders (Tschakert, 2004).

Some organizations have considered a more monetary and financial approach to encourage farmers to participate in carbon sequestration initiatives, and among these organization lie some big players of Fortune 500 (Ford, DuPont, American Electric Power and

BP America) (Yang, 2006). The driver behind this approach is considering the main goal for most of the farmers to make more benefits out of their land and operation, and when the whole system is fit within a stock exchange system, farmers encourage their colleagues to engage in the same system so to make the shares to grow in value which brings benefits to all stakeholders. Following is a case study of one of these organizations:

Chicago Climate eXchange (CCX); A case study:

To encourage farmers and other producers to take part in possible ways of increasing soil carbon, an initiative has been among the successful examples of fulfilling this task. Started in the U.S, this initiative is called Chicago Climate eXchange (CCX) (CINRAM, 2012).

As the first step rural farmers are informed about global warming and the strong role that carbon sequestration is able to play to minimize the warming. Among many methods and possible ways of sequestering carbon, (Conservation farming, Grass planting, Anaerobic Methane Digesters, Tree planting and perennial crops production) suggested to the farmers, they could choose the one (or more than one method) that suits them, by which they earn credits.

But since the possible gains in soil carbon are relatively small in the starting years and single farmers won't gain that much credits, an aggregator is elected for a number of farmers in each area, which receives the whole credits owned by them, so they are big enough to use in CCX trading system, which is a trading platform for carbon credits (CINRAM, 2012).

Each credit is awarded to a farmer after sequestering one metric ton of carbon, and this amount is calculated on regular basis considering soil type, method of sequestering carbon and the trend of carbon accumulation. The price of each credit is increasing since the beginning of CCX in 2003, starting with 98 cents per credit in 2003 and going up to more than 4 US$ in 2007.As mentioned before, some of the Fortune 500 companies are participating in this initiative and increasing its validity and economic power. These big entities can provide substantial help to this initiative by buying shares to use them as a price to pay for the pollution they produce, so they can be accounted cleaner and in the same time, increasing the value of the shares the actual farmers hold, which leads to more profit and encourages more farmers to join the movement (Yang, 2006). On the other hand, the emission cap for the big companies is being in constant reduction by 1% per year, forcing them to reduce their emissions yearly, or buy more shares from the farmers.

This is a good example of cross-section activities leading to an environmental-centered goal. Private players (farmers), commercial players (companies) and the government (by expanding the initiative to more cities) are all enforcing the effectiveness of this program. In countries where the private sector has grown independently and is effectively active in the market, this initiative seems to be very much feasible. By increasing the number and the power of the stakeholders, and providing a win-win situation, this program can eventually prove itself to be successful enough to be used as a model in other places in the world.

7. Conclusion:

In this study, soil carbon was collected from different depths under both conventional and reduced tillage systems to analyze and discuss any detectable difference in soil carbon. The total amount of SOC in the tested soil depths showed no significant change in both tillage regimes, as was expected by the hypothesis. But the results did not agree with the hypothesis in which it was expected to detect higher levels of SOC in the top 20 cm of soil in reduced tillage system when compared to conventional tillage system. Also the hypothesis on detecting lower level of SOC in the 20-50 depth of the profile in reduced tillage system could not be certified. Furthermore, increased level of N-fertilization showed no significant change in SOC in top 50 cm of soil as total, neither in each of the separate depths (0-20, 20-50) in the experimental site.

More possible reasons behind lack of any significant difference between the treatments, considering other researches, could be insufficient number of the samples, shallow sampling depth, instrument errors due to technical problems or contamination and the experimental design, which I believe all have contributed in the results with different intensities.

Economic wise, considering all the energy and cost to pay for fuel and fertilizers and their big footprint in ecosystems pollution, steps must be taken to limit their application.

Perspective for future research:

Soil carbon content trend under different production systems, its effect and contribution on yield and production of bio-fuel and biogas related crops, an analysis of environmental effects during the process.

Biofuels are very much into public focus now, considering the unreliability of fossil fuels due to political reasons and their negative footprint on the environment. This is a motive behind the growing attention on producing energy crops and even changing the final products of some other yields from food to energy (e.g. sugarcane, corn,…).

As in any other case, expansion in producing energy crops must be considered thoroughly to realize any tradeoff we have to make in any of the production phases.

An integrated process of producing energy crops comes useful in some aspects. Even if we have the benefits of the final product (biofuel) for granted, but still we can make many corrections to the conventional way of producing these plants; like land preparation strategies, irrigation efficiency, crop protection and all the logistics and industrial stages that come after harvest.

Choosing the experimental site in which I have done my research can be a promising start point for further experiments, because of the availability of long-time records of soil related factors in the past years, which makes it easier to make comparisons and conclusion on the effects of cropping systems on the soil characteristics and its elemental content.

One of these experiments can start right after analyzing the soil carbon content. After this analysis, the soil organic carbon will be compared to the previous years. Based on the results, a production of an energy crop can commence and the yield can be analyzed for the possible effect of the increased carbon in soil.

After this stage an LCA (Life Cycle Assessment) analysis could be performed with a focus on the energy aspect. By default there are some positive points, energy wise. Starting with minimum tillage and ending with an energy crop. All of these points can be reviewed with a bright view of sustainability and soil health. It can be summed up in figure 7:

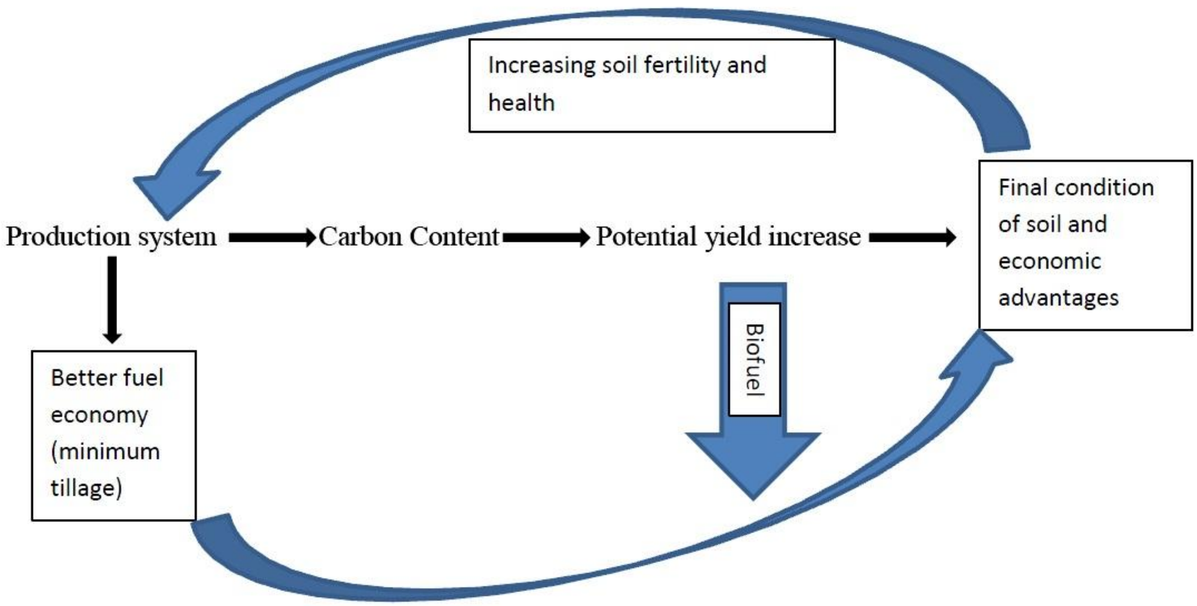

Fig 7: *A schematic view of possible advantages of integrated energy crops production system*

Appendix 1:

Rotation sequence of the experimental site:

Year	Plot	Conventional (A)	Integrated (B)
2009	I	Oats (Winter wheat after harvest)	Faba beans (Winter wheat after harvest)
	II	Winter wheat_2	Winter wheat_2 (Oil radish after harvest)
	III	Spring barley (Winter rapeseed after harvest)	Ley (Winter rapeseed after harvest)
	IV	Winter wheat_1	Winter wheat_1 (with undersown ley)
	V	Sugar beats	Sugar beets
	VI	Winter rapeseed (Winter wheat after harvest)	Winter rapeseed (Winter wheat after harvest)
		Winter wheat_1	Winter wheat_1 (with undersown ley)
		Sugar beats	Sugar beats
2010	I	Winter rapeseed (Winter wheat after harvest)	Winter rapeseed (Winter wheat after harvest)
	II	Spring barley (Winter rapeseed after harvest)	Ley (Winter rapeseed after harvest)
	III	Oats (Winter wheat after harvest)	Faba beans (Winter wheat after harvest)
	IV	Winter wheat_2	Winter wheat_2 (Oil radish after harvest)
	V	Spring barley (Winter rapeseed after harvest)	Ley (Winter rapeseed after harvest)
	VI	Oats (Winter wheat after harvest)	Faba beans (Winter wheat after harvest)
		Winter wheat_2	Winter wheat_2 (Oil radish after harvest)
		Spring rapeseed (Winter wheat after harvest)	Winter rapeseed (Winter wheat after harvest)
2011	I	Winter wheat_1	Winter wheat_1 (with undersown ley)
	II	Sugar beats	Sugar beats
	III	Winter rapeseed (Winter wheat after harvest)	Winter rapeseed (Winter wheat after harvest)
	IV	Spring barley_1	Spring barley_1 (with undersown ley)
	V	Sugar beats	Sugar beats
	VI	Spring barley_2	Spring barley_2 (Oil radish after harvest)
		Spring barley (Winter rapeseed after harvest)	Ley (Winter rapeseed after harvest)
		Oats (Winter wheat after harvest)	Faba beans (Winter wheat after harvest)
2012	I	Winter wheat_2	Winter wheat_2 (Oil radish after harvest)
	II	Spring barley (Winter rapeseed after harvest)	Ley (Winter rapeseed after harvest)
	III	Oats (Winter wheat after harvest)	Faba beans (Winter wheat after harvest)
	IV	Sugar beats	Sugar beats
	V	Winter rapeseed (Winter wheat after harvest)	Winter rapeseed (Winter wheat after harvest)
	VI	Winter wheat_1	Winter wheat_1 (with undersown ley)

Appendix 2:

Factsheet:

Soil organic carbon

And its importance

Overview:

Soil Organic Carbon (SOC) is a type of carbon which is present in top soils almost all over the world, but in different concentrations. It is originated from plant litter including roots and animal bodies getting decomposed by soil biota (living microorganisms). This carbon will return to the atmosphere in the form of CO_2 after decomposition within a certain timescale dependent on its nature.

Importance:

The presence of SOC has numerous positive effects on soil's physical, chemical and biological characteristics. For example soil structure and infiltration capacity, its potential to hold water and provide the plants with it when necessary, providing plants and microbes with nutrients and micro elements. These advantages mean less soil erosion, less nutrient leaching and higher biological activities around the roots of the plants. Simply, it increases soil quality.

How to keep and increase it?

Unfortunately, SOC maybe lost from soil as CO_2 into the atmosphere, making the soil poorer and increases atmosphere emission, which is leading to increased effect of GHG and higher temperatures in the coming years.

Full inversion tillage (moldboard plowing) is one of the biggest players in releasing SOC into the Atmosphere

The full inversion tillage, which is used widely everywhere is a main cause of releasing the SOC in the form of CO_2 into the atmosphere. It releases the trapped carbon and aerates the soil for further decomposition.

Reincorporating crop residues into the soil after harvest with minimum soil disturbance techniques has been proven as an effective way in increasing (or at least stabilizing) soil carbon and bring all of its benefits to the soil. Getting rid of the residues like taking them away or burning them must be strongly avoided, especially burning residues. Because it increases the temperature in the top soil to very high levels and destroys soil's biota, which affects soil health and decomposition of the residues in both short and long terms.

So to achieve the highest possible levels of SOC and all of its advantages it is strongly recommended to:

- Reduce the intensity of soil disturbance during land preparation to the lowest possible amounts by using more conservation methods like chisel plowing,…
- Management of residues as mulch and incorporating them in the soil is necessary to achieve satisfactory results
- Reducing the amount fertilizer application and chemicals. Beside the benefits to the economy and environment, this will reduce the rate of decomposition and increases SOC concentration in the soil.
- Setting up a long term schedule of applying all of the mentioned steps, as carbon increase in the soil takes a while but losing it due to inappropriate management happens very fast.

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