PARTICIPATORY DEVELOPMENT OF NO-TILLAGE SYSTEMS WITHOUT HERBICIDES FOR FAMILY FARMING: THE EXPERIENCE OF THE CENTER-SOUTH REGION OF PARANÁ

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Abstract. It is currently estimated that 40 million hectares worldwide are cultivated through no-tillage systems (Derpsh, 1998). Small family farms account for less than 50,000 ha, half of them located in South America's Southern Cone (Wall, 1998). Many hypotheses have been offered to explain why so few small farmers have adapted to this method. The most simplistic ones relate this limited adoption to small farmers' traditionalism and to their rejection of innovation. Others point to the low technological development of animal-drawn equipment needed for this technology or the low educational level of family farmers.

Results of work done in the Center-South of Paraná, Southern Brazil, by AS-PTA[1] in partnership with the region's Forum of Family Farmers Organizations, challenge these hypotheses and draw attention to the need for new approaches and processes of research and extension if the goal is to disseminate and implement appropriate no-tillage systems among family farmers. One requisite is to lower production costs of this method through elimination of herbicides and using green manure and cover crops that shift the crop-weed balance in favor of crops.

Key words: ecological soil management, family farming, green manure/cover crops, no-tillage system, participatory development, participatory research.

Abbreviations: AS-PTA – Assessoria e Serviços a Projetos em Agricultura Alternativa; IAPAR – Instituto Agronômico do Paraná.

1. Introduction

1.1. THE REGION

Parana's Center-South region, along with the coastal and the Curitiba[2] areas, were the first to be occupied by the European settlers. For this reason the region is also known as 'Traditional Paraná'. The first settlers developed one of the most beautiful forms of peasant agriculture: the 'Faxinal System' (Yu, 1988).

The 'faxinals' combine multi-cropping with animal husbandry and exploitation of forest species. The system is an example of man's adaptation to the natural environment as it allows for a balanced distribution of farming activities over time and space, optimizing the use of local resources and satisfying the social-reproduction needs of thousands of families for more than half a century.

Since the 1960s, with the encroachment of capitalist forms of production into the region's agricultural sector, an increasing process of 'faxinal' disaggregation has been observed, entailing major changes in the agriculture/environment interface (Yu, 1988). From a self-centered development model grounded on the optimization of natural-resource use through

Environment, Development and Sustainability **1:** 235–252, 1999.

ecosystem management, agricultural practices became progressively more dependent on the use of external industrial inputs. In parallel and as an immediate consequence of this shift in technology, a gradual and steady reorganization of the rural space has taken place, starting with the ‘fencing-in’ of communal grazing land. These ‘commons’ were private spaces for collective use where small- to medium-size animal husbandry and maté[3] extractivist activities took place. Far from representing an improvement in local social conditions, as proclaimed by the mentors of technological modernization, the ‘development’ entailed by this process reorganization has simply repeated an age-old vicious circle, by combining huge social exclusion with unprecedented levels of environmental degradation.

The challenge undertaken by countless family farmers’ organizations organized in the Forum of Family Farmers Organizations of Paraná’s Center-South Region, with support from the Brasilian NGO AS-PTA, has been to break down this vicious circle through the creation of a development model that is economically feasible, socially just, culturally adapted and ecologically sustainable. To achieve this goal an intense and dynamic social process was launched, involving farmers in technological research, communication and training in agrobiodiversity and soil-ecology management, agro-industrialization, marketing, food security, etc. The farmers’ participatory research on no-tillage systems without herbicides described herein is part of this broader process.

1.2. CHARACTERISTICS AND EFFECTS OF TRADITIONAL SOIL MANAGEMENT IN THE REGION

As in several other regions of the world where traditional agricultural practices prevail, shifting cultivation and fallow periods followed by brush burning have long been the widely recognized technique adopted by family farmers in the Center-South region of Paraná. This traditional technique allows the recovery of the soil’s productive capacity. Yet the need to intensify plot use, along with the introduction of chemicals and mechanization, have brought a decline in this style of traditional soil management in rural communities.

In order to intensify land use, farmers have, to various degrees, applied lime and chemical fertilizers. High input costs, however, have constrained farmers to abandon official research recommendations, with consequently poor production results.

On many farms the burning of crop residues and grasses – mostly *papuã* (*Brachiaria plantaginea*) – is still the rule, as farmers ascertain that it is a necessity to facilitate tilling. By doing so they no longer incorporate a few tons of biomass per hectare and over-expose soils to erosive agents, eventually leading to an increase of organic-matter oxidation rates and a decrease in soil biological activity. Estimates are that a one hectare plot with corn stubble and *papuã* grass loses after burning 63 kg of nitrogen, 9.3 kg of phosphorus, and 101.2 kg of potassium. The cost of replenishing these nutrients, by means of chemical fertilization, reaches USD 89.00 (Marques and Tardin, 1996).

In mixed corn + black beans systems, after cutting and burning plant residues, plowing is done with a curved beam plow, followed by harrowing with a tooth harrow (plowing can be done twice while harrowing can be done 2–3 times). In order to control the major weed, the *papuã,* farmers use a low-cost pre-emergence herbicide, trifluraline. It is applied to the open soil, after plowing and harrowing. It is later incorporated to the soil with a new harrowing. With this kind of management, soils remain exposed for a long period, which coincides precisely with the year's most intense rainfall – and the highest erosion risks. Some researchers have estimated that soil loss due to erosion can reach as much as 180 t $ha^{-1}yr^{-1}$, with evident short- and medium-term repercussions on the soil's productive potential (Merten, 1994).

1.3. SOIL TURNING: AN INHERITED CULTURE

European settlers in Paraná's Center-South region brought the plowing practice along with them. This practice was so widely used that it became common sense that a crop's success would be closely related to good plowing. Truly, plowing greatly facilitates planting and weed control activities.

Despite many reports on the failure of plowing techniques in tropical and sub-tropical soils since colonial times, Brazilian authorities relied heavily on new European settlers' abilities to 'compensate for the Caboclos'[4] backward and elementary practices" insofar as the immigrants would be carriers of more evolved farming methods and techniques (Yu, 1988). Thus it seems that technical models imported from other social/environmental context, over-simplification of problems and the choice of false saviors have indeed long prevailed over observation and accurate study of complex ecosystems to develop technologies adapted to local conditions.

1.4. NO-TILLAGE PLANTING IN THE CENTER-SOUTH REGION OF PARANÁ AND IN BRAZIL

The history of no-tillage planting in Brazil is not a long one. As it started, it was connected to highly capitalized farmers with large estates. This trend prevailed during the entire period when machinery used for no-tillage planting was big and expensive, therefore inadequate for family farmers' environmental and economic conditions. Starting in 1985, a group of IAPAR (Parana's Agronomic Institute) researchers invested time and effort into an attempt to extend the practice to this major farming sector. One of the first research steps was to develop a planting machine adapted to agricultural systems prevalent among family farmers, with special concern for the fact that such farm land is usually located on rough terrain and thus the use of draft animals is a basic need. That first phase has now been virtually completed, since efficient planting machines appropriate for typical family farms conditions in the region are now easily available. Yet the practice has not been adopted at large. What are the remaining limitations?

In the attempts to explain the low numbers of family farmers adopting no-tillage techniques, it is always inevitable to find individuals who will favor a simplistic analyses of the problem, focusing on the farmers' 'traditionalism' and their rejection of innovation. Others believe that '*adoption of the no-tillage planting system is strictly connected to the farmers' level of knowledge of the herbicides, the formulation of dosages, and mostly the safety conditions for applying them*' (Merten, 1994). Still others have considered that the lack of special lines of credit for the acquisition of machinery and inputs to correct chemical deficiencies in the soil has been a strong limiting factor. No doubt that access to credit to acquire equipments for planting and managing soil-cover plants as well as their seeds would permit a larger number of family farmers to adopt the no-tillage seeding method, especially because animal-drawn planting machines greatly increase labor efficiency in seeding operations. However, experiences of many local farmers show that, for successful no-tillage planting, the use of animal-driven equipment is not a must, since the use of the hand seeder, locally known as 'pica-pau', or wood-pecker can be an important alternative.

The example of many farmers suggests that one of the major limiting factors in the adoption of no till system may be that this practice was first perceived as being closely associated with the need to use expensive equipment and inputs, by definition inaccessible to most family farmers. Of these inputs, herbicides are certainly the most expensive and troublesome ones from the viewpoint of family farmers' sustainability. Some estimates consider that herbicide expenditures in no-tillage systems may reach 25% of production costs in local corporate farming systems (Merten, 1994). It is not unrealistic to estimate that herbicides may even reach 50% of the production costs for family farmers, especially since other costs tend to be very low for this category.

The 'marriage' between no-tillage planting and herbicides is so much a part of technicians' and farmers' common sense that dehydrators (a practice to dehydrate weeds established in a crop's pre-emergence phase) are recommended for winter-cover species, such as black oat (*Avena* ssp.), whose life-cycle, in Center-South Paraná's climatic conditions, makes that practice unnecessary (Tardin et al., 1998).

This type of definition contributed to the common belief that no-tillage planting was absolutely impossible without the use of herbicides, which is, to a certain extent, one of the factors that keep many family farmers in Center-South Paraná from adopting it. After all, family labor is the heaviest cost item in local farming family productive systems and the low demand on external input is a strategy toward self-sustainability. Therefore, explaining family farmers non-adoption of the no-tillage planting system as being due to a lack of resources to acquire planter machines or simply due to the families' traditionalism is not supported by the existing evidence.

The above analysis points of the fact that widespread use of no-tillage planting among the family farmers of the Center-South region of Paraná will only be possible if the technology does not rely on industrial inputs, especially herbicides.

The first results of AS-PTA's work in the region give credibility to the above assertion.

2. No-tillage planting without herbicides: some ecological foundations

One of the key purposes for turning the soil in tropical and sub-tropical environments is to control spontaneous plants that might compete with crops. If soil turning is suppressed, one of the most important strategies farmers use to deal with these plants ceases to exist. Weed control, therefore, becomes one of the major problems faced by farmers, especially during the transition point between conventional soil management and no-tillage planting.

During the conventional period, chemical, physical, and biological soil properties are degraded as a result of repeated environmentally inadequate practices. In such situations, the spontaneous plants that tend to appear are very rustic and adapted to the less favorable edaphic conditions. These plants are very efficient in transforming the available nutrients, water and radiation into complex carbon chains, forming hard and resistant structures, usually with a high C/N ratio. This is the reason why these species pools have been named ‘lignine systems’ (Vaz, s.d.). The nearly exclusive presence of grasses such as *papuã* and hay in these situations is the most evident demonstration of this phenomenon in the Center-South region.

Being more efficient than the crop plants in the use of scarce nutritional, water and energy resources, spontaneous lignine-system plants are effective competitors. Not even plowing and weeding are enough to allow crops to compete with spontaneous lignine-system plants. Under such situations, nutrients become firmly fixed and crop plants have difficulty obtaining them. In such circumstances the strategy traditional farmers use is to fallow the field.

During fallow, the pool of spontaneous plants undergoes some changes. With time the qualitative characteristics of these plants begin to change, either due to greater diversification of species or because the plant species that become dominant exhibit a lower C/N ratio. The plants that used to compete with crops now provide a priceless ‘environmental service’ through promotion of soil cover and protection against erosion, by efficiently mobilizing and recycling nutrients, by constantly contributing with phytomass to the system, by increasing organic matter content in the soil, by improving the soil’s water economy and promoting more favorable environmental conditions for increased soil biological activity.

During the first year of cultivation following a fallow period, spontaneous plants tend to show a better C/N ratio and cultivated plants do not suffer extreme competition. In spite of that, spontaneous plant are considered unwanted plants to be eliminated. This notion is strongly reinforced by a farming culture that still perceived a good farmer as one who keeps his crops ‘clean’. Those who sponsor spontaneous plants in their fields are said to keep ‘dirty’ crops.

In order to make no-tillage planting without herbicides feasible, one must first overcome the widespread notion that each and every spontaneous plant is harmful to crop yields. In order to reduce the need to control spontaneous plants, ecological conditions favoring plants that are less rustic, more sensitive to environmental stress factors and therefore less competitive with crops must be promoted in farmers fields. Such plants can be regarded as permanent components of the productive system. In this sense, spontaneous plants will then move from a competitor status to one of crop plant companions. Most such spontaneous plants tend to be more easily managed by means of mowing, hand weeding and hoe weeding. They are considered by farmers as ‘soft plants’.

The constant use of herbicides eventually affects the spontaneous process of species succession, invariably with self-defeating results. By using herbicides farmers are neglecting the environmental services that spontaneous plants may provide, and also accelerating soil degradation rates. During AS-PTA’s 1995 rapid and participatory appraisal of agro-ecosystems, carried out in three different communities in Paraná’s Center-South region, interviewed farmers invariably highlighted the need to increase herbicide dosages for the control of growing weed populations apparently due to increased resistance to herbicides by spontaneous species (Christoffoleti et al., 1994).[5]

2.1. FROM CONVENTIONAL PLANTING TO NO-TILLAGE PLANTING

How long does it take for the conversion from conventional planting to no-tillage planting system and how long does it take for a field to have a predominance of less rustic spontaneous plants? The answer to these questions depends on two major ecological factors:

1. The field's initial stage of degradation: the more degraded it is, the longer it will take for the field to be colonized by less rustic spontaneous plants. In a highly degraded field, existing pools of rustic spontaneous plants dominate. Thus, colonization by less rustic species will depend on the presence and abundance of the 'seed bank' of such species in the field.
2. The environment's capacity for regeneration: In Paraná's Center-South region, this factor is closely linked to the potential for mobilizing fixed nutrients, notably phosphorus. It is thus to be expected that, for instance, soils with high total phosphorus contents will regenerate more readily than those with less total contents of this nutrient. Routine soil analyses do not offer us much in the way of data needed for this assessment because they only identify the amount of soluble phosphorus.

Based on above factors, it is possible to interfere in the conversion rate by means of practices that seek to 'speed up the plant succession process' via introducing exotic plants, selecting spontaneous plants and changing the pool of critical nutrients in the soil.

2.1.1. Introducing and selecting plants in the field

Introducing plants into farm fields is one way to alter the populations of spontaneous plants. The selection and use of legumes that act as green manures is an invaluable practice to achieve such end, as this practice has varied effects on the population of spontaneous plants.

Green manures can exhibit an allelopathic action. Through allelopathy, certain plants, either living or decomposing, may inhibit other plant species (spontaneous or cultivated). The black velvet bean (*Stizolobium aterrimum*) exhibits persistent inhibiting action over sedge (*Cyperus rotundus*) and the 'picão preto' (*Bidens pilosa*) (Lorenzi, 1984). Several authors mentioned by Favero (1998) have reported allelopathic action of jack bean, against sedge.

Other effects of green manures on spontaneous plant populations include competition for water, nutrients, and light. Research conducted in the Philippines, mentioned by Altieri et al. (1978), reports excellent spontaneous plant control in the association of corn and *mungo* bean (*Phaseolus mungo*), which is a fast-growing, short-cycle leguminous plant.

Another effect is the modifications provided by green manuring on the soil's physical, chemical and biological characteristics making the soil environment more favorable to less stress-tolerant species.

Another plant selection practice in fields is the suppression of the lignine-system species in order to favor the development of plants that are components of later stages of succession. Hand weeding of the spontaneous plants before they produce seeds can achieve this end. This operation avoids rapid and wide-ranging dissemination of species that typically produce plentiful and longevous seeds. According to Monegat (1991), this is a highly efficient method that very few small landowners use, possibly due to its labor-intensive nature. In the Conceição de Baixo community, Rebouças municipality, the Bischoff family control the *papuã* by means of hand weeding in 24.2 ha before the plant's stage of seed maturation. During the first years of this management, hand weeding was carried out 5 times during each crop cycle, and regarded 8 workers to toil. The task is today carried out by 4 people and it is much less labour-intensive. The development animal-drawn weeding machines adapted to no-tillage planting systems is a major requirement during the onset of the transition period, when there is a greater incidence of lignine-system plants in the pool of spontaneous plants.

2.1.2. Changing the pool of critical soil nutrients

The balance of critical soil nutrients, such as phosphorus, calcium, magnesium and aluminum, can be altered by adding nutrient sources of low solubility such as natural phosphate and limestone. The objective here is not so much to fertilize plants but rather to speed up the process of biological succession, in order to create better ecological conditions for crop development through greater availability of phosphorus, calcium and magnesium.

3. Participatory experimenting in Paraná's Center-South: some methodological foundations

Far from being clusters closed-off to innovation or indifferent to outside suggestions, family farmers rely on selective criteria that are beneficial to their production units, preserving them as much as possible from modifications that they may consider risky. Therefore, there are social factors that determine the acceptance or rejection of technical approaches that may be alien to their cultural heritage. In order to be integrated into traditional farmer's operations technological innovations undergo a constant process of transformation and adjustment. This is, indeed, the spontaneous process of technical experimentation that has always been responsible for the evolution of techniques throughout the history of agriculture.[6] Ignorance of such process has led to verticalized research and extension systems so often called 'technology-transfer' systems, to not be able to satisfactorily cope with demands for appropriate alternatives needed to solve farmer's typical problems.

Understanding and potentializing family farmers' knowledge is a pre-condition for developing effective participatory approaches to generate and promote technology. Participatory approaches value the complex and diverse wisdom accumulated by farmers and rural communities regarding processes and techniques to manage the natural environment, just as much as scientific knowledge produced by researchers and extension agents. This balance is rather subtle, and difficult to achieve in practice. AS-PTA's experience in Paraná's Center-South region has provided some important clues to that effect. Here we will succinctly present some of the principles involved.

3.1. RECOGNIZING THE INNOVATIVE SPIRIT

The best farm-management practices have been discovered by farmers themselves. Even in the most culturally closed agrarian societies, there are always cracks and openings for the development of knowledge and skills. Otherwise, there would be no evolution of farming cultures and thus they would eventually disappear. Where do innovations come from? How do they move beyond the status of innovations to become widely used and incorporated by other families? There are apparently two opposing forces in this process: on the one hand, a certain technical routine determined by more-or-less rigid cultural norms that end up imposing a certain immutability in the management of productive systems; on the other, deviations from this routine implemented by some farmers on an individual basis. As farmers dodging the norms, the latter are often discriminated by their peers – even seen as 'crazy' – in their communities. 'Crazy but not mad'[7], as they know perfectly well why they are deviating from the norm and what they expect in return; they are farmer-researchers (F/Rs). Starting from a problem that affects his crops or livestock, an F/R is the one who has an idea about what may be the cause of this problem and decides to try something to solve it. It is therefore a formal process of experimentation, just as the most systematic process of scientific research (Hocdé, 1998).

Contrary to what most people think, these F/Rs (deviant) are not rarities. It is hard to find communities without them. In Paraná's Center-South region, there are many such farmers whose capacity for innovation varies considerably. What really matters is that the 'germ of innovative spirit' is there and it needs to be stimulated in a process of participatory development of technologies.

3.2. SOCIAL VALUATION OF THE F/R

To start with, the social value F/Rs must be recognized if they are to enhance their inventive/adaptive capacity. They must no longer be isolated, and a favorable environment should be created to socially legitimize them so that they feel they are part of a broader process of community problem-solving. The idea is to stimulate individual creative actions and integrate them into a collective process. 'I am not alone' is the immediate realization for someone who has always innovated in isolation despite his/her neighbors' prejudice, and who learns for instance from a video or a radio program that other farmers are doing the same thing in other communities or municipalities. In the process, self-esteem is a key value and a driving force in the participatory process. Besides having someone to listen to the knowledge he/she acquired from his/her experiments, an F/R who is somehow connected to a collective dynamic of trials is likely to assimilate ideas from other F/Rs in order to improve on those very experiments. Knowing he/she is part of a broader process, the F/R is stimulated to carry on with his/her experiments. He/she is therefore awakened to his/her possibility of breaking the technological dependency treadmill imposed by the Green-Revolution's research and extension system and gaining the courage to stand and face his/her own problems.

3.3. INTERACTION AMONG F/RS

At first, a greater diversity of experiments increases the chances for new advances in management practices ('diversity is the matrix of evolution'). However, for these advancements to be used in the collective process of knowledge construction, it is key that F/Rs share ideas with one another. F/R meetings are, in that sense, essential forums for such interaction, like 'idea fairs'. The greater the exchange at such events, the greater the possibility for deviation from cultural norms that hinder an innovative spirit and the greater the stimulus to research. Thus, a simple exchange process may end up accelerating a farmer's innovative capacity.

This exchange of ideas, however, is not to take place exclusively amongst farmers. It will be even richer with a greater diversity of insights, opinions and knowledge in debate. As such, the technicians' participation in the process plays a key role in the F/Rs' collective and individual thinking, both in terms of stimulating them and in providing new technical and scientific knowledge.

3.4. EXPERIMENTING/TRAINING/COMMUNICATING: THE INTERDEPENDENCY OF PROCESSES IN THE PARTICIPATORY APPROACH

The combination of different people's knowledge is the essence of the participatory approach. As the technicians' knowledge is added to the F/Rs' research and exchange forum, as part of a strategy for on-going technical training, the troublesome process of management practices is thus eased. This is why technical training must both feed and be fed by the farmers' research process. As such, both technicians and farmers are trainers, each bringing in his/her own content, in a synergetic dynamic of generating knowledge built upon empirical/rational methods and grounded on developing a spirit of hypothesizing.

Establishing an efficient communication process is, in this context, an essential condition for giving momentum to the farmers' research and to the strategy of technical training. Research, while mostly individual, lies within a collective process of seeking technical alternatives. This is why it loses potential outside an efficient communication process. In this sense, the three processes of experimenting, training and communicating must be tied together in a Gordian knot, to ensure their indissolubility in a chosen methodological strategy. Research processes and results, as well as the technical training contents involved, must be systematized and communicated, otherwise they lose much of their social impact. They are communicated both through witnessing, at F/Rs' exchanges and in training events, and from remote information on radio programs, videos, newsletters and newspapers etc.

3.5. SPREADING THE EXPERIMENTATION PROCESS

The participatory approach to agricultural development breaks with the vertical logic of 'technology transfer (or dissemination).' Instead of disseminating technologies, it disseminates a process of generating and adapting technologies. In other words, instead of generalizing a technical proposal, it is interested in generalizing the social process that generated this proposal. This means stimulating mass research, always in combination with training and communicating processes. This dynamic gives farmers leading roles by means of a horizontal 'farmer-to-farmer' process.

In this process, several F/Rs will simultaneously take the role of farmer-promoters, shouldering the tasks of providing technical training and stimulating research in their municipalities and communities. The intention is to start something like a kind of 'social metastasis' by multiplying the F/Rs' initiatives so that research processes become cornerstones in a collective dynamic of agricultural problem-solving.

In the Center-South region of Paraná, there are 147 farmers currently carrying out training activities in their respective municipalities and communities. These farmers are organized in theme groups. Eighty F/Rs work in the ecological soil management group, 22 in the *mate*-tree agroforestry management group and 45 in the genetic-resources management group. Below, we present the development of this process for the F/R group on ecological soil management, with emphasis on research in no-tillage planting systems without herbicides.

4. Participatory experimentation with practices of ecological soil management

In 1993 a process of participatory experimentation was launched through a partnership between AS-PTA and Paraná's Center-South region farmers' organizations. A participatory appraisal (done in three communities representative of the region's socio-environmental conditions) identified several flaws in the productive systems, some of which are specifically related to soil management problems. Identification of the problems provided the basis for a technical strategy composed of a number of proposals involving the agroecological reconversion of traditional soil management.[8] These proposals included: elimination of crop-residue burning; green manuring/cover crops; contour lines; sub-dosages of limestone, rock powder phosphating; no-tillage planting without herbicides.

Some of these practices were already being stimulated by official rural extension agencies in the region, but with low levels of efficiency in terms of farmer adoption. The reason for this low adoption varied from one proposal to another but, by and large, the inadequacy of the methodological process, which was based on a logic of technology transfer rather than a truly participatory approach was to be blamed for this poor result.

Many farmers, however, had been incorporating some of these proposals into their individual productive systems. Such is the case of Mr. Frederico Princival and his family in Rio Azul who, stimulated by the IAPAR, have planted dozens of contour lines with elephant grass. It is also the case of the Filipak family, in São João do Triunfo, who developed an interesting crop-rotation system, including several species of summer and winter green manures as well as spontaneous-plant management. This was also the case with the Bischoff family, in Rebouças, who started their own minimum-till system, without the use of herbicides, based on manual weeding of spontaneous plants. It is certainly the case of hundreds of other families as well who, even as the creators of technical innovations and management knowledge of great value to many family farmers in the region, had not gained social recognition for their practical results, but were instead often discriminated for their innovative spirit.

Stimulus for soil management research in the region was significantly enhanced by the pioneering experiences of such families. When meetings were structured so that experiences could be exchanged between farmers and technical training fostered, many of these farmers eventually formed a regional group of farmers-researchers (F/Rs) with institutional support from the Family Farmers' Organizations Forum and technical and methodological assistance from the AS-PTA. The main objectives of the regional F/R group of ecological soil management are:

- To connect F/Rs, promoting an exchange of experiences among group members and between these participants and other farmers.
- To technically and methodologically prepare group members to become actively involved in training other farmers.
- To analyze the research methods used by the group's members.
- To expand technical knowledge on ecological soil management.
- To promote methodology studies for the training, production and/or use of techniques and didactical/pedagogical tools.
- To discuss world-views pervading the group and local rural population, seeking a philosophical formulation that will unify and provide coherence to the group.
- To develop a technical-political educational plan in connection with the theme of ecological soil management, in order to implement an on-going training plan for local farmers and orchestrated actions to influence public policies in the area.

With such a variety of objectives, this group frequently holds two-day workshops in communities where experiments of major interest to the group's technical and methodological training process are conducted. The workshops are planned and carried out to favor a pedagogical dynamic involving on-going feedback between theory and practice.

Group members are multipliers of the research practices and processes in their own communities and municipalities. Their actions are institutionally backed and logistically supported by producers' organizations at the community level (informal associations and groups) and at the municipal level (mostly unions).

An intense production of communication material (videos, newsletters, brochures, posters, radio programs, newspaper information etc.) supports the entire process. The use of video-process and video-product methodologies, in this context, has been extremely helpful.

Experiments with the technical proposals are carried out in single plots of sizes that vary according to the availability of appropriate areas and the families' own land-use patterns. Farmers experiment with innovative technical proposals in their own fields, either in isolation or in combination with other innovations. Options are discussed and the families decide what experiments to do and how, thus safeguarding the principles of autonomous decision-making, a critical aspect of the participatory process. Proposals for no-tillage planting experiments without herbicides were the most numerous. These experiments and their results are described below.

4.1. NO-TILLAGE EXPERIMENTS WITHOUT HERBICIDES

4.1.1. The process

In total, 36 experiments were conducted by 24 family farmers during a four-year period, from the winter of 1994 to the summer of 1997. The experiences emerged from 19 farms located in 7 different communities, located in Irati, Rebouças, Bituruna, and Imbituva.

The 19 participants came from four different technical groups. The first group was composed of six F/Rs from Irati and one from Rebouças, all of whom applied used to constantly applying herbicides such as trifluraline and low-dosage chemical fertilizers. A second group was composed of farmers used to applying large amounts of chemical fertilizers, herbicides and other toxic chemicals, comprised of one F/R from Irati and two from Imbituva. The Bituruna F/Rs, from the third group, traditionally applied mechanical methods to control spontaneous plant dispersion in the crop area. They did not normally apply herbicides, this practice having been recently introduced to their communities. Finally, the Bischoff family from the Rebouças municipality was a unique case, with a solid 14 year experience with the no-tillage planting system without herbicides. It was, therefore, the most advanced and solid experience in this area.

Distinct environmental conditions, different production systems, differentiated stages of land degradation and each F/R's level of experience influenced the decision-making process throughout the experiments. An additional factor was that most of the experimental plots were quite large and were therefore submitted to the same risk-assessment as the remaining production areas. Thus, even with experiments in areas managed without herbicides, some farmers decided to use them in situations when it was not possible to control spontaneous vegetation that vigorously re-sprouted, thus competing with crops subjected to no-tillage planting. This was the case in four out of the thirty-six experiments.

The experiments basically involved the planting of winter species of green manures, followed by no-tillage planting of summer crops and, in some cases, subsequent planting of summer species of green manures. The choice of GM/CC species was based on a bibliographic review of IAPAR research results (Derpch, 1992; Calegari, 1995) and followed green manuring recommendations made for southern Brazil (Monegat, 1991; Costa et al., 1992) following criteria such as rusticity; possibility of local production of seeds; adequacy to summer crops rotation, especially corn and black beans; good phytomass production. Twenty species were used in all the experiments, 13 of which were winter species and 7 summer species (Table 1).

The summer crops planted in no-tillage planting over the straw of these GM/CC species were mostly corn (*Zea mays*) and black beans (*Phaseolus vulgaris*). Some F/Rs planted these species associated and others alone. The corn/soy-bean (*Glycine max*) association was also tried in no-tillage planting, as well as the single planting of rice, onions and adzuki beans.

Regarding machinery, the experiments revealed a variety of possible implements that could successfully be used. F/Rs did their planting by digging holes with *sengo* (a one-blade digger) and hoe, opening rows with a ridging plow, with hand seeders, conventional planters and others appropriate to no-tillage planting. To prepare the soil before no-tillage system and manage the cover plants, conventional instruments such as a curved beam plow, tooth or disc harrow, wood rollers and cutting rollers were all used in an attempt to make no-tillage planting adequate to the farmers' specificities and possibilities.

Soil preparation operations for planting winter cover species involved plowing and harrowing, preferably with animal-drawn equipment, followed by seed broadcasting and incorporation with tooth or disc harrow or cultivator, or by means of minimum cultivation followed by disc harrowing for seed incorporation, and also with no-tillage planting in grooves with a hand seeder or *sengo*. In their full vegetative development, major straw-producing species, such as naked oat, were managed with cutting rollers. Species producing

TABLE I. Green manure/cover crops species used and their use in various farmers experiments

Common name	Scientific name	Number of experiments
Naked oat	*Avena strigosa*	25
Annual ryegrass	*Lolium multiflorum*	2
Rye	*Secale cereale*	1
Chick pea	*Lathyrus sativus*	1
Sam hemp*	*Crotalaria juncea*	1
Grey pea	*P. sativum var. arvense*	1
Common vetch	*Vicia sativa*	5
Hairy vetch	*Vicia villosa*	3
Corn spurry	*Spergula arvensis*	6
Jack bean*	*Canavalia ensiformes*	3
Pigeon pea*	*Cajanus cajan*	2
Millet*	*Pennisetum typhoideum*	2
Lyon velvet bean*	*Stizolobium niveum*	3
Fodder radish	*Raphanus sativus*	2
Papuã grass*	*Brachiaria plantaginea*	1
Serradela	*Ornithopus sativus*	2
Blue lupine	*Lupinus* sp.	4
White lupine	*Lupinus albus*	1
Melilot	*Medicago hispida*	1
Beech wheat*	*Fagopyrum* sp.	1

* Summer species

little biomass or knocking over naturally did not undergo any kind of management or were knocked over with wood rollers. Except for one researcher who used mechanical traction, all of the rest made no-tillage planting of black beans using animal-drawn planting machines. In most cases, corn was planted with a hand seeder. The F/Rs who did no-tillage planting with onions used planting machines to open up the rows and then manually transplanted the seedlings.

Most F/Rs chose areas previously farmed intensively with annual crops, for 5–40 years. By and large, high acidity and low phosphorus contents were reported. Most of the areas were not subjected to any acidity correction procedure, and only five had received a 3–4 t ha^{-1} lime application in the past ten years. Two researchers had used rock phosphate and lime correction in a period prior to the experiment. Summer crop chemical fertilization with urea cover was used only by some.

The F/Rs were responsible for recording and observing, and the most important aspects to be observed were discussed by the entire group. Evaluations were made individually and during collective activities involving other members of the community, municipality or region. Observations, especially qualitative ones, were made in an attempt to highlight the evaluation indicators chosen by the farmers as much as possible. During the first year, the dry mass was evaluated from 10 m^2 samples of each winter species tested. In subsequent years, evaluations were restricted to visual observation of the cover and production of mass, graded as poor, passing, good or excellent. Control capacity over spontaneous vegetation was also evaluated by means of visual observation, and records were kept of species persisting after introduction of no-tillage planting as well as the intensity of their cover. Yields and overall performance of annual crops were evaluated. The final amount of information varied according to each F/R's skill and dedication to the task of experimenting and monitoring.

4.1.2. Results

The way in which the experiments were conducted did not allow for strictly quantitative analyses, as with experiments under controlled conditions. Nevertheless, observations are qualified by the fact that experiments were conducted in several areas and relied on the farmers' mastery of good management practices.

Of the winter cover species that were evaluated, common vetch, hairy vetch, grey pea, chick pea, naked oat and annual ryegrass stood out in phytomass production and suppression of spontaneous species. Corn spurry also stood out as a promising species for the no-tillage planting of rice. Association of rye or oat with vetch or grey pea also exhibited good performances.

Experiments which included summer cover species in association or rotation displayed good potential. The lion velvet bean proved to be an excellent choice for soil cover, better than the other tested species. The jack bean, dwarf pigeon peas, sam hemps (*C. juncea* and *C. spectabilis*), beech wheat and dwarf velvet beans tested in association or in succession were reported as being good for phytomass production and control of spontaneous plants. Among the spontaneous species, the *papuã*, which is best adapted to the region, stood out as a good phytomass producer in edaphic conditions that are usually unfavorable for most cover plants that were introduced.

The experiments also showed that the success of no-tillage planting without herbicides depends on the right timing for different management practices. In plots with less incidence of spontaneous species, the no-tillage planting of summer crops carried out in the beginning of the agricultural period minimizes competition problems, since the main crop will eventually smother spontaneous species. In terms of timing the planting of GM/CC species, experimental results suggest that lion velvet beans should be planted in December or January and early-cycle winter plants between March and April.

Erratic climatic conditions that occurred frequently during the period made it more difficult to conduct the experiments. Two of the three experimental years were very bad for local agriculture due to negative weather. Nevertheless, these weather conditions helped reveal some of the limitations of the chosen GM/CC species. Years of heavy rainfall accelerated the decomposition of species such as vetch and corn spurry, disturbing the predicted sequence of practices.

Annual increases of plot sizes and the number of farmers involved in the experimenting process have indicated a growing interest and potential for widespread adoption of the no-tillage system without herbicides. It is important to point out that these increases have been taking place despite adverse weather conditions, which at times hindered the productive performance of the crops tested to date. This growing interest in no-tillage planting has been stimulated by the training, evaluating and sharing events on experiences in ecological soil management, which involved more than 400 farmers over the three-year period. There were cases, such as that of the Campina de Gonçalves Jr. community, in Irati, where thirty families had started large-scale experiments with the practice on their own farms by 1998.

Agronomic results of the crops subjected to no-tillage planting without herbicides, reveal significant improvement in productive performances. For black beans and corn, average yield gains of 56% and 60% respectively were reported. These results can be explained by these crops' currently very low average yields locally – 960 kg ha^{-1} for black beans and 1.500 kg ha^{-1} for corn.

Besides improvement in crop yields, farmers have noticed the positive effects of the no-tillage planting on erosion control. Beyond this conservationist effect, a possible gradual improvement of several chemical, physical and biological properties is presumed to take place as a result of the process of biological succession in plots managed under this system. In this sense, the natural tendency is a progressive improvement in the soils' productive capacity when continually submitted to the ecological management proposals currently experimented in the region.[8]

4.2. POSSIBLE REGIONAL IMPACTS OF WIDESPREAD ADOPTION OF NO-TILLAGE PLANTING WITHOUT HERBICIDES

Taking regional black bean and corn crop statistics as a basis, it can be anticipated a significant production increase for these species if the no-tillage planting system without herbicides becomes widespread (Table II).

Considering a current average annual production obtained by a family farmer of 2.34 t of black beans and 3.75 t of corn (based on 48,000 family-owned productive units in the region), widespread adoption of no-tillage planting without herbicides will have a positive impact on family income as a result of improved crop yields with no considerable increases in current production costs. Based on expected yield gains, an average increment in family production of black beans and corn is anticipated to reach 1.31 and 2.25 t per year respectively. Based upon average prices in the regional market during the 98/99 harvest, these could be an income increment of USD 563.00 (USD 387 from black beans and USD 176 from corn). With the average farm size of each family in the region reaching 2.43 ha for black beans

TABLE II. Area sown, with current and potential average yields for black bean and corn crops managed with herbicide free no-tillage by family farmers of Paraná's Center-South region.

Crop	Area sown (ha)	Regional output $1 = P1$(t)[a]	Average regional yield $1 = Pd1$ (kg ha^{-1})[b]	Regional output $2 = P2$ (t)[c]	Average regional yield $2 = Pd2$ (kg ha^{-1})[d]	$\Delta P1 - P2$ (t)[e]	$\Delta Pd1 - Pd2$ (kg ha^{-1})[f]
Black beans	117000	112320	960	175500	1500	63180	540
Corn	120000	180000	1500	288000	2400	108000	900

[a] Current production in the region.
[b] Current average yield in the region.
[c] Potential output with widespread use of no-tillage planting without herbicides in the region.
[d] Potential average yield with widespread use of no-tillage planting without herbicides in the region.
[e] Potential output gain with widespread use of no-tillage planting without herbicides in the region.
[f] Potential average yield gain with widespread use of no-tillage planting without herbicides in the region.

TABLE III. Cost/hectare of inputs needed to start no-tillage planting without herbicides (in US$)

Input	Unit cost	Requested quantity	Total cost
Rock phosphate	41.05 t^{-1}	444 kg	18.23
Lime	14.70 t^{-1}	3,000 kg	44.11
Green	NO = 0.23 kg^{-1}	NO = 33 kg	
Manure	V = 0.49 kg^{-1}	V = 17.75 kg	17.30
Seeds*	T = 0.71 kg^{-1}	T = 1.3 kg	
Total	—	—	79.64

*Considering use of the consortium composed of naked oat (NO), turnip (T) and vetch (V) and including the demand for seed production in 605 m^2 multiplication fields.

and 2.5 ha for corn, and with the average input cost for implementing no-tillage planting without herbicides to be around USD 80 ha^{-1} (Table III), the total cost for converting to no-till systems reaches at most USD 394, especially when considering that corn and beans are sown in polycultures in a significant portion of the area.

In contrast to systems based on external input use, no-tillage planting without herbicide does not rely on annual replenishment of agrochemical inputs. Such replenishment will only happen when and where a need arises. As such, initial costs must be distributed through the various crop years with no need to replenish the stock of inputs. This characteristic allows families to develop a plan for gradual conversion of their productive systems, so that innovative proposals can be implemented gradually, enabling conversion of the total farm in a few years. Evidently, given the small savings of local family farmers, the pace of this conversion is likely to be significantly increased if public resources are made available in the way of credit for purchasing the key inputs (seeds, equipment, etc) required to adopt this system.

5. Conclusions

Results of the various participatory experiments conducted so far suggest that:

1. No-tillage planting is technically and economically feasible for family farmers in the Center-South region of Paraná, provided these system are managed without the use of external inputs, especially herbicides.
2. Rock powder phosphating and liming in association with intensive use of GM/CC species (spontaneous and/or exotic) in the field are key for the success of no-tillage planting without herbicides.
3. A combination of rock powder phosphating, liming, GM/CC and no-tillage planting without herbicides bring rapid production results at low cost, even in situations of extreme soil degradation and with adverse weather conditions.
4. Widespread use of no-tillage planting without herbicides in the Center-South region of Paraná will allow for notable increments in the production of traditional crops, with significant impacts on family economies and the regional economy as a whole.
5. Careful management allows for GM/CC crops to be grown without the use of herbicides and reduces their possibility of reseeding.

6. Spontaneous species can have a roll and be used positively in soil management and conservation. Further understanding of their successional steps and role in recycling nutrients would be an important contribution to using them more appropriately.
7. Community production of seeds for GM/CC species is an important and decisive element for small farmers to adopt this practice.
8. Low-cost implements such as the wood rollers 'rolo-faca' and 'rolo-pau', and tooth or disc harrows are efficient for managing cover and spontaneous species. Development of an animal-drawn weeding machine adequate for no-tillage planting conditions would be a valuable contribution towards the development and spread of this system on small farms.
9. Further studies on the combined use of rock powder phosphating, liming, GM/CC and no-tillage planting without herbicides are needed, particularly concerning the system's nutrient dynamics as a result of different combinations and forms of management.
10. The above technical considerations and production improvements under family-farming conditions in the Center-South region of Paraná, were possible through a 'farmer-to-farmer' dynamic process of generating and sharing technologies.
11. Capitalizing on the family farmers' innovative spirit is a basic condition that adds momentum to the participatory research process.
12. Creating a favorable environment for exchanges among farmer-researchers will foster the development and sharing of innovative agroecosystem management approaches.
13. Public (municipal, state and federal) funds to finance the purchase of community equipment and to stimulate community production of green manure seeds is key to fostering the scaling-up of no-tillage planting on small farms.

Notes

[1] AS-PTA – Assessoria e Serviços a Projetos em Agricultura Alternativa (Advisory and Services for Alternative Agriculture Projects).

[2] State capital.

[3] *Maté*: Native tree whose leaves are used for a very popular infusion.

[4] *Caboclos*: mestizos of whites and Indians who inhabited the region before the wave of European immigration at the end of the last century.

[5] In this context, the herbicides toxicity must be considered. However low toxicity levels may appear in their manufacturer's sales promotions, there is extensive research to contradict this statement by showing that herbicides can seriously harm human health and the environment. California public health studies reveal that exposure to Glyphosate is the third major cause of agricultural workers' intoxication. Other studies with the same active principle revealed possible carcinogenic and mutagenic effects (Cox, 1995; Pearse et al., 1993; U.S. EPA, 1982; Kale, 1995), as mentioned by Tardin and others (1998).

[6] Upon studying the history of agriculture, one clearly notices that farmers themselves, without a systematized research method, have devised practical processes of solving countless problems in their production systems more efficiently if compared to institutional research. Moreover, it would not be an overstatement to say that most classical research successes are the outcome of 'officializing' (through experiments in controlled media) and disseminating (through rural extension) practices that had been used long before official research agencies took an interest in them.

[7] 'Crazy but not mad' is the title of a text by Henri Hocdé on farmer-researchers in Central America.

[8] In addition to proposals for ecological soil management, other techniques already undergoing a process of participatory experimenting in this work scenario will concur toward increasing the productivity of these crops in the region. Such proposals include the use of varieties adapted to environmental stress, involving varietal collection, selection and breeding activities as well as an overall enhancement of technical processes for producing and storing seeds.

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