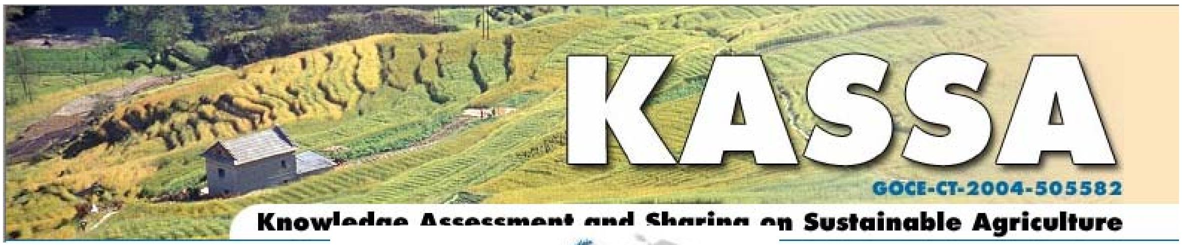

Deliverable 1.4 - Appendix A2

Conservation agriculture research in Bolivia

C. Paz

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AGROECOLOGICAL AND SOCIOECONOMIC CONTEXT OF THE COUNTRY

The agricultural sector plays a strategic role in the Bolivian economy. In the years 1993-1998, this sector generated between primary and processed products, about 21% of the PIB, and 32 % of the total exports value (US$ 345 millions per year) of the country; this produced 80 % of the raw material destined to the agroindustrial sector. Provided employment to near 42% of the work force, and contributed with most of the products that build the base of the National feeding (SIBTA, 2001). On 2002 the agricultural sector contribution was 14,2 % at PIB and participated with the 38,3 % of the total country exports (INE, 2003).

The agricultural activity in Bolivia, is developed in four great agroecological macroregions (Plateau, Valleys, Humid Tropic and Chaco), with big differences because of its agrophysical characteristics (altitude, climate, soil, vegetation and hydric resources) and because of the way natural resources are managed. This difference boldness the type of production and technological levels. In the Plateau and the Valleys regions predominates a family farm agriculture, with small farms traditional structures (ayllus); the productive activity developed in there, presents low technological and investment levels, with a greater demand of the work force, low income for its producers and a production mostly oriented to the internal market and own consumption (subsistence and family farms). In the Chaco region there is an extensive cattle production of low productivity. In contrast with the other regions, the farmers in the Humid Tropic are relatively consolidated, with a highly integrated agricultural production, mostly oriented to the external markets (SIBTA, 2001).

While family farms production practically stayed suspended and with low levels of profitability in the 90's, the sector's real annual growth (4,00%), was almost exclusively originated in the exporting subsection of the Humid Tropic. Around 42% of the 7.8 million of the Bolivian inhabitants that live in the rural area, around 94 % (3 million people) are considered poor (Poverty Map –Human Development Ministry, 1994) and according to the rural poverty ($us. 30 per capita monthly) estimated by the Interamerican Development Bank (BID) to Bolivia in 1999. This inhabitant proportion that do not generate enough income to satisfy their basic needs, represents one of the highest rural poverty levels of the continent. The rural poverty in Bolivia is associated with low work force productivity aspects, limited development of the human capital; lack of support services to the producers of this sector, specially in the technology, sanitary services, commercialization systems, and productive infrastructure (irrigation and highways), and limited access to productive agents like soil and capital assets (SIBTA, 2001).

Although Bolivia has a land extension of 109.8 million hectares, the agricultural soil availability is little. Of around 5 million hectares of soil with arable potential, less than the 40 % (around 2 million hectares) is cultivated and the other part is dedicated to either pastures, or has no operation (SIBTA, 2001).
The 700 thousand properties that are exploded near 25 million hectares (including agricultural soil cultivated, pastilles and forest areas), around 68% don't exceed 5 hectares (87 percent have less than 20 hectares) and only 1.5% with exploded soil. In contrast, in the

other regions 1,5 % of the properties occupy more than 80 % of the soil (farms from 1,000 to 17,000 hectares). This soil distribution defines a productive structure with noticeable technological differences and income levels for their farmers. It also has a close relation with the poverty levels in the Bolivian rural area. The indicated productive structure and the existence of low productivity traditional agriculture and deficient sanitary practices, determine in average, that the Bolivian farming productivity indicators are highly inferiors to those of the other countries in the CAN and MERCOSUR; they locate the Bolivian farm sector like one of the less productive of the continent (SIBTA, 2001).

1.1 PLATEAU REGION

The plateau region has a great plain elevated to an altitude between 3500 and 4200 msnm, located between the Andes Mountains western and eastern branches. Western Bolivia includes La Paz, Oruro and Potosi, and it represents 15,6 % of the national territory; in the central and north region of the Plateau, the topography is waved, alternated with lofty Slope Mountains and intermittent rivers. Its weather can be compared to the tundra and High Mountain polestar weather; annual temperatures of 7 to 11°C are registered, with risks of reaching more than 200 days per year. The precipitations fluctuate between 300 mm on the south (Potosi) and 600 mm per year (Titicaca lakes circunlacustre area) with a decreasing gradient from north to southeast, and concentrated between December and March. There is a reduced air pressure and a low oxygen volume, with logical consequences on the human and animal labor. On the other hand, because of the major radiation and insulation, there is a high evapotranspiration and an elevated hydric deficit accentuated by the little and inadequate rain distribution. Under those weather conditions, the most favorable season for the corps is short; it reduces the variety of products, and allows only an annual harvest (FAO/SNAG Bolivia).

The soils are stony in some places but in general cultivable; the plain altiplanic regions are known for their deep, heavy and with strong alkaline salts soil (PRONALDES, cited by PROTRIGO, 2002).

1.1.1 Subsistence or Familiar Farms Agriculture

The agriculture practiced in this area is traditional, basically a subsistence and familiar type; it is represented by rural communities heiress of the Inca civilization tradition. The communities in the north Plateau are organized in “aynoquas ” or “ayllus”. As a result of the inheritance lands can get fragmented. Farmers work small parts (lower than 2 hectares in general) and develop agricultural activities through an integrated system that mainly includes: potatoes, quinoa, barley, oats and grass). To improve the fertility of soil, they leave resting between one fourth and the half of the lands. After a rest of 3 to 6 years, a determined rotation, begins with the potato crop. After that, and according to the eating habits of each region, and that availability of seeds, they proceed with other crops for two to three year, and with this the land rests again. The Central Plateau is a region with soils and water problems. The native Andean crops and cereals are the main agricultural activity, but the cattle (ovine, bovine and camelidae) offers better possibilities to the farmers. The milk production has had an important development in the last years.

The llama, ewe, cattle, pig and poultry production is important because of the farming production. The cattle feeds of natural grass from the noncultivated areas (that is used by all the community), and waste of the harvest in cultivated lands (time between two agricultural cycles).

In general, an important part of the products is eaten in the same farm, except for the potatoes and the meat production; which is mostly designated to the direct to direct sale or commercialized in the regional fairs. In the irrigated areas it is common for farmers to develop a production system and to assign most of the water to those crops that satisfy in first place the family eating needs and are also commercials (abba, quinua, potatoes and wheat). (PRONAR, 2003).

Men do the hardest tasks, like soil and harvest preparation; and the women and children do the easiest ones. In the periods if easy work many men go to work in the mines as workers or seasonal laborers.

The small minifundista agriculture (0.1 – 12 ha) of the Plateau (tubercles, cereals, camelidaes and ovine) is made with rudimentary technology, in soils with low fertility and under severe weather conditions, with high risks of losing production because of droughts, hailstorms and frosts. The high pressure exerted in the soils use because of the coming together of its population an the sobrepasturing, has caused a significant deterioration of the natural resources, with a loss of the vegetative layer, accelerated erosion and reduction of the fertility of soils (SIBTA, 2001).

Animal traction and wood plow make the soil preparation. The sowings start in a specific date for each crop. In the case of potatoes, the fertilization used is made of ewe guano.

1.2 Valleys Region

The central region of the country, is called The Valley Region, and it is located to an altitude of 3500 –2000 msnm, occupying 19.4% of the national territory. The terraces and waved plateaus, alternated with high mountainous areas, tubes and narrow valleys, originate from little height differences to high strongly inclined slopes. This region covers two subzones differentiated by weather and vegetation conditions: the tempering and subtropical valleys also called Yungas.

The tempering valleys, that include parts of Cochabamba, Chuquisaca, Potosi and Tarija, have medium temperatures of 15 to 18°C and precipitation between 400 to 800 mm. The sub tropical valleys have higher temperatures (22 to 25 °C) and precipitations from 1100 to 3000 mm distributed throughout the year although with greater concentration between November and April. The soil characteristics can vary a lot; even in short distances because of the geomorfological conditions heterogeneity (Fertisuelos/Miradas-FAO/SNAG, Bolivia) the entisoles, inceptisoles and aridisoles predominate. The soils are not very deep, with light textures, poor in nutrients and with an intense erosion process (PRONALDES, mentioned by PROTRIGO, 2002).

Table 1. Soil Decription in Fisiográficas Provinces and Great Landscapes

Fisiográfica province	Great Landscape Rate of Erosion	Soil Description	Taxonomic Classification	Capacity of Use
C Cordillera Oriental	C.3 Valleys 10 t/ha/año	Very deep, frank Mountain range argillaceous to argillaceous; neutral to strongly alkaline; poor in nutrients.	Fluvents, Ustalfs, Ochrepts, Orthids, Orthends y Argids.	II, III, IV, V, VI y VII, s,e,c.
	C.6 Plain of Piedemonte	Little to mod. Deep, frank sandy to argillaceous, poor to mod. fertile.	Ochrepts, Ustalfs, Orthepts, Fluvents, Orthids, y Argids.	II, IV, V, VI y VII, s,c,e.
S Andean	S.3 Valleys 10- 50 t/ha/year	Deep to very deep, frank sandy to argillaceous, neutral to slightly alkaline, moderate fertility.	Orthepts, Fluvents, Psamments, , Ochrepts y Ustalfs.	II, IV, V , VI, s,e,c

Geobol, Map of Fisiográficas Provinces of Bolivia, 1994.

The social Organization is similar to the Plateau in the higher zones, and there is a pronounced minifindismo in some regions, there are also zones with an intensification of the agriculture, some other labors (soil preparation), access to irrigation, mineral fertilizer and the use of other agrochemical products.

1.2.1 Subsistence or Familiar Farm Agriculture

In tempering valleys, the weather conditions and the best rain distribution allow the production of a variety of crops, and in some places two harvests per year can be gathered. The most important crops are, Potatoes, wheat, oats, barley, vegetables haba, tarwi, alfalfa as well as smaller tubercles and grain, and also fruits; in the areas under irrigation, it is common that farmers develop a production system and put priority in the use of water to the crops that satisfy the family eating needs and are also commercial (pea, maize, potato, and wheat) and in last place, to the ones that are just commercial, like peach and grape in the irrigation system of Calamuchita (located in Concepcion, near the city of Tarija) or peach in Guadalupe Vallegrande (PRONAR, 2001).

In the Subtropical valleys, most of the tropical crops like corn, maize, yucca, papaya, pineapple, citruses, bananas, aguacate, even though coca is still one of the main and the most rental crop.

In the Valleys region, the technological limitations go from an excessive percolation of lands, to low levels of mechanization in several crops. The sanitary problems are reflected in the existence of several pests and diseases that affect the crops, and because the use of pesticides increase the production costs.

1.2.2 Large-scale/market oriented Agriculture

In Santa Cruz, in the region of valleys there is a commercial horticultural irrigated production; this production is intensive. Tractors are used a lot for the soil preparation, not many of them have tractors, so they hire manual labor (PRONAR, 2003). The peanut crop for export is important in this region too, and the tobacco as a traditional crop in some zones of Valleys.

In the Plateau and Valleys regions, inhabits 64% of the country population, and it represents only 35% of the national territory. About 450,000 farms smaller than 5 ha, more than 64 % of the country's total farming (700,000), are mainly operated by farmers from several indigenous cultures, mostly Aymaras in the Plateau region, and Quechuas in the Valleys. This farmers generate about 40% of the agricultural PIB, and most part of the eating products (SIBTA, 2001).

1.3 Humid Tropic Region

The Humid Tropic region, presents a landscape with plains, furrowed by rivers, brooks and streams, combined with waved plateaus and a mountainous complex in the earth. This region that is located at the northeast of Bolivia, includes Beni, Pando and part of Santa Cruz, has an altitude of 150 to 500msnm, a rainfall between 800-1900 mm, and an average temperature of 23 °C, with temperatures of 40 °C during summer, and less than 10 °C during winter. The wind is an important characteristic in a big part of this region, the wind average speed in the weather station of the city of Santa Cruz de la Sierra, is 11,5 Km/hour, being the average grater during winter and maxim in august. The weather and the ecology of the Humid Tropic in general allow tropic crops during summer time and temperate crops during wintertime. The rain distribution gives the opportunity of having two crops annual in the areas with more than 1000 mm of annual rainfall, in spite of this, the winter cycle is riskier because of the minor precipitation in this season; rains concentrate 70% from october to April.

In Santa Cruz's Humid Tropic mechanized agriculture is developed with agroindustrial crops such as soybeans, rice, maize, sugar cane, sorghum, sunflower, wheat, beans and sesame. In the less humid zones, the main crop is soybean, during summer time (November to April), followed by maize in a lower proportion. During winter time sorghum, sunflower and in a lower proportion wheat is sowed; of farmers can just leave the fields resting. In the most Humid zones, the main crop is soybean joined by rice during summer; and soybeans sorghum, wheat and Maize during winter. (ANAPO, 2003).

Beni develops its main activity in the bovine cattle production; and in Pando they develop extensive bovine cattle production, chestnut in agriculture, and wood.

In Santa Cruz, the soils are characterized because of having a young alluvial with variable texture and drainage, although, with an Alfisoles of medium texture and Inceptisoles of high fertility, predominance, but with unsuitable structures (PROTRIGO, 2002).

1.3.1 Subsistence or Familiar Farms Agriculture

In this region, the subsistence or familiar farm agriculture makes the "Chaqueo" (manual cuts and burns of the forest); the farmers who use the chaqueo method, generally have less than 50 ha. These farmers produce rice, yuca and maize. After this there is still a lot of stumps and a lot of roots of trees in the land, so the harvest is made by hand; a chaqueada land is cultivated for three years, after that the land is abandoned. Later the vegetation starts to grow again, and the farmer chaquea another surface.

There are a lot of other farmers that mechanized their agricultural labor; these people normally have like 50 ha of land, and between them are the migrants of other regions of the country that were located in the east by the agrarian reform, and other foreign like the Mennonites; they normally produce extensive crops like Soybean, sunflower, and others that are mechanically made and with an intensive use of agrochemical products.

1.3.2 Large-scale/market – oriented agriculture

The dynamism observed in these regions production, particularly in Santa Cruz, is associated with an intensive and oriented towards export agriculture, and an extensive cattle activity. The accelerated expansion of the agriculture has deteriorated the productive capacity of its soils, because of irrational and inadequate practices.

This agriculture is settled in the zones named Integrated (Central and North) and Expansion (East), is highly mechanized and with technology application. There are operations with exclusive products for the market (20 – 1500 ha). In this part of the Humid Tropic, there are farmers from several parts or the world; the small Bolivian farmers (< 50 ha) that got the land by endowment from the "Colonization programs"(agrarian reform); small Mennonites farmers that migrated from European and Latin-American countries with 50 ha of land, Russian farmers, and other people that migrated from Brazil with different farm sizes, in general from medium to large scale of production.

1.4 Chaco Region

The southeastern region of Bolivia, is known like Chaco, it goes from the south of Santa Cruz, to part of Tarija and Chuquisaca; it is a barren zone with forests. The main activity is the extensive cattle production, with low technological level.

1.4.1 Subsistence or family farm Agriculture

In some parts of the Chaco, like Villamontes and Yacuiba, irrigation agriculture is practiced, with crops like: onion, haba, maize, peanut, potato, tomato, carrot, grape and citric, and to dry land maize, peanut, potato, watermelon, soybeans and yucca. These farmers have lands of about 2 to 30 ha of which they normally irrigate around 1.5 has; farmers use fertilizers and pesticides; the use of machinery is normally renting them for some labors like the soil preparation. The family do the work, although, sometimes they hire labor force.

The agriculture is basically in small scale and conventional tillage. Sowing soybeans in Yacuiba, and sesame in some areas of the Santa Cruz Chaco; this production is totally designated to be saled.

The Humid Tropic macroregions and Chaco include 69% of the Bolivian territorial extension and 36% of the national population. Although most of the farmers in these regions are also classified as small farmers (smaller than 20 ha lands) the levels of rural poverty are also high; there is also a higher number of medium farmers (between 50 and 300 ha of land) and large farmers (between 300 and 1000 ha of land), than in the other two regions.

2. CONSERVATION AGRICULTURE

2.1 Principles

In the Plateau and Valleys ecoregions that represent the areas where most of the erosion of soil effects (hydric) are, practices of the soil conservation and water that reduces the run off that generates the hydric erosion, are taking place such as walls or stone barriers ground barriers, carcavas control with stones, deviation ditches, slow formation terraces with land edges, barriers with grass or shrubs, positioning of mulch (dry straw) on the soil, etc (JALDA and SLOPES Project). The minimum tillage and No tillage are permitted, so, the agriculture conservation is very distant from this, talking about the soil management. In the Chaco ecoregion, where there are more plains and with extensive cattle production areas, the cattle are fed eating the branches of the native vegetation, locally known like “ramoneo”.

In the Humid Tropic ecoregion , that is mostly flat, it isn’t just the erosion the only component of the soil degradation; in the oldest part of Santa Cruz around 250,000 ha with degraded soil by extensive pasturing, with a very low cattle productivity (PROTRIGO, 2002). In this region of the Humid Tropic No tillage is practiced, mainly in annual crops, although with many deficiencies, still to reach the agriculture conservation, although, experiences from other farmers that have followed that production line; it will be about this part of the Bolivian agriculture that we’ll develop the present report.

Table 2. Systems Tillage (%) by Crop in the Humid Tropic of Santa Cruz

Crop	No-Tillage		Conventional Tillage		TOTAL
	Ha	%	Ha	%	
Maíze	50.000	38.5	80.000	61.5	130.000
Sorghum	42.000	60.0	28.000	40.0	70.000
Sunflower	80.000	90.0	9.000	10.0	89.000
Wheat	18.000	72.0	7.000	28.0	25.000
Soybean	610.000	66.0*	310.000	34.0	920.000
Cane Sugar			100.000	100.0	100.000
Rice	11.000	6.0	159.000	94.0	170.000
sesame	3.000	9.0	32.000	91.0	35.000
Others**	4.000	17.5	19.000	82.5	23.000
TOTAL	**818.000**	**52.4**	**744.000**	**47.6**	**1.562.000**

Winter + summer ** Cotton, beans, macororó (ricino).
Elaborate: ANAPO, own elaboration on the basis of preliminary numbers

2.2 Sistem and its components descriptions

In the Humid Tropic ecoregion of Santa Cruz, there are two harvest seasons a year; one is “summer season”, from November to April, and the other one is “winter season ”, from May to October. The main crops are: soybean, rice, maize, sugar cane, sunflower, sorghum, sesame and wheat, in that importance order, with an approximated crop area of 1.562.000, occupying an approximated soil area of 1.100.000 has. Which represents more than 50% of the total cultivated soil in Bolivia.

Figure 3. Area Cultivated (ha) by Crop in the Humid Tropic (winter 2004 and summer 2004/05)

Crop	**Integrated Area**	**Expansion Area**	**TOTAL**
Maize	70.000	60.000	130.000
Sorghum	20.000	50.000	70.000
Sunflower	10.000	79.000	89.000
Wheat	17.000	8.000	25.000
Soybean	540.000*	380.000	920.000
Cane Sugar	100.000	0	100.000
Rice	150.000	20.000	170.000
Sesame	20.000	15.000	35.000
Others **	9.000	14.000	23.000
TOTAL	**936.000**	**626.000**	**1.553.000**

* 265,000 have winter + 278,000 ha. Summer ** Cotton, bean, macororó (ricino) Elaborate:ANAPO/CAO, preliminary numbers

In the two seasons, No tillage is practiced, but there are some farmers that practice it only during winter; in all of the mentioned crops No tillage is used too, but this tillage systems more common with sunflower, wheat and Soybean. In this zone, No tillage is used before the descompactation and leveling of the land process, although the investigation suggests starting this system with crop cover: maize or sorghum.

In Santa Cruz’s Humid Tropic there are three agroecological areas, mainly differenced by the rainfall, main factor for the crop rotations (ANAPO/CIAT/CIMMIT, 2001).

Figure 1. Main characteristics of the three agroecológicas zones of the agricultural area of Santa Cruz with respect to the determination of the crop rotations.

Rainfall	**Rains**	**Relation Crop summer - winter**	**% Area cultivated Winter**

Low (dry zone)	<800 mm	3 x 1 ó 1 x 0	0 a 33
medium (médium zone)	800-1200	2 x 1	50
High (humid zone)	>1200	1 x 1	100

2.2.1 Low Rainfall Zone

During the summer seasons the crops cultivated are: soybean, sesame, sorghum, cotton, sunflower and macororo; during the winter season most areas are resting or are used in less proportion to produce sorghum and sunflower when they have the right humidity conditions.

Figure 2. Crop Rotation in the zone of low rainfall (< 800 mm) humid tropic

	First Year		Second Year		Third Year	
	Summer	Winter	Summer	Winter	Summer	Winter
Summer / Winter	Soybean	Sorghum	Soybean	Sorghum	Soybean	Sorghum
Summer / Winter	Soybean	Sorghum o Sunflower	Soybean	Sorghum o Sunflower	Soybean	Sorghum o Sunflower
Summer / Winter	Soybean	Fallow	Soybean	Fallow	Soybean	Fallow
Summer / Winter	Sunflower	Fallow	Sunflower	Fallow	Sunflower	Fallow
Summer / Winter	Sorghum	Sorghum o Sunflower	Sorghum	Sorghum o Sunflower	Sorghum	Sorghum o Sunflower

There are some crop under irrigation system with central pivot, that don't have high yield, that must be because of the equipment bad sizing, that do not cover the water necesities, high temperatures, and elevated rates of evapotranspiration.

Because of the dry wintertime, there is less weed in the areas in rest, (fallows) are normally managed with roller blades and herbicides; the objective is to avoid weed, and save water in the soil profile.

Normally no fertilizer is used on the soils, because they present highfertility; in some crops, farmers use foliar fertilizers with the purpose of giving the plant more support under stress conditions. The traditional management of weeds in no tillage is based on 2 to 2.5 li/hs glifosato application 2,4-D (0.5 l/ha) before sowing, and a second application when the sowing is taking place. The rains are irregular, therefore, the sowing is not programmed in advance and it is based on the available humidity of the soil. The diseases incidence (Macrophomina, Rizoctonia, etc). Favored under stress conditions, is a problem that shows more frequently in the soybean crop; foliar diseases are not shown in any crop. The soybean's roya is changing the diseases management; other pesticides do not have big differences in relation with the conventional tillage, except in some seasons where crickets appear, more frequently in "no tillage".

2.2.2 Medium Rainfall Zone

During the summer seasons, farmers produce soybean, maize, cotton, sorghum and sesame; during the winter season: sorghum, sunflower and wheat, and the other part of the soil are resting. The different situations presented are the following ones:

Figure 3. Combinations of crops in the medium rainfall zone (800 to 1200 mm) of the Humid Tropic

	First Year		Second Year		Third Year	
Summer	Maize		Soybeans		Soybeans	
Winter		Sunflower		Sorghum Fallow		Wheat Fallow
Summer	Soybeans		Soybeans		Soybeans	
Winter		Sunflower Fallow		Sunflower Fallow		Sunflower Fallow
Summer	Soybeans		Soybeans		Soybeans	
Winter		Sorghum Fallow		Sorghum Fallow		Sorghum Fallow
Summer	Soybeans		Soybeans		Soybeans	
Winter		Sunflower Fallow		Sorghum Fallow		Crop cover (forage sorghum)

Normally, during wintertime there are not many rains, there is not much weed in the rest areas, and fallows are managed with heavy roller blades. When there are frequent rains they do this process twice; and sometimes they use herbicides (glifosato and 2,4-D) instead of the roller blades. In this area the use of sorghum for strubble production is increasing; this sorghum is being used with roller blades or a smooth wood to squash the crop, this is previous to the grain mincemeat to wait for the grain to grow again, and then be killed by herbicides as soon as they reach certain independent growth when it is close to the summer production.

Normally no soil fertilizants are used, because this soils present a high fertility, in some crops, the farmers use foliar fertilizers, with the purpose of giving the plant more support under stress conditions. The traditional no tillage weed management is based on 2 to 2.5 l/ha glifosato applications before the sowing and a second application when the sowing with just glifosato is taking place. The rains are irregular, that id why the sowings are not programmed in advance, and it is based on the soil available humidity. The disease incidence (Macrophomia, Rizoctonia, etc) favored under stress conditions is a problem-taking place more frequently in the soybean crop. The soybeans roya is changing the diseases management; there is not much difference with other pesticides in relation to the conventional tillage, except in some seasons where crickets appear in no tillage.

There are some irrigation with central pivot crop systems, that are not giving high results, maybe because of the bad equipment sizing, that do not cover the water necessities, and because of the environment conditions like low air humidity, high temperatures, radiation and alevated evapotranspitacion rates.

2.2.3 High Rainfall Zone

Durin the summer season farmers produce soybean, rice and maize; during the winter seasons most of these areas asr cultuvated with soybeans, maize, sorghum and wheat; rice in some low areas is left in rest; the crops combination normally presented are shown in figure 4.

In this zone with grater precipitation, there is a permanent pressure for weed emergency, although this condition allows the two crops a year, therefore the weed incidence occurs in no tillage. Farmers try to produce a forage crop (sorghum) between the summer harvests (March), and the winter sowing (July) with that objective of building a soil cover to simulate a “rotation” including sorghum between the two seasons of soybean, and to keep the soil covered with crop. In some cases, farmers put some herbicide before the sowing, to avoid the weed, and to save water to have the full profile before possible dry periods during the winter season and a second application when sowing is taking place. Between winter harvest and summer sowing, there isn’t any space for weed sprouting.

Small-medium farmers practice No tillage system, but they have problems with the weed control, Some other farmers use this system because they don’t understand the long-term system.

Figure 4. Combinations crops in the zone of high precipitation (1200 mm) of the Humid Tropic

	First Year		Second Year		Third Year	
Summer	Soybeans		Soybeans		Soybeans	
Winter		Soybeans		Soybeans		Soybeans
Summer	Soybeans	Sorghum	Soybeans	Sorghum	Soybeans	Sorghum
Winter		Soybeans		Soybeans		Soybeans
Summer	Soybeans		Soybeans		Soybeans	
Winter		Maize Soybeans		Soybeans		Soybeans
Summer	Maize Soybeans		Soybeans		Soybeans	
Winter		Soybeans		Soybeans		Soybeans
Summer	Rice		Soybeans		Soybeans	
Winter		Soybeans		Soybeans		Soybeans
Summer	Soybeans		Soybeans		Soybeans	
Winter		Wheat (Soybeans)		Wheat Soybeans		Wheat Soybeans

The diseases incidence, mainly during the summer season, gets better because of the frequent rains and the high environment humidity conditions, in the cases of the *Fusarium sp* and soybean's roya that tells the number of fungicides applications that are needed for its control.

It is very frequent in this zone to use foliar fertilizers based on calcium, boro, micronutrients and elements that help the plant's normal development. In the last two years, the fertilizer applied in soils has been increased for all the different crops, In the case of maize it is basically nitrogen (urea and ammonium sulfate), and in soybeans, farmers apply phosphorus, potassium, sulfur (0-20-20, 5-15-35), agricultural plaster, etc.

In the Humid tropic there are also some experiences and operations in organic soybean to large scale and for export, under No tillage; around 2,000 ha for that production, and other 1,000 ha are in the process to be integrated to No tillage. The management is differenced from traditional No Tillage, basically because the use of pre-emergent product for pests control (weeds, insects and diseases), and the use of organic and biological products authorized by internationals certifiers in combination with cultural practices, mechanical and manual control.

In organic soybeans, the weed management before the sowing is made with desbrozadora, and in some cases with roller blades. An organic herbicide is used, and they apply it when the soybean sowing is about to take place. The crop control is done with desbrozadora and it is complemented with manual carpidas, in order to improve the weed control, planted sorghum, wheat or green installment (forage sorghum) in the winter before soybeans. Organic soybean and its derivates are commercial, which prevents the farmer to have other crop options to produce.

2.3 Scientific results and Practical Experiences

2.3.1 Stability in the Crops´ Yields

2.3.1.1 Humid Tropic Region

The crops´ yield is generally the only considered parameter by the farmers that practice No Tillage. The local experiences indicate that in dry years they get better results with No Tillage, and in normal years and in zones provided by water equal levels of production are obtained. It is possible that at the beginning of No Tillage, and especially in degraded soils, to get better results while the system is being recovered and the fertility of the soil is learned and managed. With the time, the soils recover, and the results are better too (ANAPO/CIMMYT/CIAT, 2001).

The conventional tillage practices with plowed and harrowing in a frank soil moderately compacted, gave as a result a significant increase in the total efficiency of soybeans, between 14 % and 25 %, during a period of 7 seasons of soybeans crop (1985-89) Barber & Diaz (1990). The residual effects of this descompactation respectively extended for 3 and 4 years for the plowing and harrowing, in spite of the gradual relative reconsolidation of the horizons; presumably, this reconsolidation does not affect the roots growth as severely as the soil initially nonrelaxed.

The flexible system, Conventional Tillage, Zero and Vertical, did not affect the wheat yield, that varied from 0,94 to 1.08 t/ha (Herrera, 1993). These same tillage systems did not show any difference in the soybeans crop results (Ajhuacho, 1994). For Moreira.(2003), There isn´t any difference in the sorghum crop results either.

Terrazas (2002) the job done in CETABOL, obtained better results in the conventional tillage maize, as in green installment (lab-lab brown), with 5,580 Kg/ha commercial crop (wheat), with 5,230 Kg/ha, in relation to No tillage under the same treatments, 5,5190 and 4,440 Kg/ha respectively.

Lopez (2000). Mentions that the wheat grasin yield under irrigation in No tillage /crop cover (juncea Crotalaria L.), in a sandy frank soil, was bigger according to the Conventional Tillage; this very important characteristic was influenced by the physical factors and not as much by the chemical factors of the soil profile.

In order to illustrate the importance of the crop rotation, mainly in No tillage, in the medium rainfall zone (San Rafael) of 1994 – 1999 the Sustainable Agriculture Program was developed, in which three tillage systems were working (No tillage, Vertical tillage, and

Conventional tillage) in combination with crop rotation and the soybean monocultures – wheat, maize, sunflower – (ANAPO/CIMMYT/CIAT, 2001).

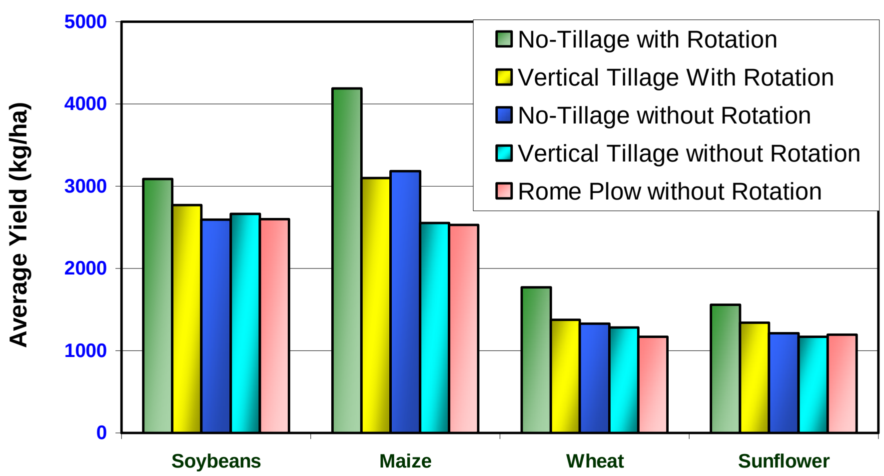
The rotation was the following one:

Figure 5. Crop Rotation in conditions of intermediate precipitation (800 to 1200 mm) in the Humid Tropic

	Firt Year		Second Year		Third Year	
Summer □	Maize		Soybeans		Soybeans	
Winter□		Sunflower		Wheat		Leguminosa (Crotalaria)

In the following Figure the results reached with these works are observed:

Picture 1. Effect crop rotation and tillage on avarage yields of 4 Summer Season (95/96 a 98/99) and 3 Winter Season(96 a 98) DESA - San Rafael



In 10 years of use soil conditions, the soybean crop in NT surpasses with almost 300 Kg/ha the vertical tillage with crop rotation. But the most important has been the No tillage with a rotation interaction, that increased 500 kg/ha of soybeans in NT in relation with the soybeans – wheat in NT succession. In maize, the NT with crop rotation has increased to 1,100 Vertical tillage, and conventional tillage is 1100 Kg/ha and 1600kg/ha respectively. The fertilization done in the same labor hasn't had any important effect in the soybean, maize, wheat and sunflower crop; eventhough there have been some tendencies to improve the uniformity of soybean and sunflower. There hasn't been any perceptible effect in the yields of any of the crops and tillage (Paz C., 1999)

In other conditions of degrades soil, in 30 years of use, the soybean crop in tillage systems presents very similar results between No tillage (NT) and vertical tillage (VT), surpassing both yields of conventional tillage (CT). With maize crop in the same soil, VT obtained around 500 kg/ha, which is more than NT; in sunflower and wheat, the NT surpassed the yields obtained in VT. But when the soybean crop enters in a scheme of independent tillage system crop rotation, there is an increase from 200 to 300 kg/ha; In these same tillage systems there hasn't been any good result in any of the crops. (Paz C., 1999)

Considering the results described previously, we can indicate the following conclusions:

1. In all crops (soybean, maize, wheat and sunflower) better results were obtained in fields under No tillage, when the same ones were developed in the rotation shown in figure 5.

2. It wasn't the same answer in No tillage under the monoculture treatments; the results in No tillage are very similar and in some cases lower to the ones with or without rotation in Vertical Tillage.

3. Lower results always take place in conventional tillage.

4. In soybean, the difference between No tillage with rotation, and No tillage without rotation was of 500 kg/ha; in maize, this difference was of 1000 kg/ha; in wheat was 450 kg/ha and in sunflower was 350kg/ha.

With the purpose of continuing the execution of the "Sustainable Agriculture Program", ANAPO has implemented similar jobs since summer 2000/2001, considering the following:

1. Tillage Systems comparison: No tillage, and Conventional Tillage.

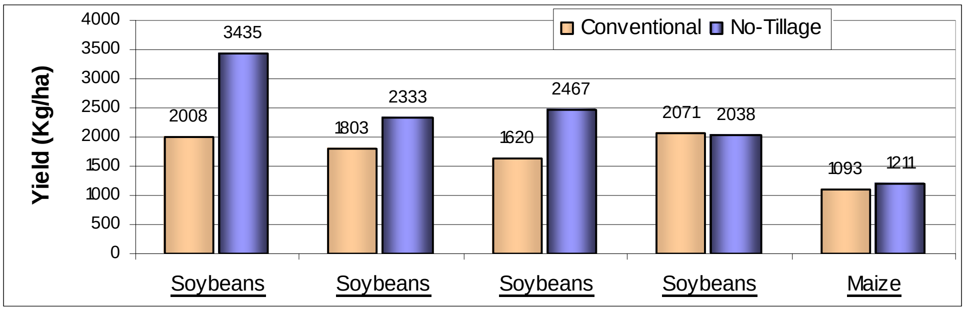
2. Crops Rotation and Succession: The cropping successions are soybean – wheat and soybean – sunflower in comparison with the rotation described in figure 6.

Figure 6. Crops Rotation in conditions of intermediate precipitation (800 to 1200 mm) in Center Experimental ANAPO – Humid Tropic

	First Year		Second Year		Third Year	
Summer	Maize		Soybeans		Soybeans	
Winter		Sunflower		Sorghum		Wheat

The preliminary results obtained and accumulated in the summer season 2003/04 are shown in the following Figure:

Figure 2. Soybean and Maize yields in summer 2003/04 on different sequences from preceding crops in center experimental ANAPO.



Winter 03	*fallow*	*fallow*	*fallow*	*fallow*	*fallow*
Summer 02/03	*Maíze*	*Soybean*	*Soybean*	*Soybean*	*Soybean*
Winter 02	*Wheat*	*Sunflower*	*Sunflower*	*Wheat*	*Sorghum*
Summer 01/02	*Soybean*	*Maíze*	*Soybean*	*Soybean*	*Soybean*
Winter 01	*Sorghum*	*Wheat*	*sunflower*	*Wheat*	*Sunflower*
Summer 00/01	*Soybean*	*Soybean*	*Soybean*	*Soybean*	*Maíze*

1. In every soybean treatment there has been a higher yield in the parts under No tillage in relation to the conventional tillage; in the monoculture soybean - wheat treatment those differences were not shown; in the case of maize the difference isn´t any bigger, because the crops was affected by the high temperatures.

2. The yield of soybean in No tillage under rotation treatment with the maize during the summer season; in this case there was a difference of around 1,000 kg/ha.

The accumulated experiences by the farmers in the Humid Tropic (ANAPO/CIMMYT/CIAT, 2001) throughout 8 years looking for agriculture sustainability under No tillage system, suggests the following:

The dry zone with less than 800 mm isn't good for winter frequent crops. It is only possible to produce summer crops (one crop a year) and a crop cover every three years. For Example:

Figure.7. A rotation 1 x 0 (without crop winter) for the dry zone (<800 mm)

	First Year		Second Year	
Summer ⇒	Sorghum		Soybeans (Sunflower)	
Winter ⇒		Fallow (Crop Cover)		Fallow

If there is enough humidity, farmers can plant maize and soybean. If the area is dry, is better to plant resistant crops, like sorghum and sunflower. If a crop cover is sowing during the winter, it is necessary to seed it earlier to take possible advantage of the humidity residual.

Figure 8. A rotation 3 x 1 (a crop winter every three years) for the dry zone

	First Year		Second Year		Third Year	
Summer □	Sorghum		Soybeans		Cotton	
Winter □		Sunflower		Fallow *		Fallow

To the zone with intermediate precipitation is demonstrated in a practical example (figure 9). The rotation is adapted where only some characteristics appear:

- There is always a summer crop.
- During winter half of 1/3 of the area is in clean fallow.
- During summer, every two years there are two leguminous (soybean) crops, a one gramineous crop (maize).
- During winter, half or all the area has gramineous crops (wheat and sorghum) in a 67 % and one (sunflower), in a 33%.

It is important to keep the fallow clean and free of weeds, so they can accumulate water.

Figure 9. A rotation 2x1 (with crops winter every two years) for the intermediate precipitation zone

	First Year		Second Year		Third Year	
Summer □	Maize		Soybeans		Soybeans (Cotton)	
Winter □		Sunflower		Sorghum Fallow		Wheat Fallow

It is possible to replace partially a fallow by a crop cover; only if they are seeded earlier. The use of crop cover for the intermediate zone, although it gives more strubble, can harm the summer crop if it doesn't rain before seedtime, or if there are droughts during the cycle.

For the high rainfall zone that has enough humidity to be able to crop every winter and to use crop cover, including like third crops between the summer and winter crops, there are many combinations of crops that can be used. The following one is an example:

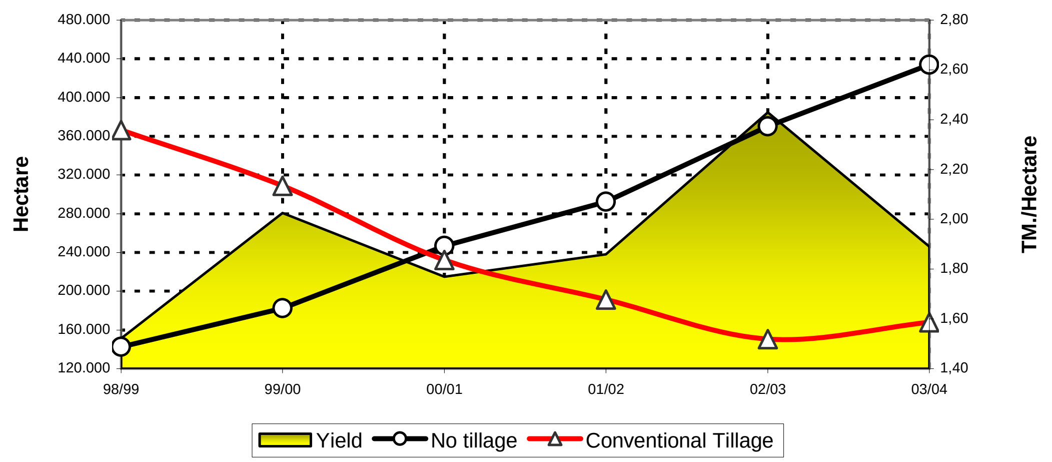
Figure.10 a rotation 1x1 (crop every winter) for the humid zone

	First Year			Second Year		
Summer	Soybeans			Maize		
Winter		Wheat	(Crotalaria)		Soybeans	(Mijo)

The answer in yield of the sunflower crop to mineral fertilizers was very significant for nitrogen in tillage, No tillage, and Vertical tillage systems, obtaining an increase of 48 % (397 kg/ha) and 59 % (446 kg/ha). But the sulfur fertilization affected neither the development nor the agronomical characteristics of the crop.

In order to illustrate the effect of conservationist farming in the performance and stability of it in time, we shall consider the available data on soybean tillage in the Humid Tropics (ANAPO, 2005).

Picture 1. Tillage and relation with the Yields for summer´s soybean
Humid Tropic - Bolivia

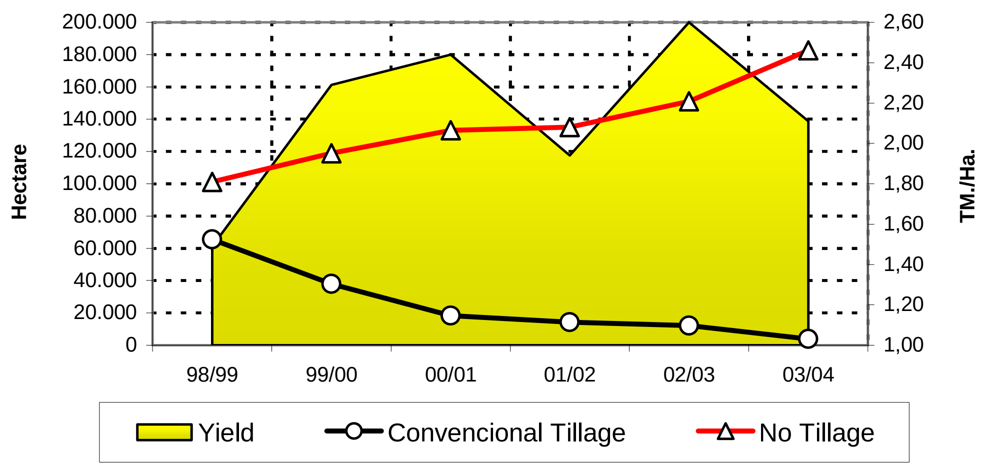


In the years when direct seeding started in Bolivia (1990 to 1992), the hydric deficit in the soil was not the main problem and the system appeared as a way of having the labor of greater exportation more efficiently. In a short term, the problem of hydric deficit became the main hindrance to the production, and under these circumstances, the advantages of direct seeding over the conventional farming became more evident in terms of the greater support of hydric deficiency and periods without rainfall.

In Figure 1, taking the available data from the last six summer campaigns, we can see the strong increase in the use of direct seeding, rising from 142,000 ha in 1998/99 (28% of the total) to 434,000 ha in 2003/03 (72% of the total planted soybean). Despite the fact that the performances are still very diverse and strongly influenced by the climate, a slight tendency to the increasing is observed in time, and what usually lowers the average are those areas still under conventional seeding.

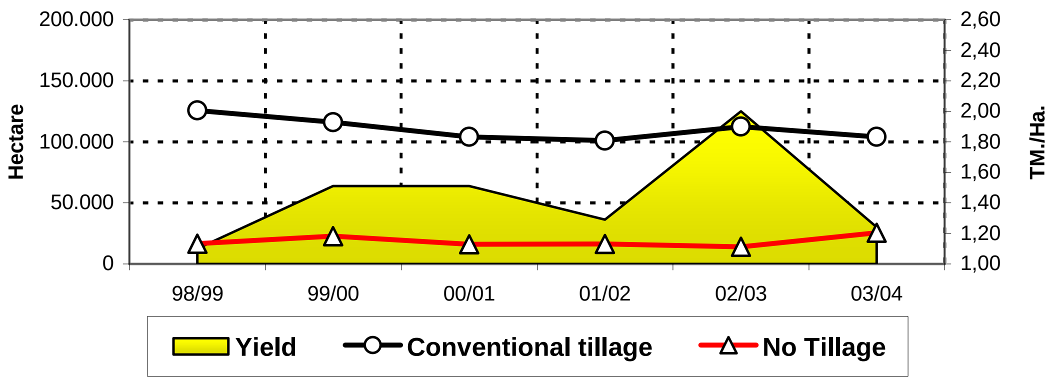
There are many groups amongst the soybean producers in Bolivia, and we shall take the example of those that contrast the most in the usage of direct seeding; the Brazilian producers are the ones who adopted direct seeding the fastest and presently more than 90% of their tillage area is under this system, whilst in the other end of the scope we have the Mennonites who started such adoption later and at a much slower pace, with a current 80% of their tillage area still under the conventional farming. In Charts 2 and 3, we illustrate the data of these producers.

PICTURE 2. EVOLUTION OF NO TILLAGE AND YIELD ABOUT SUMMER´S SOYBEAN FOR BRASILIANS FARMERS - HUMID TROPIC, BOLIVIA



Comparing Figure 2 and 3, we observe the differences relating to the fast and constant adoption of direct seeding by the Brazilians and the lower and slower case of the Mennonites. For the Brazilians, the average of the six campaigns is of 2.14 ton/ha, and for the Mennonites is of 1.44 ton/ha, a difference of 0.7 ton/ha that obviously can not be attributed only to direct seeding. The average performance of the Brazilian varied between 1.5 and 2.6 ton/ha and that of the Mennonites varied between 1.5 and 2.6 ton/ha, being the low performances more frequent in the case of the Mennonites

PICTURE 3. EVOLUTION OF NO TILLAGE AND YIELD ABOUT SUMMER´S SOYBEAN FOR MENNONITAS FARMERS - HUMID TROPIC, BOLIVIA



To analyze and attribute to the right factors the differences in the performances, we must consider that most of the Mennonites have been exploiting the soil for 20 years, while the Brazilian have done so for 10 years; however, the chemical conditions of the soil have not been as drastically affected as the physical ones due to the effect of the farming. The Brazilians generally apply more technology in the management and care of the tillage, and the use of varieties is similar, so there is no effect of genetics in this case. It is evident that an earlier entrance into direct seeding techniques, as in the case of the Brazilians, has decreased the impact of farming in the soil; while in the case of the Mennonites that adopted the direct seeding, the performance is relatively less important because, in many instances, what is happening is a recuperation process of degraded soils.

Another interesting fact is the comparison between what happened in the campaigns of 2002/03 and 2003/04, where in both cases we can observe a peak of the performance, with 2.6 ton/ha for the Brazilians and 2.0 ton/ha for the Mennonites in 2002/03 with a difference of 0.6 ton/ha in the campaign of 2003/04, with a reduction of the performance mainly due to the hydric deficit. We can see that for the Brazilian, this reduction was of 0.5 ton/ha (from 2.6 to 2.1 ton/ha), and for the Mennonites, it was of 0.75 ton/ha (from 2.0 to 1.25 ton/ha). For the Mennonites, there was an increase of 9% in the area under direct seeding (from 11 to 20%), and for the Brazilians, the increase was of 6% (from 92 to 98%). These figures show us that the decreases in performance under direct seeding are softer, tending to a greater stability of the performances in time; for the extremely adverse environmental conditions, the minimum performances are placed on a slightly higher position than those of the conventional farming.

2.3.1.2 Valleys Region

The effects that strubbles produce in the oil surface, over the hydric balance and the wheat yield (Campero & Wall, 1999), concludes with the reminders in the surface have a direct influence on the rainwater infiltration increment, and allow the humidity stored in the soil to be available for more time. The Humidity accumulation before seedtime is determining the yield in the zones with hydric deficit. The amounts of strubbles accumulated were enough to show an answer in the wheat crop. During dry years is necessary to have a minimum of 2000 kg/ ha and in humid years of 1000 kg/ha of strubbles. In reminders seedtime, because of the humidity accumulation, the crops cycles are longer and when the rains are over (April - May), the accumulated humidity in the ground is not enough for a good grain filling. To get the maximum yield we have to seed with the firts rains, or when November is about to be over.

The use of straw reminders to the soil cover contributed in 2 tn/ha favors the increment of wheat in a 67,3%, when the amount of reminders goes to 4 tn/ha, the growth of the wheat increases in 88,7% (PROTRIGO, 2002).

2.3.2 Soil Characteristics

2.3.2.1 Humid Tropic Region

In the Department of Santa Cruz, which is the region that concentrates the yearly tillage and where the direct seeding is being practiced tending to conservationist farming, the soils are generally characterized for being new alluvial soils with varied textures and draining, though with a predominance of Alfisoles of medium texture and Inceptisoles of moderated to high fertility, but with an inherently unstable structure (PROTRIGO, 2002).

The experimental Station of Saavedra/CIAT (during 14 years of agricultural season in a frank sandy soil Ustochrept Udico Fluventico, weak structure frank sandy soil, brittle to firm with reddish brown color, of medium fertility and regular draining,, has already generated changes on some of the soils characteristics by the practice of tillage; during winter 2003 (Gonza´les I. 2004) a major humidity was registered in the first 22 cm in no tillage with 77 % of soil cover (14,5%) in relation to the vertical (9,4%) and conventional (8,7%) tillage. The density values (figure 4) are variable in the for measurements and there are big changes because of the tillage system effects; between the 88/89 measurement and the one of 02/03 there was an increase of the density in No tillage and in all the depths. The hydraulic conductivity is a > in no tillage and old depths (6,1; 1,21 and 0,24 cm/hours in 0-5; 8-3and 17-22 cm respectively) in relation to conventional tillage (4,22; 0,56; and 0,23 cm/hora in 0-5; 8-13 and 17-22 cm respectively), this is inferior to soil values under mount (44,4; 8,42 and 0,7 cm/hours) to the same depths. As of the 6 minutes of initiated the simulation of the rain of 152 mm/hour, happens in the beginning of the water draining in No tillage; this time it was 4 minutes in Conventional tillage and in sandy frank soil.

Table 4. Values of density pretend (g/cc) of the soil with 14 years (2 crops/year) in different tillage in E.E.A.S., Humid Tropic.

Prof. (cm)	No Tillage				Convencional tillage			
	88/89	92/93	01/02	2003	88/89	92/93	01/02	2003

0-5	1,37	1,46	1,39	1,40	1,42	1,41	1,49	1,35
5-10	1,41	1,54	1,43	1,52 *	1,49	1,49	1,57	1,50 *
10-15	1,46	1,54	1,50	1,52 *	1,50	1,62	1,57	1,50 *
15-20	1,42	1,61	1,60	1,63 **	1,54	1,62	1,60	1,63 **

* Depth of 8 - 13 cm
** Depth of 17 - 22 cm
Source: Barber et. al, 1994; Diaz O. 2003; Gonzáles, 2004

In a muddy Humid Tropic frank soil (Okinawa 2), of alluvial formation, deep, well-drained, with regular to moderated fertility and after three years of No tillage crop rotation and 93% soil cover, it obtained humidity values between 0 to 120 cm, 19% and 46% superior to no tillage without rotation and the conventional tillage respectively (Avila, 1999). The density in No tillage was higher; the draining beginning in no tillage with rotation, happens after 50 minutes of a simulated rain of 65 mm/hour, in No tillage with no rotation (succession soybeans-wheat) and in conventional tillage was reduced to 16 and 11 minutes; when the evaluation was done with the same insensity of rains, the draining started from 27,9 to 6 minutes for no tillage with rotation, No tillage without rotation and conventional tillage respectively.

In a high rainfall zone (Okinawa I), strongly saline, specially in the superficial layers, with a muddy texture and with a lot of problems introducing new crops, a good development of the brown lab-lab crop cover was achieved (Ajhuacho & Tanaka. 2000), reducing the electric conductivity (CE) from 4,7 to 2,1 ds/m in 70 days of the installment permanence, positively correlating the amount of cover and dry material with the reduction of the EC; in a similar work done in the year 2001, the effects of the brown lab-lab y dead cover like soybeans cases, dry merketon grass and rice chala put in the soil surface, after 6 months of the covers being put, the CE went down from 6,4 dS/m, that represented in the beginning, to 1.6; 1.1; 1.3 and 0,7 dS/m fro brown lab-lab, soybeans cases, merkeron, and rice chala. In the following summer season soybean and sorghum crops were established, over the winter covers, obtaining the best results of soybean production over the rice chala covers with 2.7 tn/ha and of sorghum over soybean cases with 3,7 tn/ha.

If there are saline soil problems (Ajhuacho & Tanaka, 2003) it is suggested to use the green lab –lab brown in winter time, to reduce the CE in soils that are not over the 3 dS/m, right after the summer season harvest or after a rain, because of the salt concentration at this time is smaller, and there are better conditions for the crop cover germination. In soils with more than 3Ds/m it is recommended to use dead covers from the winter season, being careful with leaving a period of at least two months before the summer crop seedtime to allow the covered decomposition.

On fields with soil of frank sandy texture, that came from a period of 10 years of pasture, in the summer of 1995/96, integration agriculture – cattle tests were implemented, under the summer soybean and winter forage sorghum with 3 pasturing in No tillage cycles, models (Market E & Tanaka S. 2002). As a result some of the characteristic of the soil changed:

1. 50% of the total Nitrogen increment; Phosphorus and potassium increased respectively in an average og 0.41 meq/100g, 6,76 ppm ; the pH of soil did not have significant changes, but there was a change in the electric conductivity, that increased more than 300 % (table 5).

Table 5. Chemical changes in the soil in a agricultural-cattle of integration system (rotation soybeans - forage sorghum) in CETABOL- Okinawa 2, Humid tropic.

Period	Prof. (cm)	N total (%)	P (ppm)	K (meq/100 g)	pH (1:5)	CE (uS/cm)
1995/96	0-10	0,09	20,19	0,39	6,69	55,0
	10-20	0,06	10,85	0,23	8,03	31,8
1999/00	0-10	0,17	26,69	0,84	7,79	185,8
	10-20	0,14	17,87	0,60	7,9	148,2

2. Progressive formation of a dense layer is detected, from 15 to 35 cm deep, going to high levels at the end of the cycle; the same tendency registered the density, which is attributed to the compaction caused by the bovine cattle.

Vargas & Sakaguchi 2003 say that the more pasture implanted before the new crop in agricultural – cattle rotation introduction, the more increment of phosphorus the soil is going to have. In pasture with 4 years (1996 to 2000) increases from 0.12 to 0.15 %of the total nitrogen; from 0.44 to 0.56 meq/100g in potassium; from 28.39 to 36.8 ppm in phosphorus and 2.04 to 2,8% of organic matter (SOM). After the crops were introduced in this rotation, with 4 cycles of soybeans in summer and 3 of wheat in winter, there wasn’t a significant difference in the soil’s nutrients contents, and its tendency couldn’t be determined.

In an area characterized by the predominance of exceptionally fertile Ustrochrepts and Haplustalf soils, searching for a way to reduce the impact of deforestation on the characteristics of a Typic Haplustalf soil, moderatedly well-drained, with a frank oozy horizon in the first 20 cm covering another of finer texture, slime-sandy to frank loamy oozy of 20 to 80 cm deep, Barber and Romero (1993) found the following results measured a few months after the deforestation and with the first tillage still on the field:

Parameters	Forest	Deforest
Apparent Density 0-5 cm (g/cm³)	0,91	1,11
Apparent Density 5 – 10 cm (g/cm³)	1,04	1,24
Apparent Density 10 – 15 cm (g/cm³)	1,20	1,33
Apparent Density 15 – 20 cm (g/cm³)	1,28	1,41
Apparent Density 20 – 25 cm (g/cm³)	1,34	1,44
Apparent Density 25 – 30 cm (g/cm³)	1,39	1,46
Accumulated Infiltration in cm/30 min.	15,08	4,36
Accumulated Infiltration in cm/60 min.	18,82	6,52
Minimum Rate of Infiltration cm/h	1,25	2,81

pH in water	6,50	6,98
Ca (cmol/kg)	7,70	11,60
Mg (cmol/Kg)	5,37	4,94
K (cmol/Kg)	1,31	1,58
P (ppm)	35,3	44,5
Organic Matter (%)	3,97	4,00
N (%)	0,25	0,28

The increases in the apparent density show a compaction of the first 20 cm of the soil, that was equivalent to a net loss of porosity of 6.2%. Comparing the apparent density until 30 cm deep, the soil compaction is equivalent to a flattening of 32.5 mm. The minimum rates of infiltration, obtained after 5 to 7 hours, were very low in both cases, probably due to the dominant influence of the finely structured underground over the final balance of the infiltration.

2.3.3 Weed Management

There are three biological and cominant forms of weed under No tillage, Fanerofitos, being mainly sprouts of natural vegetation species; Terofitos erectus, that are species of annual weeds, which prepare themselves very well for the crops cycles, for example *Bidens seguetum;* labeled Hemicriptofitos, that are biennials species that are considered resistant or very aggressive, for example *Boerhaavia caribaea* , its behavior is more aggressive in older and under no tillage fields. There is a predominance of germinated plant of certain weeds that can indicate how many years of use the no tillage system has, like in *Boerhaavia caribaea and sida* sp in fields with years of soil under no tillage, use; *Leonotis nepetifolia* in fields where the the general sowing is maize, and *amaranthus sp* in fields with less years of use under no tillage system. Among the species considered aggressive in fields with more years of direct seeding (>6 years), we have: *Boerhaavia caribaea, Digitaria insularis, Senna obtusifolia and Sida rhombifolia,* underbrush that tend to turn perennial due to the non-removal of the soil. In younger fields (<6 years), besides the previous species, we find *Chloris polydactyla, Cynodon dactylon, Cucumis dipsaceus, Alternathera paronichioides, Brachiaria sp, Amaranthus sp and Panicun trichoides*, with a predominance of gramineous, from where we can deduce that some species with greater aggressiveness are selected over the years of direct seeding, which results in a less significant diversity of underbrush (Bustamante, 1997).

Mostacedo (1999) found, in a site with 40 years of farming and after 3 years that direct seeding had initiated, that the total density of the gramineous underbrush does not differentiate between direct seeding and other farming treatments (vertical and conventional); however, the latifoliate species have a greater density in direct seeding, *Sida rhombifolia* was the species with more density and there was a significant reduction of *Cynodon dactylon*, with less diversity of species in direct seeding than in the other farming systems; with no effects of the farming rotation in the underbrush dynamics. In another site, with 9 years of farming and after 3 years that direct seeding had initiated, no differences in the densities of underbrush species due to the effect of farming were found, there are tendencies towards the reduction of the underbrush species population in direct seeding.

There was a significant reduction of the diversity of species in direct seeding and vertical farming in relation to that of conventional farming, the increase on the population of *Commelina erecta* in direct seeding and vertical farming in relation to conventional farming. Also significant was the decrease on the total population and the group of latifoliate species due to the effect of farming tillage (Mostacedo, 1999).

Very little pre-emergent incorporated herbicide has been used in Bolivia, and there was a greater use of post-emergent ones. With the increase of direct seeding, the use of post-emergent herbicides continued and the use of pre-emergent herbicides increased, yielding good results, since the amount of stubble covering the ground under direct seeding is generally scanty.

The intensive use of ALS inhibitors herbicides (pre- and post-emergent) has generated the resistance of Amaranthus sp to this action mechanism; however, this fact holds no relation to the farming systems. Its management is, on the other hand, facilitated at a smaller cost by the use of gliphosphate in the dissections, be it during pre-seeding or latent periods; the use of 2,4-D in the tillage of wheat in the zones that include it in the rotation is another management scheme of this resistance. The management of this resistance is also being facilitated by the introduction of gliphosphate-resistant soybean..

The crops of organic soybean in great scale go through the use of direct seeding at medium and long terms; in the first years of deforestation, it is usually made under conventional farming with little incidence of underbrush and manual-based management control. With direct seeding, the use of organic herbicides is indispensable for the total dissection of the underbrush. There is a product with such characteristics commercialized in Bolivia under the name of Bioherb. The management usually consists of two applications of Bioherb before the seeding, considering that the latent period (no tillage) was short. When the latent period preceding soybean seeding is long, the underbrush is usually managed with clearer tractors. During the tillage period, mechanical management is used, with a clearer tractor between the ruts while the tillage is not closed, and complemented manually in the ruts and in the periods after tillage is closed.

2.3.4 Pest Management

In direct seeding systems there is generally a greater numerical amount of insects, both pests and beneficent, which contributes to a greater biological activity; the competition, predation and parasitism occur more intensely, searching for a balance. The stubble creates favorable conditions for the populations of Diplopoda, Scarabaeniae, Formicidae, Gryllidae and Arenae, these groups were frequent, constant and very abundant along the whole cycle of tillage and represent the biggest difference between direct seeding and conventional farming. Plagues of soybean tillage are the same in both systems; the systems affect positively some insect populations that inhabit the ground surface; however, plagues and beneficent insects of the air do not present significant statistic differences between direct seeding and conventional farming (Guamán I., 1995).

In the Humid Tropic of Santa Cruz, Guaman (1995), the same author could verify the following Arthropodos families were present in soybeans, No tillage had more compared with the conventional tillage: Araenae, Carabaidae (Selenophorus, Clivina, Lebia, Calosoma, Scarites, Calleida, Galerita, Neoaulacoryssus, Pelecium, Collincina and tetragonoderus), Cicindelidae, Gelastocoridae, Chrysomelidae, Coctuidae, Grillidae, Formicidae, Scarabaidae.

Most insects families are mostly in no tillage: Chrysomelidae (Ceratoma, Diabrotica), Elateridae, Grillidae; there are some species (Spodotera sp and Anticarsia) that are mainly in Conventional tillage.

2.3.5 Water Efficiency

In evaluations done by CIMMYT between 1997 and 1998, the major water pick up in the soil was demonstrated with No tillage, especially when it was combined with crops rotation. In the dry winter of 1998, the vertical or conventional wheat tillage produced 509 kg/ha with no tillage in monoculture 811 kg/ha and no tillage crop rotation of 949 Kg/ha, due to the humidity stored in the soil benefit. (PROTRIGO, 2001).

The stored in the soil water effect before seedtime, the wheat in the winter of 2000, was evaluated in 60 farmers´ fields, it showed that each millimeter of water was translated in 9,6 Kg/ha of wheat grain. In other works done in 1992 (rainy) and 1993 (dry) showed that during the dry year, each millimeter of water was translated to 46,2 Kg/ha of wheat grain whereas in the humid cycle, when there is enough rain, it lowered to 6.9 Kg/ha (PROTRIGO 2001).

Analyses made by Wall, P. 2001 (nonpublished data), with 34 fields of soybean data and 15 maize fields of a leader in no tillage system with crop rotation farmer showed the following results:

1. The soybean yields differences are explained in a 53 % by the rain, the processing winter crop, cariety and sowing date this for soybean. The 83 % of the differences were explained with rain, preceding cultive, and other variety.

2. The results in soybean, show that each millimeter of accumulated water (rain in the fallow) before seedtime had a benefit of 10.1 Kg/ha of grain.

2.4 Socioeconomis Impacts (production, works, benefits, quality, health)

2.4.1 Small – Medium Scale Agriculture

Conventional an No tillage, has had a vertiginous growth in the Bolivian Tropic, reaching near to 65% of the cultivated area, with annual crops like: soybeans, wheat, maize and sorghum; all associated to the impacts the farmers have observed, mainly from medium to high production, such as: (1) Lower machinery and equipment wearing down; (2) Less expenses in the equipment and machinery maintenance; and (3) Manual labor reduction.

2.4.1.1 Equipment and Machineries

The machinery wearing in No tillage is lower, because it works with less dust and less effort, for example: a tractor can work for 10 years under the conventional system, snd it will life fro 3 to 4 more years working under no tillage. There is less use of pieces and lubricants, as well as less time repairing machines.

An economic evaluation of 3 tillage systems (Level, ET AL. 1995), No tillage, Flexible tillage, and Vertical tillage, compared with conventional tillage, and considering equipment, machinery, fuel, manual labor, concludes with “no tillage is more efficient than the other tillage systems”. The economic evaluation was based on a test with 12 agricultural seasons and is valid to get to know about a small and medium production.

Table 6 - Percentage differences in use of machinery and equipment, fuel consumption and use of Labour Force between No Tillage, Flexible Tillage, Vertical Tillage, compared with the Conventional Tillage, in the Humid Tropic zone of Santa Cruz (Bolivia).

Factor Analysis	Tillage Sistem			
	Conventional	No tillage	Flexible	Vertical
Use of machineries and equipment (hour/ha)	0	-46	-33	-20
fuel Consume (lt/ha)	0	-42	-39	-13
Use of manual labor (hour/ha)	0	-46	-33	-20

In table 6 we can observe that no tillage has a major impact than other systems, because of the following reasons:

1) In the equipment and machinery use, there is hours of time average decrement of 46 % related with no tillage, and it is better than in the otter tillage systems. It is because of its minimum use in no tillage. It is not necessary to to plow and track de soil, and the activities concentrate in sowing and fumigation decreasing the need of tractors.

2) Because of the machinery (hours/tractor) decrement, the use of fuel and lubricants in decreased too. As it is shown in figure 3, the average difference is about 42%, lower than in the other tillage systems.

3) The use of manual labor in no tillage is related to the machinery and equipment use, because of being qualified manual labor (operators). In figure 3 an average perceptual of 46 % lower tan in the other tillage systems can be noticed.

2.4.1.2 Costs and Profitability

One of the no tillage impacts in the Bolivian tropic zone is related with the operative costs under this system decrement. Although the cost of the sowing machinery is higher to the conventional tillage, it is not important at the time of avoiding the discs use.

The economic evaluation of the "test established with 3 tillage systems compared with conventional tillage, during 12 Agricultural seasons in the central zone of Santa Cruz" (Llanos, et.al.1995), it ends with the decrement of no tillage in a higher percentage the operation costs related to the other tillage systems.

Table 7 - Percentage differences in use of machinery and equipment, fuel consumption and use of described manual labor, between no tillage, Flexible tillage, and Vertical tillage, compared with Conventional tillage, in the zone of the tropic of Santa Cruz (Bolivia).

Factor Analysis	**Tillage System**			
	Conventional	**No Tillage**	**Flexible**	**Vertical**
Use of machineries and equipment ($us/ha)	0	-35	-35	-27
Fuel Consume ($us/ha)	0	-42	-39	-13
Use of manual labor ($us/ha)	0	-38	-24	-9

It is shown in table 7 that there is a big decrement in no tillage costs, related to the other tillage systems, because of the following reasons:

1) Lower costs because of the equipment and machinery use, because in no tillage, it is necessary to plow and track the soil as in the other tillage systems. Its sowing cost is higher, but even this, the final total is lower tnah the other systems.

2) Less cost in the fuel consumption (-42%) in relation to the conventional system.

3) Less cost in manual labor.

The economic evaluation of tillage systems compared with conventional tillage, considering the total costs, in no tillage presents a total cost > other tillage system.

Table 8 – Cost ($us/ha) . E.E.A.S 1995

Cost	Tillage System			
	Conventional	**No Tillage**	**Flexible**	**Vertical**
Depresation	21,14	13,78	13,73	15,34
Combustible Cost	23,66	13,73	14,39	20,59
Pesticidas Cost	85,39	127,05	123,65	88,05
Manual Labor Cost	7,48	4,60	5,70	6,82
Total Cost	137,67	159,16	157,47	130,80

The higher cost of no tillage is because of the herbicide use during the firts five seasons, where gifosato (4 to 5 lts/ha) is used.

2.4.2 Large Scale Farmers

2.4.2.1 Equipment and Machineries

In relation to the large-scale agriculture, farmers have had experiences using the most of the machinery in no tillage, and the decrement of the qualifies manual labor (30%) as in a company in the Humid Tropic of Santa Cruz (ANAPO-CIMMYT-CIAT, 2001).

In table 9 there is a company that had 6,390 ha (summer + winter) in 1993 to 13,633 ha (summer + winter) in 1996, with an increment from 15 to 80 % of the no tillage area in that time, without machinery investments, with the following results:

1) The tractor use (hours/tractor) incremented 23% , improving the efficiency of this equipment, HP/ha decreased during the summer from 0,40 to 0,27 that means less intensive work for the team, and the harvest area increased from 59 to 88 % the harvest with own machinery area, because the availability of operators for this labor.

2) There is an efficiency improvement in the use of manual labor, from 148 to 217 ha/operator during the summer, and from 178 to 379 ha/operator all year.

Table 9 - Efficiency of Use of Machineries and manual labor in a Company of Santa Cruz

Year	1993	1996
Hectares seeded/year	6.390	13.633
Hectares seeded in summer	5.020	7.800
Percentage in no tillage	15	80
Hours/tractor	1.560	1.923

HP/ha in summer	0,40	0,27
ha. harvested with own machinery	3.776	11.953
% area harvested with own machinery	59	88
Number of Operators	34	36
ha/operator (summer)	148	217
ha/operator (total year)	178	379

2.4.2.2 Costs and Profitability

In large-scale farming, according to the agricultural companies' experiences, the maximum use of the machinery brings high maintenance costs (ANAPO et. Al. 2001), but the ha cost is still being lower than the machinery maintenance cost in conventional tillage.

Table 10 - Costs of machinery and maintenance in a company of Santa Cruz

Year	**1993**	**1996**
Hectares seeded/year	6.390	13.633
Hectares seeded in summer	5.020	7.800
% in no tillage	15	80
Net Value of Machinery ($us)	716.209	668.468
Net Value/ha ($us/ha)	112	49
Expenses and repairs * ($us)	74.719	131.581
Cost in repairs ($us/ha)	12.47	9.65

*It includes tractors and other implements. The machinery has not been renewed, so the expenses with older machinery were higher.

It is observed in table 10, the company lowered its costs in machinery maintenance (replaced and repairs) from 12,47 to 9,65 $us/ha. Although the reduction has not been significant, is necessary to consider that they were able to maximize the sowing area without higher machinery investments (tractors), the same machinery was used with higher intensity, improving its efficiency. The company said that, with conventional tillage, they must have had to replace the old tractors for new ones, but no tillage system allowed them to use the old tractors.

In relation to the profitability, we can indicate that the no tillage cost decrement has incremented the annual crops rentability, as in the case of: wheat (PROTRIGO, 2002), incremented 50 % in the all crop benefit.

Table 11-Comparation of the net benefit in the wheat under no tillage and Conventional tillage. ($us)

Description	No Tillage	Convencional Tillage
Income	240,00	240,00
Operative Cost	202,00	183,00
Net Benefit	38,00	57,00
Percentage Increase		**50%**

2.5 Environmental Impacts

2.5. Erosion mitigation erosion

Few Works have been developed in Bolivia and particularly in the region of the Humid Tropics, which is generally very flat. Works carried on by Montenegro R.M. (1987), measuring the soil losses due to hydric erosions in the zone of the humid tropics (plains) showed the following values of C, factor that measures the influence of the tillage systems in the calculation of soil loss:

Values of C for different tillage systems in the calculations of soil loss due to erosion, Humid Tropics - Bolivia

Tillage System	% of shadow	% leaves trash	Value of C
Cocoa with shadowy trees	60	80	0,003
Coffee with shadowy trees	70	80	0,002
Rice cut and burn	70	60	0,036
Cocoa or coffee with plantain	50	20	0,05
Tillage in strips	60	20	0,24
Continuous rice in conventional farming		30	0,22

The lower values of soil loss occur in the system of coffee with shadowy trees and the main factor that influences in the low values of soil loss is the value C; in this case, the losses due to hydric erosion present variations of 0.04 to 3.2 ton/ha/year according to the erosive characteristic of the soil. The system of continuous rice in conventional farming presents the highest values of soil loss due to hydric erosion (4.3 to 353.8 ton/ha/year) in an area considered of highly erosive rainfalls.

Ávila (1999) found lesser soil losses due to hydric erosion in a frank soil without slopes in measurements made under simulated rain in direct seeding with tillage rotation in relation to other farming systems. The applied rain was of 65 mm/h (during one hour) in the first evaluation, and other 65 mm/h (during half an hour) 48 hours after the first one; the sum of both evaluations measured a soil loss of 0.05ton/ha for the direct seeding with tillage rotation, 0.94 ton/ha for direct seeding without tillage rotation, and 4.69 ton/ha for conventional farming. These results hold relation to the soil covering and the time of the beginning of water glide.

2.6 Levels and Problems of Adoption

2.6.1 Valleys Region

In the valleys region, where the main practice is associated to low scale agriculture, the adaptation levels of conservation technologies, are still an issue, eventhough everything done in technology transference through programs and projects supported by international organisms.

The problems in the adoption of new technologies are generally associated to the little economic availability from farmers to adopt these technologies, for example:

- The effect in the use of crop covers is evident, but to let the strubble in the field to protect and feed the soil implies a cost from the farmers, because the farmers use the strubbles to feed his animals, although they marinate, roof their houses, or sell them as forrages.

- To start with no tillage, that would be the way to work the crops and to leave the strubble, an investment in machinery is needed, it would be the animal traction to start with the labor.

- The used of turning the communitarian lands for the cattle pasturing after the harvest and manual beats of the crops, specially cereals, are practices that difficulty the strubble maintenance in the field.

2.6.2 Humid Tropic Region

2.6.2.1 Small-Medium Agricultural Scale

Although there have been necessary efforts to promote no tillage, there are two groups of farmers who do not care about the system: the small farmers, mainly because there isn't any adecuated machinery for their farms sizes; and Mennonites farmers, mainly because of their tillage history, and their technical decisions associated to their religious beliefs.

But there are also some small farmers that have adopter no tillage. Other Mennonites colonies have adopted conservationist technology; in both cases important adoption levels are being registered.

Although thy have managed to validate direct sowing machines using animal traction, it have generated expectation of small farmers, considering it was a new and interesting option to surpass their dependency of hiring big equipment, but it has not been possible to reach the adoption levels because of the lack of a major effort in the diffusion and transference of technology.

Considering the importance of transferring no tillage system technology nowadays, ANAPO is working on two projects oriented to that purpose, which are: 1) Technologies for Sustainable soil use in the Humid Tropic integrated and of expansion zones; and 2) Diffusion of conservationist technologies for the Mennonites colonies.

2.6.2.2 Large Scale Agriculture

The achieved success with the No tillage system promotion, covering 65% of the seeded area with annual crops (soybean, maize, wheat, sunflower, and sorghum, among others) was mainly because it was practices by big scale farmers. This kind of farmers mainly use Conventional tillage, that allowed the to stop the degradation of their soils.

In every production scales, the fact was the adoption of no tillage, as not having to labor the land, but even with this the level of adoption of no tillage system is very low. There is also a very low crop rotation, in most cases the crop rotation only takes place during the winter season for the dry zone, and summer and intermediate season for the humid zone. In general no tillage is decreasing the total advantages of the system, and is causing bad results to a lot of farmers; hardening of the soil and higher incidence of root diseases and soil.

The tropical conditions with high humidity and temperature, in which humid tropic agriculture takes place, causes the strubbles degradation to be intense and makes it impossible to get good levels of soil cover, which forces to introduce crop rotation with some species that contribute with big amounts of dry matter and strubble to the soil.

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