NO-TILL AGRICULTURE IN SOUTHERN BRAZIL

Factors that facilitated the evolution of the system and the development of the mechanization of conservation farming

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The authors.

PREFACE

In the modern era the intensification of agriculture in Brazil has received strong influences from the technologies used in northern countries as a result of the various immigration events experienced by the country. Conventional tillage with mouldboard and disc ploughs as well as heavy harrows is one of the most dramatic examples of this influence which has had huge negative environmental impacts that have led to the destruction of large areas where natural resources were not optimal and which were not particularly apt for agricultural production.

In the 1970s, even at the height of the green revolution, several separate initiatives arose in the south of Brazil which aimed to modify the tillage techniques employed in order to protect the environment and, crucially, at the same time maintain the profitability of agribusiness.

A common feature of these initiatives was a concern to generate and adapt technologies for agricultural production in tropical and semi-tropical Brazil because of the lack of relevant knowledge from other countries experiencing similar conditions. Since then, the unprecedented joint efforts of various sectors of society, focused on the need to maintain the sustainability of the agricultural enterprise, have led to the development of the no-tillage conservation agriculture system currently prevailing in southern Brazil.

The widespread adoption of agricultural production systems based on conservation agriculture techniques (no-tillage, crop rotations, soil cover / cover crops) was undoubtedly one of the factors responsible for the spectacular evolution of Brazilian agriculture, especially in the last two decades, which has raised incomes and sustainability in the regions of intensive agriculture in Brazil.

The present publication is an account of the technological developments in no-tillage systems that took place in southern Brazil from the viewpoint of the principal actors in this process. Special emphasis is given to the technological development of mechanization of conservation agriculture as it is in this area that the domestic agricultural machinery industry has played a key role in adapting and developing indigenous technologies suited to different soil and climatic conditions and soil conservation management strategies practised in the country. The ability to generate innovative technological solutions, in flexible and diverse ways and also for different categories, of farmers has put the agricultural machinery industry of Brazil at the forefront of the global market. The country is now a reference point in the field of mechanization of conservation agriculture.

Conservation agriculture is being spread by international organizations as an alternative to conventional agricultural practices in Africa, Asia, Central America and the Caribbean as it reduces the energy demand for agricultural production whilst helping to recover soil fertility and ensuring high levels of crop production. And so, an understanding of the evolution of the Brazilian experience of mechanizing no-tillage and conservation agriculture, and identifying its determining factors is of fundamental importance to enable the expansion of the system in other regions of the world and to avoid repeating mistakes and possibly wasting resources. This is the desire of the authors.

Gavin Wall

Director of Rural Infrastructure and Agro-Industries Division (AGS)

The Food and Agriculture Organization of the United Nations

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Director-President

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ACRONYMS

ACARPA	Paraná Association of Credit and Rural Assistance
ABIMAQ	Brazilian Association of Machinery and Equipment Industry
CA	Conservation agriculture
ACARPA	Paraná Association of Credit and Rural Assistance
Agrishow	International Fair of Agricultural Technology
AGS	Rural Infrastructure and Agro-industries Division
AMI	Infrastructure and Agricultural Machinery Unit
CAAPAS	Confederation of American Associations for Sustainable Agriculture
CAPAL	Arapoti Agricultural Cooperative
CA-SARD	Conservation Agriculture for Sustainable Agricultural and Rural Development
Castrolanda	Castrolanda Agricultural Cooperative
CAT	Friends of the Earth Club
CNPMS	Embrapa National Corn and Sorghum Research Center
CNPT	Embrapa National Wheat Research Center
COCAMAR	Maringá Agri-food Manufacturing Cooperative
COOPERSUL	Campos Gerais Central Cooperative
EMATER	Paraná Institute of Technical Assistance and Rural Extension
Embrapa	Brazilian Agricultural Research Corporation

ENPDP	No-Till National Meeting
Expointer	International Fair of Livestock, Machinery and Agricultural Products
FAO	Food and Agriculture Organization of the United Nations
FAPEAGRO	Research Support and Agribusiness Development Foundation
FEBRAPDP	No-till Brazilian Federation
FUNDAÇÃO ABC	Foundation ABC – Agricultural and Cattle Raising Research and Development
FUNDAÇÃO MS	Foundation MS for Agricultural and Cattle Raising TechnologiesResearch and Extension
FUNDAÇÃO MT	Support Foundation for Agricultural and Cattle Raising Research of Mato Grosso
FUNDACEP	Rio Grande do Sul Agriculture and Cattle Raising Cooperatives Research Foundation
GO	Goiás State
GTZ	Gesellschaft für Technische Zusammenarbeit (German technical cooperation)
IAPAR	Agricultural Research Institute of Paraná State
ICI	Imperial Chemical Industries
IPEAME/MA	Southern Agriculture and Livestock Research Institute of the Ministry of Agriculture
METAS	Rio Grande do Sul No-till Feasibility and Diffusion Project
MG	Minas Gerais State
MT	Mato Grosso State
PARANÁ RURAL	Rural Development Program of Paraná

PIUCS	Integrated Project of Soil Use and Conservation
PMISA	Soil and Water Integrated Management Programme
PR	Paraná State
PRODONORTE	Soil Erosion Special Project in Northwestern Paraná
PROICS	Soil Conservation Integrated Programme
PRONAF	National Farm Family Support Programme
RS	Rio Grande do Sul State
SC	Santa Catarina State
SEAB-PR	Paraná Agriculture and Supply State Agency
Show Rural	Coopavel Agri-food Manufacturing Cooperative Rural Show
SP	São Paulo State
NTS	No-till System
UFSC	Federal University of Santa Catarina
TVU	Test and Validation Unit

INTRODUCTION

This work is part of the technical cooperation partnership between FAO, IAPAR and FAPEAGRO concerning the FAO project 'Conservation Agriculture for Sustainable Agricultural and Rural Development CA-SARD'[1], which supports the development of conservation agriculture in the East African countries of Kenya and Tanzania. The study highlights the main steps in the evolution of the adoption of the no-till system (NTS) by farmers in southern Brazil, with emphasis on the technological development of NTS mechanization (especially no-till planters).

Sixty-six interviews were conducted between November 2007 and February 2008 with: industry representatives and agriculture machinery sales people; farmers; researchers; technicians from technical assistance and financial institutions; besides specialized agricultural industry publishers from the states of Paraná, Santa Catarina and Rio Grande do Sul. The aspects dealt with in the study include: the history of the no-till system's evolution; the problems faced as well as the methods employed during the technological development; and the interaction between the manufacturing and agricultural sectors. It is an empirical study in the sense that the analysis is based on reports of the interviewees' personal experiences and it does not use any theoretical model to explain the technological development under review.

The analysis of the information enables a deeper understanding of the technological, economical and social evolution of the NTS in southern Brazil, the relationships between the various rural development agents, as well as the role of: partnerships; the multi-farm use of machines; farmers' associations; provision of credit; and governmental support. It should be noted that, in some instances, there are contradictions within the information obtained from different sources, which make personal experience and knowledge of the context even more important for an understanding of the evolution of NTS. The study does not intend to paint a full and complete picture, but rather to contribute to the analysis and deeper

[1]GCP/RAF/413/GER

understanding of the evolutionary process of NTS as well as of the specific machines for conservation agriculture in southern Brazil. The text is organized chronologically, with special emphasis on the main factors determining the evolution of NTS in each historical phase, according to the interviewees' opinions.

In the text, the terms "no-till system" (NTS) and "conservation agriculture" (CA) are used as synonyms, though the authors recognize that there are conceptual differences between them and these are discussed in other technical texts. The term "no-till" refers to the placement of seeds in soil that has not been previously ploughed or harrowed; however, it has been used in a general way to include many soil conservation management practices. It has currently become such a comprehensive concept in Brazil that it is now a synonym for conservation agriculture. The latter, though, is a wider concept which encompasses any crop production practice that maintains at least 30% of the soil surface covered with organic matter (BAKER et al., 2002). Strictly speaking, the "no-till system" should include the requirement of minimal soil movement, sufficient only for the placement of seed and fertilizers in the soil, maintenance of a permanent organic soil cover (usually crop residues) and the adoption of crop rotations and green manuring (BOLLIGER et al., 2006; CALEGARI, 2006; MUZILLI, 2006).

1 AGRICULTURE IN SOUTHERN BRAZIL AND THE ORIGIN OF THE CONSERVATIONIST APPROACH (PHASE 1: 1972 TO 1979)

The European immigrants who, in the 1950s and 1960s, started to open areas for agricultural production in Rio Grande do Sul, Santa Catarina and Paraná, employed the technological model from their original lands. This was based on the use of disk ploughs and heavy harrows powered by tractors, for the incorporation of vegetal biomass and for weed control. Such techniques were frequently preceded by residue burning for the purpose of reducing the volume of vegetative biomass and facilitating the work of the machinery. According to Amado & Eltz (2003), the rapid expansion of the agriculture frontier, which grew from 800 thousand hectares cultivated, in 1969 to 4 million in 1977, based on conventional soil preparation, caused soil erosion losses of up to 10 tons/hectare for each ton of grain produced. As a consequence, soil degradation in this region during the 1970s and mid-1980s, compromised the gains in crop productivity resulting from technological advances in plant genetics, effective and efficient use of chemical inputs, and improved machines.

At the end of the 1960s, due to soil degradation and the need to open new lands for cultivation, the agricultural frontier in the extreme south expanded to new regions such as the west and east of the state of Paraná, and the same environmental problems happened again. Soil exposure to rain and its compaction by conventional management, which reduced water infiltration capacity, resulted in huge losses of the soil to erosion. This increased sediment-laden run-off that made flooding and the destruction of bridges and physical constructions widespread during and after intense rainfall events. From that time, farmers, technicians and researchers started to look for new crop establishment systems with reduced soil movement. The search indicated two possible avenues. The first was the use of subsoil ploughs, mainly in the west of Paraná, and the other focused on the implementation of no-till as a system with minimal soil disturbance, as was the case of Herbert Bartz in 1972, among other pioneer farmers in that decade. Figure 1 indicates the regions cited in southern Brazil.

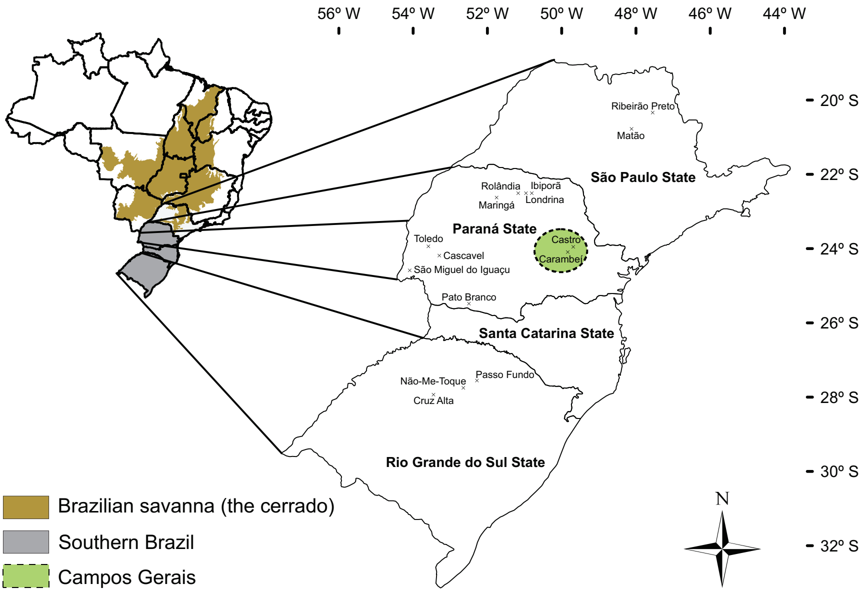

Figure 1. Location of the regions, states (São Paulo, Paraná, Santa Catarina, Rio Grande do Sul) and sub-regions mentioned in the text.

However, at the beginning of the 1980s soil erosion in the west and north of Paraná still constituted the main problem for many farmers. In order to counter it, some organizations (professional associations, farmers' cooperatives, research institutions, rural extension services, banks and others) got together and decided to constitute the first municipal soil commissions with the objective of convincing farmers to construct contour terraces because up to this point soya, the main crop, was cultivated predominantly at 90° to the contour.

During a 50 year period, a lack of planning in the colonization process of Paraná reduced the state's vegetative cover from 87% to 10%, bringing about serious consequences for the management of soil and water (VIEIRA, 1991). Soil erosion by water had the main and most visible destructive effect as a result of this inadequate management of the state's natural resources. The destruction was a consequence of the degradation of the soil structure which was exacerbated by the impact of rain drops, followed by runoff, with the transport and deposition of soil sediment.

In Paraná, the challenge really started to be confronted when the conservation organizations began to articulate actions integrated with programmes of rural development and management, including soil conservation. These programmes were promoted during the 1980s and 1990s by successive state governments with the support of international financial organizations. The actions were, to a great extent, defined by local entities (including farmers) and developed and executed with the financial support of the programmes. Besides the construction of physical works, actions also included training and capacity development of technicians and farmers through lectures, field days, courses, regional and state meetings on soil management and the publication of technical manuals.

The severe environmental problems experienced in southern Brazil were the catalyst for scientific studies on improved soil management practices with a conservation focus. In 1969 in the experimental station of the Ministry of Agriculture, in Não-Me-Toque, Rio Grande do Sul, a pioneer plot of no-till seeded sorghum was established on crop residues with the use of a 'Buffalo' North American machine. By 1973, there were experiments conducted in Ponta Grossa, Paraná, with different soil preparation systems, including cultivation without soil inversion. The results of this work were published in 1974 and constitute the first research record on conservation soil management in Brazil. Still within the ambit of the Ministry of Agriculture, in the early 1970s, experiments were conducted in the north of Paraná. These no-till studies were only possible after the 1961 launch of the contact herbicide "Paraquat" by Imperial Chemical Industries (ICI). In 1971, ICI made the first demonstrations of no-till in the north of Paraná with the soya-wheat rotation and, in 1974, started to work in the plateau in Rio Grande do Sul (MUZILLI, 1981). In São Paulo, the first experiments by ICI were established in 1976, in the region of Ribeirão Preto.

Undoubtedly though, the farmer Herbert Bartz from Rolândia (PR) was the pioneer in the application of no-till on a commercial scale. His interest was aroused in 1971, during a 90 mm/hour rainfall event, when he walked in his soya crop and observed severe erosion with broken terraces and seedlings being uprooted and carried off in runoff water. He was a tenant farmer at the time and it was then that his obsession was born to find an alternative to the conventional soil preparation system. His first attempt, in 1972, was to mount a seed hopper on a rotary cultivator to sow three hectares of wheat, but a 60 mm rain storm destroyed 40% of the crop. He therefore concluded that any destruction of soil structure would compromise its conservation. At the time he sought out the IPEAME/MA in Londrina, where he encountered Dr. Rolf Derpsch, and was fascinated when he heard about "minimum tillage" and "no-till".

Bartz escorted an ICI study tour on a visit to barley and wheat producers in England who were practising no-till with a machine similar to the 'Rotacaster' (Figure 2), with surprising results, mainly in relation to water conservation. Subsequently he traveled

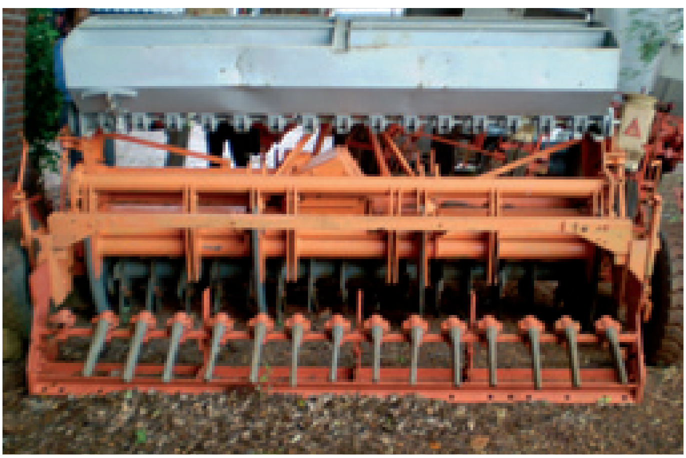

Figure 2. Planter model Howard ROTACASTER in Herbert Bartz's farm, Rolândia, PR.

to Kentucky in the US, in order to meet researcher Shirley Philips, who was advising farmer Harry Young in the state of Virginia. On his own Young managed an 800-acre farm sowing corn with the no-till system. Young sowed his corn with a six-row Allis Chalmers planter (Figure 3) which had a work rate of 30 to 50 acres per day. Bartz confessed that, at that moment, he became convinced that the change to no-till was possible and so ordered an 8-row machine for soya and a 6-row for corn from the manufacturer.

The positive results were apparent from the start, but it was during the energy crisis of 1973 that the economic benefits were evident due to the reduction of 60% of the work done with tractors. This aspect proved to be the main stimulus for the adoption of the no-till system both by Bartz himself and other producers. Bartz's main problems at the time were weed management, soil borne diseases and the difficulty of achieving good penetration of the seeder disks in clay soil, which affected soya germination. At this time, the Rotacaster equipment arrived from England and, with the help of technicians from the Brazilian representatives, it was assembled on his property. The biggest deficiency of the seeder

Figure 3. Planter model ALLIS CHALMERS in Herbert Bartz's farm, Rolândia, PR.

was its low operational output, as it required two hours to sow a hectare. Controlling invasive weeds was also difficult because of the low efficiency of herbicides when there was straw on the soil surface, due to the neutralization of the active ingredient. Bartz applied the herbicide with direct spraying on the moist soil aiming at obtaining immediate effect, but in 1977, alexandergrass (*Brachiaria plantaginea*) was so abundant that he lost 40% of the soya production.

At the time, other farmers, such as Manoel (Nonô) Pereira and Franke Dijkstra, from Campos Gerais, Paraná, also became interested in no-till. According to Nono, in the 1970s the milling companies became established in Ponta Grossa and encouraged the spread of soya and wheat production. The sandy soil in the region, coupled with the customary excessive soil preparation, favored erosion, which became more and more severe year after year. Terraces for run-off control were built but did not solve the problem. About 40% of the crops in Campos Gerais had to be replanted due to erosion and this situation led to the foundation of a conservation association by ACARPA and cooperatives in the region. The problem was so serious that the Brazilian national bank (Banco do Brasil) would only give authorization for financial support for crop production on the presentation of a report, approved by the association, which certified that the land was terraced. Nonô started to be interested in no-till and to learn of the experiences by Bartz in Rolândia, Bráulio Barbosa in Ibiporã, Décio Vergani and Lúcio Miranda, in Campos Gerais, among others. At this point he was contacted by ICI and agreed to experiment with no-till using the herbicides Paraquat and Diquat. The initial difficulty was the non-availability of the seeder, which made him buy a Rotacaster in September 1976 and put the sprayer between its rows. Unfortunately a hailstorm damaged his crops, but in terms of erosion, Nonô could see the benefits. He also noticed that ICI's products, all of them contact herbicides, would not solve the weed problems, and so he tried other products.

In a meeting that Nonô Pereira had with the researchers Osmar Muzilli and Fernando de Almeida, from IAPAR, and John Wiles from

ICI, he surprised them when he maintained that wheat was the most harmful 'weed' in crop production. The fact was that wheat grains germinated after the use of the Rotacaster due to soil disturbance, stimulating germination and producing a weed problem if chemical control was not effective. In the 1976/77 crop, Nonô consulted Franke Dijkstra, who had used a Semeato PS6 to successfully sow through wheat straw by using double disk openers for fertilizer and seed similar to the conventional system. In December 1976, at the end of the recommended planting window, Nonô sowed soya with a PS6 on rye straw cut 1 meter high, with excellent results in both yield and weed control. After this experience, he attached a tool bar to the front of the PS6 to locate a vertical cutting disk in a way similar to what Dijkstra had done (Figure 4). Besides, the PS 6 presented some advantages in relation to the Rotacaster as it was trailed and had independent hydraulic controls which made it ideal for traversing terraces. The Rotacaster, on the other hand, was heavy and three-point linkage mounted, which, even with front ballast on the tractor, could cause rearing up and damage to the

Figure 4. Semeato planter model PS6 in the Nono Pereira's farm museum.

hydraulic system. Another problem with the Rotacaster was the reduced capacity of its fertilizer hopper and, consequently, its low field efficiency.

1.1 Beginning of No-Till System Research

In 1975, after establishing a technical cooperation partnership with ICI and the cooperatives CAPAL, Batavo and Castrolanda, IAPAR started a wide-ranging research project on no-till in Paraná (in Londrina and Carambeí at the time, a district belonging to Castro), with the participation of 25 researchers. Changes were monitored in the soil, crops, weeds, pest and disease incidence, as well as the economic impacts. Research studies were conducted on large experimental plots of conventional and no-till crops, with and without rotation, for soya, corn, cotton, beans and wheat. Such experiments were carried out over a period of more than two decades.

In 1977, IAPAR established another important partnership, this time with GTZ, which enabled the involvement, of several foreign researchers from various areas of specialization. One of the biggest contributions of the partnership with GTZ, among many others, was the introduction, selection and recommendation of cover crop plants to enable crop rotation in no-till. This research allowed the institute to study more than 150 different summer and winter species validated as alternatives for crop rotation in the state. As a result of this work, in 1981 IAPAR published the first national book on no-till entitled “No Till in the state of Paraná”[2] (INSTITUTO AGRONÔMICO DO PARANÁ, 1981) which reports on experiences gained on no till by the research team. Another important initiative was the agreement established in 1977 between ICI and CNPT/ Embrapa for research and development of no-till machinery.

[2]In Portuguese: “Plantio Direto no Estado do Paraná”.

2 DEVELOPMENT OF MECHANIZED NO-TILL (PHASE 2: 1980 TO 1991)

According to Denardin et al. (2008), the evolution of the area under no-till in Brazil transversed three distinct periods with respect to rates of adoption. The first one was up to 1979, and was discussed in the previous section. Between 1980 and 1991, agricultural research had proven the effectiveness of no-till for controlling soil erosion by water; soil losses are reduced by a factor of five when compared to conventional tillage practices. Furthermore, the main principles of no-till were consolidated during this period, that is, minimal soil disturbance, permanent organic soil cover with crop residues or live plants, and crop rotation.

In this period, IAPAR increased its research on no-till, including trials and validation of systems with farmers. In the region of Rolândia (PR), Bartz accelerated these advances, mainly by including the use of black oats in the crop rotation, which helped to control fusarium, and seemed able to 'break' lime into its cations and anions so helping it to penetrate the soil. Due to this capacity, oats started to be called the 'biological plough'. Also during this time, the cover plant technology studied by IAPAR began to be spread all over Brazil, into other Latin-American countries and throughout the world. Adoption rates increased following the positive results achieved and there were numerous talks, field days and demonstrations in agricultural shows, highlighting the advantages of the no-till system from an economic perspective as it reduced the use of fertilizers and herbicides both in annual and perennial crops. However, many researchers still claimed that there was a need to have a transition phase of minimal cultivation before the implementation of the full NTS. This discussion lasted for almost a decade. Some would also say that a rotation was necessary in soil tillage, which was completely disproved by studies, so long as the NTS was properly implemented.

There was a huge effort by IAPAR and SEAB-PR to make information on NTS widely available, which led to the publication of the following documents:

a) "No-Till in Paraná State" (INSTITUTO AGRONÔMICO DO PARANÁ, 1981);
b) "Guide to herbicides and their appropriate use in no-till and conventional cropping" (ALMEIDA & RODRIGUES, 1985);
c) "Guide to green manure species" (DERSPCH & CALEGARI, 1986);
d) "Allelopathy and plants" (ALMEIDA, 1988);
e) "Winter green manure plants in southwestern Paraná" (CALEGARI, 1990);
f) "Manual of the soil management and conservation sub-programme" (SECRETARIA DA AGRICULTURA E ABASTECIMENTO, 1994);
g) "Summer green manure plants in Paraná" (CALEGARI, 1995)[3], among others.

However, the biggest obstacle for the expansion of no-till, chemical weed control, still required appropriate technical solutions. During the 1970s, there were a few products such as Paraquat and Diquat (contact desiccant herbicides), Glyphosate, (still little used due to its high cost) and a few soil-applied herbicides like Atrazine, 2,4-D and Trifluralin. The biggest problem was the low efficiency of the herbicides when applied on straw-covered soil, as the post-emergence chemicals had been developed for application on soils without cover. Apart from that, in no-till it was common to have weeds in different development stages and with deep roots at the time of control. In 1984, Glyphosate started to be produced in Brazil by many companies, resulting in reduced prices. At the time there was already a wide variety of crop rotations and many options of cover plants available.

[3]The original names in Portuguese are: "Plantio Direto no Estado do Paraná" (INSTITUTO AGRONÔMICO DO PARANÁ, 1981); "Guia de Herbicidas e Contribuição para o Uso Adequado em Plantio Direto e Convencional" (ALMEIDA & RODRIGUES, 1985); "Guia de Plantas para Adubação Verde" (DERSPCH & CALEGARI, 1986); "A Alelopatia e as Plantas" (ALMEIDA, 1988); "Plantas para Adubação Verde de Inverno no Sudoeste do Paraná" (CALEGARI, 1990), "Manual do Subprograma de Manejo e Conservação do Solo" (SECRETARIA DA AGRICULTURA E ABASTECIMENTO, 1994); "Plantas para Adubação Verde de Verão no Paraná" (CALEGARI, 1995).

Permanent soil cover with straw started to be considered an important component for weed control, given that the use of herbicides still presented limitations. The increase in the amount of straw covering the soil began to be an important objective in no-till. However this was sometimes difficult, especially in hot regions because, while it was possible to achieve 7 t/ha/year or more of straw in southern Paraná due to its mild climate, in the northern area no more than 2 t/ha/year was achieved. At the time, a mixture of Glyphosate and 2,4D was effective in desiccating the cover crops; however, with the legal prohibition of 2,4D use in the country, the reduction in the price of Glyphosate and increasingly easy access to it, this product started to be used alone or in a mixture with post-emergence residual herbicides.

In 1981, under the initiative of Franke and Nonô Pereira, the first ENPDP (National No-Till Meeting) was held in Ponta Grossa with the support of COOPERSUL, IAPAR and the Ponta Grossa Conservation Association, with the attendance of 645 people. The second and third Meetings were held in 1983 and 1985 with 849 and 1200 people respectively and the no-till cultivated area in Campos Gerais was, at the time, 200 000 ha, and in Brazil, 500 000 ha. The foundation of the Earthworm Club, also organized by the two farmers, was essential to unite other interested farmers and organize events and other actions to exchange experiences in NTS. The Club inspired the establishment of several other similar entities all over the country, an outstanding example was the Friends of the Earth Club, whose first initiative was in Cruz Alta (RS). In 1981, after the first ENPDP, it was decided to create a foundation in order to intensify research and validate technologies to support no-till expansion. A year later, the ABC Foundation was created, which served as a model for other similar organizations such as the MS and MT Foundations. The resources stemmed from joint projects with multinational companies conducted in the four experimental sites belonging to the ABC Foundation.

2.1 Soil Management and Conservation Governmental Programmes

In the early 1980s, soil erosion was still a big challenge in Paraná, and that made agricultural organizations, such as agronomists' associations, EMATER, IAPAR, agricultural cooperatives and the Banco do Brasil to work together and constitute the so called "soil commissions", aimed at promoting the use of contour terraces, as it was still common to sow soya "downhill". Facing the challenge commenced with a regional organization through State government rural development programmes, which enjoyed World Bank support. Such programmes, which focused on soil management and conservation, were implemented all over Paraná in the 1980s and 1990s, and their main strategies were the increase in water infiltration into the soil, and the reduction of surface run-off.

In 1982, the PMISA, Soil and Water Integrated Management Programme was implemented, its focus was on soil and water management in micro catchments with emphasis on the integration of terraces between adjacent properties, chisel ploughing, correction of soil acidity, rectification of road routes and gully erosion control. At the time, the municipalities of Maringá and Toledo, northwestern and western Paraná, were the pioneers in these actions.

From 1988 to 1993, soil management and conservation interventions were developed under the Programme PARANÁ RURAL (Rural Development Programme of Paraná). The focus was on hydrographic catchments, though it also involved integrated actions of no-till promotion, research, extension, and farmers' organization, among others. The strategic objectives, however, were the same, that is, to avoid surface run-off and increase water infiltration into the soil. Programme assessments indicated high levels of adoption of no-till by farmers.

Similar programmes aimed at stopping the severe processes of natural resource degradation were started in Rio Grande do Sul. Outstanding examples included: the integrated project of soil use and conservation named PIUCS (1979); the Saraquá project on the basaltic hillslopes from 1980 onwards; and the hydrographic micro-catchment programme started in 1984. A series of conservation practices were disseminated such as the elimination of wheat residue burning, reduction in soil preparation frequency and intensity, terracing, contour planting, gully elimination, evaluation of soil cover, relocation of rural roads, diffusion of minimal soil preparation, minimum cultivation and no-till.

2.2 Beginning of No-Till Seeder Development

In 1975, CNPT/Embrapa started research with no-till machines and, in the following year, began to test Herbert Bartz's Allis Chalmers. Bartz also assisted in the selection and import of other planters. In 1978, Embrapa brought a Danish Nordestern minimal cultivation seeder and, subsequently a Bettinson-3D from England (the design concept of this machine gave rise to many no-till planter models in Brazil), and another planter that inspired the Semeato PS8. Meanwhile, Franke and Nono, in their search for innovative ideas, adapted a seed hopper from a Jumil seeder to the Semeato PS6, sowed wheat with good results, and started disseminating the idea to interested companies. Semeato, however, was more interested in the Bettinson from CNPT/Embrapa, as they believed that farmers should have one machine for the summer and another for the winter.

The first no-till seeder resulting from a national design was the TD model by Semeato, with a continuous flow seed metering system, mainly for wheat and other winter cereals, and triple-disk openers. The project was the result of a partnership between ICI, Embrapa and Semeato and the TDA 220 model was launched in 1979 (Figure 5a). According to the engineer Paulo Montagner, this design was inspired by the Bettinson machine, which was attractive in that it was heavy and robust, but had a deficient system of fertilizer distribution. Although equally robust and with low maintenance demands, the TD's ground wheels were initially attached to the chassis, which caused problems on irregular surfaces and floodplain areas. This motivated the consequent development of a TDA with articulated wheels. The model TDA 300 was launched later and became even more popular (Figure 5b). With the dissemination of

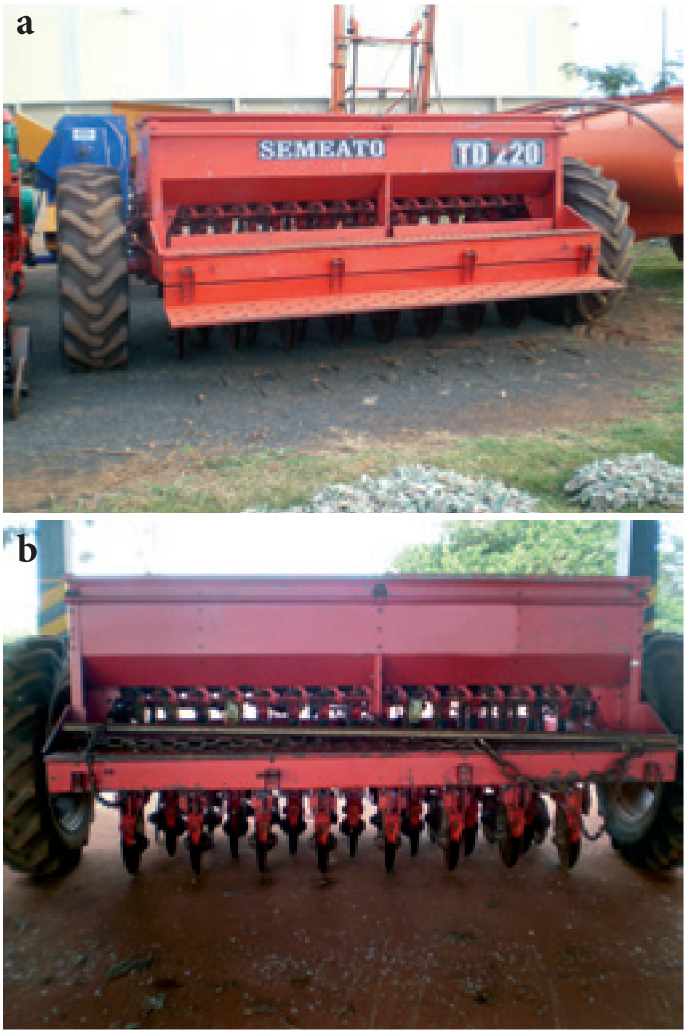

Figure 5. Semeato planter models TD220 (a) and TD 300 (b) adapted for no-till.

the triple disk and tine by CNPT/Embrapa, other companies such as Imasa and Lavrale started to approach Embrapa. Lavrale, a rotary hoe manufacturer, wanted to construct a seeder based on the Rotacaster concept, but after seeing the Bettinson machines from Canada, with staggered double disks, the company embraced the challenge of launching them in the market.

Another important manufacturer at the time was Fankhauser, whose planters with a continuous flow seed metering system had wide acceptance in the market. According to director Pedro Fankhauser, the Rotacaster was not of interest to him because the rotary hoes caused excessive soil disaggregation and subsequent erosion; and the Bettinson was too heavy, which helped consolidate the myth that no-till seeders should necessarily be heavy.

As Fankhauser's market consisted mainly of small farmers, the company started to look for lower cost alternatives that were accessible to its clientele. This led to the development of the PH6U model, with fluted roller seed metering for drilling, front-mounted furrow openers followed by a disk coulter. Subsequently, Fankhauser launched the MSTA model, which was similar to other models manufactured by Semeato, Marchesan and Baldan. The first no-till seeder with precision metering for soya seed was the 4010 model, which was three-point linkage mounted on the tractor and performed well, although it was heavy for the small farmers' tractors.

In 1980, Imasa developed its no-till multiseeder SDT model with reversible seed hopper which had fluted roller metering for small seeds and horizontal plate seed metering system for large ones. It was the precursor of the most popular MP model and presented some advantages for adaptation to summer and winter crops such as the removal of the short row double disks and changeover to the long row to open the fertilizer furrow, change of the seed metering mechanisms, and independent articulation of the wheels to give uniform pressure in the lines for operation in low land rice production.

The first no-till planter made by Vence Tudo was developed in the early 1980s, though unsuccessfully. According to Marcos Lauxen, managing director, in 1985 after visits to CNPT/Embrapa, FUNDACEP in Cruz Alta and cooperatives, the company concluded that it was a matter of survival to develop machines for NTS; otherwise they would soon be out of the market. Consequently, they visited farmers and industries in Ponta Grossa, bought kits to adapt their machines and, in 1987, developed the first no-till seeder with five rows mounted on the three-point linkage of the tractor. The machine had external wheels, very narrow tine openers and double disks for seed deposition. There was no disk coulter in this model because, in general, NTS was practised on wheat, soya, oat and ryegrass straw. Its performance was satisfactory with low straw densities on the soil surface. With the inclusion of maize in the rotation in the early 1990s, the factory introduced the disk coulter and staggered the planting rows to improve the performance on stover.

In the 1980s, a concern of the CNPT/Embrapa mechanization team was to incentivize industries to manufacture multiseeders. At the time, Imasa already had a perforated horizontal plate metering system suitable for many kinds of seeds. The multiseeders with small seed hoppers, which were nicknamed 'popcorn pans', were developed by Fankhauser and, after that, Semeato launched the SHM model. Up until this point, Semeato insisted on having distinct models for large seeds (PS and PAR) and for small grains (TD). Other manufacturers, also from São Paulo State, only manufactured small grain continuous flow drills. The no-till precision models came later and Jumil was one of the first industries from São Paulo to manufacture them. According to Rubens de Moraes, Jumil president, the first tractor-mounted two-row seeder by Jumil was manufactured in 1962. It had conventional mechanisms and was basically a copy of the Massey-Allis with a John Deere fertilizer distributor. Jumil was a traditional manufacturer of animal drawn planters, and the industry Sans was its main competitor. When NTS started, the industry had difficulties to catch up with its expansion due to both the distance from southern Brazil and the costs of post-sales services.

The industry Marchesan, from Matão (SP), started its activities in 1946 and specialized in animal powered and transport equipment. Only after the 1960s, when tractors started being manufactured in the country, did it start producing tractor powered equipment and improving its industrial processes. In 1970, with the opening of the Brazilian savanna (the cerrado), there was a sharp increase in the number of agricultural machinery manufacturers and until 1985 they manufactured many medium and heavy harrows. For Marchesan, the beginning of seed drill manufacturing was in 1983, for conventional machines. These were later adapted with double disks and disk coulters (to make them triple disked planters) and utilized in no-till, resulting in the SD model, which had wheels directly on the chassis and so presented problems in irregular land. In 1985, they launched the SDA, which had articulated wheels to correct this problem, thus becoming a novelty in the market. The main competitor, the TD by Semeato, also had triple disks, but the SDA was then designed and built with offset double discs with different diameters without the disk coulter.

2.3 Regional Adaptations in No-Till Seeders

Parallel to the industrial development, there was strong demand from farmers for small workshops to adapt conventional seeders to no-till. In order to meet this demand, in 1981, Luiz Külzer and farmer Julio Kliemann installed a front tine on a PS6 Semeato seeder, with the function of opening the furrow and depositing seeds. The PS6 was a conventional system machine, with forward disk coulter, a staggered double disk for fertilizer deposition and a second pair, aligned with the disk coulter, for seed deposition. In view of the successful acceptance received by the seed drill, in 1983, Külzer and Kliemann introduced another opener for fertilizer distribution, thus aligning all the furrow openers and making no-till viable in the clay soils in the region of Toledo. Later, Luiz Külzer also developed a system to transfer weight on the seeding rows by using steel cables, managing to compensate the pressure on the rows when working on terraces or highly irregular land. According to Külzer, no-till in the region of Toledo started to expand in 1989 and spread quickly after 1993.

Another company with a lot of experience in adaptations was Morgenstern, from São Miguel do Iguaçu, western Paraná. According to Mario Morgenstern, the search for furrow opener adaptations started in 1978, with the introduction of out-of-season maize, which aroused interest in no-till to gain time at planting. The conventional seeder models that were most demanded for adaptations were the F13 and F15 by Fankhauser, as well as the precision models PH5 and PH2700 by Semeato. Soya under no-till was not viable yet at the time due to lack of appropriate herbicides. Only after 1985 did no-till intensify in the region, broadening the diversity in adapted precision seeder models, with the predominance of PH2700 and PS8 by Semeato, FX15 by Fankhauser, and models from Sem Rival and Eda. The main difficulty was to select disk coulters and furrow openers for soils with high clay content in the western region and for operation in dry or wet soils. The adoption of NTS by farmers was widespread and the company was expanded to meet the new demand, which became national.

In the region of Maringá, northwestern Paraná, Planticenter was another company incentivated by COCAMAR to work with no-till seeder adaptations, as soil compaction was common in the area and it was difficult for furrow openers to penetrate, resulting in fertilizer and seed remaining on the surface without adequate contact with the soil. The main models in the region were the PS8 by Semeato and a model by Marchesan, which presented disk coulters and double offset disks for fertilizer, staggered in relation to the seed double disks. Planticenter's main innovation was to mount a knife tine for fertilizer distanced from the disk coulter and aligned with the double disks for seed, besides a depth-limiting wheel and a 'V'-shaped compacting wheel that placed the soil on top of the furrow. Besides the cited models, Planticenter made many adaptations to the TD, PS Master by Semeato, MP by Imasa, Jumil 11 and 13 rows and other models from Baldan, John Deere and Menegaz.

3 CONSOLIDATION OF THE MECHANIZED NO-TILL SYSTEM (PHASE 3: AFTER 1992)

The creation of Confederation of American Associations for Sustainable Agriculture(CAAPAS) resulted from the participation of Mauri Sade, from the ABC Foundation, in a meeting in Chile during a visit to Carlos Croveto, farmer and president of the Chilean Soil Conservation Society. Sade brought the request to the Brazilian group, who decided to create the FEBRAPDP, which was decided during the National Sorghum and Corn Meeting in Ponta Grossa in 1992, and sanctioned during the VI ENPDP, in Cruz Alta, in the same year. CAAPAS was founded in the same year, with its headquarters in Rosário, Argentina, and representation of member countries in the vice-presidency. FEBRAPDP was created with the objective of disseminating NTS nationwide and had international outreach by including legal entities as associates, such as the Friends of the Earth Clubs and similar organizations, scientific institutions and companies. The influence that the original Earthworms Club group had on the expansion of NTS was important mainly in the 1980s, when it worked more intensively in comparison with others in the country. Meanwhile, in Rio Grande do Sul, the work by CATs and FUNDACEP was also impressive.

In the 1990s, important fairs and exhibitions started to be organized in the country, in which there were dynamic presentations of working agricultural machines, turning such events into reference points for launching new machine models (predominantly aimed at no-till) on the market. The Expointer fair in Esteio was already traditional in RS, but the machines were only exhibited, rather than operated. Agrishow in Ribeirão Preto (SP) stood out for its dynamic presentation of agricultural machines, along with the static exhibition, and became the leader in new machine launching and sales in Brazil. After that there was the Show Rural in Cascavel, also with dynamic machine demonstrations, but also with emphasis on other agribusiness segments. From the year 2000 on, there was a multitude of medium- and large-sized exhibitions in Brazil such as the ones in Não-Me-Toque (RS), Rondonópolis (MT), Sabáudia (PR), Uberlândia (MG), Santa Helena (GO), among others.

3.1 No-Till System Research and Development Actions

In 1993, there were only 300 thousand hectares of NTS in Rio Grande do Sul, and several public and private entities decided to stimulate its expansion with emphasis on the capacity development of farmers and technicians. Thus, Embrapa organized a series of three-day courses on several topics, such as soil liming, phosphate fertilization, machines for small farms, micronutrients and inoculants. This project was named METAS and, besides the participation by Embrapa, it also counted on EMATER and private seed, chemical supply, fertilizer and machine companies. Four years after the beginning of the project, the NTS area in the state had already reached 850 thousand hectares.

In the early 1990s, only 13% of the farmers in Paraná had adopted NTS (EMPRESA DE ASSISTÊNCIA TÉCNICA E EXTENSÃO RURAL DO PARANÁ, 1996) and several initiatives were aimed at increasing the area of adoption. One of these initiatives was by ITAIPU Binacional, in the extreme west of the state. Concerned with minimizing the run-off and sedimentation from conventional system agricultural areas into their reservoir, ITAIPU diagnosed the situation with 280 farmers and decided to implement technological validation actions to improve NTS quality with IAPAR's support.

Such actions were based on the identification of partner farmers willing to test new technologies, together with a group of researchers, as a consequence of discussions of the problems they faced in their farms. The technologies introduced in these areas were related to crop rotation, cover crops, reduction in input use, no-till planters and cover crop seed production. During five years, a multidisciplinary team from IAPAR interacted directly with farmers, ITAIPU technicians, cooperatives, municipalities and EMATER, among other regional agents. The team organized numerous courses, field days, meetings, working machine demonstrations, production and distribution of cover crop seeds, besides other activities. The main results of this work are reported in the book "No-till system with quality"[4], published by IAPAR and ITAIPU in 2006 (CASÃO JUNIOR et al., 2006).

[4]In Portuguese: "Sistema Plantio Direto com Qualidade".

At the end of the 1980s and beginning of the 1990s, two research groups from Embrapa (CNPMS and CNPT), aiming at generating technical information so that agricultural machinery industries could improve their products, decided to carry out comparative field tests between commercial conventional seeders and no-till seeders. This work produced a rich exchange of experience and ideas and facilitated innovation within the Brazilian industry. It was during this period that Marchesan, for instance, introduced the auger-feed for fertilizer distribution and, two years later, all the industries already had this device in their machines. A pneumatic seed metering system was also introduced by Jumil during this period, and was soon followed by the other manufacturers.

In the mid-1990s, IAPAR realized that a lack of reliable technical information for the selection of commercial no-till seeders was an important limitation for farmers, and decided to evaluate the field performance of such machines in the main soil conditions found in the State, with the aim of generating subsidies for the farmers (Figure 6). From 1996 to 2003, more than 100 models of commercial precision seeders, seed drills and multiseeders were evaluated and it is estimated that approximately 5000 farmers and extension

Figure 6. Dynamic exhibition of no-till planters in Guaíra, Paraná, in 2003.

workers were trained. Besides collaborating with industries in the identification of the positive and negative aspects of each model, an important conclusion of this work was the need to optimize the tine design, commonly used in many regions presenting medium to clay soils, with the objective of reducing power demand and soil disturbance. A detailed study on the performance of several furrow openers was conducted and its results have been employed by several manufacturers.

3.2 Development of Machines by Industries

For the company Semeato, there were two important phases in the development of NTS machines, i.e. the TD in the early 1990s and, later, the PAR. The PAR model had pantographic articulation of the planter lines and better distribution of seeds. This enabled a reduction in the number of planting problems experienced by the previous model, namely PS. The PAR also introduced the guillotine, which solved many straw cutting problems, and the NG compacting wheel, developed to improve soil compaction along the seed line. Also in the 1990s, Semeato launched the Line 90, aiming at reducing straw accumulation on clay soils, which was based on John Deere's Maximerge 2 planter. This presented innovations such as location of furrow openers, depth control, and compacting wheels. For Semeato's important export market, the company adapted its machines for different locations and operational conditions. For instance, it removed the fertilizer hoppers from the machines aimed at the Bolivian market, as the soils there are relatively fertile and crops are not fertilized; in Chile, where the soils tend to be abrasive, it was necessary to design disks that were more resistant to wear; and for Europe, it was necessary to adapt components for stony areas. For the central-west region of Brazil, which requires bigger machines due to the large farms, Semeato designed the PF line, including the model Land Master, which was conceived from the models PS Master, PS, PAR planter version and TD seeder version.

With the METAS project, there was the development of the SHM, which represents another important landmark of the company as it is a multiseeder for small farmers (Figure 7). This machine started with eleven rows spaced at 17 cm, was widened to 17 rows and currently, with the model SSM, can have up to 27 rows.

With the expansion in the trade of machines adapted to NTS in Paraná in the early 1990s, Jumil decided to design a machine for the clay soils of the western area of the state that could be used all over Brazil. As a result, they developed the Magnum 2800, which sold around 500 units, and was one of the pioneer models in the use of auger-feed metering system for fertilizers. This model was an improvement on the Magnum 2000 that, in fact, was the first NTS machine produced by the company from the adaptation of the model Jumil 2000, developed back in the 1970s. The Magnum 2800 and the later models 2850 and 2880 were designed so that their structures and components could support heavier loads in the NTS and could cope with more demanding operational conditions with more powerful tractors, more speed and working depth in relation to conventional seeding.

Figure 7. Multiseeder model SHM by Semeato.

In 1992, Jumil brought the pneumatic system by Monosem from France, as at the time there were problems with seed grading, and flaws in plant stand with the use of horizontal plate seed metering system were common. The acceptance by farmers was good, mainly in the savannas, but the region's high temperatures caused deformations in the polyethylene support and blocked the stainless steel metering disk. The problem was solved by replacing the stainless steel with bronze. During the 1997 Agrishow, Jumil launched the pneumatic machine model Exata and the Magnum line with polyethylene seed hopper. Although it took some time for its adoption, the pneumatic metering system reached 60% of the machines sold by Jumil, contributing immensely to seeding precision, mainly of corn, cotton and sunflower. After that, the company introduced a pantographic system in the seeding units with the development of the no-till seeder model named Guerra, which achieved important sales volumes in 2005 and 2006. Nowadays Jumil has a multiseeder model called Múltipla, which sows forage seeds between the rows of the main crop. It has three tool bars to allow a wide staggering between the rows and components, helping the straw to flow and avoid accumulation. It does not use a disk coulter and summer seeding can be carried out with the pneumatic system.

The first NTS machine made by Fankhauser was the precision seeder model 4010, which was already pantographic, followed by models 5030 and 5010. The latter presented from 11 to 16 rows, high structure and offset rows, aimed at reducing accumulation in conditions of high straw volume. Model 5010 gave origin to model 5040 in 1995, which had plastic hoppers, gearing systems for seed and fertilizer metering, and disk coulters up to 20 inches (0.5 m) in diameter. In 1998, the line transmission system started to use drive shafts instead of chains to avoid accumulation under heavy residue conditions. According to Pedro Fankhauser, the company's director, an important aspect to avoid residue accumulation in no-till is to assess the soil moisture level correctly, and to take the machine's limitations into account. He also highlights that the

Brazilian farmers are now sufficiently informed about no-till issues and that, currently, they contact the industries much more often about specific technical problems rather than due to their lack of knowledge of NTS.

Imasa always had a commercial strategy to offer NTS multiseeders because of the importance of wheat in southern Brazil. However, with the decrease in the production in the 1990s, it decided to develop the precision model Plantum, which used the same seed metering system as the previous model, the MPS, and had disks of greater diameter than its competitors', lower peripheral speed and better durability. Besides, Plantum had an auger-feed metering system for fertilizer, expansion rather than compression springs to reduce wear, narrow and reversible furrow openers and narrow, greater diameter depth control wheels to reduce residue accumulation. After the precision seeder Plantum, Imasa developed Technum, which did not sell in large numbers. It was the first to be produced with laser cutting, which enables the construction of any design and makes the manufacturing of small batches of machines viable. Besides, it enables the reduction in the use of cast pieces. Plantec, also manufactured recently, is a multiseeder whose novelty is the possibility of moving the rows on the tool bar without the need to unbolt them. Therefore, the operational change from big seeds into small seeds is achieved with the movement of a shaft. Apart from that, it can place the fertilizer next to the seeds and sow up to three types of seed at the same time.

The model PST by Marchesan was launched in 1985 for precision seeding in the conventional system and, though its structure was light, it started to be adapted for NTS by small workshops in the early 1990s. In this model, the industry introduced the offset double disks from the SDA model, increased the disk coulter diameters from 13" to 15" (0.33 to 0.38 m), and started to sell it for NTS, though still with fertilizer double disks out of alignment with the seeding disks, which was a common configuration at the time. Another novelty launched by Marchesan was the auger-feed metering system for fertilizer, when the industry standard was still the rosette metering system. This machine evolved into the model SDA2, with more robust structure and greater number of rows, as well as the need for more tractor power. After 1992, the industry aligned the furrow openers, placing the disk coulter in the same line as the offset double disks for fertilizer and seed. However, there were a few problems such as the lack of weight in the row, which made penetration difficult and left the seeds exposed, and the occurrence of structural failures as stresses were greater. In 1994 there was another novelty: the rows were staggered because, with the increase in straw volume, accumulation problems had become frequent. At the time, several NTS seeder models offered many configuration possibilities, for instance: with only offset double disks; disk coulter and double disks; disk coulter and tine opener, with all these components and also with the option of having two toolbars and having staggered rows. The model PST2 D44 became the most complete and famous NTS seeder during that period.

In 1998, following Paraná farmers' suggestions, Marchesan decided to strengthen the structure in model PST2 with two 100 x 100 mm tool bars, which gave rise to model PST3. This required a change to the cast linkage pieces in the machine, changes in the depth control system, which allowed more versatility in the adjustments, adoption of a gear box for the fertilizer and seed metering systems, adoption of plastic hoppers for seeds and fertilizers, and increase in the machine working width. The market absorbed the extra cost, as it demanded such changes.

The PST4 model was designed with an odd number of rows as an even number, common in previous models, made it difficult to transform the line spacing from 45 cm to 90 cm. In 2008, the PST4 Flex was launched with pantographic rows and a wider platform, along with the improvement of several ergonomic aspects.

The multiseeders were born with the PDCM model, which aimed at using as many existing parts as possible. The PST3 was used as a basis, introducing offset double disks and a hopper for small seeds. The transformation of big-seed machines into small-seed ones was fast so as to meet regional demands.

In 2000, Marchesan launched the COP model to compete with the imported models by Case and John Deere. The COP presented a parallelogram system in the rows with the aim of always keeping them level with respect to the ground. One of Marchesan's characteristics is the use of offset double disks and depth control wheels with position adjustment, which allows them to be positioned near or far from the double disks, and the soil compaction system. The depth control wheels with "V" design were apparently not well accepted by the market.

Initially, Metasa developed the precision seeder PDM and, in 2002, the multiseeder SDM, from which multiple commercial models were developed to meet regional demands and market niches. The SDM has been a favourite for export to Spain and South Africa as it is robust, versatile and easy to use and adjust. It can sow up to four crops at the same time, including forage seeds between the main crop rows. The PDM incorporated parallelogram rows due to market demands. With its joining Kuhn, the company incorporated the pneumatic system, which is important when the seeds are not well graded. The main market for pneumatic machines is in the central region of the country, with the still not widespread crops of cotton and sunflower, besides castor-oil plant and canola, due to the expected expansion in biodiesel production.

In 1991, the company Vence Tudo launched the no-till precision seeder PA and, in 1996, the multiple SA, both aimed at small farmers. Because of the market expansion, the company decided to develop drawbar machines, therefore designing the SMT, the SM, the Premium, the TSM, and most recently, the Panther model (Figure 8). Until the SA model, the main market was the southern area of Brazil and the seeders were light, three point mounted, and required low draught force, which was obtained with a narrow tine and a small rake angle. Another characteristic of this model is the concave seed-covering disks, which provide good planting uniformity even in the irregular undulating lands of southern Brazil. In 1994, the SA 13500 model was the only machine of the category that was appropriate

Figure 8. Multiseeder model Panther by Vence Tudo.

for family agriculture, for which it was awarded the Gerdau prize “Improvement of the Land”[5] at Expointer. An important quality leap was the development of the “jump-stone” system, with articulation in the disc coulter support for safe working in stony conditions. This increased the demand, including that for large and small-sized machines. Nowadays, the SA is manufactured with 3 to 7 rows for soya and 7 to 14 rows for wheat. In 2000 the company began to structure an export department, starting in Colombia in 2001, although they already had foreign commercial experience with Uruguay and Paraguay. The export demands came mainly from the fairs such as Expointer, Agrishow and Show Rural. Through ABIMAQ they met Intrac Trading, which became the company’s representative in South Africa. They went to Mexico, the United States and, mainly through FAO, their products have been disseminated in Latin America, Asia and Africa. In the first six years of the export department’s existence, the company did business with 20 countries. In 1998 the Brazilian savanna started its big expansion and Vence Tudo began to participate in it with the

[5]In Portuguese: “Melhores da Terra”.

Premium seeder, with 8 to 18 rows for soya, which could be coupled in tandem and reach 28 rows, planting up to 200 hectares/day. As the company expanded its market, new demands appeared and, today, it has appropriate models for small, medium and large-sized farms, and is an important player in the manufacture of no-till seeders for family-run farms in Brazil, with annual sales of up to 1200 units. The introduction of the parallelogram system occurred with the SM Panther model, and it was so successful that it already has models of up to 13 rows available.

Planticenter started to manufacture no-till seeders in 1999 with machines to sow 7 rows of soya and 4 of corn, with narrow tines and easy adjustment for 75 hp tractors. In 2001 it already had models with up to 11 rows and, in 2002, launched the transversally articulated precision seeder for terrace operation. In 2004, the company developed a drill seeder with good small seed covering capacity. After that, it launched its cassava planter, and recently, a sugar cane planter.

The industries of horizontal plate seed metering systems and seed distribution plastic tubes were fundamental to improve the quality of no-till machines in Brazil. Scherer, from Cascavel (PR), is the biggest manufacturer in the country and its line of products includes 44 different models of disks and orifice configurations. Its main market consists of seed production farmers. Recently, it developed a universal disk that can be coupled to any Brazilian precision seeder. Another important company in the sector is Socidisco, which was created in 1986 to meet the demands by Pioneer, with the aim of improving corn seeding quality. The disk with a double line of holes especially for soya distribution was patented by the company, as well as the double seed ejector mechanism, these were unique innovations with nothing similar anywhere in the world, since with the pneumatic system, the perforated disc system is being superseded.

Both Scherer and Socidisco state that the high cost of the pneumatic metering systems does not justify the improvement obtained in the seeding quality. Although pneumatic machine companies have disseminated the idea that there was no need for adjustment, in fact, the density variation of the seeds requires adjustment of the suction pressure which, if not carried out, may increase the possibility of multiple seeds being planted.

4 ORIGIN AND EXPANSION OF ANIMAL POWERED NO-TILL SYSTEM (AFTER 1985)

Interest in the development of small farms in Paraná arose mainly in the early 1980s, in the context of the re-democratization process in the country. At IAPAR there was a concerted effort to deepen the knowledge of the rural reality in the state of Paraná. This included both socio-economic and technological aspects and was aimed at, among other objectives, identifying research demands concerning this target group. Small farmers were characterized by presenting limitations in terms of natural resources, particularly soil and topography, and farm structural conditions (family workforce, low capitalization and small cultivated area). Animal energy was important due to the high number of farms resorting to it (around 80% in 1980) and the number of potential beneficiaries.

In 1984 the Paraná government implemented a programme to boost animal power according to regional socio-economic realities, with the objective of making small farms viable by means of rationalization in the use of manual labor (SECRETARIA DA AGRICULTURA DO ESTADO DO PARANÁ, 1984). In this programme, the plethora of animal powered equipment available in the country was assessed for conventional tillage systems in the regions of the state where there was a concentration of draught animal power. After the assessments, it was possible to establish parameters to design new animal powered equipment, which led to the development of new models of stump removers, mouldboard ploughs, knife rollers, conventional and no-till seeders. All the new models of equipment were patented with public right of use.

In the case of the animal powered knife roller design, the aim was to determine the appropriate dimensions for its construction by modeling the necessary energy to cut different cover crop plants, such as black oat and vetch under different conditions such as equipment weight, operation speed, dimensions, thickness and cutting angle of the blades (CASÃO JUNIOR et al., 1989). From the model and experimental determination of the cutting energy required for the cover crop plants, it was possible to dimension knife rollers appropriate for animal traction, i.e., with the power demand both compatible with the weight of the animals available in each region and capable of crushing the most common cover crop species.

An animal powered no-till seeder was developed in 1985 and improved in the following years (Figure 9). The challenge was to develop an approximately 70 kgf no-till machine considering that, for the disk coulter to work efficiently, it would be necessary to have 60 kgf of vertical load. In order to achieve success, the linkage between the animal harness and the seeder was placed above the virtual traction line, which enabled not only the transference of part of the machine´s rear weight to the disk coulter, but also the addition of a tine to provide the machine with better penetration capacity and stability.

Another initiative related to the development of machines for small farmers was the work by Dellagiustina (1990), from the State University of Santa Catarina (UFSC), who also focused on the development of a no-till seeder model. Other work on the theme is mentioned in the book by Tomiyoshi & Silva (1997).

A further research area undertaken by IAPAR and aimed at small farmers was the study of traditional soil management systems

Figure 9. The first Gralha Azul animal powered no-till commercial model and the researcher in charge (Dr. Ruy Casão Junior).

in comparison with no-till and minimal cultivation with crop rotation. Associated corn and bean cropping systems were studied in the northeastern, central-southern, southwestern and central regions of the state, with the inclusion of cotton in the latter. The cover crop species used were black oat, lupin, vetch and velvet bean, and the soil management systems were conventional ploughing, chisel ploughing, and no-till planting with animal powered and manual (hand jab) machines. Besides cover crops, IAPAR also studied farmers' traditional winter fallow management and straw burning before seeding. This work allowed the researchers to verify the viability of the new management systems in relation to the traditional ones and provided the team with confidence to start the activities of technology validation with the farmers.

4.1 Validation and Dissemination of No-Till System in Small Farms

The first testing and validation units (TVU) of animal powered no-till were implemented by IAPAR in 1989, on farms located in the central-southern region of Paraná. Each unit had around one hectare, where oat was sown before beans and oat + vetch before corn. The winter cover crops were sown by broadcasting and incorporated by animal powered disk harrow and later managed with knife roller and herbicides, whereas the summer crops (beans and corn) were sown with the no-till planter "Gralha Azul". All the inputs used were monitored and the labor reductions and herbicide input costs were verified in the NTS.

Taking into consideration the good results of this pilot work, IAPAR decided to expand it and, in 1993, began a series of consultations with state governmental agents, industries and farmers' organizations. MH Equipamentos, an industry from Cornélio Procópio, agreed to participate in the work by producing an initial batch of no-till seeders partially financed by FEBRAPDP and Paraná State government. Thirty two farmers from the southern region were selected to receive a “Gralha Azul” planter unit each. IAPAR and EMATER technicians trained the farmers and provided technical back-up to the new validation units in the farms. The objective was to confirm animal powered NTS viability as long as the technical conditions were right and farmers’ training was provided. Technical follow-up and the on-farm field day programme lasted for three years. The TVU follow-up was made by IAPAR and EMATER teams who met 3 to 4 times a year with the farmers for joint assessment and planning, and once a year everyone took part in a workshop to analyze the results. The main reasons for the adoption of NTS reported by the farmers were reduction in workload and production costs.

In 1993 and 1994, MH sold around 600 units of Gralha Azul, though the model presented some limitations and required improvements. In 1995, the company, which produced a broad line of products, experienced financial problems and closed, but was subsequently reopened with the name Metasil by former employees. At the time, several small machinery industries started to show interest in animal powered NTS due to the expansion of the system, and began to manufacture new models based on the “Gralha Azul”, although incorporating improvements such as maneuverability, stability, better straw cutting, etc. It was a time of exchange of experiences between industries and technicians which enabled the identification of several technological solutions still used up to the present day in animal powered planters. As a consequence of the new animal powered no-till seeders in the market, IAPAR, by means of the Ponta Grossa group, started a study to assess the field performance of such machines. The first assessment compared models by Mafrense, Buffalo, Picetti, Ryc, MH and Sans.

Sans was a traditional manufacturer of animal powered conventional seeders and simply placed a disk coulter at the front of its machines, but soon after left the market. The model by Buffalo, from Rio Grande do Sul, was developed for seed drilling and tobacco fertilization and, because of that, had a rigid furrow opener that worked up to 15 cm deep and two wheels in front of the disk coulter functioning as a guillotine, thereby facilitating better residue cutting.

However, the machine was too heavy for animals to pull. The model by Ryc, just like the one by Buffalo, presented good straw cutting capacity but, as it had two rear support wheels for operation on sloping land, demanded too much effort from the operator to keep it in a straight line. In 1997, Ryc was sold to Triton and new changes were introduced in this model. Mafrense brought improvements related to handling and maneuverability, besides presenting many other adjustment options. More assessments were conducted later, with other commercial models. The model Iadel presented easy adjustment and good planting performance; however, its structure was too long, the ground drive-wheel was small, which sometimes caused loss of contact with the soil, and its hoppers were located towards the rear of the machine, making maneuverability difficult. The model by Werner was appropriate for hilly areas with good performance in tests in southwestern Paraná and western Santa Catarina. Its main advantage was its low weight, around 30 kg, and low draught requirement, around 60 kgf. Nevertheless, its main problem was its small fertilizer capacity as every 50 meters the hopper required re-filling. Later, models by Knapik and Fitarelli were launched and also assessed. Such assessment studies led to the conclusion that the choice of the best animal powered no-till seeder depends on the situation and that, in general, the model by Iadel is the most appropriate for clay soils, the model by Mafrense, for medium soils and the one by Werner, for irregular land. Besides IAPAR's work, other study initiatives to improve animal powered no-till seeding were carried out in Brazil. Among them, the studies by the UFSC group should be highlighted, as they resulted in the development of a prototype with several innovations.

Aiming at disseminating the experiences with the development work, in 1993, IAPAR organized the I Latin American Meeting on No-till for Small Farms in Ponta Grossa, which counted on the presence of technicians and farmers from several Brazilian states, neighboring countries, as well as FAO representatives, machinery industries' and farmers' organizations. The second meeting was held in 1995 in Paraguay and the third in 1998 in Pato Branco (PR).

4.2 Rural Development Programmes with a Conservation Emphasis

Public policies aimed at soil conservation have been included in Paraná state governmental programmes since the 1970s, two outstanding examples were PRODONORTE from 1970 to 1974 and PROICS from 1975 to 1980. In the 1980s and 1990s, broader conservation concepts became even more influential in the state's rural development programmes, these included PMISA, from 1984 to 1988, and Paraná Rural, from 1989 to 1997. Initially, PMISA supported farmers by subsidizing the costs (fuel and operators) of conservation practices, mainly those relating to the repair and maintenance of rural roads and terrace construction to reduce run-off in agricultural areas. In the Paraná Rural programme, there was a qualitative change in the focus, and the subsidies started to be directed to the acquisition and use, individual or collective, of no-till machines, such as planters and equipment for cover crop management. With the positive results of animal powered NTS validation in the state in the early 1990s, in 1995 the programme started to subsidize planters, knife rollers, sprayers and animal drawn lime spreaders as well, with EMATER's support in the promotion of regional events to disseminate the machines and NTS.

The Paraná 12 Meses programme, which succeeded Paraná Rural, continued with the same policy and expanded the support to NTS, increasing incentives to farmers' collective use of machines and the use of cover crop species and organic fertilizers. During the six years of the programme, approximately 100 tons of cover crop seeds such as jack bean, pigeon pea, velvet bean, vetch, oat and fodder radish were bought and provided to the farmers, previously access to seeds of such species had always been difficult for them.

As a consequence of such support, in 1988 EMATER and Syngenta started the project Grãos, which covered 35 municipalities in central-southern Paraná, and had the aim of diversifying production and adding value in small farms. The strategy was to provide conditions for the transition from conventional management to NTS and, with the rise in crop yields and farmers' capitalization, introduce other crop species and enterprises, such as fruit growing, milk production and horticulture. In the beginning of the 21st Century, with governmental incentives for the acquisition of tractors, there has been a significant transition from animal powered NTS to mechanized NTS, which is currently the predominant practice among the 110 farmers of the project.

The consolidation of NTS in small farms resulted in higher production diversification, as there was more free time for the farmer to devote to other activities, mainly cattle raising for milk and meat production, horticulture and fruit growing. Besides, the adoption of NTS presented the possibility of keeping the family working on the farm due to the better prospects as a consequence of mechanization of farm work and the possibility of financial support with accessible interest rates.

The agencies and institutions responsible for the financial support of farming in Brazil started to give attention to small farmers in 1997, with the first PRONAF investment operations, including those for buying agricultural machinery, though engine-powered machines were not very much used by the farmers at the time. In 2003, there was an important change in the federal government's policy, which included financing policy reformulation, interest rate reduction and pegging, and the possibility for small farmers to have access to credit with lower interest rates and longer grace and pay-back periods by using a credit line called PRONAF D. In the PRONAF C line, which was conceived for even smaller farmers, it was possible to finance the purchase of draught oxen, which was a novelty in the country.

4.3 Manual and Animal Powered No-Till System Equipment Industries

Krupp, a manual seeder-fertilizer industry (manufacturing hand jab planters), was founded in 1947 in Araricá (RS), and currently does business all over the country with a wide range of hand jab planter models, not only for tobacco seedlings but also for other plants, and a model for tobacco fertilizing with a good back-pack tank capacity of 20 litres. No-till hand jab planters were developed to meet market demands and the main difference in relation to the conventional version was the incorporation of a double sharp beak. These products have been exported, though still intermittently, and always in small batches. Recently, the industry made a partnership with a sales representative in South Africa and expects to consolidate exports.

Fitarelli, an industry from Aratiba (RS), was founded in 1952 and initially manufactured weapons, but soon, due to market demands, started to manufacture simple hand jab planters for smallholder farmers. In 1976 fertilizer metering systems were incorporated in the hand jab planters as a response to the increase in input use in the local agricultural production systems. In 1982, the industry already produced animal drawn planters with wide tines; in 1988, it introduced a long beam design to be attached to the ox yoke. In 1990, it incorporated a disk coulter and a narrower tine with appropriate angle, aimed at meeting farmers' no-till demands. After that, the company developed a two-row model. Exports represent 30% of its revenues and the company does business with 39 countries in Africa, Asia and Latin America through strong associations with international organizations promoting conservation agriculture. An important market for the company is Paraguay, where sales have exceeded 300 no-till planters by means of a locally-based sales representative, apart from those in South Africa and Mozambique. Today, besides no-till two-row seeders and hand jab planters, Fitarelli produces a no-till 3-to-5 row tractor-mounted precision planter whose market has been expanding due to its simplicity and good performance even with heavy straw cover.

The Werner factory, from Campo Erê (SC), started its activities with the production of hand jab planters developed by the company itself and, from 1992 on, designed animal powered planters for hilly lands and lands with stones and stumps (Figure 10a). The model has a long beam that provides the machine with increased stability and improves its maneuverability, as compared to chain-pulled planters. From 1997 to 2000, Werner sold more than 5000 planters via a network of agricultural input suppliers. The company already has a small tractor-mounted planter in the market and is developing self-propelled combine harvesters also for smallholder farmers.

Triton is a well known brand in southern Brazil having earned its reputation through manufacturing trailed threshers, which were in common use up to the 1970s. The appearance of more versatile and cheaper equipment led the company to diversify its products and to start the manufacturing carts for transport, threshers and sugar mills and also animal powered conventional seeders. In the 1990s, they began to manufacture animal powered sprayers and, in 1997, the company bought Ryc, a company that manufactured animal powered no-till seeders (Figure 10b). More recently as tractor-powered mechanization has been more and more adopted by small farmers due to financial subsidies for the acquisition of low horsepower tractors, Triton has been adapting to the market by manufacturing no-till seeders with 2 to 4 rows for maize. It has experience with exports and is opening a specific commercial department to that end, apart from its plans to develop equipment for the pre-processing of bio-fuel crops such as castor-oil beans.

The Mafrense company, from Mafra (SC), specialized in the manufacturing of equipment for tobacco crops due to the presence of a big tobacco company in the city. However, in 1997, it also began to manufacture animal powered machines for the regional market, which soon became its main activity with national sales, as well as international sales to more than 14 countries. The Gralha Azul design, developed by IAPAR, was the basis for its commercial no-till seeder model, which went through several improvements up to 1999, when the model developed was well accepted by the market for being light and cheap. At present, the industry has a complete line of products for animal powered no-till which includes, besides seeders, 20-, 100- and 200-litre sprayers, lime spreaders and knife rollers, and is also producing a model of three-point mounted tractor powered no-till planter.

Figure 10. Animal powered no-till planter models Werner (a) and Triton (b).

Knapik, from Porto União (SC), was founded in 1985. At first it worked with agricultural machinery maintenance and repair, but soon started to develop equipment for small farms in the region. The first product was a manual sprayer that was presented successfully in several national fairs and was awarded a prize by the Ruraltec Show[6] in Londrina (PR). After that, there was an animal powered no-till seeder, with the collaboration of the Ponta Grossa IAPAR group, which was also awarded a prize in the innovation category by Gerdau prize “Improvement of the Land” in 2001. Today the industry manufactures a tractor mounted planter model that provides good performance and requires little after-sales technical assistance. Up to 2007, 250 planting lines had already been sold. Knapik counted on FAO’s support at the beginning of its export experience and already has a sales representative in South Africa.

Iadel, from Dona Emma (SC), has been operating since 1983 and has specialized in tobacco crop equipment and animal powered machines. In 1991 it began the development of an animal powered no-till seeder based on IAPAR’s Gralha Azul model. From 1994 to 1998, the industry sold approximately 600 units of that design due to the tobacco industry’s small farm diversification incentive programme in Paraná and Santa Catarina. As a consequence of the expansion of animal powered no-till, Iadel also started to manufacture lime and fertilizer distributors, knife rollers and animal powered sprayers. From 1998 on, it started the development of a tractor-powered tobacco transplanter, which was well accepted by the market. Consequently, the company stopped prioritizing its animal powered line, which, because of its lower price and small profit margin, is only interesting to the company when sales numbers are high.

Sgarbosa, from Santa Tereza do Oeste (PR), founded in 1977, is a general engineering company. At first it manufactured water turbines as there was a lack of electrical power in western Paraná. In 1993, the industry developed a sprayer and, later, a no-till seeder, both animal powered. The seeder incorporated an exclusive pressure system on the disk coulter. Nowadays, the only animal powered seeders that Sgarbosa manufactures are two row machines, which have several components that are similar to the ones in tractor-powered planters.

[6] In Portuguese: “Mostra Ruraltec”.

5 FACTORS THAT FACILITATED THE EVOLUTION OF NO-TILL SYSTEM AND THE MECHANIZATION OF CONSERVATION FARMING IN SOUTHERN BRAZIL

The main factors for the evolution of both NTS and mechanization of conservation farming in southern Brazil highlighted in the study are summarized as follows.

5.1 Soil Erosion

The conservation concern in southern Brazil stemmed from the severe soil erosion problems, which motivated several initiatives by the farming-related community to solve them. Farmers, governmental and international support programmes, research institutions, rural extension initiatives, universities, cooperatives, farmers' associations, agricultural industries, all participated individually or collectively to fight the problem.

5.2 Governmental Integrated Soil Management Programmes

In a tenuous way during the 1970s and more intensively in the 1980s, several integrated soil management and conservation programmes were implemented in southern Brazil. Some of them were financed by international organizations and, in only one decade, played a fundamental role in the substitution of conventional soil tillage, with ploughs and harrows, for minimal preparation with the use of chisel ploughs, which provided reduced soil disturbance and the retention of crop residues on its surface.

5.3 Pioneers' leadership in the 1980s

The pioneer farmers' leadership in the search for solutions and knowledge dissemination during the 1980s provoked ample discussions on NTS and motivated several initiatives, not only related to the adaptation of machines in regional commercial workshops, but also to the use of plant species for cover crops to provide permanent soil protection; besides initiatives in other aspects connected to NTS.

Simultaneously, the determination of the pioneer NTS machinery industries, based on research results and interactions with pioneer farmers, enabled the development of the first national no-till planters, which were predominantly continuous flow seed drills, rather than precision planters.

The results of pioneer scientific institutions efforts showed the viability of NTS. These were very often supported by international organizations and multinational companies interested in market expansion, mainly with new herbicides. This work was fundamental for the consolidation of NTS principles, especially concerning cover crop species, crop rotations, allelopathic and chemical weed control and soil fertility management. Such efforts provided the technical conditions for the evolution in the adoption of NTS in the region.

5.4 Beginning of No-Till System Expansion

The irreversible expansion in the adoption of NTS occurred after the mid-1980s due to a combination of factors such as:

1. The economic and energy crises at the time demanded that farmers looked for alternatives to reduce production costs and NTS met such a demand as it required fewer machine-hours with significant fuel economy;
2. The reduction in the price of the herbicide Glyphosate, which started to be produced in Brazil in 1985, along with more availability of other pre- and post-emergent herbicides in the market, making weed control easier;
3. The availability of NTS technology for all the main annual crops;
4. The market availability of several precision planter and seed drill models manufactured by agricultural machinery industries, besides the existence of several machine adaptation workshops with experience and good products.

5.5 No-Till System Consolidation after 1993

The NTS cultivated area in Brazil expanded impressively, going from 1 million hectares in 1992 to 25 million hectares in 2007. This expansion was possible due to the availability of no-till planters in the national market that were appropriate to the range of soil types in Brazil.

Several agricultural machinery manufacturers believed in the market expansion and invested heavily in the improvement of no-till seeders. They also counted on the support of research institutions through their comparative testing of commercial models.

After 1995, agricultural financing, mainly for investment, started to have lower and fixed interest rates, which resulted in an increase in machinery acquisition throughout the country. Agricultural machinery fairs proliferated, mainly the ones in which there were dynamic exhibitions of no-till machines. In this way, such fairs turned into reference events for the launching of new machine models by the industries.

5.6 No-Till in Small Farms

The government's family agriculture support policy in Paraná, implemented in the early 1980s, resulted in the development of animal powered no-till machines. In the 1990s, the main NTS technologies were validated in small farms and, in later years, were responsible for the wide adoption of the system, as well as for the appearance of small manual and animal powered equipment manufacturers mainly in Santa Catarina and Rio Grande do Sul states, which enabled the change to no-till production systems of small farms in southern Brazil.

The wide dissemination of the good results obtained by means of the technical events, the attractive agricultural investment financing facilities, the farmers' interest in changing the production system and the machinery and input industries' interest in expanding their market provided fertile ground for the adoption of NTS on small farms.

As a consequence, smallholder farmers have managed to control erosion, reduce their work load, save time, increase crop yields and diversify their activities, mainly with higher aggregated value activities. This has had a positive impact on the improvement of the quality of life of smallholder farm families. More recently, due to credit facilities and governmental support, tractor mechanization has been expanded in place of animal power in the southern region, not only by the direct acquisition of small and medium sized tractors by farmers, but also by the constitution of collective machinery use associations, generally supported by municipalities and governmental programmes.

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This publication is an account of the technical developments in no-tillage systems that took place in southern Brazil from the viewpoint of the principal actors in the process. Special emphasis is given to the mechanization of conservation agriculture, as it is in this area that the domestic agricultural machinery industry has played a key role adapting and and developing indigenous technologies suited to different soil and climatic conditions as well as to the soil conservation management strategies practised in the country. The ability to generate diverse, flexible and innovative technical solutions for different categories of farmers has put the agricultural machinery industry of Brazil amongst the leaders of the global market. International organizations are raising the awareness of conservation agriculture as an alternative to conventional practices in Africa, Asia, Central America and the Caribbean and for this reason understanding the evolution of the Brazilian experience of mechanizing no-tillage and conservation agriculture and identifying its determining factors is of fundamental importance to enable the expansion of the system in other regions of the world and to avoid repeating mistakes and possibly wasting resources.

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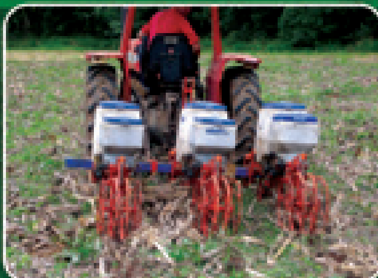

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