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Successes, growth rates and experiences with direct seeding in Latin America.

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Abstract

Paradigms of agricultural production have changed drastically in the last three decades. Maximising yield per unit area has given way to maximising economic returns. Soil resource exploitation has given way to rational site-oriented use of the soil. Unsustainable ways of agricultural production are no longer accepted and have given way to sustainable land use. It has been recognised that only if sustainable production on the farm site is accomplished, sustainable rural development can be achieved. Finally it is being recognised that sustainable rural development is a prerequisite for global sustainable development.

Despite this progress, still the majority of farmers and scientists around the world feel that soil tillage is necessary to produce a crop, that plant residues have to be buried with tillage implements, that bare soil is a normal consequence of tilling the soil and that soil erosion is an unavoidable process associated to modern farming.

In Latin America these paradigms are rapidly changing. With farmers not tilling the soil for up to 30 years, farmers and researchers have come to the conclusion that a) tillage is not necessary to produce a crop, b) plant residues have to remain on the soil surface as mulch and not be buried, c) in the tropics the soil must be permanently covered with crop residues, and d) soil erosion is merely a symptom that for that area and ecosystem, unsuited methods of farming are being used.

These changes of paradigms have brought about drastic changes in the methods of farming. In Brazil for instance no-tillage adoption increased from one million ha in 1990 to 15 million ha in the year 2001. In the same period no-tillage adoption in Argentina increased from 300.000 ha to 11.7 million ha and in Paraguay it increased from about 10.000 ha to more than 1 million ha. Although worldwide the biggest area under no-tillage is found in the USA, in this country the technology is applied only on 17,5% of the total cultivated area, against 39% in Brazil, 46% in Argentina and 55% in Paraguay. In relation to the total cultivated area, Paraguay is among the countries with the highest adoption rate of no-tillage in the world.

Introduction

No-tillage or zero tillage is defined in Latin America as the planting of crops in previously unprepared soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil preparation is performed (Phillips and Young, 1973). In Latin America also permanent no-tillage is used, rather than not tilling the soil occasionally. It is understood that the soil remains covered by crop residues from previous cash crops or green manure cover crops (GMCC's) and that most of the crop residues remain undisturbed at 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. Therefore the term "siembra directa" (direct seeding), which is generally used in South America, is better suited than no-tillage, unless we use this term in a broader sense. More appropriate than both of these terms is the term cover agriculture or the French term "agriculture de coverture du sol", since virtually all the benefits of the system come from the permanent soil cover and not from the fact that we do not till the soil. We have to understand that soil carbon and crop residues are key factors for no-tillage to function. We have concentrated too much and too long on not tilling the soil instead of concentrating on crop residues as main tool for management (Wayne Reeves, personal communication 1997).

Control of soil erosion, which is combined with greater profitability and less work, are among the main driving forces for no-tillage adoption in South America. According to Baker et al., (1996), no technique yet devised by mankind has been anywhere near as effective at halting soil erosion and making food production truly sustainable as no-tillage. The long term gains from widespread conversion to no-tillage could be greater than from any other innovation in third world agricultural production. (Warren, 1983).

Constraints and limitations for no-tillage adoption in Latin America and other parts of the world

The constraints and limitations for no-tillage adoption in Latin America and how they have been overcome, have been extensively described in a paper presented at the 10th ISCO Conference in West Lafayette, In., USA (Derpsch, 1999). Therefore they are only going to be briefly mentioned here. In the early days of no-tillage the main constraints to adoption of the technology were:

- Adequate machines
- Adequate herbicides
- Knowledge about herbicides, herbicide application technology and weeds
- Knowledge about soils, liming and fertilisation, soil crusting, soil compaction
- Mulch cover, the use of green manure cover crops and crop rotations.
- Mental change

The constraints related to these issues have been in general overcome in Latin America. Adequate machines and herbicides are now available in the leading no-tillage countries. Also knowledge is now available worldwide, although the difficulty in agriculture is that we need to adapt this knowledge to local conditions. Adaptive research and technology development done by skilled people in a systems approach is necessary to advance in the application of no-tillage in a site appropriate way. One of the biggest barriers to this technology still seems to be the mental change necessary to believe in the system, which is a prerequisite to make it work.

"**No-tillage is not a farming practice – it is a concept of the mind**. If you don't believe in it you will fail". (Rieck Bieber, No-till Farmer in South Dakota, USA) We have found that as long as the head stays conventional it will be very difficult to implement successful no-tillage in practical farming and the same is also true in research. In many countries the mental change of the scientific community seems to be a greater problem to no-tillage adoption than it is the case with farmers.

We have to be aware that no-tillage means a radical change of mind. As long as we do not accept that when changing to the no-tillage system most everything is different (fertilization, liming, the concept of compaction, etc.), that many things turn upside down and that we have to start learning again**,** we are not going to make no tillage work.

As long as we do not accept that conventional tillage methods are mining soil fertility and destroying our soil resources in the tropics, we will not be able to make no-tillage work.

As long as we have not understood that we have to avoid bare soil under all circumstances and that a permanent soil cover is of utmost importance to achieve sustainable agriculture in the tropics and subtropics, our mind is still conventional and we are not going to make no tillage work.

As long as we are not prepared to change our minds completely, forgetting many things we have learned in agricultural schools and universities, and that conventional tillage mines our soils and is not sustainable, accept that permanent soil cover is a prerequisite to sustainable agriculture in tropical and subtropical environments, we are still very far from understanding what no-tillage is and how we can make it work.

It is also worth mentioning that subsidies received for conventional farming systems in the more developed countries, are probably one of the major constraints to no-tillage adoption in Europe and may be responsible for the slow growth rates in the USA. Generally no subsidies are paid to farmers in Latin Aamerica.

Experiences with no-tillage in Brazil, Argentina and Paraguay

These three countries have experienced the fastest growth rates of the no-tillage system in the last decade. Argentina is characterized by combining no-tillage with biotechnology especially in the case of Roundup Ready (RR) soybeans. RR soybeans were released in 1996 in this country and in only four years they have conquered almost 90% of the cultivated area of this crop. The main driving force behind this move is the reduction of production costs. In Brazil and Paraguay transgenic soybeans have until now only been released for research purposes.

In Brazil and Paraguay the use of green manure cover crops (GMCC's) and crop rotation are the key factors for the unprecedented growth of no-tillage. Black oats (Avena Strigosa Schreb) for instance are planted on 3.2 million ha only in the States of Paraná and Rio Grande do Sul, Brazil. In Paraguay this cover crop is used on about 300,000 ha. Linked to the spread of cover crops is the use of a "knife roller" to put the cover crops down to the ground. This implement is not very expensive and in many cases can be made locally or by the farmers themselves. The implement can be pulled by medium sized tractors or by animal traction and has contributed markedly in reducing herbicide applications in the no-tillage system. The knife roller has become an essential tool for managing GMCC's in Brazil and Paraguay. If the implement is not available old disc harrows can be used for the same purpose. In this case steel bars can be welded on top of the discs of disc harrows and the implement used in the same way.

One of the most recent and fruitful lessons we have learned in the no-tillage system in Latin America is that farmers should, if possible, never leave the land in fallow. In general fallow periods of only a few weeks will result in weed proliferation, seeding of weeds, reduction of soil cover, soil erosion as well as lixiviation of nutrients. If instead of leaving the land in fallow, farmers seed any crop immediately or as soon as possible after harvest of the previous crop, they will reduce weed proliferation, avoid that weeds produce viable seeds, increase soil cover and the biomass returned to the soil, increase organic matter content of the soil, avoid soil erosion as well as washing out of nutrients, and improve biological conditions of the soil.

Contrary to this, tillage leaves a bare soil surface, exposes the soil to heavy rainfall or wind and heat, reduces organic matter content of the soil and is the main factor responsible for soil degradation in the tropics and subtropics. It is sometimes difficult for people in Europe to understand that 250 mm of rain can fall in Brazil and Paraguay in 24 hours. This is sometimes half of the yearly amount of rain in many parts of Europe.

The better understanding of the negative effects of tillage on the soil has led to the development of the laws of diminishing yields in the tropics (Derpsch et al, 2000) which can be summarized as follows.

1. Any agricultural or livestock production system that contributes to constantly reduce the organic matter content of the soil is not sustainable and results in poor soils and farmers.
2. Under tropical and subtropical conditions intensive and repeated tillage will generally mineralise (reduce) organic matter at rates higher than the potential for repositioning. This results in a decreasing organic matter content of the soil and diminishing crop yields over time.
3. High rainfall and wind intensities prevailing in the tropics and subtropics are generally associated, under intensive and repeated tillage, with soil loss rates (due to wind or water erosion) that are higher than natural soil regeneration. This results in loss of nutrients and organic matter and in diminishing yields over time.
4. Under tropical and subtropical conditions, intensive and repeated tillage will generally damage the soil structure and lead to excessively high soil temperatures. This will have negative effects on root growth, soil flora and fauna (soil biological processes) and on soil moisture resulting in diminishing yields over time.
5. Any agricultural or livestock production system in which important losses of nutrients occur through extraction without reposition (i.e. soil exploitation) through volatilisation (i.e. regular burning), and/or through leaching (i.e. fallow periods without crops), is not sustainable and results in poor soils and farmers.

Additionally soil carbon is lost very fast to the atmosphere (as carbon dioxide) after the soil is intensively tilled. This results in unacceptable CO_2 emissions into the atmosphere, and instead of carbon being deposited in the soil, improving its fertility, tillage contributes to the greenhouse effect and to the global warming of the planet. (Kern and Johnson, 1993 a & b, Reikosky, 2000).

The unavoidable negative effects of intensive and repeated soil tillage (in the tropics and subtropics) on organic matter content, soil erosion, soil structure, soil temperature, soil moisture, water infiltration, soil flora and fauna (soil biological processes) and loss of nutrients, result in chemical, physical and biological soil degradation. This results in diminishing yields over time and in productivity losses of the soil and leads to poor soils and farmers.

As a consequence of the laws of diminishing productivity of tropical soils, sustainability of agricultural or livestock production cannot be achieved as long as

repeated and intensive soil tillage is performed in the tropics and subtropics. Nor can sustainability be achieved as long as the soil is exploited without reposition of nutrient losses through leaching and/or extractions that occur with harvests, and as long as frequent burning of fields is performed.

A major problem is that the laws of diminishing yields in the tropics and their consequences are not being acknowledged by the scientific community. All too often, it is perceived that universities that have specialised courses for tropical agriculture, still teach their students to till the soil to produce a crop, without taking into consideration the negative consequences of this practice, especially the soil degrading effect and the impossibility of achieving sustainable agricultural production when the soil is tilled.

Paradigm changes in Agricultural Production

As already mentioned traditional soil cultivation systems in the tropics and subtropics, with intensive soil tillage, will end in soil degradation and loss of crop productivity. This will result in poverty, exodus of farmers from rural areas, resulting in an increase of city slums and marginal populations, and finally in social conflicts. If we are to offer the farm family a chance to survive on the farm and if sustainable agriculture is to be achieved, the paradigms of soil use and management must change and new farming practices must be implemented. Here the old and new paradigms are presented and the consequences of these two forms of soil management are analysed.

Old Paradigms: Soil tillage is necessary to produce a crop; burying of plant residues with tillage implements; bare soil for weeks and months; burning crop residues allowed; strong emphasis placed on soil chemical processes; chemical pest control, first option; green manure cover crops and crop rotations are options; soil erosion is accepted as an unavoidable process associated to farming on sloping land. Result: Soil resource exploitation, sustainable land use is not possible (ecologically, socially and economically). Consequences of soil preparation and bare soil: Wind and water erosion are unavoidable; reduced water infiltration into the soil; less available soil moisture; unavoidable reduction in the soil organic matter content, thus reducing soil quality; soil carbon is lost as carbon dioxide into the atmosphere contributing to global warming; soil degradation (chemical, physical and biological); reduction of crop productivity; higher use of fertilisers and higher costs of production; survival of the farm family on the farm threatened (lower yields, production without profitability, insufficient monetary income); poverty, rural exodus, increase of slums and marginal populations as well as social conflicts in cities.

New Paradigms: Tillage is not necessary for crop production; crop residues remain on the soil surface as mulch; permanent soil cover; reduced soil temperatures; burning mulch prohibited; emphasis on soil biological processes; biological pest control, first option; green manure cover crops and crop rotations compulsory; soil erosion is considered to be a symptom that for that area and ecosystem unsuited methods of farming are being used (Erosion is caused by soil mismanagement). Result: Rational, site-oriented use of the soil; sustainable land use ensured (ecologically, socially and economically). Consequences of no-tillage and permanent soil cover: Wind and water erosion near zero; increased water infiltration into the soil; more available soil moisture; maintenance or increase in the soil organic matter content; enhancement of soil quality; carbon is sequestered in the soil enhancing its quality, reducing the threat of global warming; soil improvement (chemical, physical and biological) crop productivity increased; reduced use of fertilisers and lower production costs; survival of the farm family on the farm ensured through a good profitability and a high and

sustainable crop production; basic needs are satisfied, living and quality of life of farm family are increased (Derpsch, 1999).

Development of No-tillage in Latin America

According to Javier Ekboir from CIMMYT (personal communication), "zero tillage is the most important technology adopted in MERCOSUR (Common market between Brazil, Argentina, Uruguay and Paraguay) in the last 50 years. Zero tillage reversed soil degradation, allowed an expansion of agriculture into marginal areas, boosted farmers' profitability, and increased the sustainability of agricultural systems".

In Brazil no-tillage adoption increased from one million ha in 1990 to 15 million ha in the year 2001. In the same period no-tillage adoption in Argentina increased from 300.000 ha to 11,7 million ha and in Paraguay it increased from about 10.000 ha to 1,1 million ha.

Although worldwide the biggest area under No-tillage is found in the USA, in this country the technology is applied only on 17,5% of the total cultivated area, against 39% in Brazil, 46% in Argentina and 55% in Paraguay. In mechanised agriculture adoption rate is 85% or higher in Paraguay. In relation to the total cultivated area, Paraguay is among the countries with the highest adoption rate of no-tillage in the world.

In the MERCOSUR Countries (Brazil, Argentina, Paraguay and Uruguay) the technology has experienced a twenty fold expansion between 1987 and 1997 (from 0,67 to 13,95 million ha) against a 4,6 fold increase of the area in the USA (from 4,05 to 18,62 million ha) in the same period. From 1997 to 2001 the MERCOSUR Countries experienced an expansion of 100% of the area under no-tillage (from 13,95 to 27,86 million ha) as against 13% in the USA (from 18,62 to 21,12 million ha).

The following may be the main factors that induced such a rapid change in South America: 1) Efficient and economic erosion control under climatic conditions with high erosion and soil degradation potential. 2) Appropriate knowledge was available in the region through research and development as well as farmers' experiences. 3) Widespread use of cover crops for weed suppression (reduction in the use of herbicides), organic matter build up, biological pest control, etc. 4) The same consistent message, positive to no-tillage has generally been voiced by all sectors involved (private and public) without contradictions. 5) No-tillage has been the only conservation tillage technology recommended to farmers. 6) There has been an aggressive farmer to farmer extension through farmers' associations. 7) Publications with adequate, practical and useful information were made available to farmers and extensionists. 8) Economic evaluations with system approach showed high economic returns of no-tillage, as well as the use of cover crops and crop rotations in the system. Economic returns are immediate and substantial. 9) There have been no major forces against the system. 10) Latin American farmers have had to be very competitive in the global market, since in general there are no subsidies.

Development of No-tillage in the world

When analysing the development of no-tillage in the world we have to be aware that the USA is among the few countries in the world that has yearly statistics on the different forms of conservation tillage. Information in other parts of the world is very scarce or non existent and in most countries statistics on conservation tillage are based on estimates. The leading countries in the world with the biggest area under no-tillage are the USA with 21.1 million hectares followed by Brazil with 15 million ha,

Argentina with 11,7 million ha, Australia with 8.6 million ha, Canada with about 4.1 million ha and Paraguay with 1.1 million ha of the technology being practiced by farmers (Table 1). When putting together the numbers in this table it is assumed that permanent no-tillage is practiced rather than not tilling the soil occasionally.

Table 1: estimated area under no-tillage in the world.

Country	Area under No-tillage in ha 2000/2001
USA [1]	21,120,000
Brazil [2]	15,046,000
Argentina [3]	11,660,000
Australia [4]	8,640,000
Canada [5]	4,080,000
Paraguay [6]	1,100,000
Mexico [7]	650,000
Bolivia [8]	350,000
Venezuela [9]	150,000
Chile [10]	100,000
Colombia [11]	70,000
Uruguay [12]	50,000
Others [13]	1,000,000
Total	**64,016,000**

Source: 1) Dan Towery, CTIC, 2001; 2) FEBRAPDP, estimates 2001; 3) AAPRESID, 2001; 4) Bill Crabtree, WANTFA, 2000; 5) J. Hebblethwaite, CTIC, 1997; 6) MAG – GTZ Soil Conservation Project, 2001; 7) Ramón Claverán, CENAPROS, 1999; 8) Carlito Los, 2001; 9) Carlos Bravo, 2000; 10) Carlos Crovetto, 2001; 11) Roberto Tisnes, Armenia, 1999; 12) AUSID, 1999; 13) Estimates.

It is not easy to get information about the spread of no-tillage in Asia, Africa and the East European countries. Because of extreme variations in information, no data about the spread of no-tillage in Europe is given. Definition and what is understood under no tillage are unsolved problems in Europe. Sometimes one gets the impression that the moment a farmer stops ploughing he is considered to be practicing no-tillage.

Admitting that there may be many gaps in information it is estimated that no-tillage is practiced on about 64 million hectares worldwide. Approximately 45% of the technology is practiced in Latin America, 39% is practiced in the United States and Canada, 14% is practiced in Australia and probably less than 2% in the rest of the world including Europe, Africa and Asia. There is a very big potential to bring this soil conserving technology to these parts of the world, although limiting climatic and socio-economic factors have to be taken into account. The East European countries and some countries of Asia and Africa seem to have the biggest potential for a fast growth of this technology. In order to overcome the information gaps relating mainly to the European countries as well as Africa and Asia, the author would welcome any information about the spread of the technology (under the definition presented in this paper) in different parts of the world.

Concluding remarks

To avoid misunderstandings no-tillage (direct seeding) and conservation agriculture terminology should be globalised. The main constraints and limitations to the expansion of no-tillage in Latin America have been overcome. Research has given answers to the most urgent questions of the new technology. Adaptive research and development is now needed in those regions where no-tillage has experienced small adoption rates. Adequate machines, herbicides and knowledge are now available to farmers. Heavy erosion damage and soil degradation under conventional tillage have forced farmers to a mental change and to adopt new farming practices. No-tillage results in more profits with less work for the farmer and in environmental benefits that enhance the quality of life of the farm family. As in Latin America there are virtually no subsidies, farmers have to be competitive and produce at low cost. This has led to a very fast growth of the technology in that part of the world .The highest proportion of permanent no-tillage adopters is found in Latin America. Paraguay is among the countries with the highest adoption rates worldwide.

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