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Behavior of the Technologic Innovation and diffusion in Agribusiness: The case of "No-Till" in Rio Grande do Sul, Brazil

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Abstract
In the last years, dominant technologic paradigms on technological and industrial activities and on highly innovative areas have been analyzed in the world scientific literature, but in agribusiness area this kind of study remains unusual. In Brazil, the traditional technology used great quantities of resources and the soil is revolved several times by year. It was substituted by agriculture practices known as "no-till" technology that uses less resources and minimal revolving of the soil. This paper has the purpose to analyze THIS particular agribusiness innovation within a theoretical framework which is generally used to analyze technological innovations characteristics of the industrial sector. We try to identify behavior similarities in both fields of innovation and its diffusion in farmers in the state of Rio Grande do Sul, Brazil. In this area the use of this technology started at the sixties and spillover all Brazil since then. Industrial technologic innovation and diffusion have been sofar characterized by the known sigmoidal curve. The effects of this technology it's observed a long term. The data were collected and analyzed in a period of 24 years. In this study, the progress of the diffusion of the technology "no-till" follows a sigmoidal behavior, with the supporting technologies playing an important role in making this diffusion easier. Actually, more than 50% of the surface cultivated is using "no-till" technology. The conclusion is that, in the agribusiness fields, the diffusion of a new technology follows the same behavior as generally found in the progress of the industrial technologies.

BEHAVIOR OF THE TECHNOLOGIC INNOVATION AND DIFFUSION IN AGRIBUSINESS: THE CASE OF "NO-TILL" IN RIO GRANDE DO SUL, BRAZIL

1. Introduction

The discussions concerning technologic inovation and subsequently the diffusion of technology goes along with the evolution of economical theory, but only acquires true relevance in the studies of economic development because of the discussions proposed by Schumpeter. These discussions generally report to the processes of techologic innovation and diffusion in the industry, considering productive processes in this determined economic activity.
Perhaps because of this initial characteristic, there is a certain resistance between the theorists to observe possibilities of techonologic innovation in processes that aren't directly connected to the industry. In this sense, according to Silva (1995, p.31), discussions surrounding technical progress in agriculture take back to classics like Smith and Ricardo, although these

economists “weren’t particularly optimistic about the possibilities to increase production through this way”. More than this, Smith and Ricardo both “believed industry to be the field privileged by technologic innovation and that in the agricultural sector, due to their specificities, the innovations and work divisions would have a limitied effect”.

However, advances in the productive processes of several activities in the last few decades, including those connected to the agricultural sector, demonstrate that technological innovation and diffusion doesn’t limit itself to the industrial processes, but advance in several economic activities, contributing to gains in productivity, cost reduction and the enlargement of the competitiveness of products that are results of these processes. This context results in improving the importance of agrobusiness in the Brazilian economy, for the gains of competivity in the 1990s make the country a “global player” in the agrobusiness market. As a consequence, in the begining of the 21st century, agrobusiness begins to occupy important positions in the exportation agenda (responding for about 40 percent of the total and tending to grow) and in the formation of the national IBP, on which it contributes with values that vary between 30 and 35 percent, depending on the sources of information.

Considering the affirmative that technological innovation doesn’t limit itself to industrial processes, will technological diffusion in the agricultural sector have the same behavior as in the industrial sector? The analysis and models already established for technological diffusion in industry explain the processes that occur in agriculture? Focusing on these main questions, this article has the objective of making an initial analysis of the processes of technological diffusion of “no-till” in Rio Grande do Sul, Brazil, based on the “S” curve of technological diffusion.

2. Technologic Innovation and Diffusion

The approaches on technologic innovations are an important part of the discussions connected to the evolution of companies and the organization of the industry, expanding also to the discussion of development and organization of other economic activities. Considering the research of Rogers (1976), Cassiolato (1994), Dosi (1982), Nelson and Winter (1982), it can be noted that the process of technologic diffusion doesn’t limit itself to the industry , but can be realized in several different areas, including agriculture and services. Rogers’ research (1976, p.290) points to the fact that agrobusiness was the object of several publications about technologic innovation and diffusion in the begining of the discussions surrounding this subject; and identifies the seminal article by Ryan and Gross about the diffusion of hybrid corn seeds among producers in the state of Iowa, USA, published in 1943 as a revolutionary paradigm in research of technologic innovation.

According to Schumpeter’s ideas “it is the technologic innovation that triggers the mechanism that provokes changes in the behavior of economic agents, realocates resources, destroys traditional production methods and changes, in quality, the economic structure.” (Silva, 1995, p. 44). Cassiolato (1994, p. 270) adds to these ideas by pointing that the process of technological change is characterized by a selective context that occurs through trajectories that are constantly interrupted by important discontinuities associated to the surging of new technological paradigms. It is important to emphasize that the technological paradigms, according to Dosi (1982, p. 52), can be defined as models or characteristics of the solutions of technological problems that are based on selected principles derived from the natural sciences and other material technologies. Thus, the current paradigm determines fields of research, problems, procedures, answers found and decisions taken in an economy in a certain period of time.

These affirmatives lead to a comparison of the analysis of technologic innovation and those related to the evolutionary theory. Nelson and Winter (1982) affirm that the main concern of the evolutionary theory is the dynamic process through which the standard behavior of the companies and results of the market are determined together throughout the time. The affirmatives presented until now involving technologic innovation point to the fact that this is a dynamic process that counts with the conjunction as a favorable or not environment for its development. In other words, depending on the conditions found in the economic system, it is possible to have more or less facility for the technologic innovation to happen: “the more radical the innovation, greater the unknowledge among its users, after its release”, difficulting the process of diffusion of the innovation (Cassiolato, 1994, p. 285).

In this sense, new central technologies do not always find the adequate social-institutional mark and their diffusion could take a long time due to the social limitations of the past. The shifts in the social capital, the qualification profiles, the industrial structure and the social organization that are required for the introduction and diffusion of new revolutionary technologies could take years or even decades (Cassiolatio 1994, p. 285).

More than this, there is a certain kind of dependence of the innovation of the structure already installed in the economic system. Dosi and Nelson (1994) call the attention to the “path dependence” process, which is interrelated with the processes of change and organization of the industrial structures; exactly because these depend on the path that was trailed during time and the structures (physical, cultural or social) already created. It is easy to imagine that a certain technology could be much more difficult to be established, the more radical the change required in the structures that already exist. For Nelson and Winter (1982), one of the key ideas of the evolutionary theory process is that the conditions of the industry in each time period launches the seeds for the conditions of the next time period, in the same sense of “path dependence” pointed by Dosi and Nelson.

This would justify the technology diffusion curve presented by Lissoni and Metcalfe (1996) in their research. Among the studies about the diffusion processes is the presentation of the speed of techonologic diffusion in the form of the “S” curve, as can be observed on figure 1. In this model, the initial speed of technologic diffusion would be slower (see section 1 of the figure), due to the existing barriers, such as lack of structure and lack of capacitated human resource. In a second stage (section 2 of the figure) an accelaration occurs due to the instalation of complementary conditions for the technologic diffusionand due to the increase of knowledge of the new technology. The third stage is again a moment of deceleration due primarily to the saturation of the productive system in which the diffusion is inserted. According to Reyne (1987), research was made in France by using the technologic diffusion “S” curve to identify how the expansion of the use of certain electrical appliances in French homes proceeded throughout the years.

Figure 1 – The technologic diffusion S curve.

Source: LISSONI, F.; METCALFE, J.S. Diffusion of innovation ancient and modern: a review of the main themes. In: DODGSON, M.; ROTHWELL, R. **The handbook of industrial innovation.** UK: Edward Elgar, 1996.

When the third stage establishes itself, a dominant technological paradigm could be in the process of crystallization. Possas (1989) indicates that “the technical progress inherent to a certain technological paradigm (...) constitutes the “normal” pattern of achieving the formulation and solution of specific problems inside that technological paradigm”. Therefore, in these ocasions, the foundations for a new process of technologic innovation and diffusion are being established. More than this, Moraes (1997, p. 329) confirms that the dominant paradigm acquires the shape of new products or new sets of characteristics that become essential for the competitive success of the companies. For this author, “it becomes important for companies to identify, the sooner the better, the configuration of the products hat present true possibilities to become dominant”.

Returning to the questions of technologic diffusion, Possas (1989, p. 164) points out that the “diffusion of a certain innovation usually follows two mechanisms: the company’s substitution of the old product or process by the new one, therefore progressively increasing its use; or imitation by other companies”. For this author, there are three relevant points in the selection of a technologic innovation by installed industries: a) the level of profitability considered adequate to the innovation by the companies of the sector; b) the influence of the consumers preferences and the existing regulation devices; and c) the investment and immitation processes made by the companies that compose the sector. It’s the combination off these points that will determine the course and rhythm of the diffusion process inside the economic system. Lissoni and Metcalfe (1996) point out that the profitability of the adoption grows along with the number of adopters that can exchange compatible intermediate products, components and human know-how.

Supplementary to this observation, Deza (1995, p. 205) brings some elements to ponder about in the case of innovation diffusion: a) the continuity of the inventive activity that allows the improvement of the innovation and that may have a great economic importance due to the increase of scientific knowledgethat allows a gradual reduction in the costs of the invention throughout time; b) the improvement of the inventions after their introductions in the productive system; c) the development of the technical abilities among the users (learning by using); d) development of the abiliity to manufacture machines (learning by doing); e) degree of complementation between different techniques in the productive activity; f) the perfecting of old technology and theimpact in the process of substitution by new technology; g) the institutional context in which the diffusion occurs: social, institutional, economic (among other) variables may delay or improve the diffusion process.

Research by Lissoni and Metcalfe (1996) bring geographers’ contribution to the understanding of the diffusion process, for it enables studying the transmission of technology in a spatial manner, making concepts such as distance very important in the analysis. The researches are provoked to explain why some agents identified by their localization in space always adopt the technology or innovations after other agents. Studies considered as seminal point to stages off geographic technologic diffusion: a) the innovation is introduced in a main urban center; b) spreads to the surroundings of the first centers and is trnasmited to smaller centers; c) spreads to the surroundings of the smaller centers and the diffusion process can be considered complete.

The stages of diffusion are conditioned by the two important information flows: one that follows the hierarchical path from the most important center to the secondary, and another that takes placein the surroundings of all the adopting centers. These two channels are identified by the trafic of several communication mediums such as telephones and roads. The existence of a spatial order, as well as the empiric relevance of the information as a force conduit are being seriously questioned in recent studies. Some authors summoned by Lissoni and Metcale (1996) point to the need to concern about the diffusion of a large number of innovations: not only new products and processes, but also collective goods, in a cultural geography, new ideologies and social habits. Furthermore, in other studies, they point to the need to take under consideration the heterogeneity of the companies nd the suppliers strategies, as well as the information systems.

3. Method

It is an exploratory study of qualitative nature that uses quantitative data based on secondary, documental and bibliographical data and on interviews made with no-till specialists in Rio Grande do Sul. The consultations were mainly made by using references available in the Brazilian Federation of Straw No-Till (FEBRAPDP), in the Brazilian Company of Agropecuary Research (EMBRAPA) and by researchers off the Federal University of Rio Grande do Sul (UFRGS). The bibliographical research that composes the second section of the article allowed the creation of a structure of analysis for the study of the technological diffusion process in agriculture, which considers: a) speed of the technologic diffusion; b) inventive activity and perfecting of the inventions; c) development of thetechnical abilities among the users; d) complementarity between the techniques developed; e) institutional context; f) establishment of a dominant technological paradigm; g) process of spatial diffusion.

To test the structure, one specific technology was selected, the no-till technology in Rio Grande do Sul, Brazil. The choice was made because : a) the state is considered a pioneer in the implementation of the technology; b) therre are a significant number of agricultural areas operated with the no-till system; c) counts with the development of scientific research complementary to the diffusion process, thus there is reliable information for analysis; d) due to the starting period of the diffusion, there is a historical series of representative data of more than 20 years available; e)initial data indicated that this was a technology close to its maturity, therefore it would be possible to visualize great part of the characteristics proposed in the analytical structure. The data was analyzed and interpreted in light of the theorical referential adopted based mainly on the analytical structure already presented.

The interviews were a tool used to clarify some obscure points in the literature and to ractify some facts that were presented too subtly in the documents researched. To define who would be the target of the interviews, a professor in the area of agriculture at UFRGS was contacted and offered directions for whom were the experts on no-till that should be consulted: a professor-researcher of UFRGS and one off the managers of EMBRAPA, both involved with the development and study of no-till technology as object of their own activities of research and exension. Along with these two interviews, other three others were made: one with a fertilzer industry, that now owns other companies that have throughout time contributed to the development of specific fertilizers for the no-till technology; another with the first professor consulted and the last one with another professor at UFRGS that works in the area of soil handling. The final results of these interviews were analyzed by the convergence of the answers, which occured in most of the aspects observed.

4. The Development of the No-Till System

No-till includes a set of integrated techniques that aim to improve the environmental conditions (water-soil-climate) to explore the genetic potential of culture production in the best possible manner. It's a system that requires local adaptation of the technique, but basically respects three minimum requirements: "non-revolving of the soil, culture rotation and the use of covering cultures for the formation of straw, associaed with the integrated handling of plagues, deseases and weeds" (EMBRAPA, 2004, p.2). It was first introduced in the southern states of Brazil in the 1970s (according to Borges (1993), the first experiments with wheat no-till took place in Londrina, Paraná in 1971, while there were parallel initiatives occuring in Rio Grande do Sul), as an attempt to minimize the losses in soil, fertilizer, soil correctives, seeds, fuel and work, without considering the environmental costs and the loss of the cultures' performance caused mainly by hydric erosion and bad property management (Farias and Ferreira, 2000). The main contributions of this system to agriculture are, among other factors: the reduction of work, savings in fuel, increase of the water infiltration in the soil, increase of long term productivity, reduction of machinery use and of soil compaction (Farias and Ferreira, 2000).

Still according to Farias and Ferreira (2000), until 1993, 20 years of agriculture passed without occuring a significant expansion of the areas cultivated with no-till technology. This occurs because the incursions in all the areas happened isolated from one another, independently. The institutions of research and the private sector performed in several segmented aspects of the system, such as mechanization, culture rotation, soil fertility, agrochemicals and soil covering. It was after 1993 that a partnership between Research, Extension, the Private Sector and the Rural Landowners caused the system to be discussed as an integrated system of practices which allowed concrete actions and provoked the qualitative and quantitative expansion of no-till. Mielniczuk (1999) salients that as any other process that requires a change of mentality, the results appear very slowly and many times are dificult to calculate, agreeing with Possas (1989) affirmatives about the factors that motivate the adoption of an innovation (awaited profitability, consumer preferences, regulatory devices and investment and immitation processes).

According to information by the Brazilian Federation of Straw No-Till – FEBRAPDP (2004), no-till is currently highly used in the states of Rio Grande do Sul, Paraná and Santa Catarina, as well as in the Cerrados of Goiás and Mato Grosso do Sul and is expanding in São Paulo, Minas Gerais and other Brazilian states, occupying almost 22 million hectares of the 42,5 million destined to the production of grains in Brazil. The expansion of the areas explored by the no-till system has had a growth of more than 1000% from the harvests of 1992/93 to 2003/04, what allows us to say that the areas under the system still possess a positive growth rate.

Still according to data from the Brazilian Federation of Straw No-Till (2004), Rio Grande do Sul and Paraná, the pioneer states of the diffusion of the no-till system, are also the states with the largest areas adopted, respectively 3.593 thousand hectares and 4.961 thousand hectares in the period of 2000/01, followed by Mato Grosso do Sul (1.699 thousand hectares), São Paulo (1.017 thousand hectares) and Santa Catarina (986 thousand hectares). The Cerrados, specifically Mato Grosso do Sul, presented the largest growth rate of the area, an increase of about 20% from 1999/2000 to 2000/01. These areas also present the greatest possibility of increase in the adoption of the no-till system, which still depends on an amplification of research centered in ground covering plants that could resist to long dry periods. The Paraná Agronomy Institute (IAPAR) has shown prominence in the consolidation of the no-till system in Paraná and across Brazil. One of the lines of research of this institution is directed to the small property, by developing equipment that uses animal traction.

5. The Diffusion of No-Till in Rio Grande do Sul

According to Farias and Ferreira (2000), the use of the no-till system in Rio Grande do Sul began in 1972, due to research by EMBRAPA-CNPT, Secretary of Agriculture and ICI-Imperial Cia. Borges (1993) points the year of 1969 as the initial mark of this activity, due to the activities of the Agronomy College of the Federal University of Rio Grande do Sul. In spite of the contradiction about the date of the first plantations in the field of research, Farias and Fonseca (2000) point that the first innitiatives from farmers in the use of no-till system in the Plateau and Missions regions date back to 1973. Despite of the pioneer initiatives, the true expansion of the cultivated área occured approximately 20 years ater the first plantations (figure 2) (Borges, 1993; Farias and Ferreira, 2000; Denardi and Kochhann, 2004; EMBRAPA-PR, 2004; Denardin, Ciprandi and Kochlann, 1997). The figure emphasizes the curve of growth of the cultivated area accentuated after the year of 1992, when the Goals plan begins. The advance of the total of hectares planted is followed by the growing advance of this type of productive system, as can be seen by observing the percentile it represents in all the cultivated areas of Rio Grande do Sul.

Figure 2 – The No-Till "S" curve in Rio Grande do Sul, Brazil in the period of 1978 to 2003 and the identification of the start of the GOALS Project

Source: Adapted from DENARDIN, J.E.; CIPRANDI, M.A.O.; KOCHHANN, R. GOALS Project: Viability and diffusion in the no-till system in Rio Grande do Sul. **No-till Magazine.** [s.l.: s. n.], September - October, 1997, p. 45.

FARIAS, A.D.; FERREIRA, T.N. No-till system in Rio Grande do Sul. **EMATER/RS Informative.** Porto Alegre: EMATER/RS, v.18, n.7, November 13, 2000.

MELO, I.J.D. Evolution of the no-till system in small properties in Rio grande do Sul. **9th National Straw No-Till Meeting.** Chapecó, 2004.

Nota: a) Data for the years of 2001 and 2002 were not identified.

By observing specificaly the percentile of the total planted area, there is na advance of 3% in 1990 (first estimative pointed by the graphic, since this value was irrelevant in the passed years) to 60% in 1998, followed by a small decline the next years (57% in 1999 and 55% in 2000)[1]. The volume of the area grows in 2003 to 4.250 thousand hectares, however it remains 55% of the total planted area of the state.

As mentioned before and according to research by Farias and Ferreira (2000), the time passed since the beginning of the process to its true leverage is due to the fact that all of the incursions of the first stage were isolated and independent from one another, because of a set of barriers for technologic diffusion, such as the development of equipment and technical capacitation of the users.This affirmative is supported by one of the specialists interviewed, when he points that failure of the expansion of no-till in the 1970s mainly occured because of the lack of adequate technology. This inadequate technology was expressed in the agricultural machinery, the system of weed control and the lack of an adequate variety of grains with good performance rates that could be inserted in the rotation system.

It was after 1993 that more solid partnerships between P&D, the private sector and rural producers was observed, which starts the discussion about the no-till system as an integrated system of practices. This allowed concrete actions and quantitative and qualitative expansion of the no-till system to unchain (Farias and Ferreira, 2000; Denardi and Kochhann, 2004; EMBRAPA-PR, 2004; Denardin, Ciprandi and Kochhann, 1997).

According to Mielniczuk (1999), among the several actions, we can point to: the Saraquá Project in the basaltic slopes of Rio Grande do Sul, coordinated by DS/UFRGS, since 1980; the Microbasin Hydrographic Program coordinated by EMATER, since 1984; and the GOALS project, coordinated by CNPTrigo-EMBRAPA, that encouraged the adoption of direct sowing in the state since 1992. PIUCS (Integrated Use and Soil Conservation Project), and also operation Tatu were marks in the transformation of agriculture in Rio Grande do Sul (Mielniczuk, 1999). These projects developed the conscience that the farmer should reduce the soil preparation, for the loss of soil, nutrients and defensives of some farms, as well as the rivers problems reached unsustainable proportions.

In the first stage of adoption of this new technology, farmers began to use minimum cultivation (soil preparing operation is easier than the traditional way), while the technologies of no-till support were being developed, such as adequate Planters and commercial cultures selective herbicide. The consulted specialists (in interviews A, B, C and D) point that the perception about the expansion of environmental problems caused by the traditional cultivation techniques and the tendency of decreasing performance of production were important factors that motivated the adoption of this new technology.

The Goals Project deserves a special look in the incentive of the use of this new tecchnology. In short, in 1992 Embrapa Wheat and Monsanto of Brazil made a survey to verify which were the reasons that prevented the adoption of the no-till system in the plateau region of Rio Grande do Sul. The diagnosis pointed to three main barriers: a) the regional need to adjust some technologies; b) unavailability of adequate Planters for the dominant structure (small rural properties); c) lack of plain mastery of the system by the technicians of technical assistance companies and insume and equipment supplier companies to help orient the practice (Denardin, Ciprandi and Kochhann, 1997).

It was base don these diagnosis that Embrapa Wheat developed a project, the GOALS Project – Viability and Diffusion of the No-Till System in Rio Grande do Sul, that had the main objective of “adjusting technology to regional peculiarities, adapting and developing adequate Planters that fit the land structure of thePlateau region of Rio Grande do Sul and perfecting the technical knowledge of suppliers and researchers on insumes and equipment”. Through these measures, the goal was to create the necessary conditions for the diffusion of the no-till system, or the diffusion of a specific technologic innovation (Denardin, Ciprandi and Kochhann, 1997).

Farias and Ferreria (2000) point that it was after 1993 that the concrete actions that caused the qualitative and quantitative expansion of the no-till system actually started taking place. This happened because of the partnership between research, extension, the private sector and rural producers (they do not quote the project). Denardi and Kochhann (2004), though, point that the justifications for the success of the GOALS Project are related to the systemic focus dedicated to the no-till system on the “research and development process, as well as the adoption and conduction processes involved in this system”.

The detection of the success obtained by the GOALS Project indicates that there was a research process that was paralyzed due to the non-transforming of existing knowledge in technology that could be applied to specific environments and because of the unavailable access to the necessary means so the users could indeed “use” the developed system. For the authors, it was this partnership that allowed the “continuity of the research process, transforming the knowledge in ready-to-use technology, thus diffusing this technology and making it accessible and available in the market, creating the means for the users to adopt and practice the no-till system” (Denardin, Ciprandi and Kochhann, 1997, p. 45). For them, this directly affects the change of behavior of the diffusion curve (figure 2).

According to the interviews, the most important elements for the diffusion of the no-till process in Rio Grande do Sul were: a)the sensitivity of the farmers to the harmful effects of traditional soil handling techniques that reflected in losses of productivity nad degrading of the environment (interviews A and B); b) intense diffusion of the results obtained by the use of the new technology (interview C), including large investment in advertising financed by companies interested in the growth of no-till, for this would lead to the development of specific insumes to sustain this particular system (interview D); c) thelearning process unravelled by the technology (interview A).

According to one of the specialists (interview A), “the most important events for the expansion of the no-till system in Rio Grande do Sul were those structured for the transference of technology and not only the diffusion of technology”. In this case, the researcher is focusing specifically on the capacity given to the producers so they could adopt the new technology. According to him “the success in the adoption of a complex technology , as is the no-till system, is reached through continuous and systematic training over the years and with the organization of at least one event per year approaching complementary and sequential subjects. As well as the commitment of the trainee with the learning-doing method and the practice of retro-infformation in an evolutionary process of the construction of knowledge”.

There is a convergence of opinion Amon the specialists interviewed about the complementary technologies. All of the specialists point to the importance of the adaptation of the machinery to the process and the development of specific herbicides as facilitators of the technologic diffusion process. One of the specialists (interview A) still points to the development of adequate variety of grains which represent a good preformance potential in fface of the new soil handling procedure. This affirmative is complemented by the informations of specialist B when he enphasyzes that the introduction of RR soy can be considered as a relevant complementary technology, for it facilitated, in a very economical way, the chemical handling of plants that resisted to the selective herbicides.

To conclude, other reasons can be pointed that lead the farmers to adopt the systematic planting form and that are related to the faciliation of soil handling, the reduction of costs, increase of productivity and reduction of negative environmental impact, as well as instituttional support for the capacitation of farmers. All of the specialists interviewed have the same position about the importance of these elements for the farmer to adopt this new technology. The words of specialist B, however, are the ones that better summarise the gains provided by this new technology and which lead the farmers to adopt it: a) a reduction in the consumption of diesel oil occurs of about 59,4 l/ha/year; b) the use of labor is reduced in about 4,8 h/ha/year; c) the time spent by the machinery in the farm is reduced by about 5,3 h/ha/year; d)there is an important reduction of nutrient loss in the soil of about 13,8 kg/ha/year of nitrogen, 9,6 kg/ha/year of phosphorus and 13,6 kg/ha/year of potassium; e) the handling system accelerates the speed of the sowing operation, allowing the farmer to observe the best season for planting, thus minimizing the period between harvests; f) the reduction of time spent by the machinery reduces the erosion and increases the life span of the equipment, which will have a positive impact on the reduction of the permanent costs of the rural establishment.

The interviews with the specialists demonstrate that the complementary technologies are fundamental elements for theexpansion of the main technology. All the specialists agree that the technologic diffusion takes it close to a condition of dominant technological paradigm, in spite of not confirming this vehemently.

5.1 A synthesis of the Results Observed

a) Speed of technologic diffusion: the technology analysed tends to present the shape of an “S” type curve in Brazil as well as in the analysis of Rio Grande do Sul, as can be obsrved in figures 2, 3 and 4. Thus demonstrates a low diffusion speed in the initial process and a process of accentuated acceleration in the second period. The analysis is limited to the period of greater maturity of the technology once there is data available until 2003, with a hiatus between 2001 and 2002 (moment in which the retraction tendencies are due to specific changes in the use off techniques, still not characterizing a reduction of the expansion due to the use of the technology);

b) Inventive activity and improvement of the inventions: A continuity of the inventive activity is noticed during the process, emphasizing on aspects such as adaptation of insumes, equipment and complementary techniques (mainly due to the need to adaptate the technology to the regions of application) and development of equipment and insumes for the process. The improvement of the inventions are also noticed after their introduction to the productive system, the period of 1993 standing out as when institutional actions took place aiming technologic diffusion. The participation of P&D institutions in the processes of development and implantation of the technique also corroborates this affirmative. The researchers’ concerns about the continuity of the improvement of the technique, aiming its aplication in new areas and optimized results is also evidenced;

c) Development of the technical abilities among the users: we can notice the occurance of the development of these techniques (learning by using), as well as the development of the ability to manufacture machinery (learning by doing), emphasized by the process of capacitation of the users, suppliers and technical assistance. We also notice the development of specific equipment in the Rio Grande do Sul experience, mainly because of the GOALS Project;

d) **Complementarity between the developed techniques**: a significant degree of complementarity between the different techniques in the productive activity is present in the process of technologic diffusion. There are indicatives in the text that the no-till system is a systemic process that needs this kind off complementarity. It is also evident that the first stage of the technologic diffusion occured in a vegetative way exactly because of the lack of complementary technology;

e) Institutional context: we can apreehend that the institutional context facilitated the process of technologic diffusion, mainly due to the effort and involvement of P&D institutions and the private sector in the processes of development and diffusion of technology and the creation of the necessary means to these processes.

f) Establishment of a dominant technological paradigm: since we still cannot define if the technologic diffusion is on the third stage of evolution (there may still be capacity for the expansion of the planted area using the no-till system in Rio Grande do Sul), we are lead to ponder if this technology tends to configurate itself as a dominant technological paradigm. It may indeed be the base for new technologic innovations in the following years. This tendency needs to be confirmed by accompanying the technologic diffusion process.

g) Process of spatial difusion: It wasn't possible to analyse the questions related to the geographical expansion of the diffusion, due to the limitations of the existing data. But one must consider that since it is a technology widespread in agriculture, one can expect a slightly different expansion behavior than the one that occurs in the industrial sector. According to specialist interviewed A, "it could be speculated that in agriculture, on the contrary of industry, it is not the large urban conglomerates that dictate the innovation, but the aptitude of the soil and the concept of leading region (which is not necessarily a large urban center)".

6. Final Considerations

With all the elements researched, we can affirm that the expansion of no-till in Rio Grande do Sul, Brazil, behaves according to the "S" curve of technologic diffusion and according with other elements that are characteristical of the technologic diffusion processes of the industry, considering the analytical structure proposed.

However, it must be considered that the work, because it is an initial approach and due to the timee horizon studied (insufficient for certain analysis) has somelimitations. Among these, we can salient the need to complete the data that refers to the areas cultivated with No-Till in Rio Grande do Sul until the year 2004, extending this work a couple more years, in order to confirm the estimative that this is already a mature technology and can be configured as a dominant technological paradigm.

Other studies that are made possible or have demonstrated to be interesting following this line of analysis would be: a) the identification of the geographic expansion system of the no-till technology; b) the search for more blunt data that would allow the identification of the no-till system as a dominant technological paradigm; c) the expansion of the research to other technologies, in order to confirm if the pattern found for the no-till system repeates itself; d) identifying if the adoption of the no-till system is one of the responsable factors for the competitivess of Brazilian agrobusiness, because of the impact it has on the composition of costs and productivity, as well as on the improvement of the performance of areas handled with this system; e) which would be the multiple direct and indirect impacts that the adoption of this technology have and are not observable in short term, and to which a more superficial observation wouldn't have a cause-effect relation with the no-till technology (for example, the rupture of the resistance for the adopting of other technology); f) analyse if the no-till system would be a technology oriented by the logic of sustainable development.

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[1] The reduction of the planted area occured in part because of the reduction of the use of herbicides and in great part as a consequence of the farmers' doubts regarding the productivity of the cultures in no-till systems in the intermediate stage of its use. No-till has 3 stages of establishment. In the initial stage (1 to 3 years) there is a gradual process of soil densing and the reduction of productivity may occur. The intermediate stage (4 to 6 years) is the most critical stage because if auxiliary techniques such as culture rotation and soil covering aren't used adequately there may be a reduction in the prodductive potential. And the stabilization stage, when the greater benefits in terms of soil structure and increase of productivity are accomplished. Many farmers reduced the no-till in the intermediate stage, but quicklynoticed the problems of conventional preparation and returned to the no-till system.

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