ISTRO INFO

A Publication of the International Soil Tillage Research Organization

October 2006

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Table of Contents

ISTRO INFO – October 2006

By now, I am sure everyone has returned from the 17th Triennial Conference in Kiel, Germany and shared your wonderful experiences with all of your colleagues. It was a very successful conference thanks to the excellent organization of past-President Rainer Horn and all of the members of his Soil Science Institute. Approximately 330 ISTRO members were in attendance. There were many excellent oral and poster presentations, discussions over a cup of coffee and/or beer, and of course a chance to renew friendships and make new connections with colleagues from around the World. If anyone has any special memories or pictures they wish to share with others through ISTRO INFO please send them to me and I will include them in future issues.

The conference came to a close with an exciting video highlighting Turkey, where the 18th Triennial Conference will be hosted by our new President Engin Cakir at Ege University in Bornova – Izmir in 2009. Based on the good work that has begun already, I am sure that everyone will want to begin thinking right away about a presentation and other types of activities that you will want to take part in at our next conference.

Finally, due to a very hectic personal travel schedule this issue is a bit late and shorter than usual. However there were some important items, especially the up-coming conference entitled “Agriculture between Tradition and Intensification” that will be held on the 19th and 20th of October 2006 in Iasi, Romania, that I wanted to remind everyone about. I look forward to a summary of that event for the next issue of ISTRO-INFO. Once again, I want to remind everyone to feel free to pass on your copy of this newsletter and to invite your colleagues to join in the benefits of being a member of this wonderful International Soil Tillage Research Organization.

Cheers,
Doug Karlen
Assistant Secretary General

Invitation to Annual Scientific Conference in Romania

The Academic Board of the Faculty of Agriculture, Iasi, Romania invites ISTRO members to attend the Annual Scientific Conference entitled "Agriculture Between Tradition and Intensification" that will be held on the 19th and 20th of October 2006. The conference will address current agricultural problems from four different perspectives: Fundamental research, Soil, Water and Environmental Protection, Agricultural Technologies, and Economic Sciences and Humanities. Registration fees (70 €) will include a book of abstracts (including the program), a CD with the scientific papers of the conference, coffee/tea breaks and the conference banquet. For more information see: http://www.univagro-iasi.ro/simpozion/index.php?lang=en&pagina=home.html

Farming Systems & Environmental Quality Conference

The Lithuanian Branch of ISTRO invites all members to participate in an international scientific conference on "Farming Systems and Environmental Quality" on November 16 and 17, 2006 at the Lithuanian University of Agriculture, near Kaunas. For those not familiar with Lithuania, Kaunas is approximately 100 km from the capital (Vilnius). It will take about 1.5 to 2 hours by bus or train to reach Kaunas from Vilnius.

The official Conference languages will be English and Lithuanian. The primary topics will include (1) Soil Tillage and Environment, (2) Crop Rotations, (3) Weed Control, (4) Conservation and Organic Farming Systems, and (5) Economic, Prognoses, and Modeling. The Conference will include both oral and poster presentations, discussions, and an excursion to "Old Town" in Kaunas. The registration fee is 30 € and will include a welcoming reception, conference proceedings and refreshments during the conference. For more information see: http://www.lzua.lt/intern/engl/main.php?cat=13.

Important ISTRO Branch Information

Several of the ISTRO Branches met with the Branch Coordinator (Dr. John Morrison) while at the 17th Triennial ISTRO Conference in Kiel. Key points that were made are:

1. The first priority of ISTRO is to have Branches that are highly functional

2. Each Branch is encouraged to hold national meetings/seminars/workshops/etc. uring the next 3 years. The ISTRO Treasury will pay up to 1000 Euros to help finance these Branch Meetings. Application for these funds should be made directly to Secretary-General, Jan van den Akker: janjh.vandenakker@wur.nl
3. Each Branch needs to pay Annual ISTRO Membership dues for 3 Members (usually 3 Branch Officers); this payment will qualify them as an Active Branch and the Branch will receive a free subscription of the Journal to circulate among Branch Members and later archive in their library. ISTRO (Dues should be sent to the Treasurer is Allen Torbert (atorbert@ars.usda.gov)
4. The ISTRO website: http://www.ISTRO.org is going to add a page for listing the activities of all ISTRO Branches. Each Branch should please send a ½ page information sheet to the Secretary-General so that your Branch will be represented. Also, when your Branch develops their own website, please inform ISTRO so that a link to your website can be added to the main ISTRO site.
5. Branch Members seeking cooperative research partners, manuscript reviewers, or other assistance are encouraged to send your request to Assistant Secretary-General, Doug Karlen, (Karlen@nstl.gov) for inclusion in ISTRO-INFO newsletters.
6. **Contact Persons**: John Morrison (morrison@mounet.com) will continue to serve as the coordinator for the ISTRO Branches. Inge Hakansson will continue to serve as Mentor for Branches in the Baltic States; Willem Hoogmoed will serve as Mentor for a new Branch being planned for Beijing, China; and the ISTRO President-Elect (Prof. Dr. Oswaldo Ernst of Urugay oernst@fagro.edu.uy) is available to help ISTRO Members in South America.

Are You Interested in No-Tillage or Conservation Agriculture?

ISTRO member Dr. Don Reicosky (USDA-ARS, Morris, MN) recently shared several interesting websites with articles related to no-tillage and conservation agriculture. The first (http://www.plantmanagementnetwork.org/sub/cm/research/2006/tillage/) is for a paper entitled “Influence of tillage on corn and soybean yield in the United States and Canada.” It summarizes an extensive literature review conducted to compare corn and soybean yields for no-tillage and conventional fall tillage systems. The second website: (http://californiaagriculture.ucop.edu/0603JAS/toc.html) leads to two publications from California entitled "Conservation tillage production systems compared in San Joaquin Valley cotton and Conservation tillage and cover cropping influence soil properties in San Joaquin Valley cotton-tomato crop."

Another ISTRO member (Nilantha.Hulugalle,Cotton Research Institute, New South Wales, Australia nilanthah@csiro.au) is leading a project that deals in part with developing stubble retention systems for irrigated cotton on permanent beds in Vertisols. The attached pdf file (entitled "Stubble Management")contains an excerpt from his 2005 report. It is included with this issue of ISTRO-INFO to illustrate another way for sharing information. Also, for more information, please see:

Hulugalle, N., Finlay, L., Scott, F., and Weaver, T. (2004). Managing irrigated cotton sown into standing stubble. Aust. Cottongrower, 25(5), 58-62.

Hulugalle, N.R., Weaver, T.B., and Scott, F. (2005). "Final report to Cotton Research and Development Corporation on CRDC Project no. CRC 45C (Maintaining profitability and soil quality in cotton farming systems)", 70 pp., submitted 2005.

Finally, I also want to bring your attention to an article prepared by former ISTRO Board Member (Rolf Derpsch). The paper entitled "The extent of Conservation Agriculture Adoption worldwide: implications and impact" was presented at the III World Congress of Conservation Agriculture in Nairobi Kenya in 2005. This paper examines the extent of no-tillage adoption world wide and discusses its implications and impact on the main countries and regions of the world. The file (entitled FAOAG- Conservation Agriculture) is also attached to this Newsletter.

USDA Offers On-Line Irrigation Calculator

A web-based calculator has been designed to help producers understand the cost of irrigating their crops. The calculator also evaluates opportunities to save on energy cost and improve the efficiency of irrigation management. The Energy Estimator for Irrigation is available at: http://www.usda.gov/energytools.

Meet ISTRO's President-Elect

Dr. John Morrison provided the following picture of ISTRO's President-Elect (Prof. Dr. Oswaldo Ernst) (he's the one in the middle) taken at the ISTRO Conference in Kiel. Please look for more information about both our current President (Engin Cakir) and Oswaldo in future issues of ISTRO-INFO.

Final Comments

Once again, I want to thank all of those who sent information for this issue of ISTRO INFO. For a useful and meaningful resource, please continue to share whatever might be of interest to your colleagues. I also want to encourage our ISTRO leaders in those countries where English is not easily read and understood to feel free to translate any or all of these articles into your native language. Communication is the key to a successful organization, so please do whatever is necessary to maximize the impact of our organization.

Doug Karlen, Assistant Secretary General

Paper presented to III World Congress on Conservation Agriculture
Nairobi, Kenya, October 2005

The extent of Conservation Agriculture adoption worldwide: Implications and impact

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Abstract

No-tillage is now being adopted on more than 95 million ha world wide and the technology is showing increasing interest by farmers. The countries with the biggest area under no-tillage are the USA, followed by Brazil, Argentina, Canada, Australia and Paraguay. These are the 6 countries were adoption is above 1 million ha. Adoption rates are increasing much faster in South America than in other parts of the world and also the quality of no-tillage is better in terms of permanently not tilling the soil and permanent soil cover. Adoption rates continue to be very low in Europe, Africa and most parts of Asia. Approximately 47% of the no-tillage technology is practiced in South America, 39% is practiced in the United States and Canada, 9% in Australia and about 3.9% in the rest of the world, including Europe, Africa and Asia. Despite good and long lasting research in this part of the world, no-tillage has had only small rates of adoption. Rather than attempting to draw a global picture of the impact of no-till adoption world wide, it was preferred to study and understand some of the implications and impacts that have occurred in the countries with the highest levels of adoption. Research performed in the USA shows that if conservation tillage adoption rates would reach 76%, almost half the carbon would be lost in conventional tillage in relation to the situation in 1993, while no-tillage would contribute to increase carbon deposits into the soil by almost 400 million tons, where it contributes to increase soil fertility. By adopting the no-tillage system Brazil increased its grain production by 67.2 million tons in 15 years, which, assuming conservative average prices of US$ 150/t, means additional revenue of about 10 billion dollars. At an average rate of 0.51 t/ha year Brazil is sequestering about 12 million t of carbon on 23.6 million ha of no-tillage adoption. On small farms in Santa Catarina State, Brazil, no-tillage (in addition to other soil conservation measures like relocating roads to follow the contours), has led to a reduction of 80% in the costs of maintaining roads, while at the same time increasing trafficability. The monitoring of the Lajeado Sao José watershed at Chapecó, showed a 22% reduction of its sediment load and 68.2% reduction in fecal coli bacteria from 1994 to 1998 because of no-till adoption. Similarly to Brazil grain production in Argentina more than doubled in a period of 13 years (from 28 million tons in 1988 to 74 million tons in 2001). That means that in a period of 13 years the production grew by 46 million tons or 164%. In the same period the area under production grew by 44% and the area under no-tillage grew from about a 100.000 ha in 1988 to 11.7 million ha in 2001. An additional 46 million tons of production at average prices of US$ 150/t, means additional revenue of almost 7 billion dollars, of which a great portion can be attributed to the adoption of the no-tillage technology. In Canada at a C02 sequestration rate of 0.74 t/ha, farmers that practice no-tillage would be sequestering about 9 million tons of C02 from the atmosphere each year, while at the same time they enrich the soil in carbon. Experienced agriculturalists and politicians in Western Australia have publicly stated that no-tillage increased crop production in the year 2000 by at least 3 million t from no-tillage adoption. Likewise production in 2001 was increased by an extra 5 million t and in 2002 by another 4 million t. This is an extra 12 million t of grain that has been grown in the three dry years of 2000-2002, being an extra production of 20-30%. At an average grain value of US$ 150/t, this is US$ 1.8 billion additional revenue. In Paraguay where no-tillage is used on 1.7 million ha, farmers are saving 38.2 million tons of soil. Tractor use is reduced by roughly 6 million hours saving 34.68 million l of diesel, or US$ 22.88 million in hard currency for diesel imports. All these examples show a significant impact of adopting the no-tillage technology.

Media summary
The extent of no-tillage adoption world wide and its implications and impact on the main countries and regions of adoption is shown.

Key Words
No-tillage, Conservation Agriculture, extent of Conservation Agriculture adoption worldwide, impact of no-till adoption, impact of Conservation Agriculture adoption.

Introduction

Conservation Agriculture (CA) is now widely recognized as a viable concept for sustainable agriculture due to its comprehensive benefits in economic, environmental and social sustainability. Its principles are already widely adopted (FAO, 2002). The basic elements of CA are: very little or no soil disturbance, no burning, direct seeding into previously untilled soil, crop rotation and permanent soil cover. The use of the term conservation agriculture instead of no-tillage, conservation tillage, direct seeding and several other related terms has helped greatly to improve the understanding of a more sustainable way of farming in national and international organizations worldwide. The problem of this term though, is that it comprises such a wide range of different technologies that it is difficult to understand what is meant because denominations and definitions are handled quite freely in different parts of the world. Therefore this paper will concentrate on only one technology of conservation agriculture which is the ultimate form and goal to be achieved in CA, and this is no-tillage. No-tillage is defined as "planting crops in previously untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done" (Phillips and Young, 1973). Permanent no-tillage is meant, rather than not tilling in one season and tilling in the other, or occasionally not tilling the soil. The soil should remain covered by crop residues from previous cash crops or green manure cover crops, and most of these crop residues will remain undisturbed on the soil surface after seeding. As long as this requirement is met, shanks can be used to break compacted soil layers below the seed zone on wide row crops. Therefore the French term "agriculture de couverture du sol" (cover agriculture), seems to be more appropriate than no-tillage, unless we use the latter term in a broader sense (Derpsch, 2001a). Any seeding technology that seeds into unprepared soil but does any kind of surface or subsurface tillage (e. g. with sweeps or tines) that covers most or the whole width of the seeding machine can not be termed no-tillage. Almost all the advantages of the no-tillage system come from the permanent cover of the soil and only very few from not tilling the soil. Maximum possible carbon sequestration should be the main goal of any CA system.

More difficult than in mechanized medium sized and big farms, is to estimate the area under no-tillage on small farms. There are huge discrepancies in what is meant by small farms. In the Indo-Gangetic-Plains for instance, a small farmer has less than 5 ha, a medium sized farmer has 5 to 10 ha and > 10 ha is already a large farm. In Brazil small, medium and big farms are classified by the capital investment rather than the size of the farm. Here a small farm could have as much as 50 ha and would use animal traction. Another example is Paraguay where small farmers are classified as those that have no motor mechanization and perform their farming operations only with their hands or with animal traction and operate on less than 20 ha. In Ghana there is said to be several hundred thousand ha of no-tillage being applied on small farms with average sizes of less than half hectare. For the reasons explained here it will become clear that it is very difficult to come up with numbers on the area of adoption of no-tillage on small farms. When presenting numbers on adoption of no-tillage on small farms it is always necessary to define what is understood by small farm and to also mention the number of adopters together with the area of adoption. The number of adopters, even if they apply the technology only on part of their farm or to certain crops is probably more significant than the area under no-tillage for a certain country or region.

While at the beginning it was thought that no-tillage would only work under certain climates and soils, it has become clear that the technology can be practiced successfully in a wide range of climatic, soils and geographic conditions. No-till cover cropping systems have worked from the Equator, e.g., Kenya, Uganda, to a latitude of 40º S, e.g., Argentina, Chile, to 60º N, e.g., Finland; from sea level to 3000 m, e.g. Bolivia, Colombia; in soils with 90% sand, e.g., Australia, Paraguay, to 85% clay e.g., Brazil, Paraguay, from 200 mm of rain, e.g., Western Australia, to 2000 mm of precipitation, e.g., Brazil, or 3000 mm e.g., Chile. Through the years no-tillage has been shown to work in all kind of environments. Conditions where the technology does not work are rare and often limiting conditions can be overcome by using appropriate technologies. It has been shown to be easier to adapt the no-tillage technology to physical conditions than to human conditions. Mindset continues to be one of the biggest barriers to no-till adoption and here farmers, researchers and extensionists are included.

The extent of CA / No-tillage adoption worldwide

One has to be aware that only a few countries in the world conduct surveys on the extent of no-tillage adoption and that in most cases the data is based on estimates made by farmer organizations, agro industry and others. Table 1 shows the estimated area under no-tillage worldwide.

Table 1: Extent of no-tillage adoption worldwide

Country	Area under No-tillage (ha) 2004/2005
USA 1	25.304.000
Brazil 2	23.600.000
Argentina (*)	3 18.269.000
Canada 4	12.522.000
Australia 5	9.000.000
Paraguay 6	1.700.000
Indo-Gangetic-Plains (**) 7	1.900.000
Bolivia 8	550.000
South Africa 9	300.000
Spain 10	300.000
Venezuela 11	300.000
Uruguay 12	263.000
France 13	150.000
Chile 14	120.000
Colombia 15	102.000
China 16	100.000
Others (Estimate)	1.000.000
Total	95.480.000

Source: 1) John Hassel CTIC, 2005; 2) FEBRAPDP, 2005; 3) AAPRESID, 2004; 4) Dr. Doug McKell, Soil Conserv. Council of Canada, 2004; 5) Bill Crabtree, WANTFA, 2005, 6) MAG - DEAG, Soil Conservation Program, 2005; 7) Dr. Peter Hobbs & Raj Gupta 2005; 8) Carlito Los, 2005, 9) Richard Fowler, 2003; 10) ECAF Homepage, 2005; 11) Rafael E. Perez, 2004; 12) Miguel Carballal AUSID, 2005; 13) ECAF Homepage, 2005; 14) Carlos Crovetto, 2005; 15) Fabio Leiva, 2005; 16) Li Hongwen, 2005;

(*) Preliminary information based on 40% of data collection for 03/04

(**) Includes four countries in South Asia, India, Pakistan, Bangladesh and Nepal

Readers of this paper, who think that their countries should be mentioned in this list, or that some numbers should be corrected, are invited to contact the author giving credit of the sources of the information. Above mentioned definition of no-tillage should be respected.

Numbers for China are preliminary and could be greater. In Northern China several hundred thousand ha are used in double cropping wheat and maize. Most maize is no-till seeded, but in the autumn, after maize harvesting, all the fields are ploughed to sow wheat. As this can not be considered to be no-tillage, this area is not included in the above table (Li Hongwen, personal communication 2005).

Russia and several neighbouring countries (mainly Ukraine and Kazakhstan) are claiming to have at least a million ha under no-tillage. But here we have a definition problem. In those countries seeding directly into undisturbed soil is considered to be no-tillage, even if while seeding, 100% or most part of the soil surface is tilled. AAPRESID in Argentina (the national No-till farmers association), has developed a slogan that says "seeding directly is not direct seeding (meaning no-tillage)". In Russia, Ukraine and Kazakhstan many farmers are seeding directly but not using no-tillage. In this region, there is certainly a growing number of farmers using no-tillage in the way it is understood in most countries of the world, but no figures could be obtained on the area under this system.

It is estimated that at present no-tillage is practiced on more than 95 million hectares world wide. Approximately 47% of the technology is practiced in South America, 39% is practiced in the United States and Canada, 9% in Australia and about 3.9% in the rest of the world, including Europe, Africa and Asia. Despite good and long lasting research in this part of the world showing positive results for no-tillage, this technology has had only small rates of adoption.

Data presented at the ISCO Conference in Indianapolis in 1999 (Derpsch, 2001a), showed 45.5 million ha of no-tillage being adopted by farmers at that time. More recent data presented at the I World Congress on Conservation Agriculture in Madrid (Derpsch, 2001b,) showed 62 million ha of no-tillage being adopted worldwide. That means that the area under this technology has more than doubled since 1999 and has increased by 54% since 2001. Since the II World Congress on CA (Derpsch and Benites, 2003), no-tillage adoption has grown by 25 million ha.

<u>Adoption of no-tillage by small farmers</u>: According to FEBRAPDP (Lutecia Canalli, personal communication 2005) there are about 500 to 600 thousand ha of no-tillage being adopted by small farmers with animal traction in Brazil. Assuming an average adoption of 5 ha per farmer, there would be around a 100.000 farmers using the technology in Brazil. Also in Paraguay the number of small farmers adopting the technology is growing rapidly. It is estimated that approximately 12.000 farmers are using no-tillage on about 30.000 ha. There is said to be 300 to 350 thousand small farmers with less than half ha adopting no-tillage in a slash and burn system in Ghana, but this information and the number of ha involved could not be confirmed. Another region with a huge number of farmers adopting no-tillage on small farms is the Indo-Gangetic-Plains. Here a few hundred thousand farmers are using the technology on an estimated 1.9 - 2.1 million ha.

Implications and impact of adopting the no-tillage technology

World soils are important reservoirs of active carbon (C) and play a major role in the global C cycle. The soil contains two to three times as much C as the atmosphere. In the last 120 years, intensive agriculture has caused a C loss between 30 and 50% and over the past 150 years, the amount of CO_2 in the atmosphere has increased by 30% (Reicosky, 2005a).

Since the mechanization of agriculture began a few hundred years ago, scientists estimate that some 78 billion metric tons of carbon once trapped in the soil have been lost to the atmosphere in the form of CO2. Short sighted agricultural practices have resulted in loss of an estimated 4 billion tons of carbon from soils in the United States (Lal, 2004) This is, because intensive soil tillage accelerates the oxidation of organic matter and converts crop residues into carbon dioxide, which is liberated to the atmosphere contributing to the greenhouse effect and global warming of the planet.

Rather than trying to show the global impact of the no-tillage technology as asked by the organizers of the III World Congress on Conservation Agriculture, the author of this paper has preferred to analyse some of the implications and impacts the technology has had in the main countries or regionsof adoption. The reason for this is that in general the impact of no-tillage is quite different in different parts of the world and global numbers may not reflect the real local situation. Carbon sequestration for instance is dependent on many factors such as climate (temperature, rainfall), soil type, latitude, potential biomass production, crop rotation, use of green manure cover crops, machine type and amount of soil disturbance while seeding (discs, tines), etc. So what may be true for one region of the world may not be true for another.

In terms of productivity impact of no-tillage will certainly be very different depending on crops and climatic conditions. While soybeans have shown to yield about 20% more in no-tillage compared to conventional cultivation in Southern Brazil and Paraguay, this has not happened with many crops in the region, and it certainly has not happened with crops like cereals in Europe for instance.

As will be seen in several examples later in this paper, adoption of CA/no-till is producing significant impacts in terms of achieving relevant millennium goals, as reducing the risk of desertification, alleviating hunger, contributing to food security, poverty alleviation, income generation and environmental objectives such as carbon sequestration and climate change.

No-tillage in the USA, implications and impact of the technology

Historically the United States has been leading the world showing the biggest area of no- tillage adoption by farmers. But it is interesting to note, that in this country no-tillage accounts for only 22.6% of all cropland hectares. In Brazil and Argentina no-tillage accounts for about 60% and in Paraguay for about 65% of all cropland hectares.

Another interesting point about adopters in the USA is that only about 10 - 12% of the total area under no-tillage is being permanently not tilled (CTIC, 2005). In contrast to this, more than 90% of the area under no-tillage in Argentina, Brazil Bolivia, Paraguay and Australia is permanently not being tilled.

Impact in terms of carbon sequestration: Research performed by the USDA/ARS with specialized equipment, shows that soil carbon is lost very rapidly in the form of carbon dioxide, within minutes after soil preparation and that the amount lost is directly related to the intensity of tillage. After 19 days, the total loss of carbon, from a plot of ploughed-under wheat residues, was up to five times higher than from plots not ploughed. In fact, the loss of carbon was equal to the quantity of carbon in the wheat residues which had remained in the field from the previous crop. (CTIC, 1996). It is the loss of soil carbon (in the form of carbon dioxide - CO2) during tillage which reduces soil organic matter content.

Reicosky (1997) reported that average short-term C loss from four conservation tillage tools was 31% of the CO_2 from the mouldboard plough. The mouldboard plough lost 13.8 times more CO_2 as the soil not tilled while conservation tillage tools averaged about 4.3 times more CO_2 loss.

In this respect also the Kyoto Protocol has to be mentioned. The Kyoto Protocol is an international agreement setting targets for industrialized countries to cut their green house gases emissions. The agreement has come into force on February 16, 2005 following its official ratification by Russia on November 18, 2004. The Kyoto Protocol strengthens the international response to climate change (Reicosky, 2005b).

Whilst the burning of fossil fuels is responsible for the greater part of CO_2 emitted, it is estimated that wide dissemination of "Conservation Tillage" (which leaves at least 30% of plant residue cover on the surface of the soil after planting) could offset as much as 16% of worldwide fossil fuel emissions (CTIC, 1996). The wide dissemination of no-tillage technologies would have a much greater effect

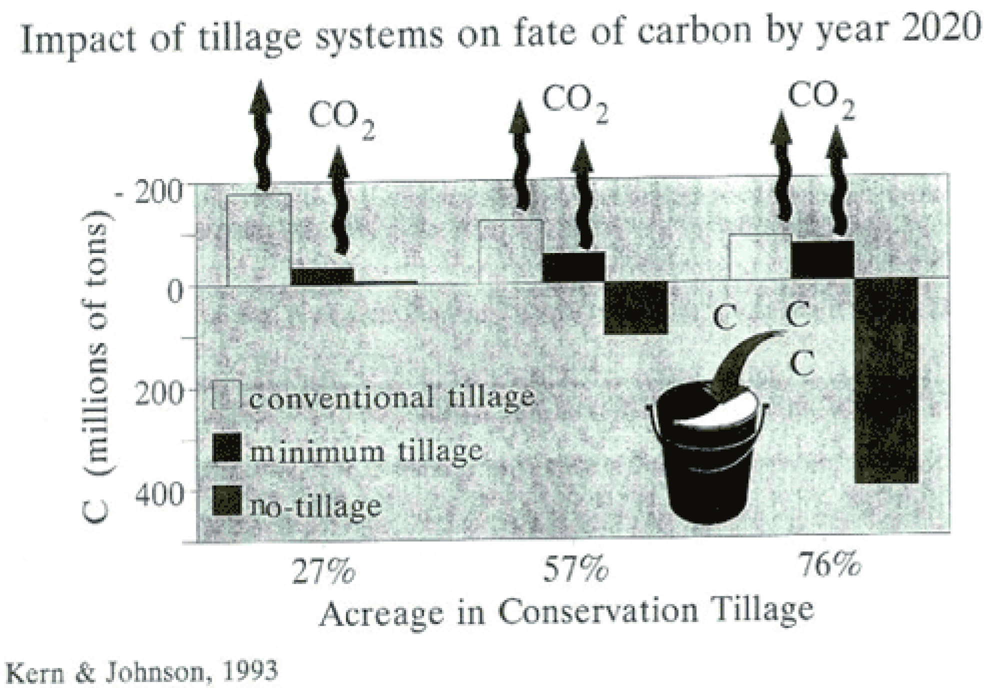


Figure 1: Impact of tillage system on the fate of carbon by year 2020. Source: Kern & Johnson, 1993. Slide prepared by Reeves, 1995.

In the USA, the fate of soil carbon considering three hypothesis of adoption of conservation tillage until the year 2020 was studied (Figure 1). In the first hypothesis, in which conservation tillage adoption rates of 1993 (27%) are maintained, and where conventional tillage prevails, almost 200 million tons of carbon are lost to the atmosphere. In the second hypothesis, in which conservation tillage adoption would increase to 57%, a reduction in CO_2 emissions can be observed. In the third hypothesis, when conservation tillage adoption rates would reach 76%, in conventional tillage almost half the carbon is lost in relation to hypothesis one, while Zero Tillage would contribute to increase carbon deposits into the soil by almost 400 million tons, where it contributes to increase soil fertility (Kern and Johnson, 1993). This is equivalent to a net reduction in carbon emissions of the same amount (liberated to the atmosphere as the greenhouse gas carbon dioxide).

Widespread conversion of agricultural production from conventional tillage to conservation tillage would change the whole soil manipulation system from a source of atmospheric carbon to a sink of organic carbon into the soil, increasing its fertility (Kern and Johnson, 1993).

According to Lal, *et al.*, 1998, the overall potential of U.S. cropland for C sequestration, fossil fuel offset, and erosion control is 120 - 270 MMTC/year. Most of this corresponds to agricultural practices with large C sequestration potential like conservation tillage and crop residue management (49%) and improved cropping systems (25%). Soil erosion prevention could reduce emissions by 12 - 22 MMTC/year, and conversion to conservation tillage could produce estimated savings in fossil fuel of 1 - 2 MMTC/year.

There is enough research evidence to show that permanent soil cover and increasing soil C storage can increase water infiltration, reduce the hazard of flooding, reduce drought stress, increase soil fertility, decrease wind and water erosion, minimize compaction, enhance water quality, decrease C emissions, impede pesticide movement and enhance environmental quality.

No-tillage in Brazil, implications and impact of the technology

With 23.6 million ha of no-tillage being applied by farmers (about 60% of cultivated area), Brazil is second worldwide in terms of area of adoption of this technology. As no-tillage is growing at much faster rates in Brazil than in the USA it can be foreseen that the North American leadership in no-till adoption will not last very long. In terms of quality of no-tillage, Brazil and the neighbouring countries have higher standards than in the USA. Green manure cover crops and crop rotation are widely used in Brazil in contrast to the USA, where little adoption has occurred. Permanent no-tillage is applied on more than 90% of the whole area under this technology in Brazil, while in the USA only 10 - 12% of the total area is permanently not being tilled. Research has shown that it takes more than 20 years of continuous no-tillage to reap the full benefits of the system (Fig. 2 and 3). Farmers that practice rotational tillage, i.e. plough or till their soils every now and than will never experience the full benefits of the system.

Research conducted by Lafond (personal comm., 2005, figure 2) has shown that after 20 years of continuous no-tillage with full stubble retention higher yields can be obtained in comparison with a short term (2-year) no-tillage system. With no nitrogen application, yields of about 1.75 t/ha were obtained in a 2-year no-tillage situation compared to 2.8 t/ha obtained after 20 year no-tillage. Moreover the protein content of the grain was much higher in the long term no-tillage. This is important for farmers in Canada, as they get penalized when the protein content of the grain is below 14%.

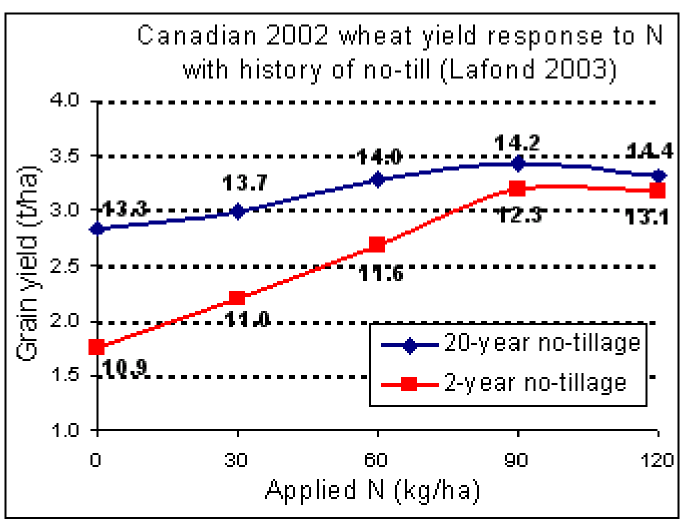
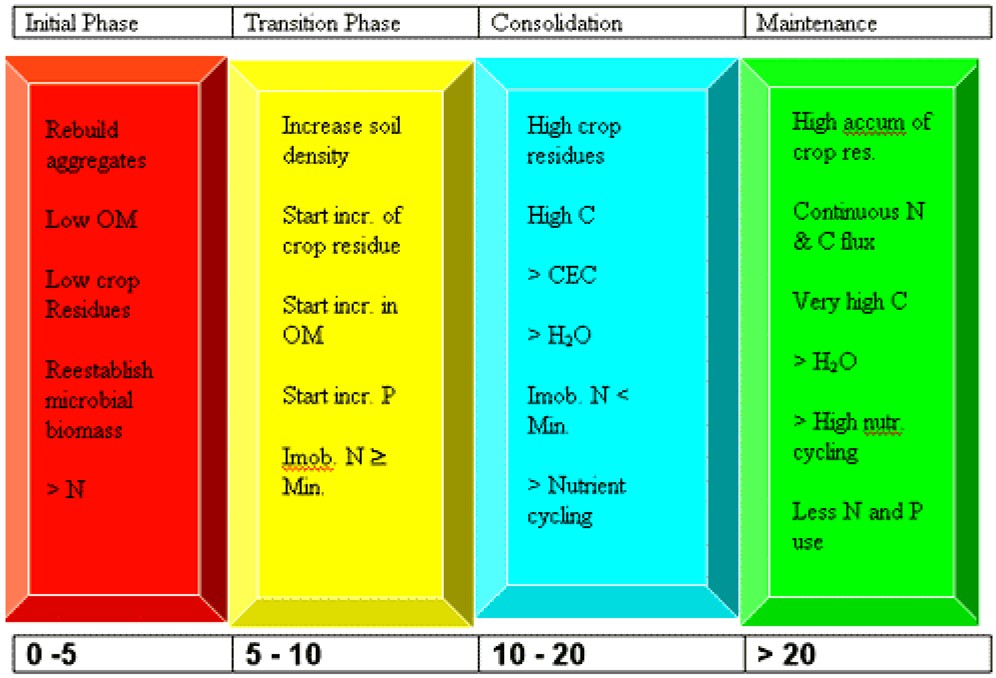


Figure 2: Canadian 2002 wheat yield response to N with history of no-till

It certainly would not have been possible to obtain these results if residues were sold, burned or eaten by animals. This graph is helpful in understanding how to get no-tillage to a higher level and to better comprehend the graph below.



Evolution of a continuous no-tillage system
Time (Years of continuous Zero Till)

Figure 3: Evolution scale of the no-tillage system (Full stubble retention permanent no-till system) (Sá, 2004)

Figure 3 illustrates the evolution of a long term continuous no-till system:
In the initial phase (0 - 5 years) the soil starts rebuilding aggregates and measurable changes in the carbon content of the soil are not expected. Crop residues are low and N needs to be added to the system.

In the transition phase (5 - 10 years) an increase in soil density is observed. The amount of crop residues as well carbon and phosphorus content start to increase.

In the consolidation phase (10 - 20 years) higher amounts of crop residues as well as higher carbon contents in the soil are achieved, a higher cation exchange capacity and water holding capacity is measured. Greater nutrient cycling is observed.

It is only in the maintenance phase (> 20 years) that the ideal situation with the maximum benefits for the soil is achieved and less fertilizer is needed.

Any tillage performed in the phases 2 - 4 means a return to the initial phase. Farmers that till the soil once in a while will never see the full benefits of the system. Farmers practicing a no-till system without full stubble retention, i.e. letting animals graze the fields, baling and/or selling the residues and/or burning the residues, will probably never leave the initial phase. If fields are well managed leaving a reasonable amount of soil cover, farmers eventually may start entering the transition phase.

The impact permanent no-tillage has on improvement of soil fertility and more efficient land use (2 crops are grown a year where formerly only 1 was grown, or 2.5 crops are grown a year where formerly only 2 crops were grown) is shown in figure 4. In only 15 years, grain production in Brazil more than doubled from 57.8 million tons in 1991 to 125 million tons in 2004. This increase of grain production matches very well with the increase in area under no-tillage. No-till adoption reached about one million ha in Brazil in 1991 and then it grew exponentially to 23.6 million ha in 2004. It is good to remember that it took about 20 years, from 1972 when the first farmer adopted no-till, to reach one million ha in 1991. The graph also shows that in the same period the expansion of cultivated land was only 11% from 37.8 to 42 million ha.

Figure 4: Grain production in Brazil in million tons (upper line) and area under production million ha (lower line) from 1991 to 2004 (Conab - Cooplantío, 2004)

In a period of 15 years, from 1991 to 2004, no-till adoption in Brazil grew by 22, 6 million ha and grain production increased by 67.2 million tons which at average prices of US$ 150/t means additional revenue of about 10 Billion Dollars. Certainly other factors as improved technology and better varieties, etc., have had an influence in this sharp increase in grain production, but it is probably fair to say that the greatest influence came from applying the no-till technology.

Another big impact no tillage has in Brazil is the reduction in carbon dioxide emissions. It has been shown that it is possible to extract 110 million tons of carbon dioxide from the atmosphere only by using no-tillage in the Cerrado Region and in Southern Brazil. Of this, 50 million t would be due to carbon sequestration and 60 million t due to erosion control (Lal, 2003).

Data presented by Sá (2004) at the Agronomy Seminar at Kansas State University shows numbers from different Brazilian authors in different latitudes of Brazil, indicating soil organic carbon sequestration rates varying from 0.51 to 1.84 t/ha/year. Considering a conservative average rate of 0.51 t/ha/year for Brazil, this country would be sequestering about 12 million t of carbon on 23.6 million ha of no-tillage adoption.

Aproximately 40% of the no-tillage area in Brazil is located in the southern states. From the 1970's to middle of 1980's this region was a source of CO_2 to the atmosphere due to decrease of soil carbon stock and high consumption of fuel by intensive tillage. Since then, no-till has restored soil carbon loss and reduced the consumption of fuel (Amado, *et al.*, 2005).

Impact on small farms: When analyzing the impact of no-tillage on small farms in the State of Santa Catarina, Brazil, it was shown that 54% of farmers increased their cultivated area after adoption of the technology, showing that because less labour was needed more area could be planted (Instituto CEPAL, SC, 1999). Comparing conventional tillage to no-tillage the same authors showed higher yields in the no-tillage system, the biggest differences occurring in maize (+20%), onions (+26%) and phaseolus beans (+ 30%). Consequently increased crop gross margins were obtained in no-tillage in all crop rotations analysed. On average crop gross margins were 58% to 164% higher in no-tillage compared to conventional tillage due to higher yields and lower costs of production. All adopters said it would be unthinkable to abandon no-tillage and go back to conventional tillage practices (Instituto CEPAL, SC, 1999).

Local industry profited from an increased adoption of no-tillage. While only about 100 no-till seeders for animal traction were produced in the State of Santa Catarina in 1994 the number increased to more than 2500, produced by several small industries, in 1998. This has generated income and jobs in remote regions of the state having a positive socio economic impact on the economy. Until 1998 the no-till machine industry has generated more than 200 jobs directly and its annual revenue reaches US$ 4 million (Instituto CEPAL, SC, 1999).

In the State of Santa Catarina adoption of no-tillage and minimum tillage increased from 194.000 ha in 1994 to 880.000 ha in 1999 (all farm sizes). Massive adoption of no-tillage has also dramatically increased water infiltration into the soil, reducing erosion and the sediment load of rivers. No-tillage in addition to other soil conservation measures like relocating roads to follow the contours, has led to a reduction of 80% in the costs of maintaining roads and trafficability of roads has increased substantially. The monitoring of the Lajeado Sao José watershed at Chapecó showed a 22% reduction of its sediment load and 68.2% reduction in fecal coli bacteria from 1994 to 1998 (Instituto CEPAL, SC, 1999).

No-tillage in Argentina, implications and impact of the technology

Also in Argentina no-tillage is adopted on about 60% of the total cultivated area. A survey made in Argentina in 2002 showed that no-tillage was being used on 16 million ha in this country. Preliminary data for 03/04 shows an adoption of 18.2 million ha. As no-tillage has been growing at rates of over one million ha/year since 1996/97 it can be expected that in 2005 the area should exceed 19 million ha.

Similarly to Brazil grain production in Argentina more than doubled in a period of 13 years. Grain production grew from 28 million tons in 1988 to 74 million tons in 2001 (Figure 5). That means that in a period of 13 years the production grew by 46 million tons or 164%. In the same period the area under production grew from 18 to 26 million ha, an increase of 44% and the area under no-tillage grew from about a 100.000 ha in 1988 to 11.7 million ha in 2001.

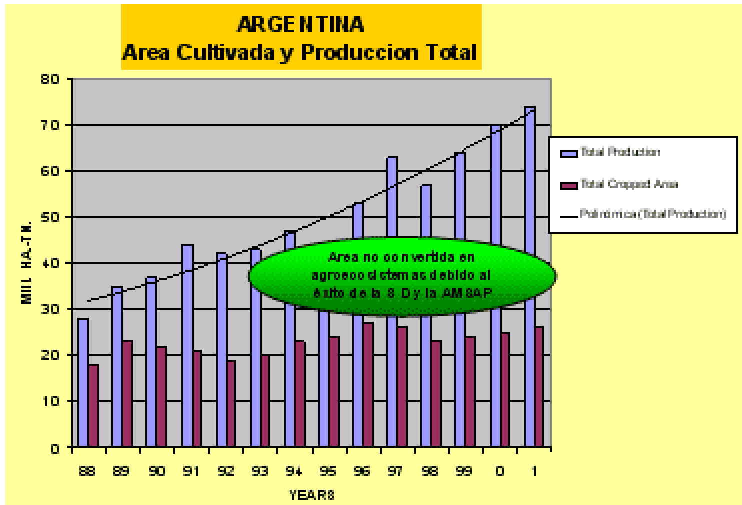


Figure 5: Grain production in Argentina in million tons (higher columns) and area under production million ha (lower columns) from 1988 to 2001 (Secretaria de Agricultura Ganaderia Pesca y Alimentos (SAGPyA) de la Nación / AAPRESID).

The green area in the graph represents the area of forest and pastures not converted into agro-ecosystems due to the success and rapid adoption of the no-tillage technology.

An additional 46 million tons of production at average prices of US$ 150/t, means additional revenue of almost 7 billion dollars, of which a great portion can be attributed to the adoption of the no-tillage technology. This additional money that enters the economy has a great impact not only on farmers income but on machine manufacturers and distributors, fertilizer manufacturers and distributors, chemical products manufacturers and distributors, transport, and consumption of goods in general, having a major impact on the countries economy as a whole.

Research performed by INTA (Yamada, 1999) shows that in a period of a hundred years, between 1880 and 1980, organic matter content of the soil in the fertile Argentinean Pampa was reduced from 6% to 2.5%. This reduction is attributed mainly to conventional tillage practices. With no-tillage and permanent soil cover this process is reverted so increasing carbon levels can be expected in Argentinean soils in the future.

No-tillage in Canada, implications and impact of the technology

With 12.5 million ha of no-till adoption, Canada ranks fourth in the list of countries with the biggest area under this technology being applied by farmers. "Due to Canada's hard economic times for farmers the area has fallen from 2004 to 2005, but our long term no tillers are experiencing very good soil quality changes with many in the position now to reduce their overall commercial fertilizer requirements" (Doug McKell, personal communication, 2005). Proof of this statement is research done by Lafond (shown in graph Nr. 2), where it can be seen that one extra ton of grain could be harvested in a 20 year no-till situation, as compared to a two year no-till situation, when no nitrogen was applied. The reason for this is explained in graph Nr. 3 which shows that a high accumulation of crop residues occurs in a long term no-till situation, with continuous N and C flux and very high C levels. Also a high nutrient cycling and less N and P requirements lead to lower fertilizer application needs in the long term.

As far as C02 sequestration is concerned, the generally accepted co-efficient for C02 sequestration when converting land from minimum till to no-till is 0.74 ton/ha. This is quite conservative as in most prairie situations that rate could be 1 t/ha or higher. However to use a standard number this would be acceptable (Doug McKell, personal communication, 2005). At the lower rate, farmers in Canada that practice no-tillage, would be sequestering about 9 million tons of C02 from the atmosphere each year, while at the same time they enrich the soil in organic carbon.

No-tillage in Australia, implications and impact of the technology

No-tillage has been the most rapidly embraced farmer technology in Australia's 100 year agricultural history. It has improved weed control, time of sowing, given drought tolerance and has enabled dry regions to use water most efficiently (Crabtree, 2004). With 9 million ha and an adoption reaching 50% in the eastern States and 82% in Western Australia, this nation is among the leading countries in terms of no-till adoption. At the same time it has to be said that in general there is a poor quality of no-tillage being practiced in this country. The reason is that tine seeding machines, which move too much soil covering crop residues, are the most widely used seeding equipment. Also in many regions most farmers keep sheep and no-till into a low to very low residue situation. Most Australian farmers have little appreciation for soil cover and the ones that would like to increase their residue cover can only do it to a certain level, because the seeding equipment does not work with high amounts of crop residues on the soil surface. But the leading no-till farmer associations like WANTFA, SANTFA, and others, are aware of this problem and together with GRDC and other government and non government organizations are making a big effort to improve the production systems in order to reach a more sustainable no-tillage system.

Adoption of no-tillage has had a big impact on the farming operation and has changed drastically the way farming operations were carried out in Australia. According do Crabtree (2004) the following benefits are experienced by farmers when using the system:

1. Greatly improved trafficability of no-tillage in wet areas,
2. Earlier time of sowing from not having to waste time cultivating,
3. Less labour, horsepower and fuel were required,
4. Superior weed control and the herbicides became more efficacious against surface weed seeds,
5. Better soil health
6. More time is available to spend with the family or expand the farm.
7. The yield is increased by 10% with a 10 day earlier time of sowing with no-tillage in WA
8. No-tillage is vastly superior to tillage based agriculture in drought years and in dry regions.
9. Soils that farmers could not establish crops on are now some of their most productive soils, where 4.5 t/ha of wheat is common in 450 mm rainfall areas.

No-till has provided both short and long-term economic gains. The soil health and fertility has improved with no-till and a lot of soil has been saved from wind and water erosion that would otherwise have been lost with tillage-based agriculture. Better soil health, with softer soil, has ensured improved soil-water infiltration, decreased evaporation and increased organic matter that is able to effectively store and release available water and nutrients to plants.

Experienced agriculturalists and politicians have publicly stated that no-tillage increased Western Australia (WA) crop production in the year 2000 by at least 3 million t from no-tillage adoption. Likewise in 2001 production increased by an extra 5 million t and in 2002 it increased by another 4 million t. This is an extra 12 million t of grain that has been grown in WA in the three dry years of 2000-2002, being an extra 20-30%. At an average grain value of US$ 150/t, this is US$ 1.8 billion in a state of 1.7 million people. The long-term soil effects have also been most profound. An economic analysis shows a US$ 52/ha advantage to no-tillage over tillage based farming. This is US$ 468 billion on 9 Mill. Ha (Crabtree, 2004).

No-tillage in Paraguay, implications and impact of the technology

Paraguay is among the 6 countries in the world that has more than one million ha of no-tillage being adopted by farmers. Adoption has been extremely rapid in this country and the area grew from 20.000 ha in 1992 to about 1.7 million ha in 2005. With 65% of the whole cultivated area under this technology, Paraguay leads the world in terms of percentage of no-till adoption. Most farmers practice permanent no-tillage rather than alternating the technology with tillage ones in a while. Erosion control, soil improvement, higher yields and higher economic returns as well as an efficient diffusion strategy are the main reasons for this quick adoption by farmers.

In conventional tillage Paraguay is losing on average 9.2 tons of soil for each ton of soybean being produced. In conventional agriculture in Paraguay 23 t of soil are lost on average per ha/year while only 0.53 t/ha/year are lost when using the no-till system, a difference of 22.47 t/ha/year (Venialgo, 1996, cited by Derpsch, *et al.*, 2000). In other words on 1.7 million ha of no-tillage being applied, farmers are saving 38.2 million tons of soil. One has to remember that the damage of lost soil in conventional tillage does not only affect farmers, soil is deposited in creeks and rivers causing sedimentation of rivers, lakes and dams, it blocks roads, often causing accidents, etc. This deposition of sediments in unwanted places has negative implications on the rural road system, hydraulic energy generation, on drinking water production, on recreational areas, resulting in significant expenditures for the State and for society as a whole. These costs are avoided or minimized through application of the no-tillage technology.

The economic results for a typical large farm (135 ha) in the Itapua region of Paraguay are summarized on table 2. In Conventional Cultivation (CC) farm income decreases (from US$ 64,690 to US$ 61,450) while under no-tillage (NT) it increases considerably (from US$ 63,670 to US$ 102,860). Farm costs (both variable and fixed costs, the latter exclusive of the cost of NT equipment) increase under NT compared to CC, but these increases are less than the corresponding increases in farm income. Thus, net farm income increases considerably under NT, from US$ 9,770 in year 1 to US$ 33,700 in year 10, while under CC it is calculated to decrease from US$ 7,300 to US$ 1,100 due to soil erosion and reducing soil fertility (Sorrenson, *et al.*, 1997).

	FIRST YEAR (US$)		TENTH YEAR (US$)	
	CC	NT	CC	NT
Total Farm Income	64,688	63,675	61,454	102,856
Total Variable Costs	38,818	36,674	41,792	56,077
Total Fixed Costs	18,567	17,229	18,567	13,075
Net Farm Income	7,304	9,771	1,095	33,703

Table 2. Economic results of no-tillage (NT) compared to conventional cultivation (CC) over 10 years (Sorrenson, *et al.*, 1997).

On a typical large farm (135 ha), net farm income increases by US$ 23,930 in year 10. As there are about 10.000 large farms in Paraguay, in year 10 farmers reap an additional income of US$ 239.3 million, assuming an average farm size of 135 ha.

While in conventional tillage soil fertility is depleted over time, a building of soil fertility occurs in the no-tillage system because nutrient losses through erosion are avoided and a build up of organic matter takes place (see figures 1, 2 and 3). The yield increases due to improvement in soil fertility over time has been rated at 1% per year or 10% in 10 years (Sorrenson, *et al.*, 1997). Soybean production in Paraguay in 2005 has been around 3,500,000 t. That means that in 10 years, on this 1.7 million ha being used under no-tillage, production is expected to increase by 350.000 t, which represents an increased production for farmers and increased hard currency generation for the country of US$ 52.5 million (at conservative prices of US$ 150/t). This is without considering the cumulative gains in the 10 year period. Research and farmer experience has shown that increasing soil fertility allows for a reduction in fertilizer inputs. After 18 years of no-tillage pioneer farmer Frank Dijkstra of Ponta Grossa, Brazil, (personal communication 1998) could (under similar climate and soil conditions as in Paraguay) increase his soybean and maize production by 50% and by almost 100% respectively (average of an 800 ha farm), while at the same time he reduced his fertilizer costs by 50% in soybeans and by 30% in maize.

Economic studies have also shown, that no-tillage produces substantial reductions in fuel consumption. While conventional tillage with the plough and traditional tillage with the heavy disc harrow uses 42.3 and 34.3 l/ha of diesel respectively, with no-tillage consumption is reduced to 13.9 l/ha of diesel (Sorrenson and Montoya, 1984). Thus, no-tillage is saving 20.4 l/ha of diesel compared to the traditional system. On 1.7 million ha of no-tillage Paraguay is saving 34.68 million l of diesel and US$ 22.88 million in hard currency for diesel imports (at US$ 0.66/l). This reduced fuel consumption also reduces CO_2 emissions. Tractor hours per ha are reduced by 33% using the no-tillage system and this reduces labour and increases life of the tractor. Previous studies made in Brazil showed that the lifespan of a tractor is increased from 8 - 10 years in the conventional system to 16 - 20 years when using the no-tillage technology (Sorrenson and Montoya, 1984). On 1.7 million ha of no-tillage in Paraguay tractor use is reduced by roughly 6 million hours (based on Sorrenson, *et al.*, 1997). In 1998 when only 480.000 ha were under no-tillage in Paraguay the total benefits of using the no-tillage system were calculated to be in the order of US$ 950 million per year (Derpsch, 1998). Because since then the area under no-tillage has increased 3.5 times it can be assumed that benefits in 2005 have increased correspondingly.

Economic analysis was also carried out on small farms. The analysis clearly shows that the effects of no-tillage and conservation agriculture, in financial terms, are much better than those under conventional cultivation (Lange, 2005). As a result of this, many farmers using the no-tillage system have built new stone houses to replace their old wooden houses. Additionally, farmers are buying new household goods like TV's, motor-cycles, fridges, freezers, etc. Some of the children of these farmers are even affording to go to university. The school-aged children attend school on a regular basis and will continue to do so, because their work is no longer needed on the farm (through less labour requirement for crop production) and their parents can afford to pay school costs. They do not need to leave in order to work off-farm, which is another indicator of the good farming performance (Lange, 2005).

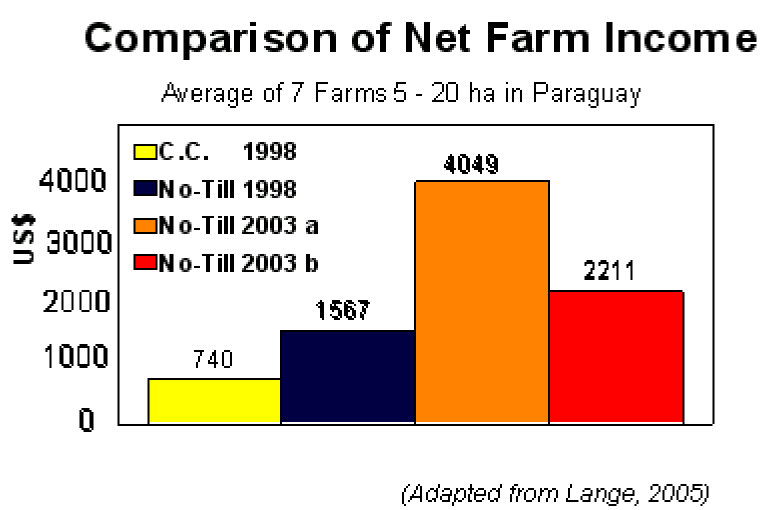


Figure 6: Comparison of net farm income in US$. (C.C. Conventional Cultivation) (average of seven farms between 5 and 20 ha) in Paraguay (Adapted from Lange, 2005).

The seven farms chosen for the study shown in figure 6 are representative for two different regions, San Pedro and Itapua, Paraguay. The graph shows the marked differences in net farm income when using conventional cultivation (C.C.) and No-till. In 1998 the study shows a 112% increase in net farm income when using no-till compared to C.C. Five years later, when the analysis was repeated in 2003, the net farm income in no-till (a) was 158% higher when actual market and product prices, input costs and exchange rates where used and 41% higher when the same market and product prices, input costs and exchange rates from 1988 where used (no-till b). This was done to find out if the financial developments are market driven or if they can also be related to conditions of the cultivation system. The difference between the two scenarios indicates that the higher income achieved by farmers is mainly derived from the improved commodity prices and cost reduction. When looking at the results of the second scenario (no-till b), it is clear that a further improvement of farming conditions such as increased soil fertility, resulting in higher yields, are based on the no-till system (Lange, 2005).

From the economic analysis it is concluded that "no-till and crop rotations constitute a technological revolution for small farmers. Never before has the senior author analysed such an impressive technology for small farmers in more than twenty years of extensive experience analysing small farm systems in South America, Africa and Asia. To the authors' knowledge, no other farming techniques have been shown to have such a high impact on farmers' incomes, reduce their production costs and risks, and at the same time be environmentally sustainable and generate very considerable net social gains to society" (Sorrenson, *et al.* 1997).

No-tillage in the Indo-Gangetic-Plains, implications and impact of the technology
(Personal communication by Dr. Raj Gupta, CIMMYT, India, 2005)
The Indo-Gangetic-Plains are composed by four countries, India, Pakistan, Nepal and Bangladesh. Zero till enhances the productivity of wheat grain by 100 - 200 kg/ha in the northwest part of the Indo-Gangetic-Plains, however in the eastern Gangetic Plains more significant yield increases of 200 - 1000 kg/ha can be achieved. In the eastern Gangetic Plains an average monetary benefit of US$ 80/ha is obtained by farmers.

Because of the time needed to till the soil, late seeding occurs often in conventional tillage. Late planting of wheat after the 8-12th of November reduces wheat yields by an average of 35 kg/day, and when planting is delayed beyond the 20th of November yield losses of 50-65 kg/day may occur. These losses are avoided when using the no-tillage system. Considering these facts the total benefits accrued in the 2004 winter to the region will come out in the range of US$ 140 - 180 million in just this winter wheat season.

More heartening is the fact that farmers have extended the technology to rice, lentil, maize, pigeon pea, indian mustard, linseed, peas and several other crops. The technology has expanded to 1.9 - 2.1 million ha and, with a little bit of adjustment, could be extended to additional 8 million ha in the region.

Savings somewhere like US$ 75/ha are obtained while using the zero till machine over conventional tillage. Then there is a few hundred kg extra yield, savings in water and fuel for pumping, less weeds, and in some cases bolder seed (earlier planting) and better prices. So it obviously increases profits and income. It also frees up time that can be used to do other productive work (Peter Hobbs, personal communication, 2005).

Economic analysis carried out in Punjab, India, also shows the higher profitability of zero till compared to the conventional system. With the zero till technology per hectare net benefit was US$ 240 whereas with conventional net income was US$ 216/ha and for the traditional system it was US$ 150. Net income was 62% higher with the zero till compared to the traditional method (Khan, *et al.*, 2001). The same authors mention significant savings in land preparation costs, water savings (0.6 million acre-inch) and savings in diesel fuel required for lifting water (1.4 million litre).

Conclusions

Positive impacts of using the no-tillage technology are manifold in the different regions were adoption has been greatest. The changes in farm production methods from conventional to no-tillage systems have reversed the former trend of declining crop productivity and led to an economically, ecologically and socially sustainable form of cropping in all countries and regions that have had significant rates of adoption.

No-tillage has great potential to increase carbon sequestration and decrease net emissions of carbon dioxide and other greenhouse gases, but policy makers have not widely recognized this potential.

The widespread adoption of no-tillage results in a win-win situation for farmers and for society as a whole. The farmer wins by reducing tillage operations thus reducing fossil fuel consumption, also by reducing erosion and thus protecting and improving his soil, while at the same time producing higher yields at lower costs. This way, farmers are increasing profitability and sustainability of their farming operation. The consumer wins by receiving a healthier product at lower cost on his table. Society wins by conserving water and soil resources and contributing significantly to reduce carbon dioxide emissions to the atmosphere. And finally our children will win, as no-tillage technologies are leaving a better world for future generations.

There is evidence that CA/no-till has had a significant impact in terms of relevant millennium goals as reducing the threat of desertification, mitigating hunger, contributing to food security, poverty alleviation, income generation and environmental objectives such as carbon sequestration and climate change, improving the quality of life of adopters and their families and improving the environment for all.

A global effort is needed to increase the adoption of no-till farming practices soon and governments need to support the adoption giving incentives to farmers in the form of financial resources for buying equipment as well as for agricultural research and extension. Aid programs should place far greater emphasis in supporting a rapid diffusion of the no-tillage system in developing countries.

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5.1.5 ***Overcoming some management constraints associated with sowing irrigated cotton into standing crop stubble***

While sowing cotton into standing wheat or vetch stubble retained on beds and in furrows has many advantages, disadvantages related to crop management such as blocking of "gas knives" by stubble during injection of anhydrous ammonia as fertiliser, waterlogging during irrigation and suffocation of cotton seedlings by vetch stubble regrowth exist.

Blocking of "gas knives" by wheat stubble during application of anhydrous ammonia can be avoided by attaching coulter discs to the front bar of the gas rig, in front of the gas tines, to cut through wheat stubble (Fig. 20). A press wheel, which follows the tine, seals the soil and leaves a rolled surface ready for planting. The gas tines and press wheels are fastened onto the back bar of the gas rig. During the pass of the rig, the only stubble disturbed is that on the top of the bed. After anhydrous ammonia has been injected, a 10-cm wide stubble-free strip, remains on top of the beds. This modification to the gas injection rig, which was developed during 2000-2001 (see Final Report for Project no. CRC 12C) was evaluated during the past three cotton seasons in the experiments at ACRI. We are convinced that it can eliminate the problem related to blocking of “gas knives” during injection of anhydrous ammonia.

Figure 20. Modified anhydrous ammonia rig with coulter discs in front of gas knives

Figure 21. Clearing standing wheat stubble from furrows with sweeps. (A) Uncleared furrow with standing stubble; (B) Cleared furrow with 2-m stubble buffer

Waterlogging during irrigation events can be avoided by retaining the stubble in the furrows only until the start of the irrigation season (Fig. 21A). (This is done because the stubble facilitates rainfall harvesting during winter and early spring). At this point, except for a 2 m long strip in the furrows at the tail drain end of the field, the point of a sweep is run through the furrow to a depth of about 10-cm to clean out the stubble from the furrow bottom (Fig. 21B). This increases the rate of water flow through the field. However, the retained 2-m strip slows water flow just enough to settle out dispersed clay and silt (Fig. 22). Salts, nutrients and pesticides attached onto clay particles are deposited in the furrow and do not move off field with runoff.

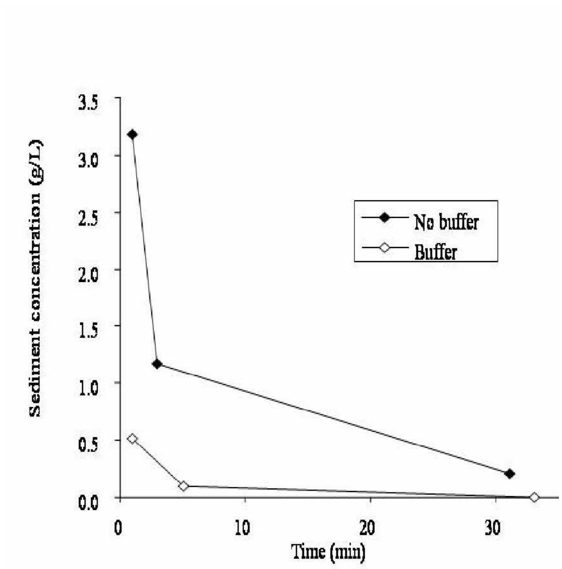

Figure 22. Effect of 2-m vetch buffer on sediment concentration in runoff from 1st irrigation in October 2003 at the Australian Cotton Research Institute, near Narrabri, NSW, Australia

Regrowth of vetch can be best controlled by mowing/slashing the vetch at 50% flowering, followed by running a set of coulter discs along the plant line to cut off the runners, and finally 2 applications of spray seed at a rate of 3 L/ha (Figs. 23 and 24).

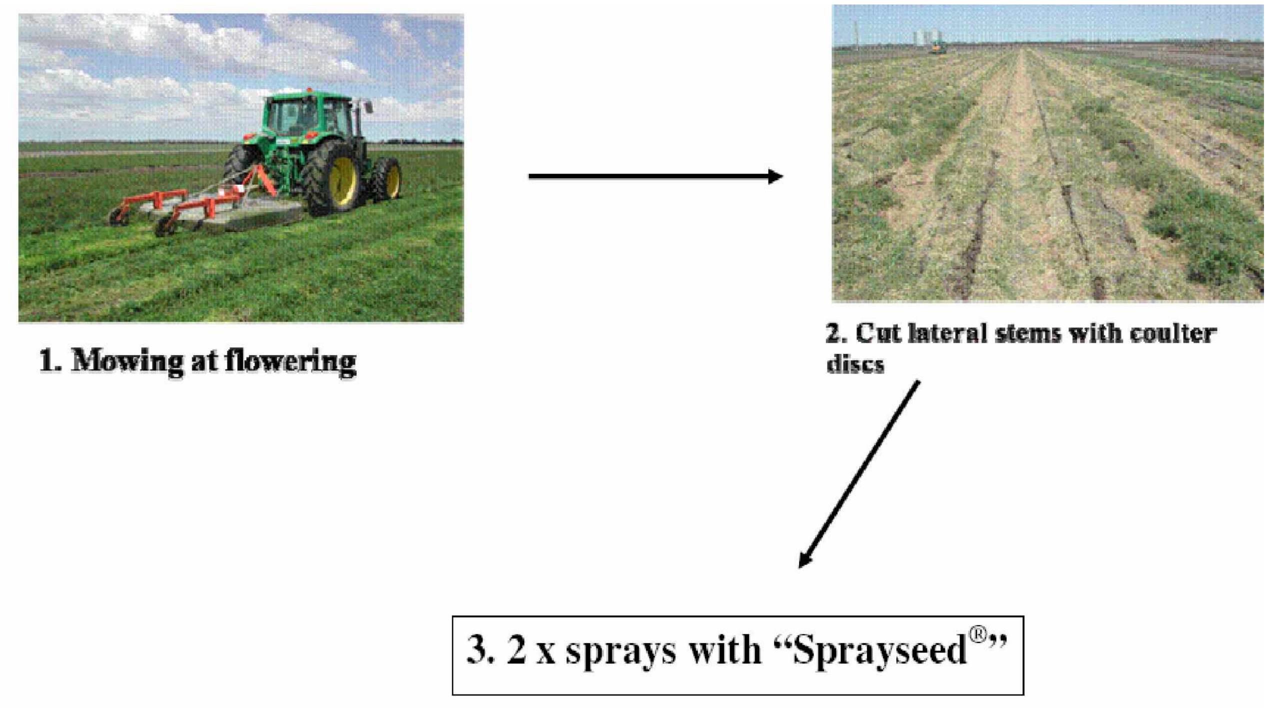

Figure 23. Process of controlling vetch regrowth

Figure 24. Sprayed-out vetch stubble ready to be sown with cotton, October 2004