

Soil management and conservation for small farms

Strategies and methods of introduction, technologies and equipment

FAO
SOILS
BULLETIN

77



Food
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Strategies and methods of introduction,
technologies and equipment

Experiences from the State of Santa Catarina, Brazil
by
Valdemar Hercilio de Freitas

A joint publication
Land and Plant Nutrition Management Service
FAO Land and Water Development Division
and
Agricultural Engineering Branch
FAO Agricultural Support Systems Division

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Rome, 2000

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ISBN 92-5-104499-6

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Preface

In many places in the world, efforts are underway to improve the living and working conditions of farming communities. It is becoming clear that the active interest and initiative of the farmers is crucial for the success of such efforts.

This report, originally in Portuguese, is intended for development practitioners, extensionists and leaders or pioneers in farming communities, to inform them about the experiences and initiatives of farming communities with conservation agriculture in Santa Catarina State, Brazil.

On the basis of several local initiatives, inventions and developments, there have been widespread improvements in soil management in various parts of the state, resulting in lower costs and improved returns, combined with conservation and improvement of the soil resources.

While these developments probably cannot be simply duplicated elsewhere, the methods and strategies may well inspire others to adapt and modify them for application in their own environments.

Acknowledgements

This publication, by V. Hercilio de Freitas, was translated from the original Portuguese by Anjali Barber and edited by Robert Brinkman and R. Dudal. Photographs are by the author except where indicated in the captions. Figures were prepared for printing by Marina Zanetti. The text was formatted by Lynette Chalk and prepared for camera-ready form by Chrissi Smith-Redfern.

The concept for this publication originated from José Benites, Land and Plant Nutrition Management Service (AGLL), Land and Water Development Division (AGL), and Theodor Friedrich, Agricultural Engineering Branch (AGSE), Agricultural Support Systems Division (AGS), of FAO, who also jointly coordinated the production.

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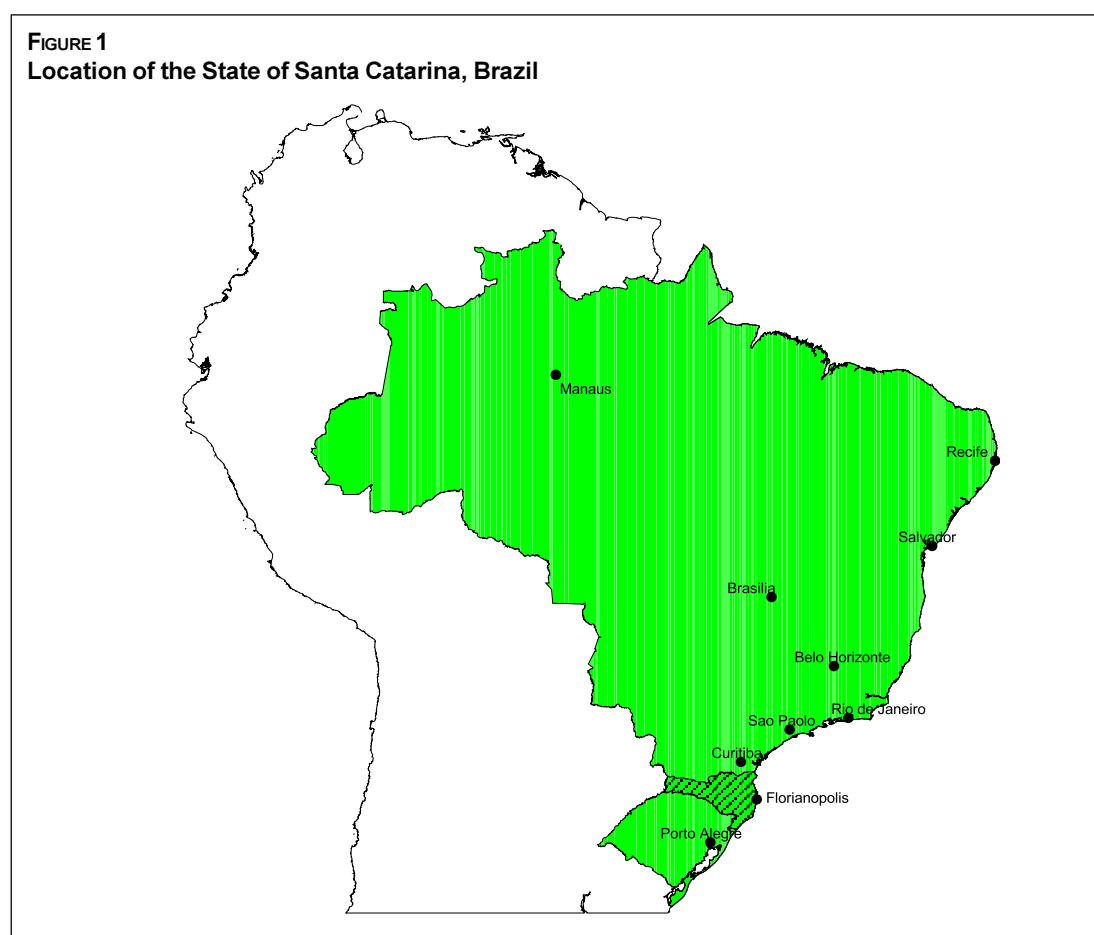
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Chapter 1

Santa Catarina: natural conditions and organizations

The state of Santa Catarina is located in the south of Brazil between latitudes 25 and 29 degrees south and longitudes 48 and 53 degrees west; it occupies an area of almost 10 million hectares, representing only 1.1 percent of the national territory (Figure 1). The population of the state is 4.5 million, of which about 30 percent live in rural areas.



Settlement of the Central Planalto region, which is 300 to 1 000 metres above sea level, was started during the 17th and 18th centuries by livestock breeders from the states of Sao Paulo and Parana, who established large properties and practised extensive farming. Colonization by Europeans started around the middle of the 19th century and developed in the coastal strip (at altitudes up to 300 metres above sea level), as a system of small farms using family labour with a great variety of crops and livestock.

From the beginning of the 20th century to around 1960 the western region was settled by farmers of mainly Italian and German origin from Rio Grande do Sul, who occupied basaltic hilly areas with 25 hectare plots aligned at right angles to the rivers. This is where the major production of cereals is concentrated today. This land has pronounced slopes: 41 percent of the area has slopes in the range 20 percent to 45 percent (IBGE/DGC and SAA/DIRN, 1994).



PLATE 1
In the State of Santa Catarina, 82 percent of the farmers are landowners

Around 40 percent of rural properties are less than 10 hectares in size (IBGE, 1998). In Brazilian conditions this situation is typical of small properties and represents one of the lowest indices of land concentration (IBGE, 1998).

CLIMATE

The climate in southern Brazil is humid subtropical, with large seasonal differences in temperature in the state of Santa Catarina. The summer season (21 December-21 March) is hot, January being typical with the average temperature exceeding 22°C and the maximum temperature reaching up to 40°C. In the Planalto region the summer is less hot.

The winter season (21 July- 23 September) is cool, July being typical with temperatures between 10 and 15°C in more than 80 percent of the territory during pronounced winters. From May to August temperatures stay relatively low and frosts may occur. In 3 percent of the territory in the Planalto region winters can be quite severe, with temperatures lower than 10°C, and sometimes dropping to 0°C with snowfalls. The coastal region of Santa Catarina has more moderate winter temperatures.

The state of Santa Catarina occurs in a region of high rainfall distributed fairly uniformly throughout the year. Average annual rainfall ranges from 1 220 to 2 280 mm and there is no typical dry season. The region can suffer from polar fronts which provoke excessive rains or periods of drought.

SOILS

The state of Santa Catarina has a great diversity and heterogeneity of soils.

Soils from sedimentary rocks (sandstone, siltstones and shales, separate or mixed) present varied physical and chemical characteristics. The majority are acidic with low base saturation, high saturation of aluminium and low phosphorus availability. They are generally cultivated with maize, beans, tobacco, cassava, potatoes and onions. The soils in high altitude zones may have higher organic matter contents and acidity, and are predominantly associated with extensive

livestock and commercial forestry. The main representative soil classes are: Cambisols and lithic soils and to a lesser extent Acrisols (podzolic soils in the Brazilian soil classification).

Soils from extrusive volcanic rocks (mainly basalt) are heavy clay soils with a high content of Fe and Al oxides. Where they occur in a gently rolling landscape they are characterized by a high degree of weathering; they are normally acid with a low natural fertility but high potential productivity. The major production of grains in Santa Catarina, such as maize, soybean, beans and wheat is concentrated in these areas where the principal soils are Ferralsols and Nitisols (Latosols and structured earths: Terra Roxa estruturada, according to the Brazilian soil classification).

Where soils from basalt occur in steep terrain they normally have a good natural fertility but poor physical characteristics, indicating a low degree of weathering. These are shallow soils with stony surfaces and stony profiles, with a low water storage capacity. The majority of the small farms in Santa Catarina are located in this area where there is intensive use of farmyard manure and green manure, animal traction and family labour. The main crops are maize, beans and tobacco. The region is also a major producer of pigs and poultry and in specific situations the production of citrus, potatoes, garlic, apples, grapes, peaches and other fruits is notable. The main soils are Cambisols and lithic soils.

Soils from intrusive volcanic rocks (granites) occur in the coastal region where the climate is milder in winter and temperatures are higher in the summer. The soils have a low natural fertility, and many are predominantly stony with a strong textural gradient. This, in association with their occurrence in steeply sloping areas makes them susceptible to erosion. The most important products in this region are tobacco, maize and beans. In areas less favourable for tillage, pastures and reforestation predominate. The main type of soils are Acrisols (podzolic soils in the Brazilian soil classification).

Soils from transported sediments in the coastal region of the Atlantic comprise alluvial soils formed from sediments transported by rivers, and soils formed directly from mountain hillsides. The majority are acidic, shallow and with drainage problems. They are commonly used for irrigated rice or pasture. In the most favourable areas, there is mainly horticulture. The dominant soils in these areas are Gleysols. The soils from marine sediments found in coastal zones are very poor, with more than 70 percent sand. Tobacco, cassava, fruits and vegetables are produced, and commercial forestry is increasing. In these areas quartzitic sandy soils predominate (Arenosols).

PRODUCTION

In spite of the limitations previously mentioned, and despite forming only 1.1 percent of Brazil's territory, Santa Catarina is the fifth largest food producer amongst the 26 states. Santa Catarina is:

- the top producer of apples and honey
- the second largest producer of garlic
- the third largest producer of onions, rice and wheat
- the fourth largest producer of beans
- the fifth largest producer of potatoes
- the sixth largest producer of maize, bananas, grapes and milk
- the seventh largest producer of tomatoes
- the ninth largest producer of cassava and soybean

Santa Catarina has about two million hectares of cultivated land, of which more than a million are planted with maize, which is the principal food supply for 4.4 million pigs (ICEPA, 1997). The quantity of excrement produced by the pigs is equivalent to that produced by a population of 44 million people, and gives rise to high risks of surface water and human food contamination in rural areas.

ORGANIZATIONS OF THE FARMERS

In Santa Catarina farmers participate in different social institutions and are organized in different ways.

The microcatchment commissions. Each microcatchment forms a commission with the aim of self-management, made up exclusively of farmers representing all the communities. Other objectives of the commission are to assess whether the project's incentives have been properly applied, to participate in the elaboration and monitoring of road-improvement works, to coordinate actions such as buying machinery, equipment and inputs for communal use, and to administer communal activities such as the operation of grain dryers. Each commission generally has an internal set of rules, with a defined process for electing representatives, who normally stand for two years.

The municipal councils of rural development. Practically all municipalities in Santa Catarina have a Municipal Council of Rural Development with participation of the syndicates, cooperatives, and leaders of the rural sector. These councils are generally coordinated by the municipal Secretary for Agriculture. It is essential that farmers from all the municipality's communities are represented in this council; they have the fundamental role of defining and implementing the Municipal Rural Development Plan, and of promoting the collaboration of the various public and private organizations interested in rural environmental activities.

The rural syndicates. Until a short time ago most of the syndicates of Santa Catarina merely had the role of helpers, principally in the field of health. Nevertheless, this situation is changing rapidly with farmers' growing awareness that without representation, the rural sector is discriminated against in the formulation of government policies. The representative bodies of farmers in the state are the Federation of Farm Workers (FETAESC), the Federation of Agriculture (FAESC) and the recently created Federation of Agricultural Family Workers of Santa Catarina (FETRAFESC).

Producers' associations. There is an increasing number of recognized farmers' organizations in the state, usually Associations of Farmers at the microcatchment or community level, which are often known as residents' associations. They are usually organized for the construction of community silos, the purchase of equipment, marketing of products, the acquisition of inputs and other similar activities. Some prefectures are also delegating the administration of municipal agricultural machinery centres to these associations, in the move towards decentralization and the shift of responsibilities to the beneficiaries.

Agricultural and Rural Credit Cooperatives. The cooperative system of Santa Catarina is one of the strongest in the country. There are 67 agricultural cooperatives and four central cooperatives which are represented by the Organization of Cooperatives of Santa Catarina State (OCESC). The West Catarina Central Cooperative Ltd. in Chapecó has sixteen affiliated cooperatives with over 4 600 members, and operates a refrigeration facility for pigs and poultry combined with meat processing and the preparation of animal rations and concentrates. There

is also a central credit cooperative with 32 affiliated cooperatives and two other cooperatives for the marketing of milk. A federation of agricultural cooperatives (FECOAGRO) also exists to provide support to marketing, purchases and sales.

Forms of Integration between Farmers and the Private Sector. One of the characteristics of the Catarina agricultural model is the integration of the private sector (agro-industries and cooperatives) and farmers, principally for the production of pigs, poultry and tobacco. In animal production, farmers normally receive the necessary inputs as well as technical assistance, and in the case of poultry production day-old chicks are also provided. The agreement with the farmer is to give the whole of his production to the agro-industry or cooperative with which he is linked, within the weight and quality limits of the product.

In the case of tobacco production the situation is similar. The farmer receives all the necessary inputs for production (e.g. fertilizers and pesticides) and free technical assistance. However the farmer agrees to apply the technology recommended by the tobacco company, to which he will sell his production. Prices are based on the classification of the quality of the product.

Chapter 2

Agricultural land degradation in Santa Catarina: process and causes

COLONIZATION

A hundred years ago, 85 percent of the territory in Santa Catarina was covered by forest. As the most fertile soils were located on hillsides, mainly in the western region, these areas were naturally settled by farmers. Many farmers in Santa Catarina are of European origin with a strong farming tradition. With the beginning of colonization the landscape was slowly changed, the changes becoming more marked in the 1950s with the subdivision of farms between family members and the sale of farms to new settlers. Because of the need for firewood and timber, pastures for animals and food for family subsistence, small farmers began to fell extensive areas of forests, which together with the irrational extraction by timber companies resulted in a drastic loss of the original native vegetation. Today only 29 percent of the state is covered with primary or secondary vegetation and hardly 4 percent of the area has been reforested (SDM, 1977).

CHANGES IN FARMING

The felling of forests was followed by burning the remaining vegetation to facilitate the sowing of crops and pastures. In the beginning, crops were planted using simple tools such as the hoe with little or no external inputs, little soil disturbance and low production costs, all of which were reflected in low yields.

With the creation of the Rural Extension Service in 1956, new technologies reached the small farmers. Animal traction substituted simple tools until the first tractors arrived on the market, and in the 1970s so-called 'modern farming' arrived in Santa Catarina with incentives to use mineral fertilizers, toxic pesticides, and heavy machinery and implements such as tractors, disc ploughs and harrows which were to contribute to the degradation of farm land. Nevertheless, some farmers achieved maize yields of up to 7.2-7.8 t/ha using this technology.

At the same time, agro-industrial processing of meat, mainly pork and poultry, was introduced into the state with government subsidies, and later strongly expanded by cooperatives, which brought about great social,



PLATE 2
Twenty-nine percent of Santa Catarina is covered by primary and secondary vegetation and 4 percent has been reforested

economic and environmental changes in some areas. The development of these agro-industries, together with the establishment of the tobacco industry, had a great influence on the type of crops grown by small farmers, especially in the case of maize, which with soya, beans and tobacco formed the so-called economic crops that were mainly produced during spring and summer (September to March). From the end of autumn to the beginning of spring, soils are normally bare due to a lack of suitable crops, apart from wheat on a small scale. This has aggravated land deterioration.

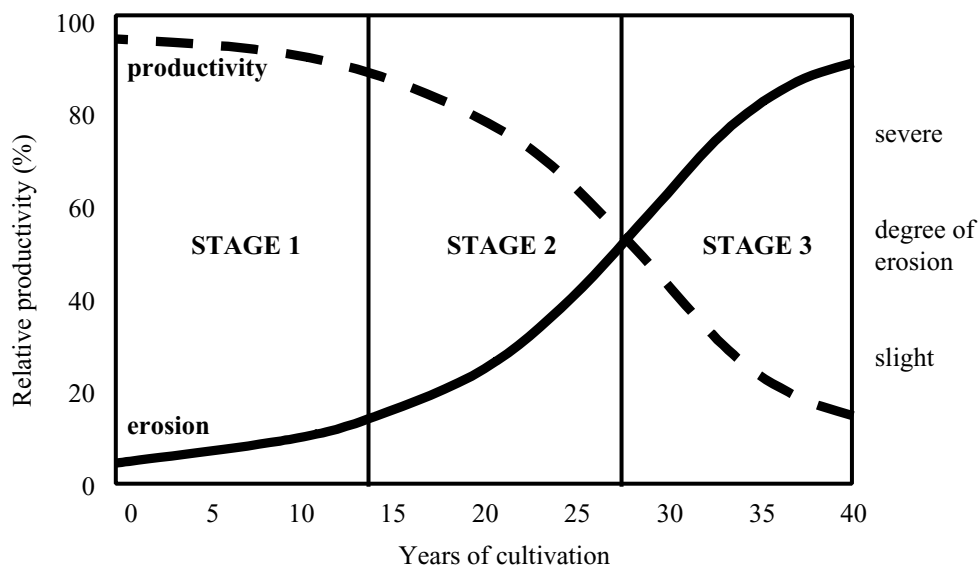
POOR SOIL MANAGEMENT

The modernization of farming and the cultural traditions of the settlers of European origin had a strong influence on the promotion of conventional land preparation practices. Intensive use of disc ploughs and harrows damaged soil properties through the pulverization of soil aggregates and the reduction of pore spaces leading to reduced infiltration and increased runoff. At the same time, cropping systems were monocultures, or at best a succession of wheat and soybean. It was also common to burn crop stubble which was sometimes incorporated into the soil. The continual use of these harmful practices reduced crop productivity and resulted in accelerated erosion which promoted and aggravated the degradation of farm land. Production was often maintained by increased application of mineral fertilizers.

Mielniczuk and Schneider (1983) postulated three stages for this process as shown in Figure 2. In stage 1, the initial good characteristics of the soil (organic matter and structure) are gradually destroyed. The land user does not perceive this phenomenon as production is maintained through the application of fertilizers, and erosion is maintained at tolerable levels.

In stage 2, soil organic matter is reduced to low values and the soil becomes structureless. Intensive use of implements causes compaction below the tilled layer, which impedes water percolation and root penetration, accelerates soil and nutrient losses by erosion and severely

FIGURE 2
Stages of degradation of agricultural land



reduces productivity. The application of fertilizers and soil amendments become less efficient because of the adverse plant growth conditions.

In stage 3, erosion becomes so intense that the farmer begins to abandon land due to the low productivity and the difficulty of operating machinery. The time required for a soil to reach stage 3 depends on the intensity of the poor management practices, the slope and soil textures. Social and economic problems usually arise in stages 2 and 3.

Lack of vegetative cover

Incomplete soil cover is a function of inadequate quantities, burning, removal or incorporation of the aerial parts of plants, as for example by incorporating green manure, maintaining soil in clean fallow, or low plant populations. These practices, which were common in Santa Catarina, left soil aggregates exposed to the direct action of raindrops of high kinetic energy, which in turn encouraged the loss of pore space (or loss of structure), and the formation of crusts of about 1 mm thickness on the soil surface which drastically reduced the entry of water and caused an increase in surface runoff.

The lack of soil vegetative cover is a result of traditional practices such as deforestation, burning, leaving the soil bare after harvest, introduction of pastures, incorporation of residues, green manure and cover crops, conventional land preparation, and monoculture.

Deforestation and burning

The loss of forest cover removes the natural protection of soils against the sun's rays and the direct impact of raindrops. There is a reduction in the infiltration of water into the soil and a simultaneous increase in surface runoff; the levels of organic material are also reduced. These factors combined with planting on steep slopes, the natural susceptibility of certain soils to erosion, and the coincidence of land preparation with erosive rainfall, accelerate the erosion process and consequently intensify land degradation.

When burning destroys trees, it also damages the flora and fauna, and affects water availability, for example springs. The problem is no less serious when farmers burn crop residues. It is through crop residues that nutrient recycling occurs in nature. The residues accumulate on the soil surface and release nutrients which are absorbed directly (in the case of potassium), or indirectly by first being incorporated in the organic matter (in the case of phosphorus, nitrogen and sulphur). With burning these nutrients are almost completely lost. Another problem caused by burning is the elimination of the supply of fresh organic matter (straw) to the soil. This, combined with conventional practices of land preparation (ploughing and harrowing), and the fluctuations in heat and moisture cause an accelerated mineralization of soil organic



PLATE 3
Deforestation and burning - causes of the deterioration of farmland

matter and a reduction in its original level resulting in negative effects on the physical, chemical and biological characteristics of the soil.

Burning crop residues leaves the soil exposed to erosion and at the same time eliminates the major source of energy for the survival of micro-organisms. Although soil temperature next to the burning stubble can be higher than 200°C, the population of micro-organisms is relatively little affected. However the population of meso- and macro-fauna (worms, insects) which inhabit the surface soil is completely destroyed, and this can subsequently cause a disequilibrium between the pests of cultivated plants (which cause infections and diseases) and their natural enemies. Because the straw burns for a brief time only, the evaporation of water keeps the soil temperature relatively low. Therefore there are no pronounced changes in the population of soil micro-organisms, and the magnitude of the reduction does not become significant because the population density is rapidly restored to its original level. The biggest changes are observed in microbial activity, which is noticeably stimulated in areas where burning is very light. However, with continual burning, microbial activity is appreciably reduced. The initial stimulus of the burn on microbial activity is related to the greater speed of mineralization of partially burnt residues and of the population of organisms that has been destroyed.

Conventional land preparation

The prevalent conventional ploughing and harrowing practices derive from the culture of farmers of European descent and from the type of training received by specialists. These farmers, who originated in colder climates, introduced their traditional systems of soil management. In addition, the training of Brazilian academics in agronomy was based on knowledge acquired in countries with conditions very different to those of Brazil, there was a lack of soil management research, the problems of land degradation were not perceived and there existed a deliberate policy of encouraging a dependency of agriculture on machinery and on the chemical industry. Under these conditions it was natural to recommend and adopt a system that left the soil devoid of vegetation, and loose and well pulverized for seedbeds at the start of the season.

At this time, investigations on soil management were focused on methods of controlling erosion, and there was little information on the negative impact of these systems of soil preparation, and on the soil physical, chemical and biological characteristics under the specific conditions of Santa Catarina. Subsequent investigations carried out in Brazil, particularly in Santa Catarina, proved that the passage of machinery, and the continual use of ploughs and harrows at the same depth and during periods of high moisture content, creates compact sub-surface layers known as a plough pan or harrow pan at 20-25 cm or 10-12 cm depth, respectively. These have very damaging effects on the development of plant root systems, oxygen availability and soil water movement. The consequences are



PLATE 4
Ploughing followed by harrowing, associated with the direct impact of raindrops on exposed soil, are the important causes of the degradation of farmland

disastrous. The rate of water infiltration is drastically reduced with a simultaneous increase in surface runoff, loss of soil, nutrients, organic matter, calcium and seeds. The microbial activity is also negatively affected.

Leaving the soil bare after harvest

Until a short time ago, it was common for farmers to leave the soil bare between successive summer crops (i.e. during the winter period) due to the lack of a crop which would give an economic return, apart from wheat, and to the use of conventional systems of land preparation in which it was not necessary to leave the straw and other residues on the surface. Often the land was maintained without any type of vegetative cover, including spontaneous cover, due to ploughing and harrowing operations, and so soils were left exposed to the direct action of raindrops and the sun's rays. Moreover, changes in the types of root systems were limited to the summer crops, and the addition of fresh organic matter was practically eliminated.

Where the residues of maize, beans, soybeans and wheat were not burnt, farmers incorporated them into the soil with ploughs or harrows. When the use of green manure started again due to the oil crisis, and this was reflected in the price of inputs known as "modern inputs," and also because the problem of erosion and its consequences were perceived to be affecting productivity, farmers continued to incorporate all of the biomass produced into the soil. This practice continued for some time because it was a common belief, even in scientific and technical circles, that incorporating biomass resulted in a greater release of nutrients, mainly nitrogen, for subsequent crops. In Santa Catarina the incorporation of biomass, which is mainly produced in winter in the period between crops, leaves the soil exposed and accelerates the process of land deterioration, because of the intense rainfall of high erosive potential which occurs during this period.

Monoculture and pastures

In the state of Santa Catarina, it is common for farmers to plant the same crop, particularly a cash crop, on the same land in successive years. In fact, there are not many options because of the close relationship between maize, which represents more than half of all cultivated land in the state, and pig production. However, small farmers still have the option of planting tobacco or beans. In winter, or the period between crops when wheat is not planted, the land remains exposed or in a fallow of spontaneous regrowth generally of low plant density. These systems therefore give few opportunities to alternate the type of root systems and their depth of penetration, which impedes the improvement of soil aeration, affects microbial life, and favours pests and diseases leading to a more intensive use of pesticides.

In pasture areas under poor management, such as with an excessive stocking rate, with poor quality grasses, continuous grazing, and generally located on steep slopes and at higher altitudes than the arable crops, if the soil is not adequately protected a significant loss of rainwater occurs which runs over the arable land below, causing serious erosion.

Chapter 3

Soil recuperation, conservation and management: concept and process

Research carried out in Santa Catarina and elsewhere in the country has shown that the direct impact of rain drops on bare soil is responsible for 95 percent of water erosion. The kinetic energy of the drop detaches soil particles, which is the first stage of the erosion process.

Subsequently, runoff water moving downslope promotes the transport of detached particles. This is the second stage of the erosion process - the transport of soil particles detached by the impact of raindrops. The transported material is finally deposited at a lower point on the land, on roads or in a river. This is the final stage of the erosion process, known as deposition. It can be concluded that the erosion process will only occur where external factors promote soil detachment.

Therefore in order to maintain soil losses within tolerable limits, similar to those which occur in nature, as for example in a forest, a farmer must cause minimum soil disturbance regardless of the situation and the agricultural activity. However, history shows that this was not the practice adopted by farmers in Santa Catarina. For a long time the dominant concept was that of sowing in clean pulverized soil to produce a good seedbed. In this way, soil detachment was, and still is, caused in many farms by humans through their interaction with the environment.

Natural physical factors such as slope, stoniness, soil depth, drainage and erosion susceptibility may favour soil erosion but are not the dominant factors responsible for erosion. When the problems first began to be felt acutely, field activities focused on the control of runoff, i.e. the transport stage of the erosive process, using mechanical means such as constructing terraces. Research on the other hand was looking for alternative solutions to the problem, without understanding that the cause of land deterioration extended beyond the problem of erosion. The manner in which man was managing the land was causing physical, chemical and biological soil deterioration. Much time passed before these fundamental concepts were understood by the scientific community, which allowed the accelerated deterioration of farm land to continue.

As research studies developed, scientists confirmed that the erosion problem was due to the way the land between terrace banks was managed. Even if the



PLATE 5
Effect of the impact of raindrops on bare soil. The breakdown of aggregates is started by the impact of raindrops, and the runoff transports the detached particles.

terraces were well constructed, the rate of rainwater infiltration was progressively reduced due to excessive soil disturbance and compaction. The disaster was evident and the technique presented as a solution, i.e. the construction of terraces, accentuated the problem even more. It is easy to imagine how terraces can be destroyed by the impact of a torrent of water.

A FOCUS ON REDUCING RAINFALL IMPACT

These problems in combination with other factors already described resulted in the revival of the ancient practice of green manuring. Firstly with the clear objective of erosion control, which later developed into what could be defined as good soil management. More important than using physical barriers to control runoff, which is responsible for only 5 percent of erosion, research showed that the ideal solution is to maintain soils covered as much of the time as possible with growing plants or crop residues. By avoiding the detachment of soil particles by raindrop impact, which accounts for 95 percent of erosion, soil losses will be avoided and at the same time the soil can be cultivated in conditions similar to those found in forests.

Nevertheless, the problem was not entirely resolved. Initially, green manure options were few, and knowledge about green manure was limited especially for the conditions of Santa Catarina. Moreover, until a short time ago the prevailing concept was that green manures were to be incorporated into the soil to provide nutrients, especially nitrogen in the case of legumes. As the use of green manures increased, other factors contributed to an increased use of conventional methods of land preparation which consist of incorporating the green manure or crop residues by cultivating the whole soil surface by one or more ploughings and two or more passes with a harrow; these factors were:

- the possession by farmers of traditional soil preparation implements such as ploughs and harrows;
- the nature of the technological package which was in widespread use, and which is still being promoted by the machinery and chemical industries;
- the lack of machinery adapted to conservationist systems of land preparation, especially for small-scale farmers;
- the lack of interest of bigger entrepreneurs to invest in this sector.

Fortunately, this situation was gradually changing, and research services, in addition to studying green manure in detail, began to look for other options.

GREEN MANURE, COVER CROPS AND RESIDUE COVER

The traditional concept of green manure involved the incorporation by ploughing or disking of the undecomposed vegetative mass to improve soil fertility and consequently crop yield.

It is not possible to maintain the soil covered for the entire year if the biomass is totally or partially incorporated. Moreover, since the more erosive rains often occur at the time of land preparation, it is essential that the soil is disturbed as little as possible so that the maximum amount of biomass is retained on the soil surface.

The present concept of green manuring or the use of cover crops is to maintain the soil covered with the living or dead biomass of these crops for as long as possible, with the object of protecting the soil from the direct impact of rain drops, excessive insolation and wind action and in order to maintain and improve soil physical, biological and chemical characteristics.

This is accompanied by the emergence of new systems of land preparation as alternatives to the conventional practices introduced from temperate climates.

MINIMUM TILLAGE, DIRECT SOWING AND CROP ROTATION

In the small farming sector, minimum tillage refers to a system that uses the minimum number of field operations in land preparation and crop management. Depending on the crop to be sown, the area of soil to be disturbed is limited to a narrow strip, between 10 and 50 cm wide. In this strip, the vegetative biomass is partially incorporated and the soil surface is 60-80 percent protected from raindrop impact and the sun's rays.

Direct sowing consists of the elimination of ploughing or soil disturbance using traditional equipment such as the plough

These technologies are widely used in Santa Catarina. Between 1994 and 1997. There was a 5.5 fold increase in the use of conservationist tillage systems for land preparation, from 124 000 to 685 000 ha, which indicates that the strategy used to extend this technology in Santa Catarina was effective.

Nevertheless, neither the scientific community nor the farmers consider this to be sufficient to permanently resolve the problems of soil physical, chemical and biological degradation. In the majority of farms producing grains, the preference for a particular species of green manure or cover



PLATE 6

The revival of the ancient technique of using green manure or cover crops has been the basis of the recuperation of degraded soils



PLATE 7

Minimum tillage



PLATE 8

Direct sowing is practised through a cover of crop residues or in a narrow partially cleared strip, avoiding ploughing and minimizing soil disturbance [Administração Regional da Epagri de São Miguel do Oeste]

crop, such as black oats (*Avena strigosa*) and vicia (*Vicia* spp), often associated with a specific subsequent crop such as maize, has created serious problems such as soil compaction, nutrient concentration in the surface soil, and certain pests, diseases and invading weed species, which have resulted in an increase in the use of toxic pesticides.

Therefore, it is not sufficient merely to maintain the soil covered and to use tillage systems that cause minimum soil disturbance. Direct sowing has come to be considered as a system and not just a method of land preparation. For the system to be successful, it is necessary to introduce crop rotations, i.e. the use of a sequence of different species in time and space within the farm. Crop rotation is the basis for the sustainability of direct-sowing systems.

In summary, the recuperation, conservation and adequate management of soils must necessarily include:

- the use of different types of green manure or cover crops with abundant and vigorous root systems
- the continual supply of fresh organic matter
- the use of conservationist systems of soil preparation, such as minimum tillage and direct sowing
- crop rotations.

Government investment and the private sector, especially tobacco companies, popularized these concepts through soil conservation seminars and meetings on direct-sowing methods. As a result there was a considerable increase in the area planted with green manure and cover crops, and of conservation tillage systems such as minimum tillage and direct sowing, in all regions of Santa Catarina.

Chapter 4

History and changing concepts in rural development

For a long time soil and water conservation works were implemented in Santa Catarina in an isolated manner, using traditional planning units such as the community or the farm. The main thrust was always towards mechanical practices such as constructing terraces and live barriers. The degree of adoption could be considered high, but after a short time the practices were abandoned because the management of soils on the terraces was carried out conventionally using ploughs and harrows.

From 1978 onwards a campaign was launched to promote vegetative practices for erosion control such as green manure and land preparation systems based on minimum soil disturbance. Good results were achieved with the dissemination of various species of cover crops and green manure. However, the activities continued to be localized, which diminished the efforts of rural extensionists; added to this was the lack of any integrated action between the different bodies working with farmers, and the limited participation of the public sector.



PLATE 9
Isolated mechanical practices such as terracing do not solve the erosion problem

In 1983 and 1984 the consequences of two great floods were felt, which led the authorities, scientists and affected population to seek solutions that would at least minimize these problems. Taking into account the experiences since 1980 of the neighbouring state of Paraná, a project on the management of natural resources was initiated which considered the hydrographic watershed as the planning unit.

In 1984, three municipalities were selected to initiate these projects, which formed part of the large hydrographic watershed of Santa Catarina (watershed of the river Itajai-Acu), of 15 000 km² where the floods of 1983 and 1984 had been so disastrous.

In 1985-86 the project was extended to 14 municipalities, bringing the total to 17 catchments. In 1986, with the support of the Federal Government through the Ministry of Agriculture, the National Program of Hydrographic Catchments was created with the objective of covering one watershed in each municipality of Brazil (4 000 in total). With this support the project was expanded to work in 68 municipalities. Regrettably at that time the project was closed by the

Federal Government causing a disincentive to continue the work, mainly because of the transfer of rural extensionists to other activities.

Subsequently in July 1991, a loan was signed by the State Government of Santa Catarina and the World Bank, and activities were restarted. The value of the loan was US\$33 million, with a state contribution equivalent to US\$38.6 million, giving a total of US\$71.6 million for the Recuperation, Conservation and Management of Natural Resources in Hydrographic Catchments Project, better known as the Catchments Project/IBRD.

The objective of the project is to recuperate and conserve the productive capacity of the soils, to control the pollution of rural areas, and to lead to a sustainable increase in productivity and farmers' income. In 1998 the project had been going for seven years, benefiting 81 000 families in 200 municipalities and 520 hydrographic catchments.

This was the first project in Santa Catarina to become involved simultaneously with four State Secretaries, three public companies, one university, the meat and tobacco industries and various municipal mayors.

The technical strategy of the project is to:

- increase the degree and permanence of soil vegetative cover
- improve the structure and internal drainage of soils to increase rainwater infiltration
- control runoff both within and outside the farm.

The project encompassed the following components and activities:

- Agronomic research on forestry, soil use and management, agricultural engineering, agrometeorology, and basic seed production of green manure species.
- Mapping and supervision of the use of soils, including maps on the use, land use suitability and land use conflicts, amongst others, for each of the catchments.
- Rural extension and technical assistance, to develop by participatory procedures 520 hydrographic catchments selected according to technical criteria in 200 municipalities of Santa Catarina for the benefit of 81 000 families.
- Pro-Soil, a programme of incentives for soil and water management and pollution control for communities, groups and individuals, especially machinery and equipment adapted to soil conservation for the small farmer.
- Erosion control along catchment roads, through repairs and improvements to 3 900 km of roads in rural communities.
- Forestry development and the protection of natural resources, through establishment of plant nurseries, environmental inspection and supervision of watercourses.
- Training of technicians and farmers, team support, publications and marketing.
- Administration, supervision and evaluation.
- Project management and initial, mid-term and final evaluations.

A FOCUS ON HYDROGRAPHIC CATCHMENTS (WATERSHEDS)

It is recognized by governments, national and international organizations that limiting development to some specific components can result in global problems being only partially resolved. A rural development programme can only achieve its objectives if all land in the catchment is taken into

account, as well as its suitability for the proposed use, and its capacity to produce food, timber and other products. The selection of production systems on the basis of economic parameters to increase rural family incomes must also consider the long-term maintenance of soil productivity, and the re-establishment of the original equilibrium which influences the hydrological cycle. In this context, the plan must take account of existing infrastructures such as marketing, transport and storage. The activities designed to reduce



PLATE 10

Farm and community boundaries are political and administrative boundaries established by people

physical, social, economic and environmental deterioration will have little impact, unless the activities are carried out within natural boundaries, such as within a hydrographic catchment, or within each of its sub-catchments and micro-catchments.

Traditional units for planning agricultural activities have always been the rural communities, and more specifically, *farms* (political planning units). Their limits generally do not coincide with those established by nature, mainly because human actions extend the farms and communities to cover the whole of the geographical complex in which they are located. Therefore these traditional planning units are being replaced by a geographical unit, defined by topography. According to Rocha (1989), the United Nations have been trying to carry out integrated activities in hydrographic catchments to recuperate the environment and increase sustainable food production for almost half a century. Brazil has been accumulating experience in this approach through Soil and Water Conservation Projects since the 1980s.

Hydrographic catchments, subcatchments and microcatchments

According to the theory of geomorphic surfaces, water acts at a macro-scale and carves out the landscape during its journey to the sea giving rise to hydrographic catchments. According to CAIC (1987), the hydrographic catchment is an area drained by a specific river or river system. Rocha (1989) defined the hydrographic catchment as an area (without a definite size) through which rainwater drains into a main drainage line which flows through a unique exit and drains into the sea or a large lake. A hydrographic catchment can be defined as a geographical area defined topographically, bounded by watersheds, and drained by a drainage line or by a system of drainage lines connected to each other, whose waters converge directly or indirectly into the sea or a large lake through a unique control section. A watershed is the boundary between two catchments which separates the rainfall and direct runoff into one or other of the two catchments.

Penteado (1983) defines catchments at a high level, presuming that they can be divided into subcatchments, and minimal units or microcatchments. According to Rocha (1989), the sub-catchment is an area which drains rainwater by gullies, waterways and tributaries into a main water course which flows out through a single control section discharging directly into another larger river. Hydrographic systems can be progressively broken down into smaller and smaller units until the minimum spatial unit, the microcatchment, is obtained.

At the time when the whole world was working on sustainability, microcatchments became the reference units for carrying out agricultural development projects according to Ryff (1995). This is because microcatchments permit environmental impacts and the social and economic results of actions in the catchment to be evaluated from changes to geographic, social and economic baseline data. Moreover, they have a universal character which permits lessons and experiences to be disseminated on a large scale.



PLATE 11

Hydrographic microcatchment - natural limits of the forces of nature, principally rainwater

Tejwani (1981) claimed that management of hydrographic microcatchments involves the rational utilization of soil and water, with the objective of optimizing and sustaining agricultural productivity with minimum risks to the environment. The actions to be executed in hydrographic microcatchments therefore must take into account improvement or maintenance of soil fertility, water and soil conservation for diverse purposes within the farm, protection against flooding, the reduction of sediments in the rivers, and an increase in productivity for all types of land use.

Hydrographic microcatchments provide a practical framework for planning and managing the conservation and sustainability of natural resources in the light of their social, productive and environmental characteristics. The author considers that the concept of the microcatchment is more than just the land surface where runoff convergence occurs, but includes the whole biogeomorphic, economic and social complex which makes it suitable as a planning and management unit for natural resources management.

This systematic focus on the definition of microcatchments and their management, as a scientific discipline of development and permanent enrichment, enables the complexity of the problems of a region to be considered. However, Bruno (1996) points out that the most important aspect is that the object of study for establishing a developmental strategy should not be the area of the microcatchment itself, but the people within the microcatchment and the natural resources which sustain them. The author also concludes that the principles of management of hydrographic microcatchments represent a wide and complete approach to integral rural development, allowing an active institutional interaction and making it a strategic element for state decentralization and greater commitment to farmer participation.

It is not possible to establish a fixed size or shape to define a microcatchment. On the other hand it has also been shown that there is not always a direct correspondence between the microcatchment and the area of work. In dense drainage systems with very small microcatchments, the intervention area could cover more than one microcatchment, as for example when trying to eliminate water pollution problems from animal excreta in the watercourse which is the water supply for an urban population, and when the herds occur in microcatchments upstream from the water take-off point.

In less dense drainage systems, the minimum intervention area may extend over many kilometres, including areas with specific environmental characteristics and different agricultural activities. According to CAIC (1987), this must be considered the planning unit which combines

the river system with other identifiable systems defined on the basis of soils or according to homogenous cropping areas, for which each area receives the most appropriate treatment.

There are several fundamental aspects to be considered in the planning of hydrographic microcatchments.

The degradation of agricultural lands is not related to political and administrative boundaries, which were established by man, as are those of national frontiers. Therefore, neither the community nor the rural property are appropriate units of study for natural resource management projects. The appropriate unit is geographical, limited by topography or the boundary of the hydrographic watershed or its smaller units.

Once the basic elements of a plan for a microcatchment are known, work can be carried out on a smaller scale. One starts by planning one microcatchment, and once that is finished one passes to the next and so on, until the whole hydrographic catchment has been completed.

To recuperate natural resources, principally soil and water, the work always commences in the highest part of the catchment, which is where problems usually begin. This is the most important principle even when degradation occurs throughout the watershed and on a large scale. It is important to start on the highest part because the results guarantee a rapid and recognizable success, and in this way enthusiasm is generated by the families living in the watershed to undertake new actions. Also, successful upstream conservation reduces the problems downstream.

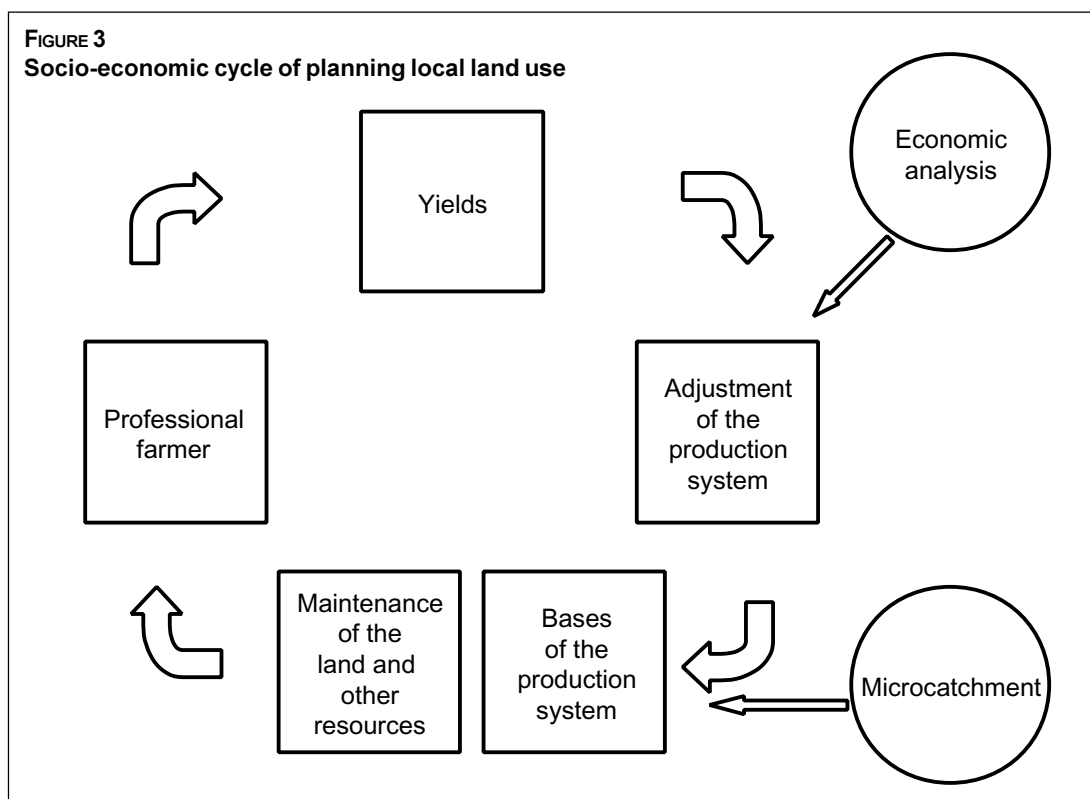
SOIL CONSERVATION – AN INTEGRAL PART OF RURAL DEVELOPMENT PLANNING

It is necessary to emphasize that soil conservation implies the use of soil within practical economic limits, and according to its capacity and needs, to maintain it permanently productive. Often pollution, or the lack of water, become the principal motive for mobilizing rural families in a hydrographic watershed. In this way they begin to see their property with a different perspective and to understand that the activities developed affect the whole geographical complex within which they are living. At other times, problems of storage or marketing may be the first reasons for a community to organize and mobilize itself to solve common problems of the whole watershed, such as environmental issues and soil and water management.

The adoption of a particular technology such as conservationist system of soil preparation can lead to other problems such as the lack of machinery and suitable implements. This may encourage the community to jointly acquire or even manufacture them locally in conjunction with craftsmen and entrepreneurs in the area.

The planning of the watershed must be based on baseline data and must include the participation of specialists from distinct disciplines. Therefore, background information must be collected on climate, soils, actual and potential land use systems, socioeconomic conditions, the aspirations of the people, and the priorities established in the municipality's development plan. According to Rocha (1989), watersheds, subwatersheds and microcatchments are the natural units where environmental deterioration take place. According to the author, integrated watershed management is the only way to recuperate the environment and arrive at an ecological equilibrium.

The author also recognizes that for adequate management of natural resources and considering the watershed as the basic planning unit, seven diagnoses must be carried out physical/conservationist, socioeconomic, environmental, and on waters, fauna, flora and soils. By means of these diagnoses problems are identified, existing conflicts are analyzed, and possible solutions are prioritized in a participatory manner.



As the concept of sustainable development is disseminated within the scientific community and among farmers, awareness increases of the need for a planning system for the microcatchment and for each farm, which takes account of the relationship between soil and man. This new concept is characterized by greater knowledge of soil potential within the catchment, of man's actions on the soils, of the development of new land use systems which give greater yields, and of modifications to existing production systems. These changes also depend on the presence of a professional farmer, able to maintain and improve the farm's resources. This concept may be presented schematically as a socio-economic cycle (Figure 3).

It is worth emphasizing that under the conditions of Santa Catarina the bases of the production systems are:

- permanent protection of the soil surface
- continual supply to the soil of fresh organic matter
- least possible disturbance to the soil
- use of conservationist systems of soil preparation
- inclusion of crops with aggressive and abundant root systems through rotations or intercropping



PLATE 12

More important than the area of the microcatchment are the people and the natural resources which sustain them [Escritório Municipal da Epagri de São Lourenço do Oeste]

Within the new concept of using the hydrographic microcatchment as a planning unit in soil and water management projects, organization of the community is a *sine qua non*. The microcatchment is a physical planning unit. The community is, and always will be, a social nucleus of decision making, even when the natural limit (watershed) does not coincide with the community's boundaries established by man. On the other hand, this situation can generate much more appropriate integrated action between farming families of two neighbouring microcatchments in order to resolve common problems.

CHANGES IN APPROACH AND PHILOSOPHY OF THE EXTENSION SERVICE

The experience accumulated since the 1980s in the three states of the southern region of Brazil, has shown that the adoption of the microcatchment as a reference unit in rural development projects aimed at solving natural resource management problems especially soil and water, has caused a change in the philosophy and working methods of rural extension and technical assistance services, together with that of farmers and their families - bearing in mind that inter-institutional programmes have always been difficult to manage.

In Santa Catarina the impact of the project's activities over seven years led EPAGRI - Agricultural Research and Rural Extension Company, through strategic planning, to define the microcatchment watershed as a priority area for carrying out field activities. This same strategic planning defined the company's aim as 'knowledge, technology and extension for sustainable development in rural areas, for the benefit of society.' One of its principal objectives was to 'promote the preservation, recuperation and conservation of the sustainable use of natural resources' (EPAGRI, 1997).

Other changes that have occurred up to the present include:

- the definition of a geographical area defined on the basis of its topography gave rise to new working areas for rural extensionists enabling them to consolidate their efforts, time and resources
- the extensionists came to have more contact with rural families and to know more about the reality of their existence
- the extensionists came to interact directly with farmers in the conservationist planning of their farms, and in this way gained their respect and confidence
- the participatory nature of a programme of this magnitude has given rise to a constant interactive process between representatives of the public sector, the private sector and of rural communities living in the microcatchment
- it was necessary to define a strategy, a system of work which guarantees periodic support and evaluation throughout the whole process through a competent team of technicians and a very small top-down vertical hierarchical structure.

The use of microcatchments is being developed in Santa Catarina with the following technical and management structure:

- an executive secretariat (with three technicians)
- a Sector Manager for each component (8) in the various public institutions
- three Regional Managers all linked to the state research and extension service.

The implementation of field work in 206 municipalities of Santa Catarina during seven years involves:

- 256 Rural Extensionists (Agricultural Engineers and Agricultural Technicians), of which practically half are contracted by the municipalities (123) and participate in microcatchment activities through agreements with EPAGRI.
- Social Extensionists who work in environmental health.

Its implementation resulted in widespread diffusion of project activities involving leaders of municipalities and rural communities. With this stimulus, the creation of Microcatchment

Commissions ensured greater participation, principally of the main beneficiaries in decisions on *what, how, when* and *how many*, to resolve the microcatchment's problems. This resulted in a big stimulus in community organizations which was reflected in the quantity of machinery and equipment adapted to conservationist soil preparation acquired by farmers for collective or community use.

There are basic differences between the work of traditional rural extensionists and that of services which adopt the microcatchment as a planning unit in environmental projects. These are listed below, adapted from Ryff (1995).

Conventional extension is often characterized by

- a passive attitude to rural development problems
- predominantly individual attention
- isolated and unconnected work without the synergistic effect which characterizes development processes
- remoteness from decision making centres, vertical administrative structures of public institutions lacking inter-institutional coordination
- no direct incentives to social mobility for farmers and their families
- predominantly solutions not directly related to the problems
- assistance mainly reactive, responding to requests for assistance or consultation made by farmers
- reactive and individualized assistance not generating the critical mass necessary to break the inertia of production systems that are often archaic, nor providing solutions to structural problems or anticipation of issues with increasing relevance such as environmental degradation
- limited reports, listing the type and frequency of visits made to rural properties and eventually the problem treated or the type of assistance given
- attention tending to be concentrated on the better informed and most influential farmers.

Extension in microcatchments often has the following features:



PLATE 13

The rural extensionist sees his work recognized by the community and hence gains enthusiasm which is the driving force of development

- technical support to farmers does not have just a preventative nature, but is part of a rural development strategy
- result of the work is expressed in economic, social and environmental indicators such as increases in production and productivity, the improvement of sanitary conditions, progress achieved in recuperation of natural resources
- supervision is continuous and lasting so that all impacts of the program can be evaluated
- the norm is collective attention provided to the community with the perspective of working together to solve common problems and the discovery and analysis of the microcatchment's potentials
- the work is characterized by the integration of extension services, research, promotion and assistance in the fields of health and education
- there are political and administrative opportunities to establish vertical articulation of government bodies linked to agriculture with decentralization of decision making
- the development of collective awareness of peoples potential is promoted
- the concept of sustainable development is the basis of the activities
- attention is directed as a priority to farms which develop family agriculture, which inadequately manage natural resources and which have a low grade of association.



PLATE 14
The microcatchment as a planning unit in Santa Catarina - community mobilization and stimulating working groups principally for the collective use of machinery and equipment

SOIL MANAGEMENT AND THE PROCESS OF RURAL DEVELOPMENT

The activities executed by the Microcatchment/IBRD Project are directly related to the recuperation, conservation and management of natural resources in hydrographic microcatchments. These activities have made a big impact on diverse sectors of the Santa Catarina society.

First, there was an increase in awareness of environmental problems in the public sector, which lead to concrete actions taken to minimize problems mainly related to pollution from animal excreta and soil erosion. The construction of manure stores for adequate storage of farmyard manure especially from pigs, created jobs in the rural environment, principally in the stone industry.

Activities in some economic sectors of Santa Catarina were greatly enhanced mainly by the introduction of conservationist systems of soil preparation such as minimum tillage and direct sowing. The development of these systems obliged the industrial sector to invest in the production and improvement of machinery to cater for a growing and ever more demanding market, especially that of the medium and large scale producers. The establishment of new agricultural machinery and implement factories, especially those directed to small-scale farmers (see chapter 7) in their

own regions, generated new jobs and assured cash flow in local and regional commerce, avoiding the flight of capital to other states.

An increase in forestry activity in the microcatchments led to an increase in traditional timber activities. The reforestation of pasture areas in small farms in the microcatchment led to the reopening of old sawmills and the establishment of new companies which are the principal generators of employment, and which contribute to an increased cash inflow to the smaller municipalities of Santa Catarina.

On the other hand, studies carried out show that this agricultural model urgently needs changes. For example, the whole of the agro-industrial and cooperative sector is undergoing an unparalleled crisis. Farmers, who are becoming progressively more decapitalized, face markets with low prices for agricultural products, and the effect of unequal competition with imported products that are heavily subsidized in their country of origin.

The search for new alternatives for agriculture, and added value for goods produced on the farm, are themes for discussion which stimulate the planning of new projects for advice and support by the public sector. The new directives for sustainable rural development which now apply are:

- better administration of farms
- better production technology
- organized farmers
- value added to products

Therefore, it is not sufficient merely to introduce new technologies, such as direct sowing for reduced and better distributed farm labour, or to reduce the long term costs of production, or to reduce the pollution of surface waters by erosion, etc. It is essential to improve farm administration, add value to harvested products, search for alternative markets, and to diversify agricultural production, but without getting lost in a multiplicity of activities.

Value is added to agricultural production by the farmers themselves processing the products, sometimes on an individual basis, but preferably through organized groups, associations or cooperatives. However, this will only be possible with the support of appropriate legislation which enables the establishment of small rural industries which are economically viable, such as cheese making, pasteurization of milk, manufacture of preserves and meat processing. Fortunately this legislation has been approved recently in Santa Catarina.

Chapter 5

The working system and organization of the rural extension service

To execute the microcatchment/IBRD project in Santa Catarina, a work strategy was carefully elaborated which consists of successive stages: motivation, training, conception and elaboration of a microcatchment development plan, implementation of the planned activities, and evaluation.

MOTIVATION AND TRAINING

The objective of the motivation stage is to bring together the municipal leaders, technicians and rural farmers through a series of contacts, visits, meetings and field excursions. It should be emphasized that the advances achieved in a relatively short time by the microcatchment project in Santa Catarina are largely due to the interchanges that took place between farmers. At the beginning of the project it was necessary to organize visits to the neighbouring state of Paraná to look for suggestions and sources of inspiration. Although inspirations for eco-development can be sought from other experiences, the solutions must be local because Paraná has characteristics which are different to those of Santa Catarina. On the other hand, external experiences help in developing appropriate participatory methods. As the project developed this interchange also occurred within Santa Catarina state, by organizing visits to those microcatchments where farmers had already accumulated a certain amount of experience.

The next stage consists of training and updating technicians of the public and private sectors and especially of farmers. At the beginning of these activities the technicians chosen to work in the microcatchments, together with the farmers, receive a first training course which was called *pre-service training* in Santa Catarina. This course lasts about two months and covers the following themes:

- the Microcatchment/IBRD Project
- concepts and principles of working in hydrographic microcatchments
- the methodological strategy of the Microcatchment/IBRD Project
- subdivision and prioritization of the microcatchments
- identification, use and management of the principle soils of Santa Catarina
- conservationist practices
- reforestation



PLATE 15
Interchange of experiences between farmers; strategic investment of the microcatchment/IBRD project

- communication and methods of rural extension
- rural administration
- environmental health.

After initiating work in the microcatchments, the extensionists together with regional leaders participate in courses, seminars, and meetings dealing principally with soil management, with the objective of maintaining them updated and aware of recent technical-scientific advances in sustainable rural development, leadership, group dynamics, farmers' organizations, environmental education, and agro-ecological production in its widest sense.

The training of farmers is a basic activity in this process. EPAGRI has eleven training centres distributed in the different ecological zones of Santa Catarina, which offer distinct professional courses based on a methodology inspired by experiences with GTZ (under a Brazil/ Germany agreement). On the other hand, farmers living in the microcatchments are offered training in specific themes, preferably in their own community.

Other training and motivation activities are the municipal and community seminars which involve a large proportion of the state, municipal and private sectors. At first these events focused principally on erosion control, advantages of maintaining the soil covered for as long as possible, use of green manure and cover crops, and conservationist systems of soil preparation. Recent seminars, which have



PLATE 16

Training of technicians and farmers is fundamental for the implementation of soil management practices in the hydrographic microcatchments



PLATE 17

Seminars on soil and water conservation and meetings on direct sowing - important for dissemination soil management techniques. The photos illustrate the State meeting on direct sowing of 1996 in Sao José do Cedro, western Santa Catarina, with 1 200 participants

grown to state-wide participation, have discussed direct-sowing methods in depth. At the same meetings, opportunities have been taken to demonstrate machinery and implements adapted to direct sowing for small farmers with the effective participation of small-scale industries.

PLANNING AND WORKING METHODS

Microcatchment mapping

This stage consists of the elaboration of microcatchment maps by a team of EPAGRI specialists using topographic maps, aerial photographs, and visits to the microcatchments. These maps serve as tools in the planning of activities. The following maps are produced as part of the final report:

- contours
- drainage systems
- physiography
- actual use
- potential use
- conflicts in use

Then, a simplified plan of the management of the microcatchment is produced, in which community and group actions to be carried out are defined. This process is actually being revised to make it more participatory, as discussed below.



PLATE 18
Construction of a new development model with the community - a basis of sustainability of the rural environment

Participative planning

A new planning methodology for sustainable development is being tested by EPAGRI as a pilot experience in two microcatchments located in distinct ecological zones of the state. This methodology is already being used in the Quirirí association in the Upper Río Negro catchment which comprises three municipalities of the Northern region of the State. The application of this planning methodology consists of seven stages according to Hidalgo (1998):

1. Promoting the Catchment Development Plan. This is an educational and participatory process to create awareness of the importance of conserving nature in development, and consists of campaigns to promote the proposed municipal sustainable development plan. In these campaigns the principal environmental problems of the hydrographic catchments and the towns are explained. At the end of these activities a proposal may be formulated to create an inter-municipality association for solving common problems, such as urban wastes or the pollution of rivers which supply water to the towns.

The plan is promoted and discussed through seminars, courses, talks, and mass communication methods at four levels:

- political (prefects, municipal secretaries and advisors)
- institutional (directors, advisors, managers, coordinators and technicians of the public institutions implementing programmes or projects with the municipalities)

- industrial (directors of those industries which use the natural resources of the hydrographic catchments)
 - community (leaders of community organizations and teachers from rural areas).
2. ***Integrated Participatory Diagnosis.*** This consists in the identification of priority problems by the community according to their perception of the environment. The community uses institutional sources in the form of existing environmental diagnosis or of appropriate methods to identify problems related to conservation, pollution, etc.; and makes use of development plans for residential areas, schools, municipality and rural communities. This tool guarantees the effective participation of the community, employs popular language, and is based on the livelihoods, experiences and needs of rural families (Simon, 1997). Using these sources, the community should define the priority problems which will lead to proposals in the environmental plan for solving the problems.
 3. ***Prioritizing Actions.*** In this stage, community and institutional participants discuss the problems and their origins in a seminar, and agree on prioritized actions to resolve the problems.
 4. ***Elaboration of Projects.*** For this stage, specific technical projects are prepared for each of the proposed activities.
 5. ***Execution of Projects.*** This consists of the execution of the previously agreed projects, using the particular experience and labour of the community together with the technical knowledge of the institutions. The community monitors the implementation of the projects.
 6. ***Evaluation of the Projects.*** This is a continuous process which should identify failings and achievements. The institutions technically evaluate the environmental impacts of the projects, whilst the community assesses the degree of achievement of their objectives.
 7. ***Ensuring Continuity of the Catchment Development Plan.*** This requires consolidation of political and managerial support for the Catchment Development Plan. This must include guarantees for the provision of necessary infrastructures and adequate human and financial resources.

Working method

The working method of the Microcatchment/IBRD Project can be summarized in ten steps (Table 1).

Implementation and evaluation

Group activities. Groups within the community are organized to carry out the priority activities. At this moment a microcatchment commission should be formed, independent and with definite aims. Public bodies such as EPAGRI, the municipal prefects represented by their secretaries, and private bodies such as cooperatives, agro-industries and tobacco companies participate in the implementation of the plan by providing technical assistance to their members.

Individual activities. Individual property plans are prepared by the extensionist together with the farmer and his family in the form of maps of the actual use, potential use, and finally the revised use of the property, together with a time-table of the required improvements and changes to the property that are to be carried out during the next four years.

Evaluation. Periodic meetings are held to evaluate the progress of the priority activities, in which the Microcatchment Commission should play an important role. The project decided that extensionists should spend only two years working in a microcatchment, and at the end of this period the extensionists must present a report to all interested parties, especially to the leaders

TABLE 1
Working method of the Microcatchment/IBRD Project

Operational Objectives (what to do)	Strategy (how to do it)	Theme
1. Interest the municipal leaders	<ul style="list-style-type: none"> • Visits 	<ul style="list-style-type: none"> • Project details • Explain the benefits and responsibilities
2. Select the microcatchments <ul style="list-style-type: none"> • sub-divide • prioritize 	<ul style="list-style-type: none"> • Interviews • Studies • Visits to the microcatchments 	<ul style="list-style-type: none"> • Identify parameters and the technical criteria for defining the microcatchments
3. Interest the authorities and other local institutions	<ul style="list-style-type: none"> • Meetings 	<ul style="list-style-type: none"> • Motivate institutional leaders • Present the criteria for prioritizing actions in the selected microcatchments • Incentivate the creation of a municipal commission
4. Interest the leaders of the communities in the selected microcatchments	<ul style="list-style-type: none"> • Visits • Meetings 	<ul style="list-style-type: none"> • Motivate on the basis of the local situation • Promote the project
5. Interest the families in the communities	<ul style="list-style-type: none"> • Visits • Meetings • Excursions 	<ul style="list-style-type: none"> • Discuss the problems • Interchange of experiences
6. Assess the support for the project	<ul style="list-style-type: none"> • Visits • Meetings with the communities 	<ul style="list-style-type: none"> • Commitment from all the farmers
7. Elaborate the micro-catchment development plan	<ul style="list-style-type: none"> • Meeting 	<ul style="list-style-type: none"> • Identify the farmers for each type of activity • Prioritize activities
8. Approve the Micro-catchment Development Plan	<ul style="list-style-type: none"> • Meeting 	<ul style="list-style-type: none"> • Present the community, group and individual improvements to be achieved in the micro-catchment
9. Planning of individual properties	<ul style="list-style-type: none"> • Visits • Meetings 	<ul style="list-style-type: none"> • Make conservationist plans for individual farms
10. Execution of the Micro-catchment Development Plan	<ul style="list-style-type: none"> • Various extension methods 	<ul style="list-style-type: none"> • Group, community, and individual activities

of the municipality, of all the activities carried out. Moreover the Microcatchment/IBRD Project conducts three evaluations to assess the impacts caused in the microcatchments: an initial evaluation before the project starts working in the micro-catchment, an intermediate evaluation, and a final evaluation at the end of the project.

ORGANIZATION OF THE SERVICES

Since 1991, research, rural extension and fisheries services have been brought together under the same public body, regarded as a mixed-economy society, maintained by the state government with the support of municipalities, and named the Farming Research and Rural



PLATE 19
Community works such as re-conditioning of roads - a stimulus by the public sector in the development of the communities in the microcatchments

Extension Company of Santa Catarina, Ltd - EPAGRI S.A. It is represented in 250 of the 293 municipalities. Its structure consists of a central administration office and 14 regional administrations.

EPAGRI participates in the implementation of three components in the Microcatchment/IBRD Project:

- Research, with a complement of 31 researchers implementing 182 experiments
- Microcatchment mapping, involving 6 technicians to map 139 microcatchments
- Rural extension, employing 131 Rural Extensionists and 107 Social Extensionists to serve 81 000 farmers in 520 microcatchments during the 6 years of the project.

The Rural Extension component in fact employed 256 Rural Extensionists; of these, 125 were contracted by the prefects of municipalities in agreements with EPAGRI, representing almost half of all technicians working in the microcatchment. This constituted a joint action between state and municipal authorities to give priority to the activities envisaged in the Microcatchment/IBRD Project. A positive effect of this joint action has been that the Mayors of the municipalities contracted additional technicians to execute the Project with their own resources. At present there are 12 agricultural engineers and an additional 24 agricultural technicians, giving a total of 161 technicians.

The private sector through cooperatives, meat and especially tobacco agro-industries, forms part of the rural extension component through agreements made with their class organizations, such as the Organization of State Cooperatives of Santa Catarina and the meat and tobacco industry guilds, all of which give technical assistance to their members following the principles and philosophy of working in hydrographic microcatchments.

Chapter 6

The principal soil management and conservation activities in Santa Catarina

The principal activity carried out by technicians in the microcatchment project from the beginning, and subsequently with support from the World Bank was soil recuperation, conservation and management in cropping areas. A series of practices was introduced to the farmers, and through experimentation it was possible to improve and adapt them to the existing production systems in the different microcatchments.

USE OF GREEN MANURES AND COVER CROPS

Green manuring has been practised for many years by farmers in the south of Brazil. When mineral fertilizers appeared it became of secondary importance, limited to a few species in certain zones of the state. With the problems that arose with the implementation of “modern farming,” the use of green manures came to be considered fundamental for slowing down soil deterioration by erosion, and for simultaneously recuperating soil fertility in cropping areas. At the same time, with support from research work carried out by the Agricultural Research and Rural Extension Company of Santa Catarina - EPAGRI S.A., various green manure and cover crop species were tested and subsequently adopted by farmers.

The increased use of spontaneous vegetation as cover crops has been a new achievement in Santa Catarina; some of the species were considered as weeds or damaging to crops until a short time ago. With the introduction of direct sowing, the use of desiccating herbicides, and the use of cutting rollers to overcome weeds, it was possible to associate these species in existing production systems, principally in areas where onions and other horticultural crops were being cultivated. The principal species used are sweet grass (*Brachiaria plantaginea*) and cushion grass (*Digitaria sanguinalis*). The resulting biomass is slashed or desiccated before planting the next crop, as discussed below.

One of the big obstacles to the adoption of conservationist systems of soil preparation has been the lack of alternatives to the elimination of the cover crops or green manures by ploughing. The vegetative cover is killed before sowing with the aim of facilitating the entry of seed-drills or planters, the uniform distribution of seed and fertilizer, and at the same time of providing a continuous supply of fresh organic matter (a source of carbon compounds which are the basis of life in the soil), and of protecting the soil from the direct impact of raindrops and the sun's rays.

Slashing of the cover crop or green manure is a mechanical operation carried out by different types of equipment such as rollers with blades; rollers with discs; disc harrows; wooden rollers; or mini-tractors and a set of discs which substitute the rotary hoes (in the rear), or with discs attached to a cylinder (in the front).

According to Monegat (1991) it is important to choose the precise moment at which the vegetative cover is to be eliminated, because most of the species used can regenerate if the cover is eliminated prematurely. Alternatively mature seeds of the cover crop can germinate if elimination is carried out late as may happen with oats, rye, chickpea, *Vicias* and forage radish. The best moment to eliminate the majority of cover-crop species is at full flowering, and in the case of legumes, the pods from the first flowering should be already formed but not yet mature. *Vicias* should have some mature pods. For oats and rye, the best moment is at the milky grain stage, when two passes of a roller with blades will be necessary. Forage radishes can be slashed at any growth stage, but in systems of direct sowing and minimum tillage, seeds should be green and physiologically immature to avoid the germination of new plants.



PLATE 20

Slashing of oats using a roller with blades. This operation can be carried out during the final phase of the cover crop's vegetative cycle without the need to apply a herbicide to desiccate the vegetative cover, and so substantially reduces the cost of production

The disc roller is the implement normally used to slash mucuna. When no other suitable implements are available, the disc harrow can be used as an alternative, although this implement gives non-uniform results, leaving some areas with less cover than others due to the dragging of residues. Modified mini-tractors can substitute for the roller discs of animal traction, and can operate in steeper areas. Rustic implements such as wooden rollers can also be useful to flatten cover crops.

Another form of slashing cover crops is by the use of manual or mechanical knives. The manual knives work by a motor which is carried on the back of the operator; this results in a good straw cover because the greater part of the biomass remains intact after cutting. The knives using mechanical traction, of which there are several models, pulverize the biomass leaving a layer of small straw particles on the soil surface, but with the drawback that the straw rapidly disappears due to decomposition.

Herbicides are applied to dry or "burn" the vegetative cover and so facilitate its subsequent flattening. This practice is normally carried out when the green manure/cover crop is not yet in the full flowering or milky grain growth stage, and it is necessary to sow the next crop.



PLATE 21

Oat biomass desiccated with herbicide, flattened with a rustic wooden roller in an area cultivated with tobacco using direct sowing

If this operation is not carried out before flattening the cover crop, this may regenerate or the seeds may germinate causing unfavourable conditions for the initial development of the subsequent crop. This situation arises in Santa Catarina because the farmers do not have many short-cycle (precocious) cover crop species that would allow economic crops to be sown in the summer, without needing to apply desiccants. Desiccants can be applied using manual, animal-traction or mechanical sprayers.

Minimum tillage and direct sowing

The practices with a greatest impact among farmers living in the microcatchments where the Microcatchment/IBRD Project is operating, are without doubt minimum tillage and direct sowing, which are intimately associated with the maintenance of soil cover using green manures or cover crops. There is a wide range of management systems adapted to different situations and to the types of machinery and equipment available on the farm. According to Landers (1994) the advantages of these practices compared to conventional soil preparation are:

- reduction of soil losses to tolerable levels (to less than 5 percent)
- increase or maintenance of soil organic matter
- soil temperature fluctuations reduced favouring the development of soil micro-organisms
- better use of nutrients
- reduction in labour requirements of up to 70 percent in animal traction systems
- reductions in costs of production of between 5 and 15 percent
- greater resistance to periods of water stress
- more flexibility in the time of sowing
- reduced costs of machinery and equipment maintenance due to less mud and dust produced in this system
- considerable reductions in sedimentation levels in the rivers
- reduction in the use of diesel of up to 70 percent.

Another important advantage of the direct tillage system is its influence on the carbon dioxide emissions to the atmosphere. According to Reicosky, cited by Gassen (1997), ploughed soils lose seven to eight times more carbon than soils in direct-sowing systems. The losses of carbon dioxide in ploughed soils varied from 27 to 67 g/m² up to 3.5 hours after sowing; in direct sowing this value was less than 0.8 g/m². The quantity of carbon dioxide released from ploughing soils is greater than the quantity released world-wide from the burning of fossil fuels.

Plates 22 to 32 show systems of minimum tillage and direct sowing, which vary according to the region and type of crops.



PLATE 22
Minimum tillage with maize and *Vicia* - precursor to conservationist soil preparation in Santa Catarina



PLATE 23
Area prepared for sowing tobacco
in residues of maize and mucuna



PLATE 24
The use of animal traction for harrowing with a straight tined harrow, combined with the simultaneous application of herbicide to strip-tilled land prepared with a micro-tractor and mouldboard plough



PLATE 25
Micro-tractor with a mouldboard plough for opening furrows in a minimum tillage system



PLATE 26
Field ready for sowing tobacco by
minimum tillage

PLATE 27
Sowing maize with a manual seeder ("matraca" or "saraquá") in wheat residues in a minimum tillage system using animal traction



PLATE 28
Maize direct-sown into *Vicia* residues desiccated with a herbicide



PLATE 29
Direct sowing of cucumber (*Cucumis sativus*) in spontaneous vegetation desiccated with a herbicide after the harvest of maize



PLATE 30
Field of black oats (*Avena strigosa*) desiccated with a herbicide and subsequently flattened using a roller with blades, and sown to onions in a minimum tillage system with a modified mini-tractor

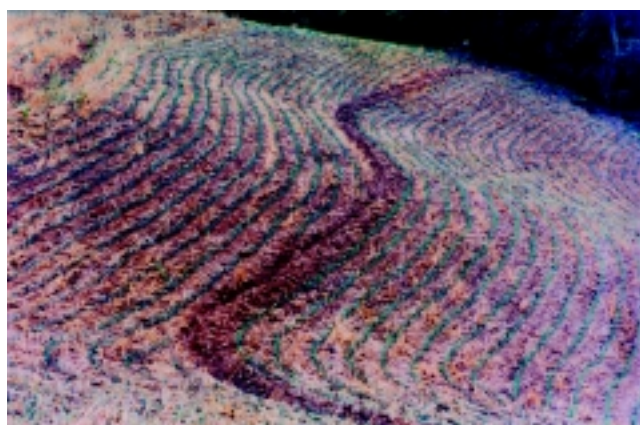


Table 2 shows the development of these practices in Santa Catarina as derived from two recent studies. It can be seen that conservationist systems of soil preparation have been adopted on a large scale in the rural communities of Santa Catarina. This does not imply that research efforts should now be reduced, but on the contrary further research efforts are needed to improve the system in the following aspects: crop rotations; reduced use of pesticides; new species of green manures and cover crops; and development and improvements in machinery and implements.



PLATE 31
A field of spontaneous vegetation after one pass of a roller with blades in beds previously prepared for tomatoes

CONTROL OF SURFACE RUNOFF

The topography in Santa Catarina (Table 3) and the predominately shallow soils are conducive to the surface runoff of rainwater. It is recommended that farmers sowing annual crops in sloping areas apply mechanical conservation practices or physical barriers which disrupt the flow of runoff. This will diminish the runoff velocity allowing it to slowly infiltrate, and thereby reduce the risks



PLATE 32
Planting of tomatoes in spontaneous vegetation desiccated with herbicides

TABLE 2
Development of conservationist systems of soil preparation in Santa Catarina over three years

Year	Annual cropping area (ha)*	Direct sowing and minimum tillage area (ha)*	Percentage (%)
1994	1 860 000	124 000	6.6
1997	1 870 000	685 000	36.6

* Except irrigated rice.

Source: Freitas *et al.*, 1996 and SDA, 1997 (unpublished)

TABLE 3
Dominant slope classes in Santa Catarina

Class	Slope (%)	Description	Extent (%)
1	0 to 8	Level to slightly undulating	5.6
2	8 to 20	Undulating	20.5
3	20 to 45	Strongly undulating	41.4
4	45 to 75	Mountainous	29.3
5	more than 75	Escarpmnts	2.0

Source: IBGE/DGC and SAA/DIRN, 1994.

of erosion. These barriers may be constructed of earth, stones or plants.

When earth is used to construct the barriers they are referred to as terraces. These are normally constructed mechanically and require large quantities of earth to be moved, depending on the type of terrace. Essentially they consist of dikes to retain the rainwater and channels to discharge the accumulated water.

When stones or plants are used, the barriers are referred to as contour barriers. If stones are used they are placed along a previously marked contour line. The height of the stone wall that is constructed will depend upon the availability of stones in the area.

The vegetation barriers may be constructed with various species according to the region, farmer preference, or the need for fodder. The following species may be used: sugar cane (*Saccharum officinalis*), elephant, king or cameroon dwarf or giant grasses (*Pennisetum purpureum*), lemon grass (*Cymbopogon citratus*) or phalaris (*Phalaris hybrida*). The slips of grasses (phalaris, lemon, cameroon dwarf) or stakes (of sugar cane or giant cameroon grass) are placed in furrows opened with a plough along a previously marked contour line, and are subsequently covered by a shallow ploughing. Depending on the species, two or three rows of plants are used.

Normally the contour lines are laid out by the farmer himself, especially in properties which use animal traction, by the use of an instrument popularly known in Santa Catarina as “pie de gallina” (chicken foot) and in other Latin American countries as the A-frame (Plate 38).



PLATE 33

Terraces joining two or more properties; they facilitate sowing and harvesting and strengthen the feelings of solidarity between neighbours



PLATE 34

The head of the microcatchment of the river Macaco/Sao Lourenço do Oeste protected by a terrace. The rain waters are diverted from the roads to the terraces



PLATE 35

Stone wall constructed using collective labour in the microcatchment Lageado das Tábuas, municipality of Faxinal dos Guedes

MANAGEMENT AND USE OF ANIMAL MANURE

Another important activity in the microcatchments is the management of animal manure. Santa Catarina state generates large quantities of farmyard manure because of the large population of pigs, poultry and cattle. There are 4.4 million pigs concentrated in a few zones of the State, with a pollution potential equivalent to that of 44 million people. This has resulted in the construction of sheds in which the manure is deposited for use as a fertilizer for crops, especially maize and pastures. In this way it is possible to increase crop productivity and at the same time contribute to a reduction in water pollution.

The farmyard manure is normally applied to the field using mechanical spreaders, which are often of communal or group use. The municipal prefectures also make equipment available, and many prefectures put these machines at the disposal of farmers' associations which administer and organize their use.

PROTECTION OF WATER SOURCES

Amongst the activities developed by the Microcatchment/IBRD Project in the field of environmental health (e.g. management of human residues, improvements to the environment of farms, management of domestic wastes), one of the most important is the implementation of practices which aim to reduce the pollution of waters used by the rural populations. Studies conducted in the 1980s showed alarming indices of up to 80 percent of waters which were



PLATE 36

Area protected by a vegetation barrier of dwarf cameroon grass in the microcatchment Alto Gropp, municipality Agronómica



PLATE 37

Construction of a vegetation barrier with slips of *Phalaris hybrida*, constructed using collective labour in the microcatchment of the river Macaco, Sao Lourenço do Oeste



PLATE 38

A rustic A-frame used in a small rural property



PLATE 39
Storage of animal manure



PLATE 40
Liquid manure spreader - equipment of group or communal use



PLATE 41
Protected water source with small outflow tubes - guarantees better quality water for use by rural families

polluted by faecal coliforms. This problem is being resolved in many properties by protecting water sources, so that contact of the water by external agents is practically eliminated before the water is used by rural families.

ROAD ALIGNMENT AND IMPROVEMENT

A large proportion of the sediments in rivers originate from roads within the microcatchment, which may be community, internal farm, or farm boundary roads. In a joint activity between the Municipal Prefecture, Transport Secretary, Public Works Department, communities within the microcatchment, and with assistance from the World Bank, new road alignments and modifications are being made to diminish this problem.

**PLATE 42**

Roads previously destroyed by erosion which are beginning to be repaired in the microcatchment of the Sao Domingos Municipality, with assistance from the Municipal Prefecture, State Secretariat of Transport and Works, and the Microcatchment/IBRD Project. Previously the run-off collected in the terrace channels was diverted towards the roads

PLATE 43

The same road after completion of the recuperation works. Run-off is now diverted from the road towards the terraces



ELIMINATION OF GULLIES

Until a short time ago, it was a common practice to construct terraces which conveyed water to the property boundary. This generally resulted in the formation of large gullies, and often led to conflicts between neighbours. The construction of terraces that are continuous across several properties, and which divert the discharge into protected waterways, has allowed these problems to be largely resolved.

FORESTRY DEVELOPMENT

Some 70 percent of the Santa Catarina territory is naturally suited for reforestation or for perennial crops because of its steep relief according to IBGE/DGN and to

**PLATE 44**

Gully which has developed at the boundary of a property - indicating an advanced state of erosion

PLATE 45
Commencing the process of gully elimination

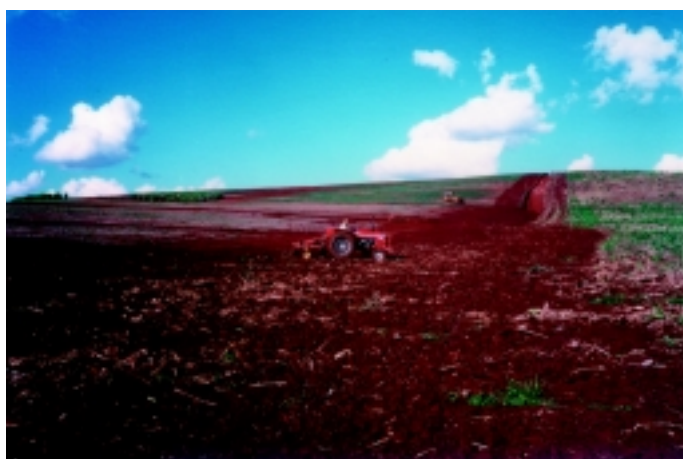


PLATE 46
Gully practically eliminated at the boundary between two properties

PLATE 47
After eliminating the gully farmers use lime to amend the new cropping area



SAA/DIRN (1994). As a result, one of the major activities for farmers in the microcatchments has been commercial reforestation, known as “Forestry Agriculture.” Farmers normally prefer to plant short-cycle species such as *Eucalyptus* or pines because of the rapid economic returns. In addition to providing a new source of income, the farmer does not need to continue utilising the native forest reserves to meet his needs within the farm. Amongst the tobacco producers

this is an even more important practice because firewood is the principal fuel used in drying tobacco.

PLATE 48
Planting trees - a promising alternative income for the small Santa Catarina farmer



Chapter 7

Machinery and implements for zero- and minimum tillage in small farms

DEVELOPMENT AND ADAPTATION BY FARMERS AND SMALL ENTREPRENEURS

The first steps taken by technicians and farmers in the search for alternatives to the conventional soil preparation method of ploughing and harrowing began in the 1970s. In 1975, the Centre for Agronomists of Western Santa Catarina, the region which produces two-thirds of the State's grain, initiated the first discussion on this theme. In 1978 in the Xavantina municipality of the Concórdia region in Western Santa Catarina, a farmer with assistance from a rural extensionist carried out the first minimum tillage system sowing maize by animal traction into the residues of common vetch (*Vicia sativa*). This system was subsequently studied and disseminated by the Rural Extension Service. On the basis of this experience the first state meeting on direct sowing was organized in 1980 in the municipality of Xanxeré in Western Santa Catarina.

As the system was evolving special attention was paid to the improvement and diffusion of rollers with blades for animal traction and tractors to slash the vegetative cover, and to the improvement of machinery for direct sowing by animal traction. With the establishment of the Soil Conservation Centre for Small Properties in Chapecó (CETREC), administered by EPAGRI, it became possible to study in greater depth all the production systems in the West of the State, especially those of maize, beans and soybean. The aim was to maintain as far as possible the characteristics of the existing production systems in small holdings, apart from the introduction of green manures or cover crops, and of different management systems such as minimum tillage and direct sowing.

CETREC also played a decisive role in the training of technicians and farmers from throughout the State, and greatly influenced the changes which occurred in small farms in Santa Catarina, especially in the Western region. Thousands of farmers had the opportunity to visit demonstration units sponsored by the municipal prefectures and, as from 1991, by the Microcatchment/IBRD Project. The following data give an idea of the importance of CETREC in this process:

Soil Conservation Activities up to 1997		
Number of events	Number of technicians	Number of farmers
557	3 105	13 236

Another important factor responsible for these changes was the creation in Chapecó of the Research Centre for Small Properties which was administered by EPAGRI. The principal research themes were green manures and cover crops, soil management, minimum tillage and direct sowing.

In 1984, the Microcatchment/IBRD Project was established in Santa Catarina, initially in a catchment of 15 000 km² in the Vale de Itajaí region which had been seriously damaged by the floods of 1983 and 1984. This prompted discussions on green manures and cover crops, minimum tillage and direct sowing for another environment, different from the Western region, with contrasting soils, climate, and production systems principally based on onions.

In 1985 and 1986, when the project first started to expand in the region, there was no machinery for direct sowing and no mini-tractor that would allow farmers to change their traditional systems of soil preparation. Today the region produces different types of machinery for direct sowing with animal traction, and various adaptations for mini-tractors designed for sowing with minimum disturbance to the soil.

The North of Santa Catarina State, a zone which traditionally produces beans, maize, soybean and tobacco, has also made an important contribution to the development of machinery for animal traction. Small rural industries without government subsidies have produced machinery for direct sowing with animal traction, and other equipment such as rollers with blades and both manual and animal traction sprayers which have been exported to more than twenty countries in the world.

Collective use of machinery and equipment. One of the most significant achievements of the Microcatchment/IBRD Project has been the promotion of collective use of machinery and equipment adapted to conservationist systems of soil preparation. This may involve small groups or the whole community. A total of more than 6 000 groups have so far been formed involving more than 18 000 farmers. Extensionists have been able to motivate farmers, mainly groups of neighbours, to jointly buy such equipment with a view to reducing purchase costs and strengthening the spirit of solidarity. Collective purchase is also justified because these systems of land preparation allow greater flexibility in the time of sowing, and therefore facilitate the distribution of the time of use of the machinery and equipment.

In some situations it has also been possible to form a Community Association for joint use of machinery and equipment, as in the case of the microcatchment Ribeirao das Pedras, municipality Agrolandia. The machinery is kept in a barn provided by one of the members of the Association, who also administers the use of the machinery following well defined rules that are accepted by all members of the association.

ADAPTED MINI-TRACTORS FOR MINIMUM TILLAGE AND DIRECT SOWING

When these changes in soil preparation methods were introduced, the major difficulty was the lack of suitable machinery and implements. In 1985, when work on



PLATE 49
Machinery barn for community use - an example of self-management of the development process



PLATE 50
Example of the first sets of rotary hoes which substituted the conventional hoe assembly

soil management was initiated in the municipality of Ituporanga, a major producer of onions, farmers first visited the neighbouring state of Paraná and acquired some abandoned direct-sowing machinery that used rotating hoes for opening furrows and placing seed and fertilizer. One of the farmers then modified this machinery by eliminating some of the rotary hoes, leaving only two lines separated by about 50 cm, with the sole objective of cutting the dry surface residues. It was still necessary for fertilizer to be applied manually in the furrows opened by the mini-tractor, but nevertheless this modification eliminated the need for ploughing and harrowing to prepare the seedbed. This system began to arouse the interest of researchers, extensionists, other farmers, and small local blacksmiths. This resulted in the development of various innovations; the first was to develop a distribution system of two hoppers for seed and fertilizer. However, at the moment of opening the furrows, the soil and the fertilizer were thrown up together and scattered. To resolve this problem a cover was fixed over the line of the hoes so that soil and fertilizer fell back into the open furrow (Plate 51).



PLATE 51
Mini-tractor adapted to the minimum tillage system for onions. Shows details of the hoppers for seed and fertilizer (which did not exist in the original version), and of the protective cover over the rotary hoe unit to avoid seed and fertilizer being scattered outside the furrow



PLATE 52
Direct-sowing equipment for grain adapted for mini-tractors - an advanced system developed by small agricultural entrepreneurs in the Alto Vale de Itajaí region

Nowadays equipment for minimum tillage of onions is manufactured throughout the region by many blacksmiths, and is known as “rotacar”, which is probably derived from the old system “rotacaster.” The process of improving machinery and implements continued, and small companies developed new systems culminating in direct-sowing machinery with a disc for cutting the straw, a furrow opener, and a distribution system for fertilizers and seeds which is coupled to the mini-tractors.

Plates 52 to 55 show the evolution of this system which made it possible to use mini-tractors for sowing grains, and which was previously used only for onions.

A manufacturing and marketing company of agricultural machinery in the Atalanta municipality of Alto Vale de Itajaí region produces direct-sowing machinery also for animal traction, as well as a farm trailer as described in the Catarina Farming Magazine (June 1998). This company started its activities modestly producing hoes and other tools, and subsequently adapted the rotary hoe for the cultivation of onions, then a farm trailer capable of transporting 1 500 kg in



PLATE 53
One of the earlier versions, with fertilizer and seed hoppers made of plastic on mini-tractors with an iron wheel



PLATE 54
Modern equipment produced in Atalanta municipality, with the fertilizer and seed hoppers in a longitudinal position



PLATE 55
Equipment coupled to the mini-tractor for sowing in oat residues

sloping areas. Today this company with a strong family participation employs an additional 12 workers. Moreover this company receives assistance from the farmers themselves, who according to the owners “test the machinery and identify defects and problems, indicating for example, what is the most appropriate size and inclination of the share that opens the furrow.”

There are many cases of farmers who modify machinery and implements. In one case an onion farmer in the zone of Barro Preto, municipality Alfredo Wagner, modified mini-tractors starting from minimum tillage equipment known as a “rotacar”. The problems to be overcome were: excessively wide furrows of up to 20 cm resulting in broad strips of exposed soil that encouraged weed growth and competition; excessive lateral compaction of the furrows, which

impeded rainwater infiltration and root penetration; and clogging of the equipment by vegetative residues. The modifications introduced reduced furrow width to 12 cm, eliminated residue clogging, and reduced compaction. The same farmer also modified the mini-tractor wheels to avoid slipping and entanglement with the stems of mucuna, and changed the rate of the rotary hoes so that work could be carried out in more sloping areas.



PLATE 56
Cart with traction in the wheels coupled to a mini-tractor, which is capable of operating in steeply sloping areas

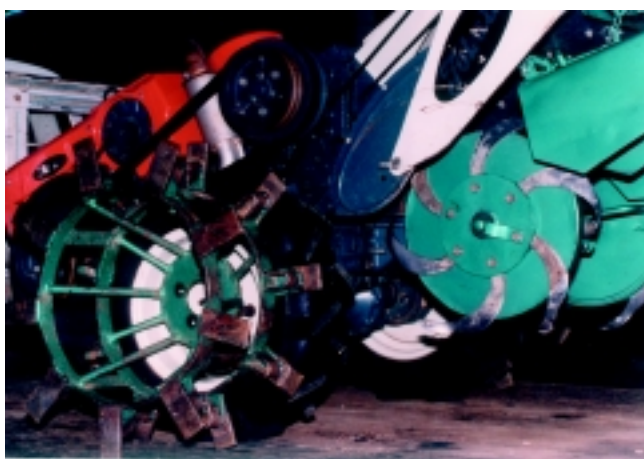


PLATE 57
Details of the disc and rotary hoe system which opens the furrow to place fertilizer as in the old models

PLATE 58
A farmer showing a mini-tractor with the improvements made in his small workshop



DIRECT-SOWING MACHINERY FOR ANIMAL TRACTION

One of the causes for the low rate of adoption of direct-sowing systems by small farmers during the 1980s was the lack of suitable machinery. During this period there were some isolated experiences, but none of these were successful on a commercial scale, probably due to excessive weight, poor seed distribution, poor fertilizer incorporation, and the difficulty of manoeuvring.



PLATE 59
Details of the rotary hoes and the protective covers over the hoes opening the furrows

PLATE 60
One of the first versions of direct-sowing equipment for animal traction produced in the region Alto Vale de Itajaí, showing details of the front disc for cutting the residues



PLATE 61
A historic moment: this meeting of farmers, technicians, and municipal leaders from Agrolândia, micro-catchment Ribeirão das Pedras, first discussed how to convert traditional animal traction equipment to direct-sowing equipment



Meanwhile the success of these technologies in other regions of southern Brazil produced enthusiasm among a number of small entrepreneurs who started to invest in the manufacture and development of the equipment, adapting them with farmers' collaboration.

In the microcatchment Ribeirao das Pedras, municipality Agrolandia, rural extension work was initiated in 1984 using the microcatchment as the basic planning unit. At this time there was no direct-sowing equipment for animal traction adapted to the needs of the small farmer for sowing maize and beans. However, with the participation of the farmers, various modifications of existing machinery were carried out using farmers' own resources and with logistic support from local craftsmen.

One farming family developed direct-sowing equipment for animal traction using its own resources, even though they possessed a tractor, so that they could plant more steeply sloping areas where the tractor could not be used. With this equipment the farmer is producing about 7 200 kg/ha of maize utilizing green manures such as vicia and oats combined, plus a farm-yard manure from pigs applied in the liquid form.

The following diagram shows the process by which the machinery and implements of conservationist systems of land preparation developed from 1984 to 1994 (Freitas, 1994):



PLATE 62
Equipment developed by a farmer with his own resources in the microcatchment Ribeirao das Pedras, municipality Agrolandia



PLATE 63
The areas where the farmer uses this equipment and harvests about 7 200 kg/ha of maize (the more steeply sloping area of the hillside is visible in the background)

1984/85	1986	1987
<ul style="list-style-type: none"> • Excursions • Formation of microcatchment commissions 	<ul style="list-style-type: none"> • Establishment of the green manure observation unit • Identifying green manure systems 	<ul style="list-style-type: none"> • Establishment of the first crop by direct sowing with animal traction
1988/89/90	1991/92	1993/94
<ul style="list-style-type: none"> • Period of testing and adapting agricultural equipment • Development of equipment for direct sowing with animal traction and tractors • Improvement of equipment for minimum tillage and direct sowing for mini-tractors 	<ul style="list-style-type: none"> • Beginning of direct-sowing systems (5% adoption rate) • Continuing the adaptation of equipment for direct sowing 	<ul style="list-style-type: none"> • Increased area of direct sowing • Acquisition of equipment by individuals and groups

Machinery for direct sowing by animal traction is also produced on a commercial scale in the municipality Doña Emma in the Vale de Itajaí region. Nowadays other equipment is produced there as well, such as cultivators, reversible ploughs for minimum tillage, balers, fertilizer broadcasters for tobacco, and chimneys for tobacco-drying sheds.

A recent innovation has been the agreement signed by the manufacturers of direct-sowing equipment for animal traction with the Bank of Brazil S.A., that enables farmers to purchase this equipment, individually or in groups, with credit repayable over periods of up to 12 months, and with similar interest rates to those of savings accounts. The bank finances 80 percent of the value of the purchase and the farmer pays the rest directly to the manufacturer.

The company in Doña Emma that manufactures direct-sowing machinery is also participating in a direct-sowing research and development project with EPAGRI, cooperatives and private companies, with the aim of diffusing and testing techniques and equipment adapted to this system of soil preparation. The agreement foresees the establishment of 180 demonstration plots in farmers' properties in three regions of Western Santa Catarina, where technicians, researchers and farmers will monitor the development of direct-sowing technologies and equipment over a period of four years. This company also receives assistance from the federal university of Santa Catarina (UFSC) through a postgraduate course in mechanical engineering in which a specialist from the Agrarian Science Centre (CCA) of Florianópolis participates. Some equipment that



PLATE 64
One of the first versions of the equipment produced in the Doña Emma municipality



PLATE 65
An entrepreneur showing the most recent version of his direct-sowing equipment for animal traction.



PLATE 66
Latest version of direct-sowing machinery for animal traction produced in Mafra municipality.

originated here has begun to be tested and improved, as for example, direct-sowing machinery for animal traction and a roller with blades (Catarina Farming Magazine, June 1998).

In the Northern region of the State at least two types of equipment adapted to direct sowing have been developed on a commercial scale for small farmers who use animal traction. In the municipality of Mafra, a company has been working for five years on the development of different types of machinery and equipment for minimum tillage and direct sowing for the small farmer, such as a combined seed and fertilizer drill, rollers with blades, lime spreaders and manual sprayers. Since 1990 representatives of the company have been actively participating in local, regional, state and international meetings which deal with direct sowing, acting as manufacturers, exhibitors, and as farmers. At the height of their production they employ between 35 and 45 workers, and have already marketed a total of more than a 1 000 units of the different kinds of equipment, of which 150 have been exported to Latin American and African countries.

Direct-sowing machinery for animal traction is also being produced by a company in the municipality of Itaiópolis. The owner worked for forty years as a blacksmith and farmer, and in recent years has dedicated himself to a small manufacturing company with his sons and partners. They also produced animal traction sprayers and rollers with blades. The activity started between 1990 and 1991 when a tobacco company requested the development of a fertilizer drill for tobacco. This led to a seed and fertilizer drill which after several versions resulted in the model shown in Plate 68. Today this company produces between 30 and 40 units per month and employs 20 workers at times of greatest activity.

In the municipality of Luzerna, western Santa Catarina, a company started activities in 1961 with the revision of petrol engines, but from 1965 it began developing machinery for the small



PLATE 67

Other views of the machinery showing the residue cutting disc and furrow-openers, and (top) details of the seed and (lower image) fertilizer distribution systems



PLATE 68
Direct-sowing equipment for animal production produced in the Itaiópolis municipality

PLATE 69
Machinery produced in the municipality of Joaçaba, Western Santa Catarina



PLATE 70
Prototype of the direct-sowing machinery developed in the region of Tubarao, south of Santa Catarina state; this was one of the first models produced in the State

PLATE 71
Latest model of the direct-sowing equipment shown in Plate 70



farmer, especially threshers, and animal traction machinery for ploughed lands. Later it diversified its production to wagons, sugarcane mills, silos, and recently in response to farmer demand, direct-sowing machinery and sprayers for animal traction. The company employs 60 workers of which 13 are shareholders.

One of the first direct-sowing machinery for animal traction was developed with assistance from a tobacco company in the Southern region of the State, Vale del Río Tubarao; after a process of successive improvements it has been marketed by the Fundisul company (municipality Rio do Sul).

A model of the direct-sowing machinery for animal traction which is well accepted by the farmers of Santa Catarina is produced in the neighbouring State of Rio Grande do Sul, municipality Aratiba, which borders Western Santa Catarina. This machinery is quite different from the others, more robust, suitable for sowing two rows, similar to the models for use with tractors, with wheels with tyres as shown in Plates 72 and 73.

The direct-sowing and fertilizing machine for animal traction from Paraná state to the North of Santa Catarina (Plate 74) was produced by researchers from the Paraná Agronomic Institute (IAPAR), which is the official State research body.



Plate 72
Two-row direct-sowing and fertilizing equipment with tyred wheels from Rio Grande do Sul. View from the rear



PLATE 73
The machinery allows the operator to work sitting down



PLATE 74
Machinery developed by researchers from Paraná state

MACHINERY AND EQUIPMENT FOR MANAGEMENT OF VEGETATIVE COVER

It should be emphasized that the large increase in area under direct sowing in Santa Catarina and in the Southern region of Brazil is closely related to the arrival of “management herbicides” used for desiccating the cover crops and green manures. At the same time a large demand was generated for rollers with blades and with discs used for slashing the cover crops to give better conditions for the movement of direct-sowing machinery, and to reduce weed germination. Over the years farmers have been learning to manage weeds by crop rotations, the selection of appropriate cover crops and the use of the “knife roller”, with the effect that the amount of herbicides and desiccants is reduced and even proves unnecessary in some cases.



PLATE 75
Roller with blades developed by a postgraduate student of the UFOS with support from EPAGRI, which is already in commercial production

Cutters and slashers for mulching biomass

The first rollers with blades were developed by farmers, technicians and blacksmiths, and are now being improved in the Santa Catarina universities.

Rollers with blades basically consist of a cylinder of wood or iron fitted with blades to cut the biomass, which can be lifted from the soil and transported. They can be used with animals or tractors. Plates 76 to 79 show the distinct types of rollers with blades produced in Santa Catarina

Rollers with discs may be constructed of wood, and consist of a roller in the front to flatten the biomass, and discs in the rear to cut it (Plate 80). They are normally used for eliminating mucuna.

Both the rollers with blades and with discs can be operated with any type of traction. Their major limitation is the difficulty of working in very sloping areas, which has



PLATE 76
Roller with blades with a wooden cylinder in the transportation position



PLATE 77
Roller with blades with an iron cylinder being used to flatten cover crops (forage radishes)



PLATE 78
 Roller with blades manufactured by a farmer following an information folder from the Rural Extension Service, Dona Emma municipality, Alto Vale de Itajaí

restricted their adoption on a large scale, especially in small farms that use animal traction.

Mini-tractors adapted for mechanical slashing have gained acceptance in some regions that predominantly use mucuna as a cover crop/green manure. A farmer from the Ibirama municipality, Alto Vale de Itajaí region, developed his own system of eliminating mucuna by adding cutting discs to a small cylinder coupled to the front of a mini-tractor which is able to work in steeply sloping areas (Plate 80).

Other modifications developed in the Ibirama municipality consisted in replacing the rotary hoes of a mini-tractor with a set of discs, and by welding parts of discs to the wheels of a mini-tractor. These adaptations are also suitable for slashing the mucuna even on steep slopes (Plates 81 and 82).



PLATE 79
 Roller with blades with two cylinders and tyres



PLATE 80
 Roller with discs developed by small farmers in the Alto Vale de Itajaí region



PLATE 81
 Mini-tractor developed in the Ibirama municipality to slash mucuna in steeply sloping areas

In the absence of more refined equipment it is possible to construct simple alternatives to eliminate cover crops, such as a wooden beam or a tree trunk which can be dragged over the land to flatten the biomass (Plate 83). The Santa Catarina farmers have shown great capacity to create and adapt equipment for such uses.

Safe spraying equipment for herbicides

An important factor responsible for the adoption of direct sowing in small farms in Santa Catarina was the development of manual and animal-traction sprayers, principally for the application of desiccating herbicides. Although it is necessary to use as little herbicide as possible, these sprayers make the work more agreeable for farmers, and diminish risks of pesticide poisoning during application compared to the knapsack sprayers that were previously used.

In some cases the management of cover crops can even eliminate the need for desiccants or herbicides. Black oats, for example, will die when rolled down with a knife roller in the milk stage, provided the stalks are not cut but only broken. Due to its weed-suppressing characteristics, there is no need for an application of herbicides in this case.

Perhaps the most important factor responsible for the adoption of sprayers has been the savings of time and labour which are becoming increasingly scarce in Santa Catarina farms. Different types of sprayers have been constructed on a commercial scale, as shown in Plates 85 and 86.

Other equipment that has been well accepted by small farmers is the



PLATE 82
Mini-tractor with parts of discs welded to the wheels to slash mucuna, Ibirama municipality



PLATE 83
Dragging beam constructed by a farmer from the Rio do Campo municipality, Alto Vale de Itajaí, for flattening cover crops



PLATE 84
A field of oats desiccated with a herbicide and subsequently flattened with the dragging beam shown in the previous Plate. Fertilizer was applied in the row using direct-sowing machinery with animal traction and the tobacco was planted manually



PLATE 85
Modification of two knapsack sprayers for animal traction, produced in the Itaiópolis municipality, Northern Santa Catarina

PLATE 86
Details of the spray bar, nozzles and tanks



PLATE 87
Operation of a manual sprayer in the Mafra municipality. Contact of the operator with the chemical product during application is practically eliminated

PLATE 88
A model currently in production with various improvements - in the tank (made of plastic, 50 litres), transport system, traction bar and spray bar (with 8 nozzles)





PLATE 89
The most modern manual sprayer with a fibre-glass tank

PLATE 90
Model with fibre-glass tank, 250 litres capacity, a spray bar of seven metres and 14 nozzles, wagon wheels for transport, and operator seat



PLATE 91
Another version for animal traction with a round tank, 150 litres capacity, motor-cycle wheels, spray bar with 14 nozzles, and operator seat

PLATE 92
Sprayer for coupling to tractors with a round tank of 150 litres (with a square tank 250 litres capacity)



manual sprayer produced in the municipality Mafra, Northern Santa Catarina. This consists of a modified knapsack sprayer supported on a framework with bicycle wheels, which is light and easily manoeuvred.

Another farmer in the municipality Cunha Pora in the western region of Santa Catarina identified problems in applying pesticides to tobacco using a knapsack sprayer. To overcome these problems he developed a model on wheels which, despite having initial stability problems, was very successful with farmers in the community. In a subsequent model the stability was improved by increasing the wheel span, which made it more interesting to other farmers. This was made on a larger scale in his workshop.

In 1995, as the area under direct sowing in the region expanded and the demand for these types of equipment, especially those for desiccating cover crops increased, the farmer established a workshop in the neighbouring city and produced 12 sprayers. In 1996 the number of sprayers increased to 35 and in 1997 to 400. This farmer receives help from his sons and employs up to eight workers. He also participates in all meetings on direct sowing held in the Western region, as well as in other regional and state meetings. Plates 88 to 92 show some of the equipment.

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Annex

Main green manure and cover crop plant species used by farmers in Santa Catarina

SPRING/SUMMER SPECIES (usually sown between September and December)

Mucunas (*Stizolobium* spp)

- 1.1. white (*Stizolobium niveum*)
- 1.2. black (*Stizolobium aterrimum*)
- 1.3. streaked (*Stizolobium deeringianum*)

Crotalarias

- 2.1. *Crotalaria mucronata*
- 2.2. *Crotalaria juncea*
- 2.3. *Crotalaria spectabilis*

Canavalia, sword-bean, or jack bean (*Canavalia ensiformis*)

Pigeon pea (*Cajanus cajan*)

AUTUMN/WINTER SPECIES (usually sown between March and July)

Oats: black oats (*Avena strigosa*), white oats (*Avena sativa*)



PLATE A1
Mucunas (*Stizolobium* spp.) are the species most used for green manures or cover crops during spring/summer in Santa Catarina



PLATE A2
Black oats (*Avena strigosa*) and vetch (*Vicia* sp.) as pure or mixed crops are the most cultivated species in the State during autumn/winter

Vetches: common vetch (*Vicia sativa*), hairy vetch (*Vicia villosa*)

Ryegrass (*Lolium multiflorum*)

Rye (*Secale cereale*)

Grass pea (*Lathyrus sativus*)

Peas (*Pisum sativum*)

Corn spurry (*Spergula arvensis*)

Radish (*Raphanus sativus*)

Serradella (*Ornithopus sativus*)

Blue Lupine (*Lupinus angustifolius*)

The main grass species used at present are:

Sweet grass (*Brachiaria plantaginea*)

Cushion grass (*Digitaria sanguinalis*)

This report is intended for development practitioners, extensionists and leaders or pioneers in farming communities, to inform them about the experiences and initiatives of farming communities in conservation agriculture in Santa Catarina State, Brazil. On the basis of several local initiatives, inventions and developments, there have been widespread improvements in soil management in various parts of the State, resulting in lower costs and improved returns, combined with conservation and improvement of the soil resources. The main elements of success were minimum tillage, soil cover management and direct seeding practices and equipment, together with an effective and creative extension service. While these developments probably cannot be duplicated as such elsewhere, the methods and strategies may well inspire others to adapt and modify them for application in their own environments.

