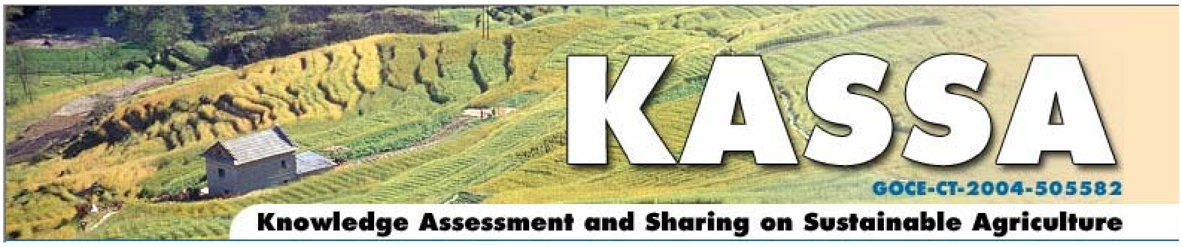

Deliverable 1.4 - Appendix A1

Conservation agriculture research in Brazil

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1 Agroecological and socioeconomic context of the “Cerrados” and the Subtropical regions

1.1 Cerrados

The “Cerrados” is a Brazilian designation for a Savanna like environmental complex and also for the natural region where this vegetation predominates, although other formations like forests, for example are also present. The “Cerrados” vegetation complex comprises different kinds of plants varying from woody to grassy. A mix of short trees with twisted trunks, bushes and grasses in different proportions gives it a peculiar aspect (Ribeiro et al, 1983). This is attributed to acid, low nutrient soils and tropical bi-seasonal climate with a dry and wet period of approximate equal duration (Adamoli et al, 1986).

The “Cerrados” covers an area of approximately 2.04 million square kilometers, (Pereira et al, 1997) spreading from near the equator (4º of latitude North) to close to the Tropic of Capricorn (22º of latitude South). Within this large extension of land a broad variety of environmental conditions occurs, but the most widespread is the tropical climate where annual rainfall ranges from 500 mm in the northeast to 2300 mm in the sub-Amazonian areas. Accordingly, the length of the dry season varies from 4 to 9 months. The mean annual temperatures are 18 to 26 ^{o}C. Solar radiation is high, with an average 364 cal/cm²/day Most of the soils are found in a flat to gently undulating topography and they are deep, friable, highly-weathered with low available water holding capacity. Phosphorus fixation and aluminum saturation are high whilst pH and levels of available nutrients are low.

The prevailing environmental conditions in the “Cerrados” favor agricultural activity. Large proportions of arable land with climatic conditions appropriate to cultivation all year round, suitable topography for mechanization, good physical soil characteristics, availability of basic infrastructure, and the existence of lime and phosphorous deposits and explorations at several locations in the region, have been pointed out as favorable factors (EMBRAPA, 1976). However, the environment also imposes some important limitations to be overcome in order to meet the requirements of plants and animals. Limited knowledge of the natural resources, irregular rain supply in the rainy season expressed by dry spells of variable length and time period (Wolf, 1975; Cochrane et al, 1988; Assad et al, 1994a, 1994b), and production systems lacking modern technology thus hindering sustainable production. The low natural fertility of the soils covering most of the “Cerrados” surface is one of the most important agronomic constraints. Almost no crop can be economically grown under the natural soil fertility conditions. These constraints have oriented agricultural research towards the development of appropriate technology to cope with the adversities, so that the favorable aspects can be fully exploited. (EMBRAPA, 1976)

The lack of information about the variability of the soil types is still a great constraint to make precise evaluations of the real potential of the “Cerrados”. Comprehensive soil geographical distribution information covering the entire Brazilian territory (1:5 million scale) is available at EMBRAPA (1981) and in the series published by the RADAMBRASIL Project in the 1:1 million scale (Brazil 1973–1982). More detailed studies are available for a limited surface of the "Cerrados". An extensive review of the available soil surveys covering the region is presented by Macedo (1996). A synthesis of the principal soil types is presented in Table 1. Descriptions of the characteristics of these soil classes are found elsewhere (Madeira Netto et al, 1982; Adamoli et al, 1985).

By far the Oxisols are the most widespread class of soils in the region (Table 1). Their good physical conditions and the resistant aggregates resulting from iron and aluminum oxides, and occurrence in flat to gently sloping terrain makes this soil class the most important in terms of agricultural potential and actual use, once the natural low fertility limitations are overcome (Lopes, 1983; Adamoli et al, 1986).

Table1. Major soil classes in the "Cerrados" region

Classification system		Occurrence
Brazil	United States	(%)
Latossolos	Oxilsols	46.0
Areias Quartzosas	Inceptisols	15.2
Podzólicos	Ultisols/Alfisols	15.1
Litólicos	Entisols	7.3
Plintossolos	Oxilsols/Inceptisols	6.0
Cambissolos	Inceptisols	3.0
Concrecionários	Ultisols/Oxilsols	2.8
Gleis	Inceptisols	2.0
Terras Roxas	Alfisols	1.7
Outros	Others	0.9

Total area = 204,000,000 ha, *Source: Adamoli et al, 1986.*

Soil acidity is a generalized problem for the oxisols (latossolos). The common pH values for those soils ranges from 4.5 to 5.5 which makes liming necessary before any form of agricultural exploration can be initiated. Phosphorus is the most limiting nutrient, but others like Zn, Ca, Mg, K, N, and S are commonly below critical levels for crop production.

Table 2. Chemical characteristics of a "Cerrados" oxisol (latossolo) (A horizon)

	Units	Extreme values
pH (H_2O)		4.5 - 5.2
C	%	0.5 - 2.1
Ca + Mg	meq/100cc	0.2 - 5.7
K	meq/100cc	0.02 – 0.4
Al	meq/100cc	0.7 - 1.4
P	ppm	0.5 - 3.4
CTC	meq/100cc	3.0 - 13.9
Bases Sat.	%	5.9 - 13.9
Aluminum Sat.	%	16.4 - 85.9

Source: Adapted from Adamoli *et al.* (1986)

Mineralogical constitution of the clay fraction of these soils typically formed by kaolinite, aluminum and iron oxides, are responsible for the low amount of negative charges in the sorptive complex. Organic matter plays an important role in providing the negative charges mainly for the superficial soil layers. Thus the adequate management of soil organic matter is a fundamental issue for maintaining and improving soil fertility. Organic matter is also vital for improving the physical properties of soils, important not only for plant growth but also for natural resource conservation (Resck et al, 1997; Lilienfein et al, 1996; Resck et al, 1998).

White men first occupied Land in the "Cerrados" in the eighteenth century. Gold and precious stones mining were the forces that had driven people to these country lands. With the economical depletion of the mines, extensive beef cattle raising became the main economical activity in the region. Subsistence agriculture was conducted in the more fertile valleys. This system persisted until the end of the first half of this century, when the first public investments were made in the region. A railroad (São Paulo - Anápolis) crossing fertile lands in the south of the region allowed for more intensive agricultural systems. However, extensive cattle raising continued to be the dominant form of use of the grass and bush lands.

Low soil fertility and the absence of sound technology to overcome this constraint, together with the lack of a supporting infrastructure for agricultural activities such as transportation, storage, agricultural inputs, and markets, were the main factors contributing to extremely low agricultural activity before the 1970's. Specific regional development programs implemented at that time, financing agricultural research and the implementation of favorable public policies allowed for the "march onto the'"Cerrados"".

A regional development program – the National Program for Central-West Development (POLOCENTRO) was responsible for the beginning of modernization of agriculture in the region between 1968 and 1980. Besides financing the necessary investments for the farmers, this program also financed agriculture research and rural extension systems. These were the most important tools for the generation and the transfer of suitable production technology in the "Cerrados". This program has established the formation of medium to large size capital intensive farms producing goods for both the domestic and the external markets. This farm model became the standard for agricultural production in the "Cerrados".

A good example of the response of the agriculture sector to official investments can be found in the "Cerrados" Development Program (PRODECER). This is a joint program resulting from an agreement between the governments of Brazil and Japan signed in 1979 with the objective to introduce modern agriculture into the "Cerrados". This program is based on the use of modern technology by experienced farmers settled on medium size farms (300 to 500 ha). The necessary investments in land, farm machinery, land reclamation (mainly liming and basic phosphorus fertilization) are financed with variable grace and payment periods (Paez et al, 1984). Pilot projects of colonization and production have been established since 1980 in different ecological zones of the region. Some studies have evaluated their performance (Paez et al, 1984; Pessôa, 1988; Pires, 1996; Lima, 1998). Besides the direct effects of the project, PRODECER has also produced side effects in regional development. This can be illustrated with the changes that occurred for example in the region of the Alto Paranaíba in Minas Gerais state. The PRODECER project was implemented in this region in 1980 and it consisted in the settlement of 26 farmers on 8,970 hectares. Ten years later the cooperative responsible for the management of the project had increased the number of members to 350 with a planted total area of 87,500 hectares (Lima, 1998). The project had a tremendous impact as 'a new development model' when the rapid increase in the planted area after 1980 is observed. Soybeans was the crop preferred by the farmers increasing at a rate of 64% or 4,000 ha per year. In the five years that preceded the project, the area planted to soybeans was increasing at a rate of only 700 ha/year. Five years later, after 1985, the rate of increase for corn and coffee was high. Irrigation was introduced in the region after 1985, corresponding with the remarkable increase in the areas cultivated with corn and coffee. Other crops such as edible beans also experienced a great increase in planted area.

Production has changed steadily since modern agriculture was introduced in the "Cerrados". In the beginning the land price, and economical incentives stimulated farmers from other locations in the country to migrate to the region. In recent years, production in the "Cerrados" has increased mainly due to the improved farming procedures adopted; sound technology such as no tillage, possibility of double cropping with irrigation, as well as the adequate combination of farm resources are making agriculture in the "Cerrados" highly competitive nationally and world wide.

For some crops like corn and soybeans, production increased 1.5 and 4 fold from 1975 to 1995, respectively. Increase in coffee production has been the most spectacular yet, almost 7 fold. The quality coffee produced in the "Cerrados" has also been recognized as one of the best in the country, making it particularly competitive in the external market.

Rice production has decreased during the same time period. This crop, was traditionally cultivated between clearing and pasture establishment, or between clearing the "Cerrados" and soybean cultivation. Because rice is very susceptible to short periods of drought spells and diseases, and because of the non-competitive prices, soybean varieties well adapted to the newly cleared "Cerrados" soils have been developed and have replaced most of the upland rice fields.

Farmily farming systems in the Cerrados

From the conceptual point of view, family farming cannot be defined as a function of the size or area of the farms, but it can be detrmined by the maximum extension that the family can explore them with their own work, associated to availble technology (Incra/FAO, 2000).

According to the 1995/1996 Agricultural Census, there are 4,859,864 farms in Brazil, encompassing an area of 353.6 million hectares, whereas, according to Incra/FAO (2000) there are 4,139,369 family farms, occupying an area de 107.8 million hectares. The family farmers represent, therefore, 85.2% of the total of the establishments and 30.5% of the total area. The brazilian Center-West areas present the smallest participation to the the family farming among all areas, represents 66.8% of the establishments, occupies 12.6% of the total area, and it is responsible for 16.3% of the regional NGAP (Net Gross Agricultural Production).

The size of family farms is closely related to the areas, and to the historical land occupation process. Thus, while the average area among family members of brazilian Northeast, for instance, is of 16.6 hectares, in the Center-est it goes to 84.5 hectares.

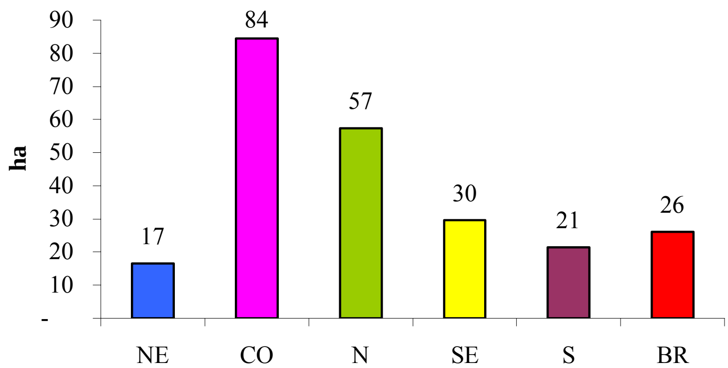

Figure 1. Average areas of family farms, per area (Source: Technical Cooperation Project – Incra/FAO, 2000).

Although the size of the establishments could be estimated, soil types and steepness of the areas of the establishments cannot be standardized, since these factors are highly variable, even at small distances of a same area, mainly in a country whose climate is so diversified as Brazil. However, family farms are going to occupy more distant areas from the great urban centers, with possess unfavorable topography and degraded soils.

The dynamics of occupation Center-West areas by farmers have been called as "pioneering or subsistence frontiers". The family farmers occupied first unexplored areas, chopped the forests, and growed basic victuals (rice, beans, corn, and cassava). As the natural fertility of the soil began to decrease, and the areas have been appropriated by other farmers (through the ownership acquisition, or through the direct leaseholding-pioneer's withdrawal), new sites were incorporated to cropping process by family farmers, expanding, thus, the agricultural frontiers (Guanziroli *et al*., 2001).

Gassen (1997) pointed out the small family farmer's situation with the example of common beans production, which adopts mainly family labor, animal powered machines, conventional seed-bed preparation, and with low technological level. To guarantee a minimum monthly income of US$ 100, a family farmer needs to crop about 24 hectares with common beans. In such a way, the obtained income and the effort to plow, seed, harrow and harvest, associated to climate instability and oscillation of prices, demonstrates the shortcomings found to motivate the youths to continue on their parents' activity, resulting in a growing rural exodus.

The use of no-tillage system on a family farm would lower the costs of production (Geraldine *et al*. 1998), would increase the available time, allowing the farmer to develop other activities that make possible the unit of production to be economically feasable. It is important to point out furthermore, that environmental laws are becoming more and more rigorous, leading the farmers to use cropping systems that would promote environmental conservation, such as the case of the no-tillage system.

Access to agricultural technology is a factor of overwhelming importance on the persitence of family agriculture. Only 16.7% of the brazilian family farmers use technical support. This percentile one varies from 2.7% in Northeast areas to 47.2% in the South areas of the country. In Center-West areas, Federal District presents the largest family farmers' percentile with access to the technical attendance, represented by 74.8% of the farms, what could be explained by the small number of family establishments. In state of Goiás, 25.4% of the family farmers have access to the some kind of technical attendance. In Mato Grosso do Sul State this percentile is of 29.1%, and in Mato Grosso it is of 21.5% (Bittencourt, 2000). Considering the available production technology, as welle knowledge generated at research institutions, one can conclude that the productivity as well as the revenues come upon farming actvities could be much higher than the figures reached nowadays, there is a need of reassessment of the transferring techniques and recommendations of technologies for family farmers (Gassen, 1997).

1.2 Subtropical region

The Subtropical and temperate region of Brazil includes the states of Paraná, Santa Catarina and Rio Grande do Sul, has 562 thousand squared kilometers. It is located between the South parallels 23°30' and 33°45' (Embrapa Clima Temperado, 2000). The following natural ecosystems are found: Plain (Central and Coastal), Plateau (Campanha Gaúcha, Araucária and Transição) and Mountain (Leste Catarinense, Serra do Mar and Serra Centro and Serra Oeste). . It differs from the other country areas by the low temperatures and, mainly, for presenting rains distributed in all of the months of the year and by presenting abundance in hydric resources and diversity of original ecosystem too. The region is entirely altered by the antropic action, exception only to the legal reserves and preservation areas.

According to MMA (2001), there is a well-delimited compartment process in the coastal plain or in the littoral band. After the plain, there is the Serra do Mar thick wall, the plateau scarps. The delimitation is not only in terms of the consolidated sediments, soil, water, surface and weather, but its regarding to the typical ecosystems too. The coastal mountains and the plateau scarps are other compartments that starting from its tectonic and geologic evolution, had created escarpments and very strong declivitous with a steep relief. The soils are not favorable, with low used material, the weather in those regions are very humid to superhumid one, reflecting in the separation between the compartments intra Serra do Mar, that forms guided crests in accordance with the geologic conditions, and the deep valleys formation.

In the Paranapanema Plateau and in the Serra do Mar there is another typical ecosystem in terms of geologic, geomorphologic and hydrologic condition. The soils, relief difficulties and the ecosystem had exerted influence on people's behavior. The Paraná river basin plateau are three: (i) Central plateau (northwest of the region) with effusive rocks, mixed with sandstone contributing to a complex environment formation; ondulate relief, soil with low aptness and different ecosystem from the pioneering coast formations, from umbrophile forests, from the mountain and Paraná scarps. Then, (ii) there is the seasonal forest. The Araucárias plateau has a different ecology with the presence of the Paraná pine tree (*Araucaria angustifolia*). It presents very high areas and weather with very low temperatures. And (iii) Campanha Gaúcha Plateau.

The south region geology includes three great geologic domains: Pre-Cambrian lands, Paraná river basin and chenozoics sediments covering. The domain of the Pre-Cambrian lands is characterizes itself by great diversity of rocks, formed from the origins of the geologic times (3 billion years) to 500 thousand years ago. Orto and parametamorphic rocks of high, medium or low metamorphism degree, of very diversified chemical composition, igneous rocks components of innumerable intrusions. The Paraná river basin domain is the widest geologic domain of the south Brazil with continental dimension structures.

The south region relief presents great variety of geomorphologic aspects due to the superimposition of weather systems, the litologic and structural varied nature and due to the biological factors, through the human being action. These associate factors are responsable for the energy change in the environment.

According to FIBGE (1990), the evaluation of the soils agricultural potential comes from chemical and physical parameters, as well as the environment aspects. We can divide the soil agricultural potential in 5 areas: A, B, C, D and E. The unit A includes an area of 24.217 km^2 (4.3% of the total area). The soils present favorable characteristics for agriculture use, without restrictive factors that hinder mechanization as, for instance, relief and stony soil. Physical properties (depth, porosity, and water storage capacity) are appropriate for a good development of plants. The fertility deficiency and the exchangeable aluminum excess can be corrected by the application of fertilizers and correctives. Unit B (18.9 % of the total area) presents a regulate potentiality for cultures. The soil of this unit is in two distinct environments: hidromorphics and no hidromorphics where the water excess is the main limitation to the hidromorphics soils. In the case of no hidromorphic soils, the limitations can be determined by several factors. There are soils with good fertility, but placed in relief that can restrict mechanization, and others placed in favorable relief, but with low fertility and exchangeable aluminum excess. Unit C (39.2%) presents soils considered with restricted potentiality for cultures and is located in favorable relief varying from plan to tie wavy fort. Specify limitations occurs in terms of landscape. Unit D (29.8%) preferentially must be used with natural pasture or reforestation, since restrictions of chemical, physical or topographical nature exist for its use with cultures. Unit E (7.8%) is considered without potential for any type of agricultural use. This unit soils are usually in very abrupt relieves and it can be used for flora and fauna preservation.

In terms of territorial extension, the Southern region comprises the smallest area of the Brazilian regions. However, it represents the second largest national PIB. Its population of 25 million inhabitants represents 15% of the Brazilian population.

In the century XX, starting from 1930 one developed in this region a growth pattern based on the farming production of foods and generation of industrial raw materials. The industry entailing is characteristic of the South Brazil industrialization process directed toward to the regional market based on the mercantile capital accumulation. In this industrialization model, the foreign immigration paper was notable, as consumer and aggregated mass of business and productive capacity, but also with creation of a society and a culture that contributed to the technology and ways of the world development.

Among the Fifties and Sixties there was emphasis in the production of durable goods and in the production modernization of no-durable consumption goods. From the Sixties to Seventies, it increased the business farming characterized by generation of essential frontiers to the industry development. In this context, the soybean played a relevant role expanding and invading natural limits. There was a transformation in the land commercialization; and part of the small farmers have been displaced to the urban centres.. From 70's to 80's, an industrial complex was configured with the soybean expansion and the modernization of the productive process associated to it. The soybean regional productive system was a little balanced and different society sectors had looked for alternative ways to construct a new development model. Starting from the decade of 80, the soybean force was decreasing and it was advanced for extensive livestock and the industries related to it. The soybean was not cultivated in the coastal plain nor in the outlying depression, but in the Paraná river basin plateau, where the conditions and the soil were appropriate. The natural potential physical environment has forces in the economic development in agreement with the technology that was implanted during these evolution periods.

With intense activity farming, the temperate weather region answers for the production of 50% of the grains, 25% of the meat, 81% of the temperate fruits, 25% of vegetables and 25% of produced milk, besides presenting, around 50% of the grains capacity storage of the country. Intensive production systems occur close to other characteristic of familiar agriculture, based on different technological strategies. One of the more tecnificated systems is of grain production, where the adoption of the low tillage system, with the maintenance of the soil covering and the rotation of cultures minimized the erosion. This system had positive impacts on the quality of the soil, increasing the yield and productivity indexes. However, it's necessary to consolidate the scientific base that it guarantees the system sustentability. In more fragile ecosystems, as of sandy soil, in the natural fields of the west of Rio Grande do Sul (Pampa bioma), arenization process are observed. The agrarian structure and the cultural diversity characterize the heterogeneity of the agricultural establishments in the temperate weather region, where there is a great concentration of small and medium familiar base properties, with subsistence business activities. There is a strong relation between the primary production and the agro-industrial complex and a reasonable level of organization among the producers. If on one side, the main productive chains are in expansion, generating increasing demand for technological solutions, for other, there is a great contingent of family base farmers. These farmers lack by public politics, including research and development politics that promote their inclusion and their social sustentability.

The farming plays an important role in the regional economy generating job, income and a significant contribution for the exports and superavits generation in the trade balance of the country. Among the regional activities of larger partner-economic expression the productive chains of the soybean, rice, maize, wheat, fruits, meat and milk are identified. Besides being the largest national producer of soybean, rice, wheat, apple, garlic and onion, the region presents the largest produtivities in the cultures of wheat, maize, soybean, rice, beans, milk and tobacco.

In only twenty years, the soybean agribusiness brought a surprising development, despite the oscillations of the grain international prices and of the worldwide supplies in the period. In the beginning of the decade of 1980, the soybean worldwide reserves were of 62 million tons. In harvest 2002/2003 it reached the record level of 196 million tons. The higher expansion of the demand in the main consuming countries of the soybean grain and its derivatives was responsable for the increasing of the production. In the same period, the consumption jumped from 68 million to 192 million tons. This evolution of the complex, before restricted to few participants in the international trade, can be explained, in good part, by the commercial opening and the largest interaction among the most diverse countries, favoring the entrance of new, with productive potential, as Brazil.

The South region is the second largest national producer with 22 million tons, or either, 39% of the Brazilian offer. Among the states of the South, Paraná produces 11.3 million tons of soybean, followed by Rio Grande do Sul with 9.8 million tons. The average productivity of the highest producing States is of 3 tons ha^{-1}, with perspectives of increase, due to the incorporation of the more recent technological advances. The technological levels of soybean grain production in the south region present two situations: the current situation and the improved technology, with application of all the recommendations available techniques. The current production system is practiced in properties among 50 to 500 ha. The production in relation to the total is of 40 %, with average fertilizers application of 200 kg ha^{-1}, without the potassium chloride use in covering, use of 70 % of certified seed, 80 % of varieties recommended by the research, use of desiccant herbicide, pre and after-emergent in 85 % of the properties, 25 % of the farmers use the biological insecticide "Baculovirus anticarsia", 70 % of them use chemical insecticide, 40 % of them make seed treatment, 50 % of them make the inoculation of the seed, 60 % of them use the no tillage, 5 % of them use micronutrients, 75 % of them make the harvest with proper machines. The improved system is practiced in the properties between 100 and 500 ha. The production in relation to the total is of 30 %. The producers use, in average, 300 kg ha^{-1} of fertilizers, 5 % of them use potassium chloride, 95 % of them use certified or fiscalized seed, 100 % of them use cultivate recommended by the research, 100 % of them use desiccant herbicides, 40 % of them adopt the biological insecticide "Baculovirus anticarsia", 60 % of them use chemical insecticide, 60 % of them make seed treatment, 80 % of them inoculate the seed, 100 % of them make no tillage, 20 % of them use micronutrients, and 95 % of them make the harvest with proper machines.

In this period, the presence of the Brazilian soybean was fortified and it should continue growing at the worldwide market, so much in terms of export production. In the next ten years (harvest 2009/2010), a growth of the world production is projected, supported mainly for the production increase in the South American continent, in special in Brazil and Argentina. However, today, Brazil is considered of the first worldwide exporter of soybean crumb and the second of soybean in grain, even suffering strong worldwide competition, with trend to incite in the next years.

In the world it's produced about 560 million tons of rice annually. According to the International Rice Research Institute (1994), in the year of 2025 it will be necessary about 760 million tons to supply the world population. Therefore, in next the 25 years, the world production should increase in 200 million tons. The concern is where and how to reach this amount, since the most important producing countries - China, India, Thailand and Indonesia - present difficulties to the cultivated area expansion and of this cereal production. The same study foresees that in the year of 2025 the Brazilian population will reach 237 million inhabitants and will be necessary 16 million tons of rice to take care of to the internal consumption, what represents an addition of 6 million tons in relation to the current production.

Some research segments and productive sections conjecture that Brazil presents potential to assist this demand, with productions coming from high lands and fertile valleys. This hypothesis leans on in the weather conditions, soil, in the knowledge generated for temperate and tropical agriculture and in new rice varieties.

The production of rice in the south region occurs in the states of Santa Catarina and Rio Grande do Sul. The production system of irrigated rice developed in a differentiated form in relation to the rest of the country. In Rio Grande do Sul, mainly, the rice farming is developed in a business way with the use of advanced technology and, therefore, it has raised its relative participation in the production value of the main agricultural products of the State. The Terras Baixas ecosystem is responsible for 40 % of the ten million tons of rice produced in Brazil, occupying only 13 % of the total of the area explored with the culture in the country. In the last ten years, the area cultivated with irrigated rice in RS was extended in 31%. Meanwhile, the medium productivity presented 32 % profits, with directed reflects in the ICMS collection and in the increase of jobs offers. This is an excellent fact, mainly in treating of a region, with only 8 % of the population, in average, in the rural way.

The Rio Grande do Sul rice activities counts on 12 thousand producers, being 40 % big, 52 % medium and 8 % small, 62 % of them tenants. It counts, still, with 37 cooperatives, 400 mills (250 in operation), more than 1200 marks of rice "agulhinha" (type 1), and an industrial park installed with capacity to benefit more than 5 million tons per year. The product participates with 30 % of the PIB of the Rio Grande do Sul agribusiness.

Of the cereals used in the feeding human being, the wheat is of the noblest in relation to quality and proteins amount, constituting important component of the alimentary diet.

In Brazil, the area of wheat plantation suffered a strong reduction in the beginning of the decade of 90, with the end of the state intervention in the section; it was remained around of 1.2-1.7 million ha^{-1} up to 2001 and presented average growth of 16 % in the year, in the last three years.

In 2003, 47.8% of the national wheat were being cultivated in the state of Paraná (1.192 thousand hectares), 42.6% in Rio Grande do Sul (1.063 thousand hectares) and 3.1% in Santa Catarina. The efforts of the improvement programs and improvements of production systems had allowed a crescent increase of wheat productivity: 692.8 kg ha^{-1} (decade of 60); 849.7 kg ha^{-1} (decade of 70); 1.310,4 kg ha^{-1} (decade of 80), 1.516,7 kg ha^{-1} (decade of 90) and 1.716,4 kg ha^{-1} (2000/03).

The priority given to the Brazilian economy opening to the external market in the Nineties, the tariff reduction (Mercosul implantation), the problems of fixed exchange in Brazil and the reorientation of the Brazilian agricultural politics had affected intensely the wheat market. It was observed that these factor associates came to reduce the competitiveness of the national wheat, becoming this less product attractive to the industry, which opted to import. The cultivated area passes of 3.854 million hectares (1987) for 971.6 thousand hectares (1995). However from 2001, the reduction of production and world-wide supplies, the increase of the consumption for animal ration, as well as the increase of prices in the international market, associates to the economic problems of Argentina (change of the cambial politics), takes the Brazilian producers to cultivate larger wheat areas. The production increase can be associated to the depreciation of the Real as to the favorable weather conditions and to the recovery pact of the national wheat culture tacked between government and business organizations. In 2003, the wheat production arrived to represent 60% of the domestic consumption. However, despite the enthusiasm for the amount and product quality gotten in the year of 2003, reduction of value receives by the wheat farmers was observed. The decline of production in some countries and raised international prices made possible the export accomplishment of 1.37 million tons of wheat, what it contributed to relieve the low pressure on the prices.

According to census data (IBGE, 1996), the wealth producing group in Brazil is of approximately 64 thousand properties, being that 70 % of these farmers cultivate less than 10 ha with wheat. According to the study INCRA/FAO, in the south region, 49 % of the weath production is carried through by familiar base property.

The storage of wheat grains is executed by state companies (CONAB), by cooperatives corporations, grain producers that act in the producing regions of wheat, and by producers structuralized and capitalized to store their proper production. The static capacity of grains storage in the country is of, approximately, 90 million tons being that 80% of this capacity are placed in the main producing regions of wheat in the country. It is considered that 94.5 % of the production is destine to the industrial processing, 2.5 % either reserve of seed and approximately 3 % are destined directly to the animal feeding (without industrial processing).

The main consntraints and challenges to the production of wheat in Brazil are: instability of the harvests in income and/or quality, quality standards not defined, import facilities (credit, periods and transport), high Brazil cost (transport, financial, inputs), among others. The strong dependence of relations established by the external market and in the commercial agreements, the subsidies offered in some countries and important easiness (credit and periods of payment) contribute to the competitiveness loss of the national product.

The south region is one of the main producers and exporters of maize in Brazil, with a significant participation on the total production, around 43 million annual tons of the culture. It has been having a reduction of the planted area due to an increment in the soybean plantation area The production originates from small, medium and big producers linked to the cooperative system being fundamental input for the production of birds, swines and milk cattle systems. The region presents an area planted around 3.2 million hectares, with a production of 14.5 million tons and 4.5 medium productivity of ton ha^{-1}. The region presents superior average produtivities to the national average. Such situation is due to technological advances in relation to the handling of the production systems, to the genetic materials made available by the research and to the increasing professionalization of the farmers.

The reorganization of the agricultural activity, occurred in the south region, still in the decade of 70, reached the beef cattle. Of the reorganization of the production, by the region, it had been part the expansion of the cultivated pastures, mainly the improvement of the native field by the introduction of winter forages as clovers, ryegrass and the flocks growth. The South, that in the decade of 70 gotten the second effective of the country, with 24 % of the national total of bovines, although an increase in elapsing of the period, loses its position, for the Center-West, and today it answers for 15.3 % of the national bovine cash. The cattle production, mainly in the areas of RS native field, is characterized by traditional systems, exploring basically, in an extensive form, the beef cattle and, in lesser scale, ovines. Animals, when used only in direct grazing in the native fields, present low zootechnic index; meat production of 80 kg ha year $^{-1}$, natality tax of around 60 %, mortality between 2 and 12 %, age to the first childbirth to 4 years and age of abates between 4 and 5 years. These indices are found on, mainly, to the alimentary deficiency, that occurs in the autumn-winter period, where the bovines lose 20 – 25 % of weight on the previous earnings, occurred in the spring and summer. The use of cultivated pastures, as practical to diminish this problem, is carried through by a very reduced number of cattle farmers. Smaller, still, it is of who use alimentary supplementation with hay, silage, and grains or concentrated and mineralization of the flocks. Beyond food lack, the job of an inadequate handling, as much of males as of females, have contributed for the reproductive efficiency losses. Another problem, beyond the alimentary insufficiency, that affects the region flock of cut, is the occurrence of illnesses, mainly infectious and parasitic, as well as those caused by toxic agents. The State of Rio Grande do Sul kept its position of detainer the biggest bovine flock of the South Region.

It is observed that agriculture comes typically occupying the areas used by beef cattle provoking the necessity of a reevaluation of the traditional production systems. An improvement of the native field with the introduction of temperate forages (grassy and leguminous) of quality and the use of appropriate technologies allow to take advantage the differential of the south region, or either, the production of pastures of high quality and the use of animals of European races.

The milk agribusiness in Brazil passed by deep structural alterations from the Nineties, with the appearance of an entirely new competitive atmosphere, result of the deregulation of the market, of the commercial opening to the exterior, of the Mercosul creation and of the economy stabilization process with the implantation of the Real Plan. The South Region, by the country partner's of Mercosul largest proximity, Uruguay and Argentina, with higher tradition and better level of milk technology, suffered the market pressures. The region presents appropriate conditions for the development of the milk activity, taking in account its edapho-weather characteristics and of the productive potential raised one of the European race animals that represent the majority of the regional flock, mainly of Dutch and Jersey races. The milk production is made, basically, based on improved winter and summer pastures, with the intensive use of ryegrass, oats, clovers and *Lottus* corniculatus. In the months of little forage production the use of conserved forages is observed, as the use, in lesser scale, of hay. The producers use concentrated ration based on grains and by-products of the nourishing industry as a nutritionally form to supplement the cattle. The region, however, demand investments in structure, formation of human resources and production technologies, mainly, matter quality excels.

Its activity is organized in milk basins and small and medium country properties predominate. It possess around 170 thousand producers that deliver milk in the industries under Federal and State Inspection. It represents, around 25 % of the total milk under official inspection of the country, which means 23 billion litters year $^{-1}$. The milk production consists in an important source of income, through the generation of tributes and chances of jobs, becoming not rare, in the main dynamic agent of the cities local economy in the region. In reason of its social economic importance FAO chose it as strategically tool for the reduction of the hunger in the world, to the improvement of the income distribution, the work ranks increasing and to the poverty reduction, especially in the developing countries. In result of the world-wide scene, following the trend of the country, the South Region is prepared to insert itself definitively in the international milky market, being its main industries already qualified and in qualification phase to export too.

Brazil is a vocated country for the fruit development in business character. This affirmation can be proven by the national production performance. The country already is considered the third world-wide producer of fruits having registered superior harvests to 45 million tons. The fruit activity is not important only for the exchange value that it provides to the country. One is about activity that employee around 4 million people in the field and the cities. For the producers it represents rude revenue, around R$ 1 thousand to R$ 20 thousand for hectare. In terms of temperate weather, the south region possess excellent conditions of weather and soil for the production of fruits.

In national level, the productions of grape, apple, peach, fig, pear, nectarine and kiwi, produced in the south region, occupy the first place between the Brazilian states and the second place in plum and strawberry. It is possible to produce, in commercial scale, subtropical fruits as kaki and citrus for table. The region concentrates more than 90 % of the production and the processing of peach in the country, placing, annually, in the market, about 50 million compote cans and other forms of processed fruits. The Brazilian market of processed fruits demand superior amounts to the offered one. In this way, there is an excellent opportunity for primary and tertiary sector investors to take advantage of this not explored market using itself the weather conditions and the experience of the existing labor. The Campanha Gaucha region, traditional in the extensive cattle production, starts to pick the first peach and wine grape harvests destined to the domestic market and export, appearing as new agricultural border for the temperate weather fruit business.

More than 90% are family farms producing 57% of the total GVP which is compounded by 35% of beef cattle, 80% of dairy cattle, 69% of pork, 61% of poultry, 83% of bananas, 43% of coffee, 81% of grapes, 59% of cotton, 92% of onions, 80% of beans, 98% of tobacco, 80% of cassava, 65% of maize, 51% of soybeans and 47% of wheat produced. Details of the four main subgroups, according to total revenue (INCRA/FAO, 2000) are presented in the table below.

A major characteristic of the family farms, is that more than 50% of the tasks are accomplished by the family. The definition of this socio-economic group has replaced older definitions such as “small farmers” or “small-scale farmers”, which have no longer been used in Brazil. One could say that “small-scale farmers” are a subgroup within family farmers. Or, that every small scale farmer is a family farmer, but not all family farmers are small-scale. This happens because this socieconomic group include a broad range farmers with different socioeconomic conditions.

An analysis at regional level indicates the socio-economic importance of family farmers at the Southern, Northern and Southern regions of the country. They are responsible for 57,1%, 58,3% and 43,0% of t he Gross Production Value and for emploing 43,3%, 38,6% and 26,8% of the total labour force (INCRA/FAO (2000)

Table 1 – Some characteristics of different groups of family farmers trom the subtropical area of Brazil (Adapted from INCRA/FAO, 2000)

Group[1]	% of farms	Average farm size (ha)	% (Pessoal ocupado)	Use of power for agricultural operations		Use of lime/fertilizers
				Animal power only	Mechanical only or mixed[2]	
A	16,7	36,9	19,3	25,2	70,7	94,0
B	32,4	20,9	31,4	42,4	50,9	86,6
C	16,7	15,7	14,4	45,8	39,9	71,9
D	24,6	15,5	18,8	32,9	35,9	56,9

1: Group A: Total Revenue> USD 3011; Group B: 1004<Total Revenue =<3011; Group C: USD 502<Total Revenue=<USD1004 and Group D: Total Revenue =< 502.
2: Mechanical + animal traction

These socio-economic groups are spread all over the region, and follow the a great regional diversity in terms of socio-economic development, as a result of many historical, economic and political factors. A study carried out by CUT-Contag by the end of 90’s identified 6 main homogeneous regions , as follows:

Type 1(Itajaí River Valley in Santa Catarina and Northeast of Rio Grande do Sul): equitable development creating employment in many activities; diversified agriculture and industrial exporting production; rural areas being urbanized and many non-agricultural activities.

Type 2 (Northern Paraná): capital intensive agriculture linked to urban and industrial development; modernization of agriculture caused the exodus of rural workers, the appearance of landless farmers and rural workers with high rates of rural poverty.

Type 3 (Curitiba and Porto Alegre): predominance of urban economic activities; urban oriented agriculture; capital and labor-intensive horticulture (green-belts).

Type 4 (Northeastern Paraná, Santa Catarina Highlands and Southern Rio Grande do Sul): weak industrial development combined with extensive agriculture and rural exodus; highly specialized economic development oriented to external markets; marginal family farms; high index of rural poverty.

Type 5 (Coast, Ribeira River Valley, Central and Metropolitan areas of Paraná, Metropolitan Florianópolis and Southern Coast side of Santa Catarina): poor family farms; low urban-industrial dynamism; highly concentrating urban development and high rate of rural exodus.

Type 6 (Western and Southeastern Paraná, Western Santa Catarina and Northeast of Rio Grande do Sul): relatively consolidated family farms; diversified economic activities (commerce, urban services,) highly integrated to agricultural production, with emphasis on the verticality, in particular in the sector of meat production (poultry and pork), dairy and grains (maize, soybeans and wheat).

2 Conservation Agriculture

2.1 Principles/Concepts

ECAF (2005) refers to Conservation agriculture as several practices which permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes (e.g. soil erosion and compaction). Generally, conservation agriculture includes any practice which reduces, changes or eliminates soil tillage and avoids residues burning to maintain enough surface residue throughout the year. Key features of Conservation Agriculture include: no ploughing, disking of soil cultivation; corp and cover crop residues stay on the surface; no burning of crop residues; permanent crop and weed residue mulch protects the soil; the closed-nutrient recycling of the forest is replicated; lime and sometimes fertilizers and surface-applied; use of specialised equipment; continous cropland use and crop rotations and cover crops are used to maximize biological control (FAO, 2001).

2.2. Description of the system and its components (FAEPE)

In terms of crop successions and rotations, several options are now available to optimize economical incomes, to fulfill the main required functions of the systems through an adequate use of cover crops, and to match the diversity of farm activities (grain production, grazing activities, and other productions) (Calegari 2001; Séguy et al. 2003, see also examples of rotations below). In terms of no-till equipment specifically suited to small-scale farmers, there are now many models available, including manual, animal-drawn or mechanized planters, sprayers or cover crop management tools such as “knife-rollers” for, thanks to effective partnerships between farmers, scientists and many private manufacturers (Ribeiro 2001). The resulting diversity of DMC systems now available explains part of their wide scale adoption in LA, it will hopefully facilitate their further adaptation and adoption in other regions and environments.

Selected examples of DMC systems

Table 1 provides an illustration of the diversity of DMC systems used by Latin American farmers, as well as some of their key characteristics. Some specific examples of such systems are described below.

Small scale farmers in South Brazil (Sub tropical)
The State of Paraná is located in the southern part of Brazil between latitudes 22º and 27º S. The climate is subtropical, with annual rainfall ranging from 1,300 to 2,000 mm/year following a fairly uniform distribution throughout the year. Small-scale farmers (<50 ha) constitute 84.5% of Paraná State farmers.
They practice diversified DMC systems according to their specific conditions and objectives (Ribeiro 2002). The comparatively poorer farmers produce both food and cash crops, they use animal traction and family labor, as well as low level of inputs. They usually plant their summer maize crop with an animal drawn no-tillage planter, in a mulch of a winter cover crop of *Avena strigosa* + *Pisum sativum* killed with an animal-drawn knife-roller. Other crops planted under DMC include common beans. Herbicides are sometime used for controlling the weeds before planting and post –emergence. The first year of introduction of DMC systems, contour bounds are built to control runoff using an animal-drawn moldboard plough, after which elephant grass is planted, which is subsequently cut and used as livestock forage.

Table 1. Some of the main DMC systems used in Tropical and Sub-Tropical Latin America

DMC System	Rotations and crops succession	Physical conditions	Type of farmers Energy used	Main products	Advantages reported	Weak points reported
Grians production in Cerrados Region in Brazil (Wide adoption)	Soybean or maize or rice or cotton-maize or sorghum or millet or other cover crops	Umid tropics Deep and acid Ferrasols (acidity is usually corrected before agriculture	Large scale farmers Totally mechanized with hard motorizatio n	Grains and fibers production Integration with livestock production using cover crops forage	Control of erosion Nutrients recycling Increase in SOM Organizatio n of farm activities	Technical managemen t of certain crops (rice, cotton) Disease control
Large scale grains production in South-Brazil, (Wide adoption)	Soybean or mayze in summer-black oat or Ryegrass or wheat in winter	Humid Sub tropics High slopes Ferralsols, sandy lithosols	Large scale famers Totally mechanized with hard motorizatio n	Grains production Integration with livestock production using cover crops as forage	Control of erosion Nutrients recycling Increase in SOM Organizatio n on farm activities	What production with fungus diseases Allelopathi c effects of Ryegrass on Maize
Small scale grains	Mayze or Soybean in	Humid Sub tropics	Small scale farmers	Grains production	Labor and external	Weed control

production in south Brazil (Wide adoption)	summer- Black oat Pisum or Vicia or Ryegrass or Pigeon pea	High slopes Ferralsols, sandy lithosols	(<50ha) Animal traction or limited mechanization No or very low external inputs	Milk and meat	inputs savings Control of erosion Increase crop yields	No makers for diversifying crop rotations Cover crops seeds production

For their part, better-off farmers produce milk and soybean for the market, they own or hire tractors, and use higher levels of inputs. They direct-plant their soybean crop on the mulch of the last regrowth of a *Avena strigosa or* ryegrass cover crop managed through either a knife-roller or a knife-roller combined with herbicide, depending on the amount of Avena residues left and weed infestation. The cover crop is grazed several times at the beginning of the winter. *Vicia villosa* is another commonly used cover crop, either as a pure crop or in association with avena. When maize is planted, a dwarf variety of pigeon pea can be sown between maize rows, 40 days after planting, to contribute to fertility replenishment, improvement of the soil physical conditions. Frost usually kills the pigeon pea during the winter.

Large scale farmers in South Brazil (Humid Sub tropical)

Four different phases of can be recognized in the development of cropping systems in this region possessing conditions similar to those described in the previous section.

The **first phase** involved soil fertility improvement, access to subsidized farm credits, within the context of a favorable world grain market. Such circumstances increased the area planted to soybean within its traditional growing region. The soybean economic boom triggered the expansion of Brazil’s agricultural frontiers. At the same time, a number of traditional production systems, as well as forests and native pasturelands, were converted into simple grain production systems, based on wheat -soybean rotations or continuous soybean. No inadequate knowledge of the soil erosion process as a whole and a predominance of export-oriented agricultural policies, distorted the perception and awareness of farmers about the need for adequate soil management and conservation methods, despite acute erosion taking place.

The **second phase** was centered on the diffusion of soil conservation practices. In addition to eradicating stubble burning and replacing ploughs with field cultivators, winter cover crops were introduced in areas which had previously lain fallow.

The **third phase** was influenced both by the implementation of the National Watershed Programme, which aimed at developing the rural communities and by the multiplication of farmers’ groups interested in developing DMC systems. Both initiatives stimulated the introduction of more diverse crop rotations, based on the integration of winter cover crops and the cultivation of corn.

The **fourth phase** was centered on the development and diffusion of DMC systems, following a systemic research and development approach. Compared to the simple grain crop cropping systems they replaced, the DMC systems included winter and summer pastures used for grazing, hay, and silage, thus providing the basis for a diversified, integrated grain and livestock production system better suited to contribute to farming income stabilization. Today, DMC systems represent a functional approach to conservation agriculture that has reached more than 80% of the cropping area in this region (Denardin 1998).

Large scale farmers in the Cerrados Region in Brazil (Humid Tropical)
In the Cerrados region of Brazil (central plateaux between 10 and 20°S latitude), the climate is humid with yearly rainfall of 1200 - 2000 mm per year during a 8-10 month period. Diversified DMC systems were developed for the large-scale grain producers of this region to replace the inefficient tillage-based soybean monoculture system that produced only small quantities of biomass (Figure 1):

• DMC systems with two annual crops in succession under continuous direct seeding, the second crop playing the role of a 'nutrient pump' (Séguy et al. 2003).

• More recently, DMC systems with three crops per year, all under continuous direct seeding, consisting of one commercial crop (soybean, rice, maize) followed by cereals (maize, millet, sorghum, Eleusine) intercropped with forage species (from the genera *Brachiaria, Stylosanthes* and *Cajanus*, single-cropped or combined) that all function as powerful 'nutrient pumps' producing large amounts of biomass in the dry season which can be grazed or used as green manure (Séguy et al. 2003).

In these last case, the combination 'commercial cereal crop + forage species' following the first commercial crop at the end of the rainy season, uses water substantially deeper than 2 m and has an active photosynthesis later during the dry season. This combination also displays very strong vegetative regrowth after the first rains of the following season or after dry season rain, thus ensuring a complete, permanent covering of the soil . As *Brachiaria sp.* are very efficient forages for cattle, the farmers may choose to convert their area into pasture or to stay in grain production for the next year. Such systems are frequently used under irrigated conditions or in wetter regions (more than 1500 mm) where it is frequent to have some periods of heavy rains during the firs crop cycle recharging deep water reserves. Under such conditions, total annual dry matter production (above and below soil) increased from 4 to 8 t/ha in the initial systems with a single annual crop to an average of around 30 tonnes/ha in the best DMC systems (Séguy et al. 2001).

Under other conditions, natural ecosystems have already served as a model for designing new sustainable cropping systems (Altieri, 2002), but these have generally been perennial cropping systems, involving either trees in agroforestry systems (Ewel, 1999) or forage crop systems in natural grassland regions (Soule & Piper, 1992). The main challenge here was to apply these concepts in annual grain production systems.

DMC systems with "multiple function nutrient pumps": operational examples

These "multiple function nutrient pump" crops are usually planted at the onset of the rainy season, or they are dried before regeneration to form a mulch layer for the commercial crops, or after harvesting these crops, at the end of the rainy season, when they are harvested and utilised by farmers as an attractive added value crop. These nutrient pumps are chosen on the basis of their ability to tap available runoff water at the beginning of the rains and deep ground water at the end of the rainy season, often under extremely variable rainfall conditions. High biomass production at both the beginning and end of the rainy season is always the main goal (Séguy *et al.*, 1996; Séguy *et al.*, 1998). At the end of the rainy season, when rainfall conditions are suitable and to better tap deep ground water, two high biomass producing species can be intercropped: one is a commercial grass (sowing staggered according to the period of the rainy season and the associated risk, i.e.maize, then sorghum, then millet) the other is a very deep rooting perennial forage species that continues to produce biomass throughout the dry season (*Brachiaria, Stylosanthes* and *Cajanus* species), which can be grazed, thus generating supplementary income for farmers (Séguy & Bouzinac, 2001a). These tree species will begin growing again immediately after an accidental fire, quickly ensuring complete soil coverage.

"Nutrient pump" cover crops can also be perennial species that produce runners and rhizomes (*Arachis, Stylosanthe* and *Pueraria* legume species and *Cynodon, Paspalum, Stenotaphrum* and *Pennisetum* grass species), that form living perennial forage covers whose growth is controlled with very low dosage non-polluting herbicide treatments to keep them from competing with the commercial crops. They recover full vegetative growth after the commercial crop is harvested and can be grazed during the dry season (Séguy & Bouzinac, 2001a). All perennial species used as live cover are exclusive of annual weeds, thus simplifying the job for farmers, who only have to manage the living cover and the commercial crop in the cropping system.

Intercropped "nutrient pumps" that become functional at the end of the rainy season and during the dry season, like living perennial covers, can produce abundant biomass throughout the year when they are well managed in cropping systems. During the dry season, which is cooler under Brazilian *cerrados* conditions, organic matter mineralisation is minimal and the high biomass production aboveground and underground (surface and deep horizons) enables maximal carbon accumulation and powerful recycling of leached base compounds and nitrates (Séguy *et al.*, 2001; Séguy & Bouzinac, 2001a).
"Nutrient pumps" can be planted in cropping systems either by broadcast seeding under the cover of the commercial crop, or by direct seeding (pure or mixed crops), depending on the target objectives.

A example of DMC systems developed on the basis of these principles in large markedly is described below:

In a humid tropical zone (HTZ) on ferralitic soils, in the central northern region of Mato Grosso state of Brazil (south of the Amazon, with 1600 to more than 2000 mm rainfall/year), conversion of a degraded soil into "forest environment" soil is illustrated in *Fig. 2*. In our experimental conditions, dry biomass production increased from 6-8 t/ha with soybean monocultures on tilled soils in 1986 to 18–22 t/ha under DMC with a two annual crop sequence in 1992, and then to 26–32 t/ha under DMC with a three annual crop sequence in 2001. In this latter situation, production was continuous throughout the year by optimising the use of crops grown under DMC and thanks to much higher available water reserves, as occurs in forest ecosystems.

Issues and Challenges for further Adoption of DMC in Latin America

Despite the significant adoption of DMC systems in South America, several issues and problems need to be discussed, if only because they correspond to actual worries of would-be users and other professionals throughout this region and elsewhere.

Integrating livestock and cropping in the humid tropics

In humid tropical conditions the more efficient species for recycling nutrients such as Brachiaria and Stylosanthes sp.are also good forage species. They can be grown as cover crops towards the end of the rainy season and grazed as soon as at the beginning of the following dry season and even more during the next cycles. Alternate periods between cropping and grazing are possible under different rotation schemes. Moreover, this succesionnal schemes offers the possibility of rehabilitating degraded pastures at basically no installation costs. Such is the case of the newly developed “Santa Fé” cropping system in the Cerrados, which associates a maize crop and a brachiaria pasture (Kluthcouski et al. 2000). Brachiaria is made to germinate after the maize either by delaying its planting or by planting it deeper. During the whole maize cycle, *Brachiaria sp.* is shaded by maize plants. At maize harvest however, the pasture is already in place, and grows very quickly over maize residues. Similar types of systems have been devised in southern Brazil, with a rotation of ryegrass used as pasture during winter followed by a soybean crop planted directly on the chemically killed pasture. The tight integration between forage and grain crops usually leads to a better use of the total farm land and a more intensive use of the pastures, with shorter turn-over and less pasture degradation (Naudin et al. 2003).

Biomass management in drier zones

In semi-arid to sub humid tropical zones, a major issue is how to produce enough biomass to protect the soil and to maintain the global efficiency of the DMC systems, as competition for available biomass is frequently high due to grazing (Jourdain et al. 2001b, Erenstein 2003). Under such conditions, the amount of mulch derived from crop residue is often quite limited, resulting in partial soil cover at best. Weed control becomes difficult especially when herbicides are difficult to purchase or to apply as in the case of small-scale farmers. However, even with partial mulching no greater than circa 1.5 t DM.ha-1, the additional water available under DMC, may contribute to significant increases in total biomass production (grain + stover) (Scopel and Findeling 2001). Further improvements are possible if, whenever possible, small isolated rainfall periods, not sufficient for crop production, are used for planting a cover crop at zero cost. Also, overall forage resources can be optimized by planning their individual and collective management at the level of small regions, in order to decrease the pressure on biomass produced on cropping lands. Similarly, weed control needs to be conceived in an integrated weed management strategy in which rotations, stand density, spatial arrangement of plants and mulching all contribute to decrease overall weeds' pressure.

3 Scientific and practical results

3.1 Crop yields and stability of yields

In Brazil during the 1970's and 1980's favorable conditions in the grain market allied to subsidized agricultural credits provided by the Brazilian government and new techniques for the improvement of soil fertility were important factors for the transformation of subtropical ecosystem into areas for the cultivation of wheat and soybean. At the first moment it seemed that this production model promoted regional development but later it became clear that in subtropical areas this type of system was the main cause of soil degradation and produced instability in grain production. In this scenery, in which the soil management systems consisted of burning of crop residues and intensive tillage of non suitable areas for annual crops and use of terracing and contour-seeding, proved to be insufficient for the effective control of soil erosion (Denardin *et al.*, 2002). As a result, increases in the regional grain production were achieved by broadening the cultivated area.

Aiming at to reverse this situation, the evolution of soil conservation systems, from the end of the 1970's, kept tight relation to the species diversification cultivated under varied annual cropping systems practiced in this region (Denardin, 1997). Although species diversification was known to be a technological solution for the control of necrotrophic pathogens of wheat (Reis, 1991), associated with the production of green manure for the recovery of soil structure (Denardin, 1997), it was the no-till system that popularized crop rotation as one of the essential features of the conservation agriculture which arose in the middle of the 1980's.

Various authors have shown that the intercalated rotation of crops from different plant families such as grasses, leguminous, cruciferous, etc. can increase the competitiveness and economic viability of agricultural production systems (Derpsch and Calegari, 1992; Santos, 1992; and Santos *et al.*, 1993). Crop diversification produces varying amounts of crop residue, reduces soil losses, recycles nutrients, interferes with pathogen cycles, eliminates weeds, extends the rooting system of plants to different depths and improves nutrient absorption as well as ensures the best use of labor and equipment and the sustainability of agricultural activity.

Crop rotation and no-till system has contributed to the stability of the profits produced by both summer crops such as soybean and maize (Derpsch *et al.*, 1991; Ruedell, 1995; Santos and Tonet, 1997; and Santos *et al.*, 1997) and winter crops such as barley and wheat (Santos *et al.*, 1995; Sacred *et al.*, 1996; Sacred *et al.*, 1998; Sacred *et al.*, 1999; and Santos and Reis, 2001), especially in the subtropical areas of Brazil where the climate is unstable. Mundstock (2004) stated that increase of maize productivity is closely related to, among other factors, improvement of soil tilt such as no-till system, rational use of fertilizers, increased planting density and use of selective pre-emergence and post-emergence herbicides. In fact, maize is the main crop that sustains no-till system because in the most frequently used production models it is the crop that contributes most to straw production and also has the highest root volume. Before the introduction no-till system maize productivity was less than six tons per hectare but now the best no-till system produce an average of ten tons per hectare (Uma Revolução, 2002).

The response of different annual grain crops varies with different soil tillage systems. The productivity of crops has been consistently higher under no-till system compared to conventional tillage (Ruedell, 1995). Calegari *et al*. (1992), Muzilli *et al*. (1994), and Hernani *et al*. (1997) observed that yield of maize, soybean, and wheat cultivated under no-tillage system was 17% higher than cultivated under conventional tillage. Long term trials by Santos *et al*. (2000, 2001, 2003a, 2003b, 2004) and Santos and Tomm (2003) have shown the following: no-till system produce higher yields than conventional system; crop rotation increases and stabilizes yield more than continuous cropping; no-till system plus crop rotation results in better energy conversion and energy balance than conventional tillage and continuous cropping; and no-till system combined with crop rotation is more lucrative and results in less risk as compared to conventional tillage and continuous cropping. Santos and Tomm (2003) emphasize that the higher productivity observed in the no-till system may be related to the improvement of total soil fertility manifested in higher levels of organic matter, phosphorous and potassium than those occurring in conventionally tilled soils. Santos *et al*. (2000) state that the higher wheat yields produced under crop rotation are due to the fact that when rotation is used the severity of necrotrophic disease is reduced by up to 50%, while in a later study, Santos *et al*. (2003a) showed that no-till system combined with crop rotation are more energy efficient, produce higher grain yields, and result in the input of higher nitrogen levels from cover plants and lower energy consumption than non-rotated conventional systems. Santos *et al*. (2004) credit the greater profitability and the smaller risk of no-till system plus crop rotation are due to the increase in gross revenue, in economies in labor, fuel, and lubricant costs and maintaining and depreciation costs of the agricultural machinery.

Field trials in subtropical Brazil comparing conventional till, reduced till and no-till systems carried out over a period of 18 years showed that annual variation in yield was not necessarily associated with the type of soil management but that such variations could be accounted for by climatic oscillations and, especially, variations in rainfall during the annual growth cycle (Denardin *et al*., 2001).

In tropical areas of Brazil, especially in the Cerrado (Brazilian savanna), agricultural expansion was first promoted by soybean continuous cropping using intensive tillage. This intensive tillage system was based on the use of plowing and harrowing and systematic use of only disks harrowing, accelerating the process of soil degradation in much of the area under cultivation (Seguy *et al*., 1996). No-till system started in areas of soybean continuous cropping because in these areas rainfall is concentrated in the rainy season (October to

March), not allowing growing other crops during the rest of the year. The absence of crop rotation and permanent cover crops prior to or after soybean continuous cropping, the use of exclusively harrowing (Farias, 1979), and the use of conventional tillage with deep plowing (Seguy *et al*., 1988), as soil management systems, resulted in higher soybean yields than with no-till system. The no-till system only started to produce yield equivalent, or superior to, conventional tillage after adjustment of production models to take advantage of the rainy season. As result, production models managed under no-till system should contemplate crops as beans, maize, millet, sorghum and sunflowers to be used as green manure (Landers, 1995).

A study carried out in tropical Brazil showed that no-till system plus crop rotation using crops such as maize, soybean and wheat and animal feed crops such as *Brachiaria* and oats has shown that such a system not only produces higher yield and profit but also improves total soil fertility as compared to systems based on conventional tillage and continuous cropping (Salton *et al*., 2001). It has also been shown that beans grown under no-till system have a higher leaf surface area index, a longer leaf surface area duration period, a larger growth rate and relative growth rate and produce more dry matter (Urchei *et al*., 2000). Data also shows that beans produce higher yields when grown under no-till system plus crop rotation and that yields are affected by the temporal arrangement in which the component crops are grown. Yield of beans are usually higher when grown in rotation with rice than it is grown with maize and when beans is grown successively in the same area for two years (Silveira *et al*., 2001).

3.2 Soil characteristics

Introduction: When no-till was introduced into Brazil, the first data produced were in respect to the high efficiency of this tillage method in controlling erosion. Therefore, no-till became known as an alternative method of soil preparation exclusively from the point of view of soil conservation in which the objective was to control soil erosion in an annual crop management system based on rotation between wheat and soybean (Denardin et al., 2001).

However, from the mid 1980's, it became obvious that for no-till to be technically and economically feasible, it should not be considered simply as a highly efficient alternative method of soil preparation for the control of soil erosion but needed to be viewed as a diversified agricultural system made up of complex interrelated and complementary processes. Because of such considerations, no-till developed into a *no-till system* based on the following factors: species diversification through crop rotation and/or the use of intercropped plants; restriction of soil mobilization to the seeding rows; permanent maintenance of soil cover using developing crops or crop residues; and minimization of the interval between sowing and harvesting in order to produce a continuous harvesting/sowing cycle. No-till system thus evolved from a reductionist concept based on simply controlling soil erosion into a complex system for the management of agricultural production systems (Denardin et al., 2001).

As a result of such considerations, it is clear that economic, environmental, social or technical evaluations of the impact of no-till system are only relevant when considered together as part of a systemic approach. Therefore, simply disregarding soil mobilization, often considered a no-till concept, does not promote the integrated effects associated to the systemic concept. Based on the above considerations, the following sections of this report will take into account only technological data from a complete no-till system concept.

Global soil fertility: From an elementary standpoint, the soil may be considered a body composing natural landscape represented by volumetric element. Such body consists of a solid matrix containing gases, liquids, and organisms, which, together, constitute a complex physical-chemical-biological system possessing characteristics and properties resulting from the effects of relief, climate, time, and the biological activity on the original material (pedogenetic processes) but also by anthropic effects.

From a functional and agricultural point of view, soil constitutes the environment in which plants grow, providing a support substrate, nutrients, and water. From the point of view of agricultural production system, soil is only a determining component of the productivity of such system because of the limitations imposed on agricultural system by its fertility (Figure 1). In this context, it is important to remember that an agricultural production system is produced by the interaction between the environment, plants, and soil in which the environment has the potential to provide energy, plants provide the genetic potential, and soil potential fertility. Agricultural productivity, measured as the amount of product produced per unit area, is the integrated result of these factors so in a agricultural production system it is not possible to consider environmental, plant or soil productivity in isolation because no product can be generated in the absence of any one of those factors or without interaction between factors. Since it is the interaction between factors which determines the productivity of the agricultural production system such productivity cannot exceed that of the limiting factor, this being exemplified by the 'limiting factor law' which states that if alterations are made in environmental or plant factors with a view to increasing productivity such alterations will be of no effect if the soil factor is at the limit of its productive potential. It may thus be said that management of a productive agricultural system is nothing less than the exploitation of the potential of the production factors that make up the system (Denardin *et al*., 2003).

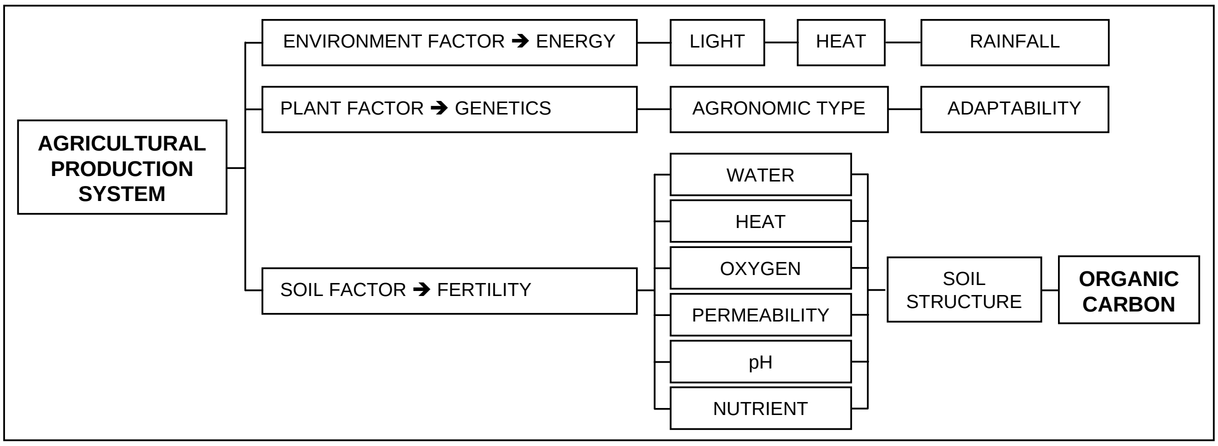

Figure 1. Conceptual structure of an agricultural production system.

Although soil fertility involves physical, chemical, and biological factors it is principally determined by the structure of the soil because this decisive parameters such as the capacity of the soil to store water, water availability, heat storage and diffusion, permeability to air, gases, roots, and water, pH and nutrient availability. Soil structure is based on the relationship between the volume occupied by the soil particles and the apparent volume of the soil and varies in function of the dimensions of the interstitial spaces (pores) between the soil particles, although pedogenetic and anthropomorphic (e.g. soil management practices) factors may also play a part in soil structure (Taylor and Aschroff, 1972). When considered in the light of an agricultural production system the application of soil structure to the concept of soil fertility extends the scope of this concept beyond the purely chemical aspects of pH, nutrient availability, and organic matter content.

The association between, and stability of, the soil aggregates determine the type and quality of the soil structure and are directly dependent of the amount and quality of organic matter in the soil which in turn can be inferred as being due to the type of plants growing in the agricultural production system of which the soil is a part, such plants constituting a primordial factor for the development of global soil fertility (Denardin *et al*., 2003). Soil organic matter interacts with soil minerals to form complex organominerals that result in the formation of secondary particles of various shapes and sizes (Tisdall and Oades, 1982), with plant roots (Silva and Mielniczuk, 1997) and fungal hyphae (Miller and Jastrow, 1990) increasing such interactions by forming and stabilizing aggregates of soil particles. The formation of soil aggregates results a decrease in microbial decomposition of soil organic matter and accumulation of organic compounds, especial in untilled soils (Feller and Beare, 1997; Six *et al*., 1999). The quantity and flux of organic material produced by the agricultural production system governs factors such as the biological activity of the soil, the production of secondary organic compounds, aggregation of soil particles and other, less well-defined, emergent soil properties all of which contribute considerably to total soil fertility. In general, carbon cycle emergent soil properties such as aeration, aggregation, cation exchange capacity, infiltration and retention of water, nitrogen balance, organic matter content, porosity, etc. serve only to improve total soil fertility (van Breemer, 1993; Vezzani, 2001).

The agricultural use of soils influences amount of organic matter in a soil due to the diversity of the plant species within a particular productive agricultural production system. Agricultural production systems involving tillage, cultivation of low phytomass species or the burning or removal of crop residues (or all these factors) normally present annual rates of phytomass accumulation which are lower than the mineralization rates of the organic material added to the soil. Some researchers suggest that it is important to consider not only the aerial phytomass but also the contribution of the root system of plants (Bolinder *et al.*, 1999) because some crops, with extensive and aggressive root system (principally perennial grasses forage crops) allocate a larger fraction of photosynthetic fixed carbon to their rootstocks than do annual species (Shamoot *et al.*, 1968) and are therefore more efficient in increasing the stock of organic matter in the soil.

The rate of loss of soil organic matter is highly influenced by tillage because tillage oxygenates the soil and homogenizes crop thereby stimulating microbial decomposition and, compared with the no-till system, tillage can double the rate of organic matter decomposition (Bayer *et al.*, 2000c). The decomposition of soil organic matter is agriculturally undesirable because improved soil fertility is undoubtedly associated with processes that maximize soil organic material and minimize losses.

The dynamics of soil carbon and nitrogen are intimately linked so that degraded soils and with low levels of organic matter are also usually nitrogen deficient and this limits carbon input from plant material, which in agricultural terms principally means grasses crops in productive (Bayer *et al.*, 2000a,b). This means that the inclusion of leguminous crops in the crop rotation cycle of some agricultural production system allied to the use of inorganic nitrogen-based fertilizers is highly efficient in elevating soil carbon stocks and improving total soil fertility and hence crop productivity (Teixeira *et al.*, 1994; Testa *et al.*, 1992; Vezzani, 2001).

Alterations in global soil fertility: In Brazil the soils of the main annual agricultural production systems for the production of grain crops are predominantly Oxisols, Ultisols and Alfisols and a smaller proportion these systems are grown on Mollisols, Inceptisols, and Entisols, mainly in the subtropical Brazilian states of Rio Grande do Sul, Santa Catarina, and Paraná. In tropical Brazil, Entisols (quartzite sands type) support some restricted areas with these systems (Miyasaka and Medina, 1981). Oxisols, Ultisols, Alfisols, and Entisols (quartzite sands type) are generally deep, well-drained soils which form undulating or semi-undulating deposits that present no limitations for the implementation of annual agricultural system for the production of grain crops, although Mollisols, Inceptisols, and some Entisols the adoption of such system due to lack of depth, stoniness, and problematic topography because they are often located in areas of uneven relief (Anon, 1999). The insoluble clay fraction of these soils is predominantly composed of type 1:1 minerals (kaolinite) and iron and aluminum sesquioxids (Anon, 1999) which are very important because they confer high structural stability to soils especially at the micro aggregate level (Kiehl, 1979). The organic matter content of uncultivated Entisols (quartzite sands type) soils is less than 2% and in Oxisols, Ultisols, and Alfisols rarely exceeds 4% while in Mollisols, Inceptisols, and some Entisols it is often 3% and can be in excess of 5%, the organic matter content of these soils being responsible for macro aggregate stability.

Under natural conditions these soils are dystrophic and limit plant growth because chemically they are acidic with low exchangeable base saturation and contain high levels of exchangeable aluminum (Embrapa, 1999). These soils are, however, physically suited to crop development because they possess considerable structural stability at both the micro- and macro-aggregate level such that total porosity can reach 0.6 m^3 m^{-3} which means that they are highly permeable air, water and the roots and consequently have low natural susceptibility to erosion. Once the chemical deficiencies of these soils are corrected these soils have high total fertility and are very suitable for annual agricultural systems for grain production (Denardin *et al*., 2003).

However, it has been postulated that the mechanical mobilization of soil (ploughing, scarification, and grading) for conditioning prior to the implementation of agricultural production systems unleashes integrated and serial chain reactions in the complex physicochemical-biological systems of the soil that alters soil structure and redefines its total fertility. Depending on the intensity of soil mobilization such changes can result in increased or decreased patterns of soil fertility (Denardin et al., 2003).

In Brazil since the 1960's there has been intense mechanical soil mobilization associated with the widespread use of soil conditioners and fertilizers in annual agricultural systems for grain production. Although soil mobilization and chemical treatment have improved the chemical quality of the soils to which these methods have been applied such treatments have also transformed soils dystrophic soils into epieutrophic soils and negatively affected the physical quality of such soils. Soils treated in this way show reduced macro aggregate stability, an increased water clay dispersion index, increase soil density and highly reduced total and macro porosity and a concomitant decrease in the water infiltration rate. Destabilization of aggregates and water clay dispersion can produce a thick penetration-resistant layer 7 to 20 cm below the surface of the soil, such a process being similar to the accelerated genesis of a textural B horizon. Such physical transformations are expressed as soil degradation as a result of intense alluvial erosion and impacts negatively on both the environment and agricultural productivity. Unsustainable agricultural practices resulting in soil erosion have been combated by soil conservation techniques (terracing, contour seeding and reduced soil preparation) and an increased emphasis on the carrying-capacity of the soil which have resulted in important reductions in erosion, even so it is only since the introduction of no-till system in the 1970's that the results of these measures have achieved acceptable relevance in terms of reduced erosion (Denardin et al., 2003).

Any transformations in the physicochemical and biological properties of soils resulting from the implementation of no-till system are dependent on environmental factors, soil type and, most importantly, the agricultural production system model, i.e. the set of species which make up the productive agricultural system. Transformations related to the creation or recuperation of total soil fertility are based on the amount of organic carbon within the system because this is the factor which is most affected the adoption of no-till system. The most important changes in soil properties originate on or near the surface of the soil due to the presence of plant residues and roots. The great majority of practical reports and scientific studies involving the implementation of no-till system support the affirmation that no-till system increase soil organic carbon, improve soil structure, and increase nutrient availability (Muzilli, 1983; Sidiras and Pavan, 1985; Kochhann, 1996; Stone and Silveira, 1999; Caíres, 2000; Sousa and Lobato, 2000; Silveira and Cunha, 2002).

Muzilli (1983) and Sidiras and Pavan (1985) have shown that four years after the adoption of no-till system soil organic matter was significantly increased in the 0–5 cm layer of Oxisols and Alfisols in the Brazilian state of Paraná and Sá (1995a) has shown that soil organic matter in the 0–10 cm layer of the same soils increased by 27% after 15 years of no-till system. Over 10 years no-till system has resulted in an overall increase of 0.5 to 1.5% in the level of organic matter in the 0–10 cm layer of subtropical Brazilian soils (Lopes et al., 2004).

Valpassos et al. (2001) conclude that the continuous use no-till system within a crop rotation management system results in organic carbon accumulation, reduced soil density and improvements in the chemical properties of the soil related to plant nutrition and constitutes a conservationist alternative for the maintenance of total soil fertility and the productive potential of agricultural production systems in tropical Brazil.

Salton et al. (1998), Bayer and Mielniczuk (2001), and Muzilli (2003) affirm that alterations in soil properties such as improved structure, elevated cation exchange capacity, controlled release of nitrogen and phosphorous and reduced acidity observed in studies of no-till system are a result of the quality and quantity of organic matter contained in no-till soils.

However, Stone and Silveira (1999), Stone and Moreira (2000), and Kluthcouski et al. (2000) in tropical Brazil and Tormena et al. (2002) in subtropical Brazil have reported that no-till system applied to production models that result in the production of phytomass in quantities inferior to the mineralization potential the soil can induce soil compaction and a fall in productivity. Corrêa (2002) that after 2 years there was an increase in the proportion of water stable aggregates in a tropical Brazilian oxisol subjected to no-till system in a production model involving the rotation of soybean and maize as compared to the percentage of the same type of aggregates in a soybean in continuous cropping. In addition, the percentage of soil organic matter correlated positively with the percentage of aggregates larger than 2 mm, the weighted mean diameter of the aggregates and the degree of clay flocculation. In the Brazilian state of Rio Grande do Sul an Oxisol was studied by Barcelos et al. (1999) who found that when this soil had been subjected to 10 years of crop rotation using three soil handling methods (conventional, minimum-till, no-till system) no-till system resulted in higher levels of organic carbon; increased soil water retention; increased weighted mean aggregates diameter; increased macro-porosity; and increased water infiltration rates. Kochhann (1996) has pointed out that in no-till system aggregates in the superficial soil layer are more stabile and that larger diameter aggregates are more common because the presence of vegetable residues in the surface of the soil protects aggregates from the impact of rain drops, surface organic material is constantly decomposing and producing adhesive substances, and absence of tillage prevents aggregate breakdown.

Reinert et al. (1984), Eltz et al. (1989), Carpenedo and Mielniczuk (1990), and Derpsch (1991) conducted comparative studies of different methods of soil preparation as applied to subtropical Brazilian Oxisols and Ultisols and found that no-till system consistently improved soil structure as expressed by increased mean aggregate diameter and increased macro aggregate water stability. However, Carpenedo and Mielniczuk (1990) also pointed out that no-till system soil macro aggregates had micro pores and were compacted in relation to the soils of cultivated pasture, natural fields or forests in which the soils contained a greater proportion of macro pores and were more porous.

Nutrient cycling and the addition of chemical soil conditioners and fertilizers promote nutrient concentration in the superficial layers of no-till system soils. Bartz (2003) states that the least mobile nutrient is phosphorus which results in this nutrient having the largest concentration gradient (measured from the soil surface) in no-till system soils. In the l0–5 cm layer the phosphorous concentration can be seven times greater in no-till soils as compared to that in conventionally tilled soil, and according to Sá (1995a), this effect is proportional to the time for the soil has been subjected to no-till system but independent of the soil order or soil textural class. Muzilli (1983), Sidiras and Pavan (1985), Sá (1993, 1995b), Caires (2000), and Sousa and Lobato (2000) affirm that the low mobility and high availability of phosphorous in the superficial layer of a soil is due the annual application in furrow or broadcasted of phosphate fertilizers, the liberation of organic phosphorous from decomposing of crop residues on the surface of the soil and reduced contact with phosphorous sequestering soil minerals such as iron and aluminum oxides, oxi-hydroxies and hydro-oxides. Bartz (2003) emphasizes that no-till system optimize the use of organically derived phosphorous and reduces retention or immobilization of inorganic phosphorous applied as fertilizer, this is because soil managed under no-till system is not subjected to mobilization, such optimization having reduced the use of phosphate fertilizer by 30 to 70% in the Brazilian state of Paraná.

Rheinheimer and Anghinoni (2001) have reported that elevated soil solution phosphate levels can result in the formation of low solubility aluminum, calcium and iron phosphates and result in decreased availability of phosphates to plants but Sá (1995b) has pointed out that as compared with conventional tillage no-till system has various advantages in terms of phosphate behavior because the absence of soil mobilization decreases phosphate adsorption by reducing contact between soil colloids and ion phosphate and the slow and gradual mineralization of crop residues occurring in no-till system results in the liberation and redistribution of organic phosphates which are more stable and less susceptible to adsorption.

Pöttker (1995) has pointed out that there is relatively little information on the behavior of potassium in soils under no-till system. Bartz (2003) has reported that in no-till system soils potassium has a similar, but less intense, concentration profile to phosphorous, with potassium levels decreasing from the soil surface downwards and that the principal potassium losses are lixiviation and/or surface runoff due to the high aqueous solubility of potassium. The improvement soil structure in no-till soils increases the rate of aqueous infiltration and reduces potassium loss by runoff but this may be offset by increased losses due to lixiviation. A further factor being that the annual pluvial precipitation in the grain producing areas Brazil is in excess of 1,400 mm and precipitation often exceeds the soil infiltration rate thereby causing potassium loss due to runoff. Such losses are important in both subtropical and tropical regions of Brazil but are accentuated in tropical regions because most of the annual pluvial precipitation takes place during October to March.

Lopes et al. (2004) have affirmed that nitrogen is the nutrient whose dynamics are most influenced by the adoption of no-till system and Freire et al. (2000) have pointed out that nitrogen is the principal nutrient limiting crop and that when the soil is the only source there is usually not enough nitrogen to assure high productivity. The soil organic nitrogen reserve represents 95% of the total soil nitrogen and is subjected to transformations that determine the balance between organic and inorganic forms of this element and, consequently, availability of nitrogen to plants. Sá (1999) states that in the initial years of no-till system plant nitrogen availability is problematic due to the high carbon/nitrogen ratio of crop residues, the presence of compaction and relatively low levels of phytomass, such effects occurring principally in degraded soils. Such problems are well-known to occur in newly implanted no-till system because the amount of fresh material on the surface of the soil but also occur when climatic conditions are unfavourable to decomposition. As the amount of surface organic material undergoing decomposition increases due to the continued use of no-till system nitrogen availability stabilizes (Sá, 1996). A solution which is often adopted has in ploughed systems is to apply inorganic nitrogen-based fertilizer to the furrow during sowing.

Most Brazilian soils used for grain production are highly acidic as expressed by pH or the presence of phytotoxic aluminum and/or manganese, liming being the recommended practice correcting these problems. The factors responsible for the re-acidification of soils under continued agricultural use are mineralization of crop residues, the type and amount of applied fertilizer and loss basic cations by lixiviation and/or surface runoff.

In Brazil, conventionally tilled soils become re-acidified and require re-liming about every five years (Pöttker et al., 1998) but in no-till system there tends to be a decrease in the level of exchangeable aluminum and or manganese with time and hence a decrease in the need for liming (Sidiras and Pavan, 1985; Sá, 1993).

Various mechanisms have been proposed to explain the reduction of acidity in soils under no-till system (Miyazawa et al., 1993; Salet, 1998; Franchini et al., 1999; Sumner and Pavan, 2000; Miyazawa et al., 2000).

Miyazawa et al. (2000) have suggested that one mechanism might be related to the level of basic cations and soluble organic carbon presents in the phytomass of the green fertilizers *Avena sativum*, *Brassica napus*, *Lupinus albus*, *Leucaena* spp, *Mucuna aterrima* and *Crotalaria juncea* during flowering than in other commercial species such as maize (*Zea mays*), soybean (*Glycine max*), and wheat (*Triticum aestivum*) post-harvest. Reduced aluminum and/or manganese toxicity can depend on the species cultivated but is mainly related to the developmental stage of the plant, with growing plants being more resistant than mature plants. This implies that in no-till system in tropical and subtropical Brazil the level and periodicity of liming may be affected by the type of green fertilizer or crop residue which are produced by the different crop rotation systems because such residues can interfere with soil organic matter dynamics, increase pH and reduce aluminum and/or manganese toxicity.

Kaminski (2000) has proposed an alternative mechanism to explain the reduced acidity in no-till system based on the existence of channels (produced by insects or the decay of roots) in the soil profile, such channels having lower levels of aluminum, higher levels of exchangeable calcium and magnesium, raised available phosphorous and potassium, more organic matter, and higher pH than the adjacent soil.

Miyazawa et al. (2000) have reported that many commercial cultures show maximum economic productivity when the soil pH is 5 (as measured in water) and the aluminum saturation is 40%. However, the frequent and intensive use of ammonium or amide nitrogen-based fertilizers can annul the effect of the plants and reduce soil pH.

In no-till system soil acidity is reduced by applying calcareous material directly to the surface of the soil without incorporation, with various workers (Pöttker, 1998; Sá, 1993 & 1999; Caires, 2000) having concluded that this procedure has dramatic results on the acidity of the first 10 cm of soil; promoting pH elevation, increased levels of exchangeable calcium and magnesium; and reduced exchangeable aluminum and/or manganese. In addition, the productivity of the species cultivated using this type of liming is equal to that in systems using conventional tillage-liming. Pöttker (1998) emphasizes that in certain soils the surface application of lime requires only half or a quarter of the quantity of liming agent required by conventional tillage-liming but that the productivity of surface-limed crops is the same as that of tillage-limed crops.

In their review of the literature on the surface-liming of no-till crops Lopes et al. (2004) affirm that when the level of soil phosphorous is satisfactory it is possible to achieve highly productive cultures in no-till soils by applying quantities of calcareous material to the soil surface without incorporation and that the quantity of material needed is lower than when the material is incorporated into the soil. These authors also state that when calcareous material is applied the surface of the soil the maximum effect on soil acidity occurs in the 0–10 cm soil layer.

In subtropical Brazil the southern regional branch of the Brazilian Soil Science Society South Regional Nucleus (*Sociedade Brasileira de Ciência do Solo – Núcleo Regional Sul*; *SBCS-NRS*) coordinates the network of official soil analysis laboratories (*Rede Oficial de Laboratórios de Análise de Solo*; *ROLAS*), conducts quality control, publishes liming-tables and stimulates research by mounting scientific and technical events catering to regional technological demands. No-till system account for more than 75% of the agricultural area under cultivation in subtropical Brazil because of which the SBCS-NRS has, since the early 1990’s, been organizing specific research related to the application of fertilizers and liming to no-till soils, the results of this research having been published in the ‘*Fertilizer and Liming Manual for the States of Rio Grande do Sul and de Santa Catarina*’ (Anon, 2004) which places an emphasis on no-till soils in subtropical Brazil, recommendations for tropical Brazil having not yet been published due to lack of data.

3.3 Weed management

The no-tillage has a major characteristic to maintain the crop residues on the soil surface eliminating the soil tillage. As a consequence, before the crop planting, it is necessary the use of herbicides to kill the plants species that are vegetating in the area. During the crop season, while in conventional tillage in small-scale farmers the weed control is based on mechanical control (normally animal draft) associated with manual or chemical control, in no-tillage system the weed control is based only on herbicides (Almeida, 1991). Accordingly, in no-till system the weed control is much more dependent on herbicides. Rego (1993) relate as a disadvantage of no-till an increase of 17% in the use of pesticides when compared with conventional tillage in general. For small farmers with animal traction, where the weed control in conventional tillage is mostly based in mechanical control, Samaha et al. (1993) in a survey in 31 farms have shown that the percentage of herbicide in relation with the total cost was of 11.8% in no-till and 4.5% in conventional tillage for common beans and of 26 % in no-till and 2% in conventional tillage for corn.

Another aspect of relying upon the use of herbicides was the development of weed resistance to some products in no-tillage (Christofoffoleti, 2003). Meanwhile in conventional tillage the weeds, which were not controlled with herbicides, were eliminated by mechanical procedures.

In the first aspect of the higher use of herbicides in no-tillage some results have shown the possibilities of reducing the amount of products and consequently reducing costs. Adegas (1998), describe a joined study with several institutes of an Integrated Weed Management program in 58 farms in the Parana State, comparing a proposed rational management including the Integrated Weed Management comparing with the farmers practices of weed control. The results after three years of evaluation were a diminution on average costs of 34.8% with herbicide reduction of 24,7%. Ruedell (1995) shows a result of an Integrated Weed Management program at Rio Grande do Sul State (FUNDACEP) where in an average of 34 areas there was a reduction of 42% in weed control cost when comparing with the farmer practices. These results demonstrate the agronomic, economic and ecological viability of Integrated Weed Management.

Another approach regarding the use of herbicides in no-tillage are the studies of no-tillage without the use of herbicides. Skora Neto (1993) in a study on experimental station verified the necessity of two hoeing in conventional tillage and only one in no-tillage. However, although it was possibly to eliminating a hoeing the time spent in no-tillage was still high and variable among different cover crops mulch. Skora Neto et al. (2003) in study carried out at farm level verified the possibilities of the no-tillage without herbicides, but again, the constrain was the labor requirements for weed control. Areas with low weed populations were the more suitable for no-tillage without herbicide.

Other studies were also carried out trying to validate a no-tillage system without herbicide. Passini & Renzo (2004) studied the production of organic soybean with no-tillage at farm level in the North region of Parana State and Bernardi & Lazaretti (2004) are also working with no-till organic soybean production with 100 familiar farmers at Rio Grande do Sul state. In Santa Catarina State a no-till system with vegetables is being studied at experimental station and farm level with a participatory development of the technology with the farmers (Fayad et al. 2004) .

To overcome the constrains of labor requirements in no-till without herbicides Almeida (1991) recommends, besides the effects of mulch and of no tillage on weed population reduction, to avoid the weed seed production as a way to reduce the weed seed bank and as a consequence the level of weed population and the inputs to control them. According Almeida (1991) and Adegas (1998) one way of reducing the weed seed production is to occupy the area all the time with crops or cover crops without having fallow periods. Several studies of the effects of cover crops on weed population were performed. Favero et al (2001) found that cover crop promotes modifications in the sequential dynamics of spontaneous species, Severino & Christoffoleti (2001) found that cover crop mass was shown to reduce the weed population in different degrees of interference according with the species, Erasmo et al. (2004) verified that the cover crops species significantly reduced the weed population, Trezzi & Vidal (2004) studing sorghum and pearl millet have found a reduction of 91, 96 and 59 % on population of the weed species *Sida rhombifolia*, *Brachiaria plantaginea* and *Bidens pilosa* by the presence of the cover crops, and Sodre Filho et al. (2004) verified in no-tillage a better development of the cover crops when compared with the conventional tillage.. Skora Neto (2004) carrying out a study at experimental station verified the effects of the fallow periods and the suppression effects of cover crops on weed population. In a period of three years it was observed a reduction of a population of 159 plants.m^{-2} to 7 plants.m^{-2} when there was not fallow period. The intervals between the crops were occupied with cover crops. Kliewer et al. (1998; 2003) in Paraguay in a no-tillage system with crop rotation and the use of short period cover crops during the intervals between crops eliminated the use of herbicides during two years with a reduction of US$ 71.00/ha in the cost of weed control.

Regarding the weed resistance aspect some (several) studies were carried out to verify the possibility of use other herbicides to control the weed species resistant to a specific herbicide. Christofffoleti (2003), Vargas et al (1999) show the occurrences of resistant weed species in Brazil and the ways to avoid the onset of weed resistant problems and also some suggestions to manage the problems already existents. Overall the recommendations for avoiding weed resistant problems are similar those to have a good no-tillage system.

Therefore, following the general recommendations to a good practice no-tillage system for weed management (Almeida, 1991, Adegas, 1998, Skora Neto, 1998, Kliewer, 2003, Pereira, 2004) has shown a minimization of the weed problems and leading to conservation agriculture with more sustainability.

3.4 Pests/diseases management

Pests

In maize crops, the incidence of *Elasmopalpus lignosellus* has been reported as lower in No-Tillage by Bianco (1998), who evaluated the percentage of dead plants and found out values of 3,6% for NT and 7,5% for conventional. According to Viana et al. (2001), the incidence of this pest can be twice as much in conventional. Higher soil moisture found in NT influence the incidence in two forms: 1) negatively in any stage of the biological cycle, mostly during the larval phase); 2) The adult female prefers to lay eggs~~)~~ in drier/disturbed soils. In addition, when the straw is burnt, the adults are attracted by the smoke. For other species such as the the larvae *of Diabrotica speciosa* and *Agrotis ipsilon*, the higher soil moisture will favour their development: Viana (2000) cited by Viana (2001) reports higher incidence of these species in No-Tillage.

In soybeans, Carvalho (1981) cited by Bianco (1998) found higher incidence of the species *Calliotrips phaseoli, Frankliniella rodeos and Frankliniella shuzei* in No-Tillage. The main factors that explain these results, according to the authors, are the higher mortality rates of the nymphs and pupae~~)~~ due to higher soil temperatures, higher effect of rains due to the abesence of soil cover and soil disturbance. *Sternechus subsignatus*, another pest of economic importance in soybeans, has been reported as increasing in regions wigh large adoption of No-Tillage (Bianco, 2002; Hoffman-Campo et al. (1991). Soil under NT provides favourable conditions for the diapause larvae to remain on the soil and complete their cycle, while soil tillage exposed the larvae.

Crop residues can provide a protection for some species such as *Pseudaletia sequax* and; *Dichelops melachantus* in wheat crops (Bianco, 1998; Chocorosqui & Panizzi, 2004) and slugs (Silva et al (1994) and Bianco (2000). However, the type of crop residues also affects pests incidence. The first generation of stink bug *Dichelops* develop mainly on residues of *Vicia* sp., and aftwerwards will attack maize seedlings (Viana et al. 2001). According to Silva et al. (1994), in no-tillage, *Anticarsia gemmatalis* have high mortality rates in yellow lupin, blue lupin and *Crotalaria spectabilis*, but this effect is not found in white lupin and grasspea (*Lathyrus sativus*). Silva & Klein (1997) recommends the rotation of soybeans with non-host gramineous in order to control *Sternechus subsignatus*, which attacks the stem of leguminous species.

The straw on the surface also affect the incidence of some insects that are sensitive to different wavelength eletromagnetic radiation Studies carried out by Cividanes & Yamamoto (2000) and Cividanes & Yamamoto (2001) found out that crop residues left on the soil surface allow the emmision of infrared radiation within a more favourable range for the adults of *Sternechus subsignatus* in relation to the infrared radiation emissions from the soil under the conventional system. In wheat crops, the yellow tonality of the straw does not allow the colonization of aphids *M. dirhodium* and *S. avenae*. (Santos (1980) and Bianco (1980) cited by Bianco (1998)).

Although the fact that some subterranean species have increased in No-Tillage - and particularly, *Diabloderus abderus* - (Silva et al 1994, Gassen (1989) cited by Bianco (1998), their beneficial effects on the soil have been raised the issue wether this is considered a pest or a beneficial insect.

Table 1 – Quantitative comparisons between No-Tillage and Conventional on the incidence of pests on some annual crops cultivated in Brazil.

Specie	Author	Soil management system	
		No-Tillage	Conventional
Elasmopalpus lignosellus	Bianco (1998)	3,6	7,5
	Bianco (1980)	9,83	22,28
M. dirhodium	Santos (1980)	14,8	87,5
S. avenae	Santos (1980)	1,34	28,9
Calliotrips phaseoli	Carvalho (1981)	228,4	134,7
Frankliniella rodeo		189,1	85,2
Frankliniella shuzei		46,2	37,8
Anticarsia gemmatalis	Cividanes & Yamamoto (2000)	3,5	4,2
	Cividanes & Yamamoto (2001)	3,4	5,4

Cividanes & Yamamoto (2002) found higher populations *of Cycloneda sanguinea* – a predator of *Anticarsia gemmatalis* – in No-Tillage plots. Sosa-Gomes & Moscardi (1994) found a higher ocurrence of the funghi *Beauveria bassiana, Metarrizium anisopliae* and *Paecilomyces* spp. In soybeans under No-tillage, in relation to the conventional, and attributed these results to differences in soil temperature, moisture and organic matter between the two systems.

Diseases

Crop residues left on the surface can enable the multiplication and survival of necrotrophic plant pathogens, as many of them depend on these conditions to survive. (Shaner, 1981 and Reis et al. , 1992, cited by Zambolim et al., 2001). It has been demonstrated that diseases occurring in winter cereals, maize, soybeans and common beans are more severe in No-Tillage associated to monoculture (Reis & Casa, 1996, 1997) cited by Zambolim, 2001. In a experiment aimed at evaluating the relationship between the amount of straw left on the surface and the inoculum density, Reis at al. (1992) compared the following treatments: no-tillage, minimum tillage, plowing with discs and plowing with mouldboard. They found out higher amounts of *Bipolaris sorokiniana* conidia and *Drechslera tritici-repentis* pseudothecia in the treatments that left more amounts of crop residues on the surface, in the following order: No-tillage>minimum tillage>disc plow>mouldboard plow

Crop rotations play a major role for diseases management in No-Tillage. From the plant pathological point of view , a crop rotation is defined as the cultivation of the same specie, at the same field and cropping season, where the crop residues of the earlier crop where biologically eliminated. Reis &Santos, 1993), so as to eliminate the disease inoculum from the field. For example, the complete elimination of the pathogen from the wheat root system it takes between 12 to 16 months. (Reis & Santos, 1993).The same author carried out experiments aimed at comparing the effect of different tillage methods (including no-tillage) associated to different crop rotations in the incidence of some diseases in wheat and found out that no-tillage asociated to crop rotations resulted in levels of incidence similar or lower compared with the incorporation of crop residues with the mouldboard plow. In a similar experiment, Prestes et al. (2002) evaluated the effect of cultural practices in the incidence of (manchas foliares) in wheat.They combined the following tillage methods: no-tillage, minimum tillage, disc plow and mouldboard plow, combined to 3 crop rotation systems. The incidence of leaf spots was higher when no-tillage was combined with monocropping. However, when crop rotations were associated to no-tillage, the incidence of diseases was lower.

3.5 Rainwater efficiency

In rainfed conditions of tropical and sub tropical regions, rainwater efficiency is usually reduced because of the important water losses by runoff during intense rainfall, direct evaporation from the soil under hot conditions and drainage of excess water during particularly wet periods.

In these regions conservation agriculture systems considerably modify the water balance of crops because of the presence on soil surface of a permanent mulch of crops residue, even partial.

As a first point runoff is generally reduced with CA systems. Depending of the soil type, the amount of residue, slope, the kind of crop and its development, reduction between 0 and 85 % have been observed (Bertol et al. 1997; Beutler et al. 2003; Cassol et al. 1999; Castro et al. 1999; Hernani et al. 1997; Levien and Cogo, 2001; Mello et al. 2003; Reyes Gomez et al 2002; Schick et al. 2000; Scopel et al. 2004).

Castro and De Maria (1993), Alves and Cabeda (1999) or Alves and Suzuki (2001) demonstrated that infiltration rate could be almost twice under no tilled situations compared with conventional ones. This important improvement of soil infiltration in CAS, is the result of 1) the increased flow path tortuosity and roughness, which slows down the water flow rate across the soil surface (Da Silva 2003), and 2) the improved topsoil structure mainly due to increased macro-fauna activity and less soil crusting (Castro and De Maria 1993, Cassol et al. 1999).

As a second point, surface residue limits the energy reaching the soil surface decreasing first-stage evaporation of soil water. Despite the difficulty to measure directly this parameter, some studies based on processes modelling, showed that this direct evaporation can be reduced under tropical conditions by 10% (Scopel et al. 2004) with a mulch of 1 Mg of dry matter ha^{-1} to about 50% with a mulch of more than 4 Mg DM ha^{-1} (Da Silva 2004, Scopel et al 2004)

As a counterpoint crop residue can also intercept an amount of water that then evaporates at first stage rate to the atmosphere. Nevertheless this amount has shown to be always less important than water conserved through the reduction of soil evaporation. Evaporation of the mulch is 2 to 3 times inferior to the reduction of soil direct evaporation with mulches between 1 to more than 6 Mg DM ha^{-1} (Da silva 2004, Scopel et al 2004). Nevertheless this effect on evaporation of the system will defer in function of the kind and size of the residue. For example, soil covering and radiation protection is usually stronger, for the same amount per ha, with maize residue than with soybean or millet residue (Da silva et al. 2003). In the same way this protecting effect will decrease in time during the cropping cycle in function of the residue mineralization rates, determinate by the nature of those residues (Sauza junior et al. 2003).

Resulting from the previous effects on runoff/infiltration ratio and on direct evaporation, more water is available for the crop if dry spells appear during the cycle. Such dry spells are frequent in January-February the Cerrados region. In those cases, available water at the beginning of the period is superior or equal than in conventional systems and water non directly evaporated can be valorised by the crop. Crop evaporation is then higher at the whole cropping cycle scale (Da Silva 2003, Scopel et al. 2004, Reyes et al. 2003).

In many sub-tropical and tropical regions where CA systems are applied in Brazil, water drainage fluxes are already important because of high rainfall amounts during the year. As a consequence of water conservation due to the mulch, the probability of increasing this drainage during the commercial crop cycle with CA systems is significant, especially for very rainy year, soil with limited storage capacity and large amount of residue (Scopel et al. 2004). In such situations, even if this additional water infiltrated into the soil is ecologically interesting to refill underground water tables, it is not useful for improving crop production. Nevertheless, many CA systems include a second crop in succession to the commercial one, at the contrary of conventional systems, so drainage has to be considered at the year scale and not only at the commercial crop cycle scale. In this case, additional water stored at the end of the first crop cycle can be used by the second one in complement of water stored during its own cycle. Additionally, some cover crops have very important and strong roots system, they are then able to reach water stored in soil layers deeper than the roots front of the previous commercial crop (Séguy et al. 2003, Scopel et al. 2004b). As an example, in the central Cerrados, after a maize crop, a second cover crop of millet was able to use 126 mm of water and to produce 3.5 t DM ha^{-1} of biomass returned to the system as soil protecting mulch (Silva 2003).

In conclusion, even in the humid conditions of tropical and sub-tropical regions of Brazil where CA systems are applied, such systems can contribute to a better total rainfall water efficiency. Specially, when an additional cover crop is introduced, yearly total drainage can be reduced considerably because of this cover crop own evaporation. Total biomass produced during the year is then more important giving opportunities to use it for economical purpose or as a more efficient protecting mulch.

4 Socio-economic impacts

4.1 Small-scale agriculture (IAPAR)

4.1.1 Labour and machinery requirements

Impacts of No-Tillage on labour has being the main factor for adoption of this systems by small-scale farmers (Ribeiro et al.1996). Impacts of NT on labour can be analysed according to three main aspects: drudgery, labour distribution among the cropping season and total labour.

Drudgery is of particular importance in farming systems based on the use of animal traction. Plowing and harrowing are considered by farmers as very harmful operations – specially when working on hilly and stony fields – which are supressed in No-tillage (Pereira et al., 1999)

The reduction of labour in small-scale farming systems has been documented by many authors for different crops and sources of power, which is summarized in Table 1. Percentage of reduction in labour requirements ranges from 11% for the cultivation of onions, to 38% for the cultivation of maize. The main factors that contributed to a reduction of labour and machinery requirements in No-Tillage are the supression of plowing and harrowing; the substitution of mechanical weeding/hand hoeing for chemical control of weeds; the reduction in the time required for the mainteinance of terraces and other mechanical pratices of erosion control (Ribeiro et al., 1993; Ribeiro et al. 1998; Toresan et al., 1999).

Table 1 – Differences in yields, labour and profitability between No-Tillage and the Conventional System for the main crops cultivated by small-scale farmers in the subtropical area of Brazil.

Author	Source of power	Crop	Difference in yields (%)	Difference in labour (%)	Difference in profitability (%)
Samaha et al. (1993)	Animal traction	Common beans	20,2	- 34,2	49,4
Ribeiro et al. (1999)	Animal traction	Maize	3,5	-24,7	11,3
Toresan et al. (1999)	Animal Traction	Maize	20,0	-19,0	20,0
	Animal Traction	Common beans	37,0	-38,0	37,0
	Power tiller	Onions	26,2	-11,0	26,0

Figure 1 indicates the labour distribution in hours per hectare for the cultivation of common beans with animal traction. It can be seen that No-Tillage reduces labour peaks from August to December, which corresponds to a reduction of the labour requirements for soil preparation and weeding (Ribeiro *et al.*, 1993). At the other side, there is a slight increase on labour requirements during the months of April and May, which corresponds to sowing of the cover crop seeds. However, this does not represent a constraint to the farmers, as during this period, there is availability of labour at the farm.

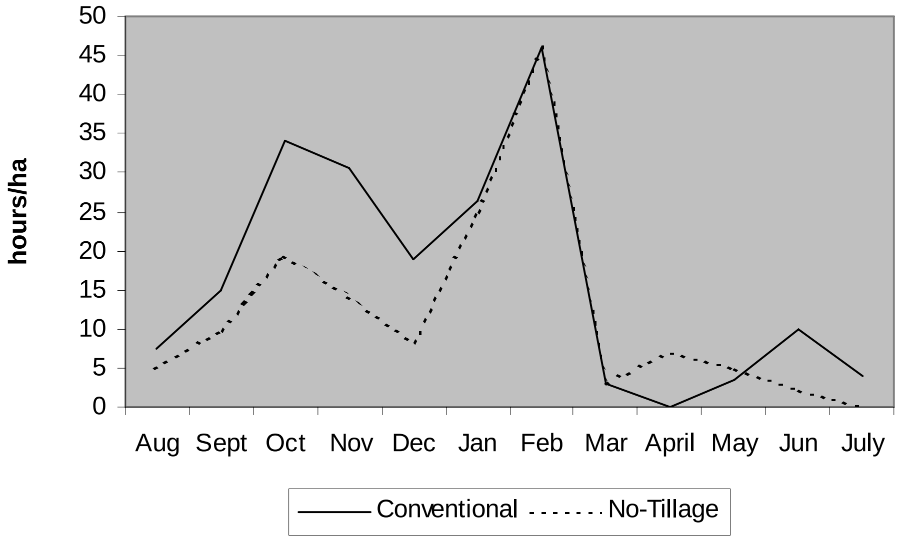

Figure 1 - Labour distribution along the year for 1 ha of common beans with animal traction (Ribeiro et al., 1991)

An assessment of labour requirements for No-Tillage systems without herbicides was carried out by Skora et al (2003) trhough on-farm trials implemented in collaboration with farmers at the Central-Southern region of the State of Paraná. In this system, weeds are controlled with hand hoe or a mechanical slasher. This systems required 53 hours/ha (average of 11 fields), in contrast to 1 to 5 hours/ha if herbicides are used (Araújo et al., 1998). These figures indicate that the high labour requirements for weed control in No-Tillge systems without herbicides remains a constraint for the adoption by farmers.

The reduction of labour and machinery requirements resulted from the adoption of No-Tillage has been opening some opportunities for small-scale farmers. An assesment of the impacts of the adoption of soil conservation practices, including No-Tillage, made by Toresan et al. (1999) at five main agricultural regions of the State of Santa Catarina has indicated that 54% of the farmers increased the cropping area, while 33% of the farmers did not increase the cropping area due to land scarcity, but they employed their surplus labour in other activities, including provision of services for neighbour farmers.

4.1.2 Costs and profitability

Economic performance of No-Tillage in relation to the Conventional Tillage cannot be analysed only in the short-term, but the long-term effects must be considered. Toresan (data?) argues that economic results during the transition phase from Conventional to No-Tillage may not be as favourable to farmers. This phase is characterized by additional learning costs , need to invest in new machinery and initial soil improvement (lime aplication and decompactation). In addition, during the first years of implementation of No-Tillage, soil conditions are not yet suitable for a better crop development and the effects of the new technology on yields are not realised. Oliveira (data?) proposed a theoretical division that would facilitate the reasoning when analysing the impact of Conservation Agriculture in the production process. In the **first phase** (improvement of tillage techniques), no increase in farm output is foressen. Decrease in labour, time and farm animal or mechanical traction power (reduction of production costs) would occur, while increases in chemicals use to control weed growth and diseases might be necessary. In the **second phase** (improvement of soil conditions and fertility), a decrease in labour, and farm animal or mechanical traction power (reduction of production costs) is expected, thus resulting in increase in yield and consequently increase in farm net income. In the **third phase** (diversification of crop pattern), increased and more stable yields are expected, as wel as increased net farm income and in soil fertility. Decrease in plant protection costs (pesticides, herbicides). In the fourth phase (integrated farming system) there is a stability in production and productivity. The full technical and economic advantages of Conservation Agriculture could seen by the farmer.

Profitability of No-Tillage compared to the Conventional System has been evaluated by many authors, but the results differs according to the approach used in on-farm trials and demonstration trials. Two main approaches have been used: the most common is the "all-or nothing" approach, where the conventional system (the farmers´practice) is compared to a package comprised of many improvements in addition to No-Tillage, such as improved varieties , levels of fertilization according to the optimal recommendation, control of pests and diseases according to the optimal recommendation. The second approach is the step-by-step", where the No-tillage is very close to farmers´s practice regarding crop varieties, seeds and levels of fertilization. Differences in these approaches explain the differences in the resulted presented in Table 1. As more intensive the package adopted for No-Tillage, profitability is higher. Toresan explains the differences between No-Tillage and the Conventional system as a result of some practices such as lime application and soil decompaction, while the Samaha et al. also included the practice of liming, together with a better ferilitzation and the use of improved varieties in the No-Tillage trials. At the other side, in the trials carried out by Ribeiro et al. (1999), the fertilization, liming and crop varietis were the same in No-Tillage and the Conventional System.

The production of cover crop seeds by small-scale farmers may also be another source of income, since farmers are organized for the commercialization. Table 2 shows a comparison between the cultivation of common beans, maize ane the production of mucuna seeds

Table 2 – Economic results from the cultivation of maize, common beans and mucuna seeds. Salgado Filho municipailty, Soutweats of Paraná, 97/98.

	Black mucuna	Common beans	Maize
Total production costs (RS$/ha)	16,2	142,06	222,20
Gross income (RS$/ha)	395,00	460,00	351,00
Return to labour (RS$/h)	6,80	2,37	1,26
Labour requirements (hours/ha)	55	134	102

5 Environmental impacts

5.1 Carbon stratification and sequestration

In Brazil, estimates of the rate of carbon accumulation have generally been restricted to the two main regions under DMC (the south and central west). In the southern region, Sá (2001) and Sá et al. (2001) estimated a greater accumulation rate (0.8 t C ha^{-1} yr^{-1} in the 0-20 cm layer and 0.9 t C ha^{-1} yr^{-1} in the 0-40 cm layer) after 22 years under DMC compared to the same period under conventional tillage. The authors mentioned that accumulated carbon was generally greater in the coarse (> 20 µm) than in the fine (< 20 µm) particle-size-fraction, indicating that most of this additional carbon is weakly stable. Bayer et al. (2000a, 2000b), found a carbon accumulation rate of 1.6 t ha^{-1} yr^{-1} for a 9-year DMC system compared with 0.10 t ha^{-1} yr^{-1} for the conventional system in the first 30 cm layer of an Acrisol, in the southern part of Brazil. Corazza et al. (1999) reported an additional accumulation of approximately 0.75 t C ha^{-1} yr^{-1} in the 0-40 cm soil layer due to no-tillage, in the Cerrado region located in the centre-west. Estimates by Amado et al. (1998, 1999) indicated an accumulation rate of 2.2 t ha^{-1} yr^{-1} of soil organic carbon in the first 10 cm layer. Other studies considering no-till systems carried out in the central-western part of Brazil (Castro Filho et al., 1998, 2002; Lima et al., 1994; Peixoto et al., 1999; Resck et al., 2000; Riezebos and Loerts, 1998), reported soil carbon accumulation rates due to no-tillage, varying from 0 to 1.2 t C ha^{-1} yr^{-1} for the 0-10 cm layer.

More detailed accumulation rates are reported in Table 1. Rates are organized by region. In the Cerrado region carbon accumulation rates vary from 0.4 to 1.7 t C ha^{-1} for the 0-40 cm layer, which is similar to the range found in the Southern region (-0.5 to 0.9 t C ha^{-1}). Mean rates of carbon storage were similar among "Cerrado" (0.65 t C ha^{-1}), "South" (0.68 t C ha^{-1}), and "Other" (0.60 t C ha^{-1}) regions, when the soil surface layer was considered (0-20 cm). More variability was found in the Southern region (-0.07 to 1.6 t C ha^{-1}) for the 0-20 cm layer, than in the other regions. However, it is important to mention that these mean values aggregate different soil and crop types and the variability is high. For instance, the Mean value of 0.68 t C ha^{-1} for the South region was obtained averaging 15 observations (Table I) and the associated standard deviation is 0.54 t C ha^{-1}.

Some other studies performed in Brazil reported that organic carbon (OC) contents under DMC and conventional systems can be very similar (Corazza et al., 1999; Freixo et al., 2002; Roscoe and Buurman, 2003; Sisti et al., 2004). These contradictory results are to be related to the high clays contents of the studied soil and probably a high stability of their organic matter.

Sisti et al. (2004) reported that the soil under native vegetation (measured in areas neighbouring the experimental site) had a high carbon and nitrogen content (37 g C and 3.1 g N per kg soil) in the first 5 cm depth. Carbon and nitrogen content declined to approximately half these values at 10-15 cm layer. The carbon concentration in the top 5 cm of soil was considerably higher in all three rotations managed with DMC compared with the conventional system, although not as high as under the native forest. Machado and Silva (2001) showed decreases in SOC of 23.4% and 47.8%, respectively, at 0-5 cm depth for DMC and conventional tillage systems, when compared to an adjacent non-cultivated area. The study was carried out on an Oxisol in the south of Brazil, following 11 years of soybean-wheat cultivation. However, the authors also found SOC at the 0-40 cm to be the same as the forest soil for both DMC and conventional tillage.

For the global impact on global warming, C sequestration is important through CO_2 depletion from the atmosphere. Regarding to CO_2 emissions, some studies seem to demonstrate that there is a very large peak of emission just after soil tillage in all conventional systems. This has been confirmed by Métay et al. (2003) who in a study made in the Cerrados region, demonstrated that this peak could occur during 2 to 3 days. During the rest of the commercial crop, the conditions of mineralization (temperature, moisture, porosity saturation after heavy rains) were more favourable under CA systems resulting in higher CO_2 emissions. However, in term of C balance over the year, CA systems presented higher C storage because of the higher biomass produced by both the commercial and the cover crops. Indeed, as a single of soybean may produce 4 to 7 Mg Dry Matter ha^{-1} of residue, a single crop of maize 8 to 11 Mg Dry Matter ha^{-1}, some of the more productive crops successions in CA with additional cover crop may produce 15 to 20 Mg Dry Matter ha^{-1} returned to the system (Séguy et al. 2003).

Nevertheless, other greenhouse gases may be taken into account. Few results have been published regarding N_2O emissions in tropical regions. One of them was realized in the Cerrados region (Métay et al. 2004). The results demonstrated that N_2O emissions were very low (< 1 g ha^{-1} day^{-1}) for both systems. Peaks of N_2O were observed after fertilization. N_2O is produced mainly by denitrification, which may be explained by low NO_3^- levels in soils and a < 60% water filled pore space (WFPS) within the soil for the majority of the time. Low WFPS under these crops can be caused by evaporation at high temperature (more than or equal to 25°C). However, measurements of gas concentrations in soil showed that the production of N_2O is reasonably prolific (concentrations of 1 to 30 times the atmospheric concentration). This suggests that N_2O is produced but cannot diffuse to the soil surface, either because denitrification is complete and N_2 is produced or because the N_2O is nitrified before diffusing.

In conclusion, CA systems seem to be an interesting cropping management option to mitigate global warming becoming from greenhouse gases effects. Soil C stocks tend to increase with CA systems application when additional cover crops are used in order to increase the total photosynthetic production during the year and provide high levels of biomass returned to the soil. In this case CO_2 emissions due to microbial activities are important but widely compensate by organic returns.

Table I. Carbon storage rates (accumulation following conversion of a conventional tillage system to DMC) in DMC systems in Brazil

Place	State [a]	Succession or dominant plant[b]	Reported soil classification	Clay (%)	Layer (cm)	Duration (yr)	Rate (t C/ha)	Source
Cerrados region								
Planaltina	DF	S/W	Latossol (Oxisol)	40-50	0-20	15	0.5	Corazza et al., 1999
					0-40	15	0.8	
Sinop	MT	R - S/So - R/So - S/M- S/E	Latossol (Oxisol)	50-65	0-40	5	1.7	Perrin, 2003
Goiânia	GO	Rice/Soya	Dark red Latossol		0-10	5	0.7	ud
Rio Verde	GO	M or S/Fallow S/M or So or Mi	Red Latossol	45-65	0-20	12	0.8	Scopel et al., 2003
Planaltina	DF	M or S	Dark Red Latossol (Oxisol)	>30	0-40	16	0.4	Resck et al., 2000
South region								
Londrina	PR	W/S	Oxisol		0-10	22	0.31	Machado and Silva, 2001
					0-20	22	0.25	
					0-40	22	-0.17	
Londrina	PR	S/W – S/L –M/O	Red Latossol		0-20	7	0.5-0.9	Zotarelli et al., 2003
Londrina	PR	S/W/S or M/W/M or S/W/M	Oxisol Typic Haplorthox		0-10	14	0.4[d]	Castro Filho et al., 1998
					0-20		0.2[d]	
Londrina	PR	S/W/S or M/W/M or S/W/M	Oxisol Typic Haplorthox		0-40	21	0[c]	Corazza Filho et al., 2002

Ponta Grossa	PR	(S or M)/(O or W)	Oxisol Typic hapludox	40-45	0-40	22	0.9	Sá et al., 2001
Tibagi	PR	(S or M)/(O or W)	Oxisol Typic hapludox	40-45	0-40	10	-0.5	Sá et al., 2001
Tibagi	PR	M/W – S/O – S/O	Red Latossol Oxisol	40-45	0-10	22	1.0[d]	Venzke Filho et al., 2002
Tibagi	PR	M/W-S/O-S/O	Red Latossol Oxisol	42	0-20	10	1.6	Siqueira Neto, 2003
Toledo	PR	S/O	Haplic Ferrasol		0-10	3	-0.68[d]	Riezebos and Loerts, 1998
		S/O	Haplic Ferrasol		0-10	10	0.37[d]	
Passo Fundo	RS	W/S	Oxisol		0-10	11	0.59	Machado and Silva, 2001
					0-20	11	-0.07	
					0-40	11	0.29	
Passo Fundo	RS	W/S	Red Latossol Typic hapludox	63	0-30	13	0[c]	Sisti et al., 2004
		W/S-V/M			0-30	13	0.4	
		W/S-O/S-V/M			0-30	13	0.7	
Passo Fundo	RS	W/S	Red Latossol Typic hapludox	63	0-10	11	0.3	Freixo et al., 2002
					0-20	11	0[c]	
					0-30	11	0[c]	
		W/S – W/M	Red Latossol Typic hapludox		0-10	11	0.4	Freixo et al., 2002

					0-20	11	0.2	
					0-30	11	0[c]	
Santa Maria	RS	M and Mu/M	Ultisol	15	0-20	4	1.3	Amado et al., 2001
Eldorado do Sul	RS	M/G	Podzólico vermelho escuro		0-17.5	5	1.4[d]	Testa et al., 1992
		M/La			0-17.5	5	0.6[d]	
		O/M			0-17.5	5	0.2[d]	
Eldorado do Sul	RS	O+V/M+C	Clay loam Acrisol Typic Paleudult	22	0-17.5	9	0.84	Bayer et al., 2002
Eldorado do Sul	RS	O/M	Clay loam Acrisol Typic Paleudult	22	0-30	9	0.51	Bayer et al., 2000b
		O+V/M+C			0-30	9	0.71	
Eldorado do Sul	RS	O+V/M+C	Clay loam Acrisol TypicPaleudult	22	0-17,5	12	1.26	Bayer et al., 2000a
Lages	SC	M or S / W or O	Cambissol		0-20	8	1.0	Bayer and Bertol, 1999
Other regions								
Campinas	SP	S or C / M	Rhodic Ferralsol Typic Haplorthox	60	0-20	3	0.8[de]	De Maria et al., 1999
					0-20	8	0.4[de]	
Sete Lagoas	MG	M/B	Dark red Latossol		0-15	10	0[c]	Roscoe and Buurman, 2003

Typic Haplustox		
	0-45	0[c]

[a]PR =Parana, RS =Rio Grande do Sul, DF = Distrito Federal, SC = Santa Catarina, SP = São Paulo, MT = Mato Grosso, GO = Goiás, MG = Minas Gerais;[b] Dominant succession: W = Wheat (*triticum aestivum*), S = Soybean (*Glycine max*), So = Sorghum (*Sorghum vulgaris*), R = Rice (*Oriza sativa*), E = *Eleusine coracana*, O = Oat (*Avena sativa*), V = Vetch (*Vicia sativa*), M = Maize (*Zea mays*), B = Beans (*Phaseolus vulgaris*), Mu = Mucuna (*Stizolobium cinereum*), C = cowpea (*Vigna unguiculata*), L=Lupine bean (*Lupinus angustifollios*), La = Lablabe (*Dolicbos lablab*), G = Guandu (*Cajanus cajan*);[c] 0 means that the difference was not significant; [d] calculated using an arbitrary soil bulk density of 1.2 g cm^{-3};[e] value reported for OM, C= OM / 1.724, ud =unpublished data from Metay.

<u>Source</u> : Bernoux et al. 2005

5.2 Nitrogen and nutrient cycling

Soils of the tropical and sub tropical Brazil are often poor and fragile. On the other hand, climate of these regions is usually characterized by strong and intense rains, inducing important soil degradation processes (hydric erosion or nutrients leaching). Nutrient cycling is then an important issue to be addressed for maintaining sustainable productivity of annual crops.

In these regions, commercial crop cycle is generally shorter than the whole rainfall season (7 to 12 months). Producing only one crop per year, as in many conventional systems, let the soil unused and unprotected during long periods of the rainfall season, before and/or after the commercial crop. These are the main periods when soil may be eroded and the nutrients coming from organic matter (OM) mineralization may lixiviate (Séguy et al 2001, Scopel et al. 2004). Stopping soil tillage and introducing an additional autumn or winter crop will be the two main changes that will interfere with Nitrogen and other nutrients dynamics.

Impact of nutrient losses through soil erosion (to be completed)(Kassol et al. 2002; Bertol et al. 2003; Hernani et al.1999)

Because of the residue mulch, CA systems generally provide, all over the crop cycle, temperature and moisture conditions more favourable for SOM mineralization (Métay et al. 2003, Reyes 2002). Dry spells have less impact because moisture is conserved during more time in the top soil surface. During strong rains, on the contrary, excess of water will infiltrate quicker in CA systems because of better conditions of soil porosity. Microbial activity will start again immediately after the rain (Métay et al. 2003) since it can disappear during several days with conventional systems. The mineralization process is more constant and more intense in the superficial organic layer resulting in higher nutrients availability for the commercial crop (Balota et al. 2004; Reyes et al. 2002).

On another hand, part of the nutrients is provided by the mineralization of the previous crop residue. The amount and the dynamic of this restitution will depend on the type of winter crop and its own productivity. Generally the residue decomposition is quick at the beginning of the next crop, slowing down after a few weeks. This decomposition is quicker for residue with higher C/N ratio (Abiven et al. 2002; Calegari 2000; Primavesi et al. 2002; Silva et al. 2003). During the commercial crop cycle, between 1/3 (Reyes 2002) with residues of gramineas and % with residues of legumes (refs), of the nitrogen they contain is mineralized. Some studies in laboratories showed that this mineralization can be very similar when residues stay on soil surface and when they are totally incorporated (Abiven et al. 2002). Nevertheless such situation could be different for residues with very high C/N ratio, because of the less availability of nitrogen on the surface and because a major N immobilisation. This is generally the case with cereals (corn, wheat or rice) or other gramineas (pastures) straws, and N deficits are possible at the beginning of the following crop. (Bayer and Mielniczuk 1999; Bertol et al. 2004; Ernani et al. 2002).

Very few studies quantified the role of the roots mineralization in nutrients balances. Only Abiven at al. (2002) showed that the mineralization of old roots of sorghum is usually slower than shoots mineralization because of their higher C/N ratio and higher contain in cellulose. Nevertheless other studies in other parts of the world stressed the important role of young roots turn-over in N cycling, and specific studies on this role under CA systems is actually lacking.

When there is no winter crop introduced in the annual succession, an important stock of non organic N can be observed at the beginning of the next rainy season (Reyes et al. 2002). Without any crop to use it, this nitrogen is the result of the global organic mineralization during the end of the previous rainy season and the flush of mineralization with the very first rains of the new cropping season. As the new crop necessities are very limited because of its early stage of development, risks of N leaching are very important at this moment. At the contrary, in CA systems, non organic nitrogen totally disappeared from the profile at the beginning of the new season as it has been absorbed by the winter crop. It has been "fixed" into the plants, being slowly returned by mineralization (Santi et al. 2003). Even with higher risks of drainage with a residue much, N leaching can be reduced by 30% with CA systems and with cover crops introduction (Reyes et al. 2002). Some authors call these additional cover crops "nutrients pumps". Their re-cycling capacity will increase for cover-crops with strong and dense roots systems (Séguy et al. 2003).

Nevertheless, in the case of legumes cover crop, synchronization between the N restitutions and the necessity of the next commercial crop needs to be taken into account for the system being really efficient. A legume will use just a few part of the nitrogen mineralized during autumn and winter and mineralization of its residue will be very quick at the beginning of the next season. In such a case, as with conventional systems, probabilities of N leaching increase too with the beginning of the rains. In very humid years this can reduce considerably the advantage of introducing atmospheric N to the system.

Recent studies are showing that with the application of CA systems soil organic matter tends to increase (Sá et al. 2001) and in this case C and organic N stocks tends to increase at the same time (Corbeels et al. 2004). Nevertheless there are very few knowledge on the consequences of these modifications on N mineralization and N efficiency.

Taking into account these processes and dynamics, many studies were realized for improving efficiency of N chemical fertilization practices (Amado et al.2000; Amado et al. 2002; Arf et al. 2003; Basso and Ceretta 2001; Bortolini et al. 2002; Ceretta et al. 2002; Guimaraes and Stone 2003; Pottker and Wietholter 2004; Teixeira and Carvalho 2003; Wolschick et al. 2003).

Some authors in new studies are recommending fertilising more intensively the cover crop in order to allow a better growth of the plants and to make them more efficient in their re-cycling function. All these nutrients are then returned to the system and less chemical fertilizers would be necessary during the commercial crops (Séguy et al. 2003).

In conclusion yearly nutrients efficiency is greater with CA systems. Soil mineralization is greater during the commercial crop cycle because of more favourable conditions of soil temperature and moisture. Additional cover-crop introduced before or after the main commercial crop permit to re-cycle the major part of nutrients mineralized during these periods. The cover-crop biomass, partly used as a residue protecting mulch, is then returned to the system by mineralization. Some of these cover crops are very efficient "nutrients pumps". Global N and other nutrients efficiency increases because of the important total biomass produced in such systems with additional cover-crops. Nevertheless some additional works are necessary to improve fertilizing practices of the commercial crops in function of the nature and the productivity of the previous cover-crop and in function of the evolution of the soil organic status under CA management.

5.3 Erosion mitigation

Soil erosion by water is the result of the interaction of the factors rainfall erosivity, soil erodibility, land relief characteristics (topographic factors), soil cover and management, and conservation practices (Wischmeier & Smith, 1978).

The rainfall erosivity and the topographic (slope length and steepness) factors represents the energetic components that have capacity to produce soil erosion, and the factors soil erodibility, cover and management and mechanical practices to control runoff and erosion represents the energy dissipation factors. Thus, different soils on distinct places under varied rainfall and slope conditions, used with different crops and management, will have as a result soil loss by erosion at a very different magnitude. In this way the water soil erosion may be interpreted as a mechanical work resulting as a consequence of incident energy on soil, which was only partially dissipated.

Rainfall erosivity: Rainfall is the main agent of soil erosion on annual cropland Brazilian soils. The potential erosivity of rainfall in Brazil, given as the “R” factor in the Universal Soil Loss Equation, ranges from 5200 to 12600 MJ mm ha^{-1} h^{-1} (Dedecek, 1978; Cogo et al., 1978; Bertoni & Lombardi Neto, 1985; Rufino, 1986). The annual distribution of the rainfall erosivity in Brazil may point out two distinct regions: a tropical one and a subtropical one, respectively at north and at south of the parallel 24^o of latitude south. At the subtropical region, in spite of the highest erosivity indexes occurring most frequently at the spring-summer periods, rains of very high erosivity potential may also occur at any time of the year, thus given a permanent risk of soil erosion. On the other hand, at the tropical region, as the south latitude decreases, the rainfall erosivity tends to concentrate at the spring-summer periods (Dedecek, 1978; Castro Filho et al., 1978; Bertoni & Lombardi Neto, 1985; Rufino, 1986). Thus, at the north of Parana State, around 76% of the annual rainfall erosivity is concentrate at the spring-summer periods (Castro Filho et al., 1978), in São Paulo State this concentration is at the order of 85% (Bertoni & Lombardi Neto, 1985) and in the Federal District it’s of 95% (Dedecek, 1978). As a consequence, at the tropical regions of Brazil the risks of soil erosion by water are concentrated in the spring-summer crops time.

Soil erodibility: The commercial annual crops of grains in Brazil are cultivated mainly on Oxisols, Ultisols and Alfisols. In less scale are cultivated on Molisols, Inceptisols and Entisols. The Entisols, however, are used only at restricted areas of annual crops in the country (Miyasaka & Medina, 1981).

The susceptibility of soil water erosion of these soils, expressed as the "K" factor of the Universal Soil Loss Equations are in the range of 0.008 to 0.044 t ha h MJ^{-1} ha^{-1} mm^{-1} (Table 1). Basis on this soil erodibility values, one may conclude that the annual crops in Brazil are cultivated on soils of low susceptibility to erosion by water. However, if on one hand this is true, on the other the risks of soil losses by erosion are high, mainly due to the inadequate soil management and the large slope length and steepness.

Soil loss by erosion: Soil loss by erosion evaluated in Brazil on experimental plots of 3.5 m wide and 22.0 m long, at different soils and regions and under different crops and management, ranges from 0.2 to 51.5 t ha^{-1} $year^{-1}$ (Table 2). It may be seen for a given soil, that the soil loss by erosion decreases as crop residues are kept on the soil surface and the soil tillage intensity is reduced. In this way is notable the efficiency of the no-tillage management system, which gives control levels of 44% of erosion in Oxisols from the Federal District (DF), a tropical region (Dedecek et al., 1986) and 97% control on Alfisol of Parana State, at the subtropical region. On the Oxisol of the tropical DF region, representative place of the Brazilian *Cerrado* area, a fast decomposition of crop residues and the lack of cover crops during the autumn-winter period, gives a low efficiency soil erosion control even at no-tillage management system (Table 2).

Putting together the values of soil erosion and the annual distribution of rainfall erosivity, one can see that in the subtropical area of Brazil, the soil erosion by water is distributed equally during the autumn-winter and spring-summer times, but in the tropical area, the spring-summer time can concentrate 95% of the annual soil erosion by water (Table 3).

Table 1. Soil erodibility expressed as "K" factor at the Universal Soil Loss Equation determined under natural and simulated rainfall on some soils from Brazil.

Soil	Region	Textural Class	Factor K[1]	Source
Alfisol	Subtropical	Clay	0.008	Ângulo et al. (1984)
Oxisol	Subtropical	Clay	0.021	Denardin & Wunsche (1981)
Oxisol	Subtropical	Clay	0.022	Henklain & Freire (1983)
Ultisol	Subtropical	Sandy loam	0.032	Cogo et al. (1978)
Alfisol	Subtropical	Sandy loam	0.032	Ângulo et al. (1984)
Alfisol	Tropical	Clay	0.012	Ângulo et al. (1984)
Alfisol	Tropical	Clay	0.036	Henklain & Freire (1983)
Oxisol	Tropical	Clay	0.013	Dedecek et al. (1986)
Oxisol	Tropical	Sandy Clay loam	0.044	Henklain & Freire (1983)
Ultisol	Tropical	Clay	0.027	Resck (1981)
Ultisol	Tropical	Clay loam	0.028	Leprun (1988)

[1]Soil erodibility "K" factor expressed in units of t ha h MJ^{-1} ha^{-1} mm^{-1}.

Table 2. Soil erosion losses at different soils and locations in Brazil under different crops and conventional tillage with crop residues burned (CPQ) conventional tillage with incorporated crop residues (CPI), reduced tillage (PR) and with no-tillage system (SPD) and relative reduction in soil erosion rates given by the SPD.

State/Region	Soil	Crops	Years of evaluation	Slope %	CPQ	CPI	PR	SPD
					t ha^{-1} year^{-1}			
RS/Subtropical[1]	Alfisolo	Wheat/ Soybean	11	12.0	-	34.0	11.3	8.8
RS/Subtropical[1]	Ultisolo	Wheat/ Soybean	9	7.5	-	13.1	3.2	0.5
RS/Subtropical[2]	Oxisolo	Wheat/ Soybean	6	9.0	10.9	3.6	-	1.5
PR/Subtropical[3]	Ultisolo	Wheat/ Soybean	4	4.0	-	5.3	-	1.0
PR/Subtropical[3]	Oxisolo	Wheat/ Soybean	4	4.0	-	3.2	-	1.1
PR/Subtropical[3]	Alfisolo	Wheat/ Soybean	4	4.0	-	6.0	-	0.2
SP/Tropical[4]	Ultisolo	Wheat/ Soybean	4	9.9	51.5	39.5	-	2.2
DF/Tropical[5]	Oxisolo	Fallow/ Soybean	6	5.5	9.0	6.0	-	5.0

RS = Rio Grande do Sul; PR = Paraná; SP = São Paulo; DF = Distrito Federal.
[1]Cogo et al. (1978); [2]EMBRAPA-CNPT (1984); [3]Derpsch (1984); [4]Castro et al. (1983); [5]Dedecek et al. (1986).

In the middle of the 80's, with the consolidation of the new concept of the no tillage system, founded on the crops rotation, minimum soil mobilization and exclusively in the sowing row, in the permanent soil covering and time diminishing between the sow and harvest, the outcome of this technology in the reduction of the erosion by water process was even higher. Data collected in Dourados, MS, a tropical climate area, shows marks of erosion control around 90% when compared to the bare soil treatment (Hernani et al. 1997).

The shown data demonstrates that technical soil management such as reducing soil mobilization intensity and culture residue preservation in the soil surface can provide reductions up to 97% of erosion by water on cultivated areas with annual cropping systems.

Even though the cover crop management plays an important role in the dissipation of the rainfall energy potentially able to cause soil erosion, it has been observed in more recent studies that with no tillage soil management system there are a slope critical length where the efficiency of this soil management system may be overcome occurring soil water erosion in this situation (Bertol et al., 1996). The soil surface covered by plants or crop residues may dissipate 100% of kinetic energy from raindrop impacts and has no the same efficiency in dissipate the shear stress energy of the runoff overland flow. At a given slope length there are a residue failure where the surface residue cover losses its capacity to dissipate the energy from the overland flow shear stress. At this moment there are a fluctuation and movement of the surface residue on the flow and the scouring of the soil under the residue causing soil erosion (Cogo et al., 2004). These processes assume a highly relevant importance especially in landscapes of a length where the flow shear stress may overcome the soil and residue cover critical shear stress.

Table 3. Soil loss by erosion at two periods of the year, under different cropping and soil management systems, for the tropical and subtropical regions of Brazil.

Region	Soil	Period/Crops	Soil management system				Total	%
			SD	CPQ	CPI	SPD		
Subtropical[1]	Oxisol	Autum-Winter/Wheat	67.5	5.5	1.7	0.7	75.4	51
		Spring-Summer/Soybean	65.1	5.4	1.9	0.8	73.2	49
Total			132.6	10.9	3.6	1.5	148.6	100
Tropical[2]	Oxisol	Autum-Winter /Fallow	4.0	0	0	0	4.0	5
		Spring-Summer/Soybean	49.0	9.0	6.0	5.0	69.0	95
Total			53.0	9.0	6.0	5.0	73.0	100

SD = Bare soil; CPQ = conventional tillage burn residues; CPI = conventional tillage incorporated residues; SPD = No tillage system
[1]EMBRAPA-CNPT (1984); [2]Dedecek et al. (1986).

Nevertheless, under empirical observations, based on the erosion soil loss reductions, was disseminated all over Brazil the concept that with no tillage system there are no needs of mechanical practices to control water runoff on the agricultural areas. The no tillage system by itself was considered as the enough practice to control the excess rainfall water flowing over the soils. As a consequence was sprayed up the work of destroy the terraces and gave up the contouring tillage and seeding, so the sowing could be done at the up-and-down hill direction if this were the largest dimension of the area. This is an actual problem with no tillage in Brazil which is even worsted by the quite often observed problem of the chemicals, especially herbicides, that are used in the crops cultivation and may be found in the runoff. This process, present when the overland flow shear stress overcome the soil and residue shear strength, produces a very enriched sediment (Table 4), which besides to cause economical losses, causes pollution and environmental contamination (Denardin et al., 2004). Thus, in the no tillage system, the excess rainfall runoff has an erosivity potential due to its flow shear stress and, no doubt is a very important vehicle to transport contaminants to water reservoirs, stream flows and rivers, rising up the risks of a dynamic hydrological disequilibrium at all agryecosystem. In this context, all the agricultural practices that shortens up the slope length insides the limits where the cover crops an residues keeps its capacity to dissipate the energy of the water running off will contribute to minimize the soil erosion problems. In this way, practices such as contouring, agricultural terraces, divergent channels, strip cropping, among others, are efficient to segment slope lengths and together with soil covered with crops and residues gives a very high level control of soil water erosion. In conclusion, in order to minimize the erosive effects of the raindrops and of the runoff flowing water it is fundamental to dissipate the erosive energy of this agents, that is, dissipate the energy of the raindrops impact and the shear stress energy of the excess rainfall running off water, keeping the soil surface totally covered and reducing the overland flow velocity.

Table 4. Chemical attributes at the original soil and at the sediments produced for intense rainfall in an area with inadequate no tillage management system, showing the enrichment of the eroded sediment.

5.3.1 Attributes	5.3.1.1 Concentration in the	
	Soil[1]	Sediment
pH in H_2O	6.4	6.6
Ca ($mmol_c/dm^3$)	34.0	44.0
Mg ($mmol_c/dm^3$)	56.0	60.0
P (mg/dm^3)	34.0	72.0
K (mg/dm^3)	270.0	609.0
Organic Matter (%)	2.9	7.3

[1] From 0 to 10 cm depth.

Source: Denardin et al. (2004).

5.4 Pollutants (organic/inorganic) in soil and water

Conservation Ariculture promotes alterations in the soil environment increasing the level of organic matter (Muzilli, 1981, Ferri et al. 2002), the soil moisture (Vieira, 1981), and also the macro and microorganisms population (Balota, 1997, Valpassos et al 2001), thus expecting greater degradation and retention of the pesticides in soil, diminishing wash off and contamination of subterranean waters (Jansen, 1999). These conditions are confirmed by results found by Silver (2004) that in the no-till system there was enhancement of glyphosate mineralization in the soil.; Ferri & Vidal (2002) that verified less persistence of the herbicide acetochlor in no-tillage; and Papini (2004) that verified that higher the organic content of the soils less is the probability of edafic organisms contamination with simazine.

Rodrigues et al. (2000) studying the retention of herbicides by the straw in no-tillage verified differences between the tested products; after irrigation with 20 mm the products with higher retention were metolachlor, alachlor, acetochlor and trifluralin with indices of 5 to 30% of wash off of the straw into the soil; imazaquin, simazine, clomazone, metribuzin and isoxaflutole as intermediate level of wash off with indices of 30 to 50%; and atrazine and sulfentrazone as the ones that more easily passed through the layer of straw with recuperation of until 90% in the soil. Ferri (2002) also verified higher soil sorption of acetochlor in no-tillage. Oliveira et al. (2004) found out that the retention of the imazaquin was higher in areas with high level of organic matter meaning the areas where the no-till was utilized by long time.

Results about the effect of crop residues, in soil managed with animal traction, show that the presence of straw reduces the soil erosion. Merten (1993) quantified the loss of soil as 113,780 kg/ha (annual average) in soil always discovered; 8,702 kg/ha in soil with plowing; and 837 kg/ha in no-tillage. However, the protection of the surface of the soil by the crop residues in no-till systems is not always followed by reduction on water losses. Results of water losses studies of Merten (1993) had shown loss of 5.2% in soil always discovered; 1.1% in plowed soil; and 1.6% of water loss in no-tillage. These data explain the results found by Ferri et al. (2004) that studied the effect of the soil management and soil cover in the transport of the herbicides alachlor and atrazine. They found out that these herbicides had higher transport by water of runoff in no-tillage when compared to the conventional system. They verified also that atrazine had higher transport than alachlor in the presence of the straw.

According to Roloff & Bertol (2004) and Denardin & Kochhann (2004) the effect of crop residues in soil erosion prevention and the possibility of minimizing field operations with machines and implements, led the farmers to neglecting complementary conservation practices eliminating the terraces and planting following the greatest length of the terrain. These factors have led, besides the runoff of nutrients and pesticides, also to the laminar and furrow erosion, even using no-tillage system.

In the small farms of the south of Brazil is usual the use of animals slurry, mainly of pigs in the agricultural areas. Port et al. (2003) verified less loss of nitrogen by volatilization of ammonium with the use of pig slurry in no-tillage. Ceretta et al. (2003), however, warn for the risk of environmental contamination by the pig slurry use. Studies of the application of pig liquid manure, associated with cover crops, about nitrification and nitrates distribution in the soil profile were studied by Almeida (2000). The lack of control of the runoff water and a possible higher wash out due to the greatest soil macroporosity can contribute for adverse effects in the environment by using manure in no-tillage.

The environmental contamination is also dependent of the quantity applied. In no-tillage there is a expectation of using higher amount of pesticides, which was estimated in 25% (Ruedell, 2000), and also higher amount of mineral fertilizers, mainly nitrogen; these factors joined to the use of manure in the family farms can reduce the beneficial effects of the no-tillage system. Higher use of pesticides also exposes with more frequency manipulators and sprayers, increasing the risk of intoxication (Foloni, 2000).

Complementary soil conservation and an efficient system of fertility, pests, diseases and weed management is necessary to make the no-tillage an agricultural practice with elevate ecological sustainability.

There is mounting pressure from different segments of society to assess properly the impact of DMC systems on the use of biocides in agriculture as well as on the environment and human health. DMC systems have been accused publicly of significantly increasing the utilization of biocides, especially herbicides. Nevertheless, different aspects should be weighted carefully before reaching a final verdict. First, the actual use of pesticides (products, rates, frequency of applications) with DMC systems must be compared to that of the conventional systems they are displacing. For example, whereas rates of 4 to 5 l/ha of atrazine and simazine-based pre-emergent herbicides were used in conventional maize management in the Cerrados region in Brazil, now, these same types of herbicides are used postemergence in DMC systems, at early stages of maize development, at rates of 1 or 2 l/ha. Moreover, very stable pre-emergent products have been substituted with post-emergent quickly degradable ones in the case of soybean production. Secondly, the introduction of cover crops in DMC systems may have important implications on pesticide use and management since they may help to interrupt some pest cycles, or may be used as natural insect traps, as illustrated by the observation that some bugs - virus vector for soybean - are clearly attracted by a cover crop of *Arachis pintoï*. Finally, comparative studies are also needed to understand the transformation kinetics for different molecules in the mulch-soil system and how this eventually affects water quality. It makes sense conceptually to consider that under DMC systems, a fraction of the biocides is intercepted by the mulch and directly exposed to the light and heat which activate their degradation. The other fraction, upon arriving in the soil matrix, could well be transformed in a short time thanks to the intense biological activity generally observed under DMC systems.

Developing DMC systems less dependent on herbicides

Despite the above considerations, present-day "classical" DMC systems are still very much dependent on biocides at planting time, because broad-spectrum or total herbicides are generally needed to control the cover crop and other weeds. In many cases however, and particularly for small-scale farmers, this dependence is both costly and risky, and may run counter to desires for achieving a fully ecological agriculture. In such situations, new systems and strategies are needed for controlling weed pressure and for decreasing the stocks of weed seeds present in the soil. Some of the key options to consider include i) the systematic use of cover crops able to compete with weeds whenever there is no commercial crop growing, and ii) ensuring the presence of a thick mulch layer during the commercial crop cycle which can shade the soil surface and in some cases liberate allelopathic substances. Generally, after a few years of these practices, weed pressure decreases significantly making the systems less dependant on herbicides. Another option is to control cover crops mechanically with "Roller-knives", which is mostly feasible for annual cover crop species, (Ribeiro 2001; Calegari 2003).

5.5 Soil Microbiology

Soil microorganisms are the living and most active (labile) part of the soil organic matter (SOM), which is the main component of soil fertility in tropical highly weathered soils, such as the oxisols found in the Brazilian Cerrado Region. Indeed, in soils dominated by kaolinitic and other clays with variable charge, SOM is responsible not only for supplying nutrients but also for retaining them because it provides most of the soil cation exchange capacity.

Modification of the soil environment by various crop management systems affect crop growth through influences on microbial activity and nutrient mineralization-immobilization processes. These modifications cause a disruption in the original soil microbiological equilibrium. The clearing and cultivation of undisturbed native areas is accompanied by a decline in soil organic matter (Ayanaba, 1976, Luizão et al. 1982, Henrot and Robertson, 1994; Mendes 2002). However, because of the presence of fractions with different turnover times in the SOM, the response of total SOM to a change in vegetation cover and soil management could escape detection for several years, whereas the response of the active, more labile fraction can occur much more rapidly. Thus, soil microbial parameters are among the most sensitive indicators of changes in total organic matter caused by management practices.

Conventional tillage practices cause a disruption in soil aggregates and place crop residues in intimate contact with soil, leading to a more rapid decomposition than surface placement with no tillage (Ghidney and Alberts, 1993). Conservation tillage practices, especially no-till, result in the accumulation of organic matter in the first few centimeters of the soil profile. On the other hand, carbon levels at lower depths are similar in both systems, or slightly higher under plow tillage (Karlen et al, 1991). The stratification of SOM observed under not tillage systems associated with increased levels of soil moisture and smaller variations in temperature, due to soil cover, reflects directly upon the soil microbial community, which has its total microbial biomass and activity more concentrated in the first centimeters of the soil profile as well (Doran, 1980). For this reason the biological functioning of soils under no tillage systems is completely different of that found in soils under conventional tillage.

Understanding the biological functioning of soils along with the identification of early warning indicators of ecosystem stress is needed to provide strategies and approaches for land resource managers and policymakers to promote long-term agricultural sustainability (Dick , 1994; Totola and Chaer, 2002). Considering the ability of soil biological parameters being early and sensitive indicators of soil ecological stress or restoration, their determination is very important when we evaluate the impacts of different crop management practices on the soil properties .

State of the art in Brazil

Some of the microbiological data available for the Brazilian conditions show that the biological parameters can be used to evaluate the impacts of different management systems on soil quality. These data refer to a few number of experiments comparing no till and conventional tillage practices especially in the southern region of the country.

Among the studies carried out in Brazil, increases in the soil microbial biomass at 0 to 10 cm depth were observed in soils under no till as compared to conventional till (Cattelan &

Vidor, 1990; Carvalho, 1997; Cattelan et al., 1997; Hungria et al., 1997; Balota et al., 1998, Hungria et al., 2002). Moreover in the Parana state a reduction in the metabolic coefficient (qCO_2) associated with an increase in the soil microbial biomass was observed, indicating that in the long term no till might increase C sequestration in subtropical soils (Balota et al., 1998, 2004; Hungria et al., 2002). Balota et al. 2003 , reported in Paraná, increases of 100%, 54% and 39% in microbial biomass C, N and S, respectively for a clayey Oxisol under no tillage for 22 years, at the 0 to 5 cm depth. These authors also reported that the crop rotations had no effect on microbial biomass C and N. In relation to biological nitrogen fixation it was observed, in Paraná state, that the number of *Rhizobium* and *Bradyrhizobium* cells and the accumulation of flavonoids (nodulation genes inducers) were superior under no tillage (Hungria et al., 1997; Ferreira et al., 2000; Hungria, 2000). Bean and soybean nodulation were stimulated under no tillage resulting in higher yields (Voss & Sidiras, 1985; Hungria, 2000). The effects of no tillage in *Rhizobium* diversity under tropical conditions are almost unknown. In only one experiment carried out in Parana state with soybean isolates, it was observed through RAPD analysis (Random Amplified Polymorphic DNA), that the greatest number of genomic patterns occurred under no tillage as compared to the conventional tillage (Ferreira et al., 2000).

At the Cerrados region, studies were initiated in 1998, at Embrapa Cerrados, aiming to determine the changes promoted by different management systems on the dynamics of the microbial biomass and its activitie, in Cerrados soils, and also to evaluate the use of microbiological indicators to detect early changes that occur in native soils after their incorporation to agricultural systems (Oliveira, 2000; Oliveira et al., 2001; Mendes, 2002; Mendes & Vivaldi, 2001; Matsuoka et al., 2003; Mendes et al., 2003; Carneiro et al., 2004; Mendes et al., 2005). Areas under native vegetation (Matas de Galeria, Cerradão, Cerrado Sentido Restrito, Cerrado Ralo and Campo Sujo), no till and conventional tillage as well as pastures and integrated pastures/agricultural systems were evaluated. Soil samples were collected at two depths: 0 to 5 cm and 5 to 20 cm, in the dry and in the rainy seasons. The soil microbial biomass-C (SMBC) was determined by the chloroform-fumigation-incubation method as described by Jenkinson & Powlson (1976). Acid phosphatase, arilsulfatase and β-glucosidase activities were determined as described by Tabatabai (1994). These soil enzymes are associated with the P, S and C-cycle in the soil, respectively. The results showed that the impacts were more accentuated at the 0 to 5 cm depth. At the 0 to 5 cm depth, the no-tillage (NT) system presented higher levels of phosphatase, arilsulfatase and β-glucosidase activities as compared to the conventional tillage (Mendes et al., 2003; Carneiro et al., 2004). These effects were related to the lack of soil mechanical preparation, fertilizers' placement, and to the accumulation of crop residues at the soil surface. In relation to the areas under native vegetation, located near the experiments, significant reductions in microbial biomass and phosphatase activity associated with increased levels of mineralizable carbon and activity levels of the soil enzyme β-glucosidase were observed in the agricultural areas (Mendes, 2002; Matsuoka et al., 2003 and Mendes et al., 2003).

Final Considerations

The inadequate management of Brazilian soils for agriculture purposes has resulted in huge extensions of areas under some stage of soil degradation. The search for agricultural practices that are able to promote high yield, while maintaining the sustainability of the agroecosystems has been one of the greatest challenges for the Research & Development institutions. Many evidences show that the microbiological indicators are able to detect early changes in soil quality, as opposed to the chemical and physical parameters, which change in advanced stages of soil degradation. The understanding about the biological functioning of tropical soils in the different regions of Brazils is at its very beginning. Since there is a variety of methods to assess the microbiological status of a soil, studies must be conducted to define what methods should be included in a data set of microbial indicators of soil quality. Considering the continental dimensions of Brazil, it is possible that this data set might vary from region to region and even among the different management systems. Another challenge consists in defining the critical values for each of the parameters of these data set, and to consider them in concert with soil chemical and physical measurements. In order to build up a vigorous and consistent data bank regarding the biological functioning of Brazilian soils it will be necessary a national effort, involving researchers all over the country, in order to standardize the procedures for soil sampling and also for the analytical procedures. The idea is that in the future, assessments of the biological status of a given soil could be made in a routine basis by using proper indicators that are at the same effective, simple, cheap and relatively rapid, allowing the farmer to evaluate the impacts of local management systems on soil quality.

It is important also to expand these studies to other regions in Brazil, specially the North and the Northeast, and also to include areas under organic agriculture. By disallowing the use of synthetic pesticides and fertilizers, relying on practices such as crop rotations, use of animal and green manures and biological pest control, organic farming systems have a completely different dynamics of soil functioning, showing greater dependence on the biological component than the conventional farming systems. Studies on the impacts of agricultural systems on soil microbial biodiversity also are extremely necessary.

References

ALMEIDA, A.C.R. 2000. Uso associado de esterco líquido de suínos e plantas de cobertura de solo na cultura do milho. Tese de Mestrado. Santa Maria: UFSM. 114 p.

AMADO, T.J.; FERNANDEZ, S.B.; MIELNICZUK, J. (1998) Nitrogen availability as affected by ten years cover crop and tillage systems in southern Brazil, Brazilian Journal of Soil and Water Conservation 5, 268 271.

AMADO, T.J.; PONTELLI, C.B.; JÚNIOR, G.G.; BRUM, A.C.R.; ELTZ, F.L.F.; PEDRUZZI, C. 1999.Seqüestro de carbono em sistemas conservacionistas na Depressão Central de Rio Grande do Sul. In: V Reunión bienal de la red latinoamericana de agricultura conservacionista. p.42 43, Florianópolis, 57p.

ANAPO (2004). No tillage rotation of crops, Agricultura Sostenible Program (PAS).

ANAPO/CAO (2005) Document without publishing.

ANDRIULO, A.; SASAL, C.; RIVERO, M.L. 2002. Los Sistemas de Producción Conservacionistas como Mitigadores de la Perdida de Carbono Orgánico del Suelo. En Siembra Directa II, J.L. Panigatti, D. Buschiazzo, H. Marelli (Editores). Ediciones Instituto Nacional de Tecnología Agropecuaria. Argentina. Buenos Aires. Págs. 17:28. ISBN 982-521-046-3.

ARZENO, J.L. 1993. Siembra Directa en el NOA. En : II Congreso Nacional de SIEMBRA DIRECTA, Agricultura de fin de Siglo. Trabajos Presentados. Huerta Grande Córdoba, 8,9 y 10 de Septiembre de 1993. Págs. 117:133. AAPRESID Paraguay 777. Piso 8. Of. 4. 2000 Rosario República Argentina.

BALOTA, E.L.; COLOZZI-FILHO, A.; ANDRADE, D.S.; DICK, R.P. Microbial biomass in soils under different tillage and crop rotation systems. Biology and Fertility of Soils, 38: 15-20, 2003.

BALOTA, E.L.; COLOZZI-FILHO, A.; ANDRADE, D.S.; HUNGRIA, M. Biomassa microbiana e sua atividade em solos sob diferentes sistemas de preparo e sucessão de culturas. Revista Brasileira de Ciência do Solo, Campinas, v. 22, p.641-649, 1998.

BARCELOS, A.A.; CASSOL, E.A .; DENARDIN, J.E. Infiltração de água em um latossolo vermelho-escuro sob condições de chuva intensa em diferentes sistemas de manejo. Revista Brasileira de Ciência do Solo, 23(1):35-43, 1999.

BARTZ, H.R. Dinâmica dos nutrientes e adubação em sistemas de produção sob plantio direto. http://www.rau.edu.uy/agro/eupp/siembra6.htm. 2003.

BAYER, C.; MARTIN NETO, L.; MIELNICZUK, J.; CERETTA, C.A. Effect of no till cropping systems on soil organic matter in a sandy clay loam Acrisol from Southern Brazil monitored by electron spin resonance and nuclear magnetic resonance. Soil and Tillage Research. 2000; 53(2): 95 104.

BAYER, C.; MARTIN-NETO, L.; MIELNICZUK, J.; CERETTA, C.A. Effect of no-till cropping systems on soil organic matter in a sandy clay loam Acrisol from southern Brazil monitored by electron spin resonance and nuclear magnetic resonance. Soil Till. Res., 53:95-104, 2000a.

BAYER, C.; MIELNICZUK, J. Inter-relações do manejo com as propriedades físicas e químicas de solos intensivamente cultivados. In: CARLESSO, R. Irrigação por aspersão no Rio Grande do Sul. Santa Maria, 2001. 165p.

BAYER, C.; MIELNICZUK, J.; AMADO, T.J.C.; MARTIN NETO, L.; FERNANDES, S.V. 2000. Organic matter storage in a sandy clay loam acrisol affected by tillage and cropping systems in Southern Brazil. Soil and Till. Res. 54:101 109.

BAYER, C.; MIELNICZUK, J.; MARTIN NETO, L. Efeito de sistemas de preparo e de cultura na dinâmica da matéria orgânica e na mitigação das emissões de CO_2. Revista Brasileira de Ciência do Solo. 2000; 24(3): 599 607.

BELLOSO, C. 1999. Análisis y Manejo del Sistema de Producción con Información Geo-referenciada. En Manuales del VII Congreso Anual de AAPRESID. Mar del Plata 18 al 20 de Agosto 1999. Tomo II. Págs. 183:188. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.

BOLINDER, M.A.; ANGERS, D.A.; GIROUX, M.; LAVERDIÈRE, M.R. Estimating C inputs retained as soil organic matter from corn (Zea mays L.). Plant Soil, 215:85-91, 1999.

BORLETTO, J.M. 2001. Franjas con Distintos Tratamientos de Fertilización. En, Resúmenes del primer Seminario AAPRESID para Estudiantes. Págs. 87:93. AAPRESID. Paraguay 777, 8vo Piso. Of. 4. 2000 Rosario. Prov. de Santa Fé. República Argentina.

BRAGACHINI, M. 1999.Agricultura de Precisión para Aumentar la Productividad. En Manuales del VII Congreso Anual de AAPRESID. Mar del Plata 18 al 20 de Agosto 1999. Tomo II. Págs. 265:272. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.

BRAGACHINI, M.T. 2000. Manejo Sitio Específico de los Cultivos, Agricultura de Precisión Presente y Futuro. En El Desafío es Innovar. Proceedings del VIII Congreso Anual de AAPRESID. Mar del Plata 16 al 18 de Agosto 2000. Tomo II. Págs. 59:65.

CAIRES, E.F. Manejo da fertilidade do solo no sistema plantio direto: experiência no estado do Paraná. In: REUNIÃO BRASILEIRA DE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS, 24, 2000. Santa Maria. Fertbio 2000. Santa Maria: SBCS, 2000. CD-ROM.

CALEGARI, A.; FERRO, M.; GRZESTUK, F.; JACINTO JR., L. Plantio direto e rotação de culturas. Experiência em Latossolo Roxo. IAPAR-COCAMAR-ZENECA. Maringá, 1992. 1 v.

CAMPERO, M.; WALL, P.C. 1999. Strubble effects in the soil surface on the hydric balance and the yield. Memories, III National Meeting of Wheat and Smaller Cereals. Cochabamba, Bolivia 115-121 p.

CARMONA, M. 2003. La Rotación de Cultivos, El porque de su escasa adopción, la relación con la Siembra Directa y sus efectos positivos para el agrosistema y el manejo de enfermedades. En: "La Hora Del Empowerment". Proceedings del XI Congreso Anual de AAPRESID. Tomo I. Págs. 227:235. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000 Rosario. República Argentina.

CARMONA, M. 2003. La Rotación de Cultivos, El porque de su escasa adopción, la relación con la Siembra Directa y sus efectos positivos en el agro ecosistema y el manejo de las enfermedades. En “Rotaciones en Siembra Directa”. Revista Técnicas de la Asociación Argentina de Productores en Siembra Directa. Diciembre del 2003. Págs. 37:42. AAPRESID Calle Paraguay 777. Piso 8. Of. 4. 2000 Rosario. Republica Argentina.

CARNEIRO, R.G; MENDES, I.C; LOVATO, P.E; CARVALHO, A.M. Indicadores biológicos associados ao ciclo do fósforo em solos de Cerrado sob plantio direto e plantio convencional Pesquisa Agropecuária Brasileira, Brasília, v.39, n.7 p. 661-669, 2004.

CARPENEDO, V.; MIELNICZUK, J. Estado de agregação de Latossolos Roxos submetidos a diferentes sistemas de manejo. R. bras. Ci. Solo, Campinas – SP, 14: 99-105, 1990.

CARVALHO, Y. Densidade e atividade dos microrganismos do solo em plantio direto e convencional, na região de Carambeí – PR. 1997. (Mestrado em Agronomia). Agronomia, Universidade Federal do Paraná, Curitiba.

CASAS, R. 2002. El Aumento de la Materia Organica en Suelos Argentinos – El Aporte de la Siembra Directa. En “XI Congreso Nacional de AAPRESID - Darse Cuenta”. Proceedings del XI Congreso Anual de AAPRESID. Tomo I. Págs. 155:168. AAPRESID Paraguay 777. Piso 8. Of .4. 2000 Rosario. República Argentina.

CASTRO FILHO, C.; LOURENÇO, A.; GUIMARÃES, M. de F.; FONSECA, I.C.B. (2002) Aggregate stability under different soil management systems in a red latosol of Paraná, Brazil, Soil & Tillage Research 65, 45 51.

CASTRO FILHO, C.; MUZILLI O.; PODANOSCHI, A.L. (1998) Estabilidade dos agregados e sua relação com o teor de carbono orgânico num Latossolo Roxo distrófico, em função de sistemas de plantio, rotação de culturas e métodos de preparo das amostras, Revista Brasileira de Ciência do Solo 22, 527 538.

CATTELAN, A.J.; GAUDÊNCIO, C.A.; SILVA, T.A. Sistemas de culturas em plantio direto e os microrganismos do solo, na cultura da soja, em Londrina. Revista Brasileira de Ciência do Solo, Campinas, v.21, p.293-301, 1997.

CATTELAN, A.J.; VIDOR; C. Sistemas de culturas e a população microbiana do solo. Revista Brasileira de Ciência do Solo, Campinas, v.14, p.125-132, 1990.

CERETTA, C.A.; DURIGON, R.; BASSO, C.J. et al. 2003. Características químicas de solo sob aplicação de esterco líquido de suínos em pastagem natural. Pesq. agropec. bras., Jun/2003, v. 38, n. 6. p. 729-735.

CHESTA, M.O. 2001. Experiencia en diez años de Siembra Directa en Suelos Vertisoles. En, Resúmenes del primer Seminario AAPRESID para Estudiantes. Págs. 94:96. AAPRESID. Paraguay 777, 8vo Piso. Of. 4. 2000 Rosario. Prov. de Santa Fé. República Argentina.

CORAZZA, E.J.; SILVA, J.E.; RESCK, D.V.S.; GOMES, A.C. (1999) Comportamento de diferentes sistemas de manejo como fonte e depósito de carbono em relação a vegetação de Cerrado, Revista Brasileira de Ciência do Solo 23, 425 432.

DENARDIN, J.E.; KOCHHANN, R.A.; DENARDIN, N.D. Adensamento e compactação em latossolos: fatos e hipóteses. In: WORLD CONGRESS ON CONSERVATION AGRICULTURE, 2, 2003, Iguassu falls. Producing in harmony writ nature: extended summary e posters =Fóz do Iguaçú: Federação Brasileira de Plantio Direto na Palha; Confederacción de Associaciones Americanas para la Agricultura Sustentavel, 2003. p. 482-485.

DENARDIN, J.E.; KOCHHANN, R.A.; FAGANELLO, A.; SATTLER, A. Evolução da área cultivada sob sistema plantio direto no Rio Grande do Sul. Passo Fundo, Embrapa Trigo, 2001. 32p. (Embrapa Trigo. Documentos, 29).

DERPSCH, R. 1997. Importancia de la Siembra Directa, para obtener la sustentabilidad de la producción agrícola. In Proceedings of the V AAPRESID annual No Till Conference. Pág. 153:176. AAPRESID, Calle Paraguay 777, Piso 8. Of. 4. 2000 Rosario, República Argentina.

DERPSCH, R.; CALEGARI, A. Plantas para adubação verde de inverno. Londrina: IAPAR, 1992. 80p. (IAPAR, Circular, 73).

DERPSCH, R.; ROTH, C. H.; SINDIRAS, N.; KÖPKE, C. V. Controle da erosão no Paraná, Brasil: Sistemas de cobertura do solo, plantio direto e preparo conservacionistas do solo. Londrina: GTZ - IAPAR, 1991, 272p.

DERPSCH, R.; ROTH, C.H.; SIDIRAS, N.; KÖPKE, U. Importância da rotação de culturas. In: DERPSCH, R.; ROTH, C.H.; SIDIRAS, N.; KÖPKE, U. Controle da erosão no Paraná, Brasil: sistemas de cobertura do solo, plantio direto e preparo conservacionista do solo. Eschborn: GTZ; IAPAR, 1991. p.147-164.

DÍAZ-ZORITA, M.; GROVE, J.H.2002. Rotaciones de Cultivos en Siembra Directa y las propiedades de Suelo en la Pampa Arenosa. En Siembra Directa II, J.L. Panigatti, D. Buschiazzo, H. Marelli (Editores). Ediciones Instituto Nacional de Tecnología Agropecuaria. Argentina. Buenos Aires. Págs. 235:238. ISBN 982-521-046-3.

EKBOIR, J. 2003. Sistemas de Innovación Política y Tecnológica. Siembra Directa en MERCOSUR. En “ XI Congreso Anual de AAPRESID – Darse Cuenta”. Proceedings del XI congreso Anual de AAPRESID. Tomo I “Actas”. Págs. 99-109. AAPRESID Paraguay 777. Piso 8. Of. 4. 2000 Rosario Rep Argentina.

ELTZ, F.L.F.; PEIXOTO, R.T.G.; JASTER, F. Efeitos de sistemas de preparo do solo nas propriedades físicas e químicas de um Latossolo Bruno Álico. R. bras. Ci. Solo, Campinas, 13 : 259-267, 1989.

FELLER, C.; BEARE, M.H. Physical control of soil organic matter dynamics in the tropics. Geoderma, 79:69-117, 1997.

FERRARI, M. 1998. La Siembra Directa y el rendimiento de los Cultivos en la Pampa Húmeda”. En Panigatti J.L. y otros. Editores “Siembra Directa”. Págs. 191:196. Editorial Hemisferio Sur. Pasteur 743 – 1028 Buenos Aires. República Argentina. ISBN 950-504-551-4.

FERREIRA, M.C.; ANDRADE, D.S.; CHUEIRE, L.M.O.; TAKEMURA, S.M.; HUNGRIA, M. Effects of tillage method and crop rotation on the population sizes and diversity of bradryhizobia nodulating soybean. Soil Biology & Biochemistry, Oxford, v.32, p.627-637, 2000.

FERRI, M.V.W., VIDAL, R.A., GOMES, J. et al. 2002.Atividade do herbicida acetochlor em solo submetido à semeadura direta e ao preparo convencional. Pesq. agropec. bras., Dez 2002, vol.37, no.12, p.1697-1703.

FERRI, M.V.W.; PERALBA, M.C.R.; ELTZ, F.L. et al. 2004. Efeito da cobertura do solo nas perdas por erosão hídrica do herbicida imazethapyr. Boletim Informativo da Sociedade Brasileira da Ciência das Plantas Daninhas (SBCPD), v. 10 (supl.), p.94. 2004.

FERRI, M.V.W.; PERALBA, M.C.R.; ELTZ, F.L. et al. 2004. Efeito do preparo do solo sobre o transporte dos herbicidas alachlor e atrazina por erosão hídrica. Boletim Informativo da Sociedade Brasileira da Ciência das Plantas Daninhas (SBCPD), v. 10 (supl.), p.93. 2004.

FONTANETTO, H.; SÉLLER, O. 2001(b). Efecto de Diferentes Secuencias de Cultivos en Siembra Directa Continua. En Siembra Directa en el Cono Sur: Coordinador Díaz Rosello, Roberto. Págs. 269:273. PROCISUR. Montevideo, Uruguay. ISBN 92-9039-515 X.

FRANCHINI, J.C.; MALAVOLTA, E.; MIYAZAWA, M.; PAVAN, M.A. Alterações químicas em solos ácidos após a aplicação de resíduos vegetais. R. Brás. Ci. Solo., Viçosa, 23(3):533-542, 1999.

FREIRE, F.M.; VASCONCELLOS, C.A.; FRANÇA, G.E. de. Manejo da fertilidade do solo em sistema plantio direto. Informe Agropecuário, Belo Horizonte, 22(208):49-62, 2000.

FREIXO, A.A.; MACHADO, P.L.O. de A.; SANTOS, H.P. dos; SILVA, C.A.; FADIGAS, F. de S. Soil organic carbon and fractions of a Rhodic Ferralsol under the influence of tillage and crop rotation systems in southern Brazil. Soil and Tillage Research. 2002; 64(3/4): 221 230.

GHIO, H. 1999. Producción en Agricultura Continua. En Manuales del VII Congreso Anual de AAPRESID. Mar del Plata 18 al 20 de Agosto 1999. Tomo II. Págs. 197:210. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.

GUDELJ, V.; otros. 2002. 16 Años de Experiencias de Fertilización en Siembra Directa. Ensayo de Larga Duración. En “Los Rastrojos y Mas allá de los Rastrojos”. Manual del X Congreso Anual de AAPRESID.Tomo I. Págs. 239:256. AAPRESID Paraguay 777. Piso 8. Of 4. 2000 Rosario. República Argentina.

HERNANI, L.C.; SALTON, J.C.; FABRÍCIO, A.C.; DEDECEK, R.; ALVES JR., M. Perdas por erosão e rendimentos de soja e de trigo em diferentes sistemas de preparo de um Latossolo Roxo de Dourados (MS). Rev. Bras. Ci. Solo, 21(4):667-676, 1997.

HUNGRIA, M.; ANDRADE, D.S.; BALOTA, E.L.; COLOZZI-FILHO, A. Importância do sistema de semeadura direta na população microbiana do solo. Londrina: EMBRAPA-CNPSo, 1997. 9p. (EMBRAPA-CNPSo. Comunicado Técnico, 56).

HUNGRIA, M.; CAMPO, R.J.; FRANCHINI, J.C.; CHUEIRE, L.M.O.; MENDES, I.C.; ANDRADE, D.S.; COLOZZI-FILHO, A.; BALOTA, E.L.; LOUREIRO, M.F. Microbial quantitative and qualitative changes in soils under different crops and tillage management systems in Brazil. In: INTERNATIONAL TECHNICAL WORKSHOP ON BIOLOGICAL MANAGEMENT OF SOIL ECOSYSTEMS FOR SUSTAINABLE AGRICULTURE. Program, abstracts and related documents... Londrina: Embrapa Soja, 2002. p.76.

KAMINSKI, J. coord. Uso de corretivos da acidez do solo no plantio direto. Pelotas: SBCS-Núcleo Regional Sul, 2000. 123p. (SBCS- Núcleo Regional Sul. BoletimTécnico, 4).

KIEHL, E. J. Manual de edafologia. São Paulo. Ed. Agronômica Ceres. 264 p. Cap. 10: Estrutura, p. 145 – 160. 1979.

KLUTHCOUSKI, J.; FANCELLI, A.L.; DOURADO-NETO, D. Manejo do solo e o rendimento de soja, milho, feijão e arroz em plantio direto. Scientia Agrícola, 57(1):97-104, 2000.

KOCHHANN, R.A. Alterações das características físicas, químicas e biológicas do solo sob sistema plantio direto. In: CONFERÊNCIA ANUAL DE PLANTIO DIRETO, 1. Passo Fundo, RS. Anais... Passo Fundo, 1996. p. 17-25.

LANDERS, J.N. Fascículo de experiências de plantio direto no Cerrado. Associação de Plantio Direto no Cerrado, 1995. 259p.

LIMA, V.C.; LIMA, J.M.C.; EDUARDO, B.J.P.; CERRI, C.C. (1994) Conteúdo de carbono e biomassa microbiana em agrosistemas: comparação entre métodos de preparo do solo, Agrárias Curitiba 13, 297 302.

LOPES, A.S.; WIETHÖLTER, S.; GUIMARÃES, L.R.; SILVA, C.A. Sistema plantio direto: bases para o manejo da fertilidade do solo. São Paulo, ANDA, 2004. 110p.

MACHADO, P.L.O. de A.; SILVA, C.A. Soil management under no tillage systems in the tropics with special reference to Brazil. Nutrient Cycling in Agroecosystems. 2001; 61(1/2): 119 130.

MATSUOKA, M.; MENDES, I.C.; LOUREIRO, M.F. Biomassa microbiana e atividade enzimática em solos sob vegetação nativa e sistemas agrícolas anuais e perenes na região de Primavera do Leste/MT. Revista Brasileira de Ciência do Solo, Viçosa, v.27, p. 425-433, 2003.

MENDES, I. C. Impactos de sistemas agropecuários na atividade enzimática e biomassa microbiana dos solos de Cerrado. In: II CONGRESSO BRASILEIRO DE SOJA /MERCOSOJA 2002, 2002, Foz do Iguaçu. Anais do II Congresso de Soja: Perspectivas do agronegócio da soja. Londrina: Documentos/Embrapa Soja, 2002. p. 246-257.

MENDES, I. C.; SOUZA, L. V.; RESCK, D. V. S.; GOMES, A. C. Propriedades biológicas em agregados de um LE sob plantio convencional e direto no Cerrado. Revista Brasileira de Ciência do Solo, Viçosa, v. 27, p. 435-443, 2003.

METAY, A. (2004) Influence of no tillage and cover plants on N2O production and emission from soils in the Cerrados (Brazil), International conference on greenhouse gas emissions from agriculture, mitigations options and strategies, Leipzig, Germany, February 2004, Congress communications.

MICHELENA, R.; otros. 2001. Fertilidad y Propiedades Físicas de Diferentes Suelos en Siembra Directa. En: Los Desafíos de la Agricultura en un Complejo Mundo Globalizado. Proceedings del IX Congreso Anual de AAPRESID. Mar del Plata 16 al 18 de Agosto 2000. Tomo I. Págs. 177:186. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.

MILLER, R.M.; JASTROW, J.D. Hierarchy of root and mycorrhizal fungal interactions with soil aggregation. Soil Biol. Biochem., 22:579-584, 1990.

MIYASAKA, S.; MEDINA, J.C. A soja no Brasil. Campinas, SP, ITAL. 1062p. 1981.

MIYAZAWA, M.; PAVAN, M.A.; CALEGARI, A. efeito de material vegetal na acidez do solo. R. Brás. Ci. Solo, Campinas, 17(3):411-416, 1993.

MIYAZAWA, M.; PAVAN, M.A.; FRANCHINI, J.C. Resíduos vegetais : influência na química de solos ácidos. In: SIMPÓSIO SOBRE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS NO SISTEMA PLANTIO DIRETO, 1., Ponta Grossa, 2000. Anais... Ponta Grossa:Associação dos Engenheiros Agrônomos dos Campos gerais, 2000. p.82-94.

MONTERO, F.; SAGARDOY, M. 2000. Estudios Microbiológicos en Suelos Cultivados bajo Siembra Directa en Argentina. . En El Desafío es Innovar. Proceedings del VIII Congreso Anual de AAPRESID. Mar del Plata 16 al 18 de Agosto 2000. Tomo I. Págs. 217-222. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.

MUNDSTOCK, C.M. A evolução da genética e da tecnologia da cultivo de milho no Rio Grande do Sul. Cláudio Mário Mundstock, Porto Alegre: Departamento de Plantas de Lavoura da Universidade Federal do Rio Grande do Sul: Evangraf, 2004. 34p.

MUZILLI, O. Influência do sistema de plantio direto, comparado ao convencional, sobre a fertilidade da camada arável do solo. R. Bras. Ci. Solo, 7(1):95-102, 1983.

MUZILLI, O. Manejo da matéria orgânica no sistema plantio direto: a experiência no Estado do Paraná. <http://www.ppifar.org/ppiweb/pbrazil.nsf. 2003.

MUZILLI, O.; VIEIRA, M.J.; OLIVEIRA, E.L. Avaliação dos sistemas de plantio direto e convencional em diferentes sucessões de culturas. Londrina, PR: IAPAR – Programa Recursos Naturais. Relatório Técnico Anual, 1994. 1 v.

OLIVEIRA, G.C. DIAS JUNIOR, M.S.; RESCK, D.V.S.; CURI, N. Caracterização química e físico hídrica de um Latossolo Vermelho apos vinte anos de manejo e cultivo do solo. Revista Brasileira de Ciência do Solo. 2004; 28(2): 327 336.

PAZ, C.E. (1999), Program of Agricultura Sostenible (PAS) in Santa Cruz of the mountain range, published in memories of III National Meeting of Wheat and Smaller cereals, p. 185 – 189.

PEIRETTI, R.A. 1998. La Siembra Directa y las rotaciones como estrategia de crecimiento empresarial. En Proceedings del VI Congreso anual de AAPRESID. AAPRESID, Paraguay 777. 8vo Piso. Of. 4. 2000 Rosario. Republica Argentina. Págs. 67-123.

PEIRETTI, R.A. 2003. The CAAPAS actions and the development of the MOSHPA. In Proceedings of the II World Congress on Conservation Agriculture. Vol. I. Págs. 127.128. Printed by Federacao Brasileira do Plantio Directo Na Phala. Rua 7 de Setembro, 800 - Sala 301 A - ,CEP 84350-210 – Ponta Grossa – Paraná – Brasil.

PEIRETTI, R.A. 2004. The No Till Cropping System and its evolution toward the achievement of the MOSHPA Model Principles. In Proceedings of the World Soybean Congress- Foz de Iguazú, Brazil, March 1-5, 2004. 282-290. Copyrighted by EMBRAPA Brazil. ISBN 85-7033-004-9 . pp. 282-290

PEIXOTO, R.T.; STELLA, L.M.; MACHULEK JUNIOR, A.; MEHL, H.U.; BATISTA, E.A. (1999) Distribuição das frações granulométricas da matéria orgânica em função do manejo do solo, in: Anais 3º Encontro brasileiro sobre substâncias húmicas, Santa Maria, Brasil, pp. 346 348.

PORT, O.; AITA, C.; GIACOMINI, S.J. 2003. Perda de nitrogênio por volatilização de amônia com o uso de dejetos de suínos em plantio direto. Pesq. agropec. bras. Jul/2003, v. 38, n. 7. p. 857-865.

PROTRIGO (Investigation and Technology Transference for wheat crop National Program) Secend phase. (2002). Technical studies about the Valleys region, Bolivia. ANNEXED 74.

PROTRIGO (Investigation and Technology Transference for Wheat National Program) 2002, Final Design, Second Phase. Santa Cruz, Bolivia. 15-20 p.

PURICELLI, C.A.; ECHEVERRIA N.E.; PELTA H.R.2002. Cambio en Algunas Propiedades del Suelo Bajo Siembra Directa. En Siembra Directa II, J.L. Panigatti, D. Buschiazzo, H. Marelli (Editores). Ediciones Instituto Nacional de Tecnología Agropecuaria. Argentina. Buenos Aires. Págs. 225:233. ISBN 982-521-046-3.

QUIROGA, A.; ORMEÑO, O.; OTAMENDI, H. 1998. La Siembra Directa y el Rendimiento de los Cultivos en la Región Semiárida Pampeana Central". En Panigatti J.L. y otros. Editores "Siembra Directa". Págs. 237:43. Editorial Hemisferio Sur. Pasteur 743 – 1028 Buenos Aires. República Argentina. ISBN 950-504-551-4.

REINERT, D. J.; MUTTI, L. S. M.; ZAGO, A. ; AZOLIN, M. A.; D. HOFFMANN, C. L. Efeito de diferentes métodos de preparo do solo sobre a estabilidade de agregados em solo Podzólico Vermelho Amarelo. R. Cent. Ci. Rurais., Santa Maria, 14: 19-25, 1984.

RESCK, D.V.S.; VASCONCELLOS, C.A.; VILELA, L.; MACEDO, M.C.M. (2000) Impact of conversion of Brazilian Cerrados to cropland and pastureland on soil carbon pool and dynamics, in: Lal R., Kimble J.M., Stewart B.A. (Eds.), Global climate change and tropical ecosystems, Advances in Soil Science, CRC Press Boca Raton, pp 169 196.

RHEINHEIMER, D; ANGHINONI, I. Distribuição do fósforo inorgânico em sistemas de manejo do solo. Pesquisa Agropecuária Brasileira. Brasília, 36(1):151-160, 2001.

RIEZEBOS, H.T.H.; LOERTS, A.C. (1998) Influence of land use change and tillage practice on soil organic matter in southern Brazil and eastern Paraguay, Soil & Tillage Research 49, 271 275.

RODRIGUES, B.N.; FORNAROLLI, D. A.; LIMA, J. et al. 2000.Comportamento de herbicidas pré-emergentes aplicados sobre cobertura morta em plantio direto. In: Congresso Brasileiro da Ciência das Plantas Daninhas, XXII. Foz do Iguaçu. 2000. Resumos. Londrina:SBCPD. p.380.

ROSCOE, R.; BUURMAN, P. (2003) Tillage effects on soil organic matter in density fractions of a Cerrado Oxisol, Soil & Tillage Research 70, 107 119.

ROSSO, H. 1992. Nuestra Evolución Hacia la Siembra Directa. En : Primer Congreso Interamericano de Siembra Directa Trabajos Presentados. Villa Giardino (Córdoba) 25 al 28 de Marzo de 1992. Págs. 28:33. AAPRESID Paraguay 777. Piso 8. Of. 4. 2000 Rosario Rep Argentina.

ROSSO, H. 2001. Siembra Directa: Por que el Cambio?. En, Resúmenes del primer Seminario AAPRESID para Estudiantes. Págs. 33:35. AAPRESID. Paraguay 777, 8vo Piso. Of. 4. 2000 Rosario. Prov. Snata Fe. República Argentina.

RUEDELL, J. Plantio direto na região de Cruz Alta. Cruz Alta: FUNDACEP/FECOTRIGO, 1995. 134P.

RUFFO, M.L. 2003(b). Factibilidad de Inclusión de Cultivos de Cobertura en Argentina. En: “La Hora Del Empowerment”. Proceedings del XI Congreso Anual de AAPRESID. Tomo I. Págs. 133:138. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000 Rosario. República Argentina.

RUFFO, M.L.; PARSONS, A.T. 2003(a). Cultivos de Coberturas en Rotaciones Agrícolas Mixtas. En “Rotaciones en Siembra Directa”. Revista Técnicas de la Asociación Argentina de Productores en Siembra Directa. Diciembre del 2003. Págs. 31:35. AAPRESID Calle Paraguay 777. Piso 8. Of. 4. 2000 Rosario. Republica Argentina.

SÁ, J.C. de M. Manejo da fertilidade do solo no plantio direto. Castro, PR: Fundação ABC, 1993. 96p.

SÁ, J.C. de M. Manejo da fertilidade do solo no sistema plantio direto. In: SIQUEIRA, J.O.; MOREIRA, F.M.S.; LOPES, A.S.; GUILHERME, L.R.G.; FAQUIM, V.; FURTINI NETO, A.E.; CARVALHO, J.G. (eds). Inter-relação fertilidade, biologia do solo e nutrição de plantas. Lavras; SBCS, 1999. p.267-319.

SÁ, J.C. de M. Manejo de nitrogênio na cultura de milho no sistema plantio direto. Passo Fundo: Aldeia Norte, 1996. 23p.

SÁ, J.C. de M. Plantio direto: transformações e benefícios ao agroecossistema. In: CURSO SOBRE MANEJO DO SOLO NO SISTEMA PLANTIO DIRETO, 1995, Castro, Fundação ABC, Anais..., 1995a. p.9-20.

SÁ, J.C.de M. Fósforo: resposta das culturas de milho, trigo e soja no sistema plantio direto. In: CURSO SOBRE MANEJO DO SOLO NO SISTEMA PLANTIO DIRETO, 1995, Castro, Fundação ABC, Anais..., 1995b. p.256-263.

SÁ, J.C.M. (2001) Dinâmica da matéria orgânica do solo em sistemas de manejo convencional e plantio direto no estado do Paraná, PhD Thesis, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

SAGARDOY, M.A.; otros. 2002. Influencia del Sistema de Siembra Directa sobre los Microorganismos del Suelo. En Siembra Directa II, J.L. Panigatti, D. Buschiazzo, H. Marelli (Editores). Ediciones Instituto Nacional de Tecnología Agropecuaria. Argentina. Buenos Aires. Págs. 69:82. ISBN 982-521-046-3.

SALET, R.L. Toxidez de alumínio no sistema plantio direto. Porto Alegre: Universidade Federal do rio Grande do Sul, 1998. 117p. (Tese de Doutorado).

SALTON, J.C.; FABRÍCIO, A.C.; MACHADO, L.A.Z.; MELHO FILHO, G.; URCHEI, M.A.; OLIVEIRA, H.; BROCH, D.L.; FREITAS, P.L. de; MUSSURY, R.M.; RICHETII, A. Impacto ambiental de sistemas intensivos de produção de grãos e de carne bovina na região oeste do Brasil. In: ROSSELLO, R. coord. Siembra Directa en el Cono Sur. Montevideo: PROCISUR, 2001. p.43-53.

SALTON, J.C.; HERNANI, L.C.; FONTES, C.Z. Sistema plantio direto: o produtor pergunta, a Embrapa responde. Brasília: Embrapa-SPI; Dourados: Embrapa-CPAO, 248p, 1998. (Coleção 500 perguntas, 500 respostas).

SANTOS, H.P. dos. Efeito da rotação de culturas no rendimento, na eficiência energética e econômica do trigo, em plantio direto. 136p. 1992. Tese (Doutorado) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

SANTOS, H.P. dos; AMBROSI, I.; LHAMBY, J.C.B.; CARMO, C. do. Lucratividade de sistemas de manejo de solo e de rotação e sucessão de culturas. Ciência Rural, Santa Maria, 34(1):97-103, 2004.

SANTOS, H.P. dos; IGNACZAK, J.C.; LHAMBY, J.C.B.; CARMO, C. do. Conversão e balanço energético de sistemas de manejo de solo e de rotação de culturas. Pesq. Agrop. Gaúcha, 9(1-2):113-120, 2003a.

SANTOS, H.P. dos; LHAMBY, J.C.B.; LIMA, M.R. de. Efeito de métodos de preparo de solo no inverno e de rotação de culturas no rendimento de grãos de soja. Pesq. Agrop. Gaúcha, 7(1):69-76, 2001.

SANTOS, H.P. dos; LHAMBY, J.C.B.; PRESTES, A.M.; LIMA, M.R. de. Efeito de manejos de solo e de rotação de culturas de inverno no rendimento e doenças de trigo. Pesq. agropec. bras., Brasília, 35(12):2355-2361, 2000.

SANTOS, H.P. dos; REIS, E.M. Rotação de culturas. In: SANTOS, H.P. dos; REIS, E.M. Rotação de culturas em plantio direto. Passo Fundo: Embrapa Trigo, 2001. p.12-132.

SANTOS, H.P. dos; REIS, E.M.; DERPSCH, R. Rotação de culturas. In: EMBRAPA. Centro Nacional de Pesquisa de Trigo. Plantio direto no Brasil. Passo Fundo: Embrapa-CNPT; FUNDACEP FECOTRIGO; Fundação ABC; Aldeia Norte, 1993. p.85-103.

SANTOS, H.P. dos; REIS, E.M.; LHAMBY, J.C.B.; SANDINI, I. Características agronômicas e controle de doenças radiculares da cevada, em sistema plantio direto em rotação com outras culturas. Pesquisa Agropecuária Brasileira, Brasília. 30(11):1297-1303, 1995.

SANTOS, H.P. dos; TOMM, G.O. Disponibilidade de nutrientes e teor de matéria orgânica em função de sistemas de cultivo e de manejo de solo. Ciência Rural, Santa Maria, 33(3):477-486, 2003.

SANTOS, H.P. dos; TONET, G.E.L. Efeito de sistemas de produção incluindo culturas produtoras de grãos e pastagens anuais de inverno e de verão no rendimento de grãos e em outras características agronômicas de soja, sob sistema plantio direto. In: EMBRAPA, Centro Nacional de Pesquisa de Trigo. Soja: resultados de pesquisa do Centro Nacional de Pesquisa de Trigo, 1996/97. Passo Fundo, 1997. p.88-93. (Embrapa-CNPT. Documentos, 35).

SEGUY, L. ; BOUZINAC, S. ; PACHECO, A. ; CARPENEDO, V.; SILVA, V. de. Perspectiva da fixação da agricultura na região Centro Oeste de Mato Grosso. EMPA-MT, EMBRAPA-CNPAF, CIRAD-IRAT, 1988.

SEGUY, L.; BOUZINAC, S.; TRENTINI, A.; CÔTES, N. A. L'agriculture brésilienne des fronts pionniers. Agriculture et Development, Montpellier, 12 :2–61, 1996.

KLUTHCOUSKI, J.; FANCELLI, A.L.; DOURADO-NETO, D. Manejo do solo e o rendimento de soja, milho, feijão e arroz em plantio direto. Scientia Agrícola, 57(1):97-104, 2000.

SEGUY, L.; BOUZINAC, S. Direct seeding on plant cover: sustainable cultivation of our planet's soils. Conservation agriculture, a worldwide challenge First World Congress on conservation agriculture, Madrid, Spain, 2001. Volume 1: keynote contributions. 2001; 85 91.

SEGUY, L.; BOUZINAC, S.; MARONEZZI, A.C. Cropping systems and organic matter dynamics. Eds: Garcia Torres, L.; Benites, J.; Martinez Vilela, A. Conservation agriculture, a worldwide challenge First World Congress on conservation agriculture, Madrid, Spain, 1 5 October, 2001 Volume 2: offered contributions. 2001; 301 305.

SEGUY, L.; BOUZINAC, S.; SCOPEL, E.; RIBEIRO, M.F.S. 2003. New concepts for sustainable management of cultivated soils through direct seeding mulch based cropping systems: the CIRAD experience, partnership and networks. In "Producing in harmony with nature", II World congress on Sustainable Agriculture proceedings, Iguaçu, Brazil.

SEGUY, L.; BOUZINAC, S.; SCOPEL, E.; SANTOS, M.F.R. dos. 2003. New concepts for sustainable management of cultivated soils through direct seeding mulch based cropping systems: the CIRAD experience, partnership and networks. In "Producing in harmony with nature", II World congress on Sustainable Agriculture proceedings, Iguaçu, Brazil, 10 15 of August.

SHAMOOT, S.; MacDONALDS, L.; BARTHOLOMEW, W.V. Rhizodeposition of organic matter debris in soil. Soil Sci. Soc. Am. J., 32:817-820, 1968.

SIDIRAS, N.; PAVAN, M.A. Influência do sistema de manejo do solo no seu nível de fertilidade. R. Bras. Ci. Solo, Campinas, 9(3):249-254, 1985.

SILVA, I.F.; MIELNICZUK, J. Ação do sistema radicular de plantas na formação e estabilização de agregados de solo. R. Bras. Ci. Solo, 21:113-117, 1997.

SILVEIRA, P.M. da; SILVA, O. F. da; STONE, L.F.; SILVA, J.G. da. Efeitos do preparo do solo, plantio direto e de rotações de culturas sobre o rendimento e a economicidade do feijoeiro irrigado. Pesq. agropec. bras., Brasília, 36(2):257-263, 2001.

SILVEIRA, P.M.; CUNHA, A.A. Variabilidade de micronutrientes, matéria orgânica e argila de um Latossolo submetido a diferentes sistemas de preparo. Pesquisa Agropecuária Brasileira, 37(9):1325-1332, 2002.

SISTI, C.P.J.; SANTOS, H.P. dos; KOHHANN, R.A.; ALVES, B.J.R.; URQUIAGA, S.; BODDEY, R.M. Change in carbon and nitrogen stocks in soil under 13 years of conventional or zero tillage in southern Brazil. Soil and Tillage Research. 2004; 76(1): 39 58.

SIX, J.; ELLIOTT, E.T.; PAUSTIAN, K. Aggregate and soil organic matter dynamics under conventional and no-tillage systems. Soil Sci. Soc. Am. J., 63:1350-1358, 1999.

SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO. Núcleo Regional Sul. Comissão de Química e Fertilidade do Solo. Manual de adubação e de calagem para os estados do Rio Grande do Sul e de Santa Catarina. 10. ed. Porto Alegre, 2004. 394 p.

SOUSA, D.M.G.; LOBATO, E. Manejo da fertilidade do solo no sistema plantio direto: experiência no cerrado. In: REUNIÃO BRASILEIRA DE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS, 24, 2000. Santa Maria. Fertbio 2000. Santa Maria: SBCS, 2000. CD-ROM.

STONE, L.F.; MOREIRA, J.A.A. Efeitos de sistema de preparo do solo no uso da água e na produtividade do feijoeiro. Pesquisa Agropecuária, 35(4):835-841, 2000.

STONE, L.F.; SILVEIRA. P.M. Efeitos do sistema de preparo na compactação do solo, disponibilidade hídrica e comportamento do feijoeiro. Pesquisa Agropecuária, 34(1):83-91, 1999.

SUMNER, M.E.; PAVAN, M.A. Alleviating soil acidity through organic matter management. In: ROTAÇÃO SOJA/MILHO NO PLANTIO DIRETO, 2000, Piracicaba. Anais… Piracicaba: POTAFOS, 2000. CD-ROM.

TAYLOR, S. A.; ASCHROFF, G. L. Physical edafology; soil structure. San Francisco, W. H. Freeman. P.309-351. 1972.

TEIXEIRA, L.A.J.; TESTA, V.M.; MIELNICZUK, J. Nitrogênio do solo, nutrição e rendimento de milho afetados por sistemas de cultura. R. Bras. Ci. Solo, 18:207-214, 1994.

TESTA, V.M.; TEIXEIRA, L.A.J.; MIELNICZUK, J. Características químicas de um Podzólico Vermelho-Escuro afetadas por sistemas de cultura. R. Bras. Ci. Solo, 16:107-114, 1992.

TESTA, V.M.; TEIXEIRA,L.A.J.; MIELNICZUK, J. (1992) Características químicas de um podzólico vermelho escuro afetada por sistemas de culturas, Revista Brasileira de Ciência do Solo 16, 107 114.

TISDALL, J.M.; OADES, J.M. Organic matter and water-stable aggregates in soils. J. Soil Sci., 33:141-163, 1982.

TORMENA, C.A.; BARBOSA, M.C.; COSTA, A.C.S. Densidade, porosidade e resistência à penetração em Latossolo cultivado sob diferentes sistemas de preparo do solo. Scientia Agrícola, 59(4):795-801, 2002.

TRUCCO, V. 2001. AAPRESID y la Innovación. En, Resúmenes del primer Seminario AAPRESID para Estudiantes. Pág. 9. AAPRESID. Paraguay 777, 8vo Piso. Of. 4. 2000 Rosario. Prov. Santa Fe. República Argentina.

UMA REVOLUÇÃO na lavoura. Anuário Brasileiro do Milho, p.16-19, 2002.

URCHEI, M.A.; RODRIGUES, J.D.; STONE, L.F. Análise de crescimento de duas cultivares de feijoeiro sob irrigação, em plantio direto e preparo convencional. Pesq. agropec. bras., Brasília, 35(3):497-506, 2000.

VALPASSOS, M.A.R.; CAVALCANTE, E. G. S.; CASSIOLATO, A. M. R. et al. 2001, Effects of soil management systems on soil microbial activity, bulk density and chemical properties. Pesq. agropec. bras., Dec 2001, vol.36, no.12, p.1539-1545.

van BREEMER, N. Soils as biotic construct favoring net primary productivity. Geoderma, 57:183-211, 1993.

VEZZANI, F.M. Qualidade do sistema solo na produção agrícola. Porto Alegre, Universidade Federal do Rio Grande do Sul, 2001. 184p. (Tese de Doutorado).

VOSS, M.; SIDIRAS, N. Nodulação da soja em plantio direto em comparação com plantio convencional. Pesquisa Agropecuária Brasileira, Brasília, v.20, p.775-782, 1985.

WISCHMEIER, W.H.; SMITH, D.H. Predicting rainfall-erosion losses: a guide to conservation planning. SEA-USDA Agricultural Handbook. N° 537. U.S. government Printing Office, Washington, D.C. 1978.

WRIGHT, S. 2001. Los Sistemas de Siembra Directa Aumentan la Estabilidad de los Agregados y de la Glomalina. En: Los Desafíos de la Agricultura en un Complejo Mundo Globalizado. Proceedings del IX Congreso Anual de AAPRESID. Mar del Plata 16 al 18 de Agosto 2000. Tomo I. Págs. 67:122. AAPRESID. Paraguay 777. Piso 8. Of. 4. 2000. Rosario. Provincia de Santa Fe. República Argentina.