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Green manure/cover crops and crop rotation in Conservation Agriculture on small farms

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GREEN MANURE/COVER CROPS AND CROP ROTATION IN CONSERVATION AGRICULTURE ON SMALL FARMS

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PROLOGUE

This publication is the result of activities developed within the framework of the "Soil Conservation Project MAG – GTZ", implemented from 1993 to 2001. The executing institutions of the Soil Conservation Project were the Ministry of Agriculture and Livestock (MAG) of the Republic of Paraguay and the German Technical Cooperation (GTZ).

The Spanish original has been published in Paraguay by the Ministry of Agriculture and Livestock (MAG) of the Republic of Paraguay, the Directions of Agrarian Research and Extension (DIA/DEAG) and the German Technical Cooperation (GTZ). The present English version has been translated by Melissa J. McDonald under the review of the original authors and is published in the FAO-AGP integrated crop management series.

The information utilized in this work is based on research done principally at the Choré Experimental Station of the Direction of Agricultural Research (DIA/MAG). Also used are experiences developed in pilot areas, especially in Paraguarí, Edelira, Minga Guazú, Caaguazú, Guairá, Caazapá, and San Pedro, among others. Diffusion and extension activities were carried out through the Direction of Agrarian Extension (DEAG), cooperatives, farmers' associations, self-help groups, etc.

The objective of this publication is to offer a reference material for extensionists, professors, agronomy students, technicians in general, and for farmers themselves. Through information that is up-to-date and richly illustrated, it strives to facilitate the adoption and diffusion of No-Tillage, the use of green manures, and the practice of crop rotation on small farms.

The wealth of this work is that it brings together the experiences of farmers, extensionists, and researchers in a way that is simple, understandable, and practical. It describes the principal species of green manures and, at the same time, informs in detail how to insert green manures into small farm production systems according to soil fertility and major crops. It also deals with the residual effect of green manures on main crops and analyzes the economic implications of these practices. Furthermore, it describes the results obtained in the recuperation of extremely degraded soils. Finally, this work strives to show the way to achieve an agriculture that is more productive, profitable, competitive, and sustainable, with the objective of improving the quality of life of rural families.

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National Counterpart

Soil Conservation Project MAG – GTZ
San Lorenzo, Paraguay, 2001

In this publication, the terms "green manure" and "cover crop" are used as synonyms. In Conservation Agriculture, the residues of green manure/cover crops (GMCCs) are always left on the soil surface, and are incorporated biologically rather than with tillage implements.

Conservation Agriculture, with the use of green manure/cover crops and crop rotation, is the way to achieve agricultural sustainability on small farms.

ACKNOWLEDGEMENTS

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We are especially grateful to agronomists Juana Caballero and María Noce for their revision of the publication, which without a doubt contributed to the improvement of its quality, and to agronomist Alba Esteche for her appraisals after having read it.

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CONTENTS

CHAPTER 1
Introduction

Soil degradation on small farms in the Eastern Region of Paraguay is the principal cause of a continuous decrease in crop production. The consequences of this are reduced economic income and increased poverty among rural families.

One of the principal reasons for this fact is the continuous utilization of inadequate methods of soil management, including the burning of vegetative residues, excessive tillage, and monoculture. The exposure of bare soil to climatic agents (high temperatures, torrential rains) accelerates the soil degradation process, as they cause excessively rapid decomposition of biomass and favor the erosion and leaching of nutrients.

The decrease in productivity is closely tied to a decline in the levels of soil organic matter. In poor soils, it is organic matter that determines the improvement of physical aspects, water retention, and biological activity, as well as the storage and slow release of nutrients. These aspects are most significant in sandy soils. Therefore, in order to maintain soil productivity in agricultural systems on small farms (where chemical fertilizers are normally not used) biomass is shown to be an essential element, due to the fact that it permits nutrient recycling and controls the microbial population that maintain favorable soil properties. One great difficulty in relation to the maintenance of biomass in tropical and subtropical climatic regions is that it breaks down much more rapidly than the capacity of conventional agricultural systems to replace it.

The strategies used by technicians and farmers to counteract the reduced yields caused by soil degradation are often based on the use of large quantities of inputs (fertilizers and pesticides), which results in high production costs. The apparent absence of agricultural systems for sustained productivity within the scope of small farmers is often due, not to lack of technology or to the low yield potential of traditional varieties. Rather, this situation is due to limited knowledge, or lack of awareness, on the part of technicians and farmers about practices that function in harmony with the environment in tropical and subtropical regions. At times, the absence of operative conditions (availability of credit, seeds, machinery, etc.) is a limiting factor in the development of this process.

Management measures to maintain soil fertility on small farms in Paraguay should be oriented toward the utilization of practices that maximize biomass production while minimizing its decomposition. In this sense, crop rotation,

together with the use of green manure/cover crops and No-Tillage, form part of a technological strategy that has been proven by research and farmer practice to be efficient and economically viable, and that has as its objective the increase and conservation of soil organic matter. These practices together are referred to as "Conservation Agriculture".

Crop rotation and green manure/ cover crops constitute a technology that is appropriate and essential to achieve sustainable agricultural production.

CHAPTER 2

Characterizacion of agricultural systems on small farms in Paraguay according to climate and soils

Knowledge of local agroecological and socioeconomic characteristics is essential for the planning of strategies for the use and management of soils in a region. The diagnosis of production systems consists of gathering information on production factors and components, considering such indicators as: climate, degree of soil degradation, actual land use, available infrastructure, the conservation practices utilized, integration of diverse production activities, socioeconomic characteristics, etc.

2.1 CLIMATE

The predominant climate in the Eastern Region of Paraguay is subtropical, humid, mesothermic, with no dry season, and classified as Cfa according to Köppen. Spring and summer are the seasons when torrential rains (over 60 mm/h) and elevated temperatures of around 41 °C frequently occur. In autumn-winter, precipitation and temperatures are lower than during the rest of the year, and with the risk of sporadic frost (Figure 1). Minimum temperatures may occasionally be lower than 0 °C.

Meteorological data for the principal regions of Eastern Paraguay are presented in Table 1. Average annual precipitation varies from 1,551 to 1,707 mm. Average annual temperatures fluctuate around 21.1 to 23.0 °C.

Rainfall distribution and monthly temperature values are similar for the principal regions mentioned. Average monthly precipitation ranges between 50 and 196 mm, July being the month with the lowest rainfall of the year. Average monthly temperatures vary between 15.5 and 27.1 °C, June being the coldest month and January the hottest.

FIGURE 1
In Paraguay there are occasional frosts that affect some green manure/cover crops that are more sensitive, such as the grey-seeded mucuna (foreground), while others such as lablab (background) are less affected.

TABLE 1
Average monthly precipitation (mm) and temperature (°C) for the principal regions of Eastern Paraguay.

Region	Month												Av.
	J	F	M	A	M	J	J	A	S	O	N	D	
North[1]													
Precipitation	132	167	125	160	141	103	50	68	112	168	161	165	1.551
Av. Temp.	27.1	26.6	25.9	23.3	20.2	18.2	18.2	20.1	21.2	23.9	25.1	26.6	23.0
Central[2]													
Precipitation	186	154	144	180	128	96	60	82	104	162	196	177	1.670
Av. Temp.	26.5	26.1	25.1	22.3	19.5	17.5	17.6	18.8	20.5	22.7	24.4	25.8	22.2
East[3]													
Precipitation	148	130	117	141	138	133	73	102	125	174	136	171	1.590
Av. Temp.	26.1	25.6	24.7	21.6	18.4	16.5	17.8	17.9	19.2	22.1	23.8	25.4	21.6
South[4]													
Precipitation	156	150	154	157	142	140	103	122	129	161	152	143	1.707
Av. Temp.	26.3	25.5	24.0	21.3	18.3	15.5	16.0	16.9	18.9	21.2	22.9	25.9	21.1

Source
1 Choré Experimental Station, Department of San Pedro (23 year average). Latitude: 24° 10' S., longitude: 56° 37' W., altitude: 220 meters above sea level.
2 National Agronomic Institute (IAN) in Caacupé, Department of Cordillera (38 y 42 year averages for precipitation and temperature, respectively). Latitude: 25° 24' S., longitude: 57° 06' W., altitude: 228 meters above sea level.
3 Agricultural Technology Center in Paraguay (CETAPAR) in Iguazú, Department of Alto Paraná (28 year average). Latitude: 25° 27' S., longitude: 55° 02' W., altitude: 280 meters above sea level.
4 Regional Agricultural Research Center (CRIA) in Capitán Miranda, Department of Itapúa (30 year average). Latitude: 27° 17' S., longitude: 55° 49' W., altitude: 200 meters above sea level.

In the eastern and southern regions of Eastern Paraguay (Departments of Alto Paraná and Itapúa) the climate is colder than in the rest of the country. In the northern region (Department of San Pedro) rainfall is less and periods of water deficiency occur with greater frequency.

2.2 SOILS

Agricultural areas in the Eastern Region of Paraguay are located over two types of soil: sandy soil derived from sandstone and clay soil from basalt.

Eastern Paraguay's sandy soils are mostly located in the central and northern regions (along the Paraguay River). They are principally red-yellow (Figure 2) and dark red Podzols[1] (Ultisols and Alfisols[2]). The clay soils are principally Clay Alfisols (Figure 3) and Latosols (Alfisols, Ultisols and Oxisols) that are found in a band that borders the Paraná River.

In general, agricultural soils originate as forest land and are very fertile in the first years of use. This is due principally to the high content of organic matter, which allows for good crop yields. Under the traditional cropping system - which implies deforestation, burning (Figure 4), cutting weeds with

1 Brazilian soil classification system.
2 American soil classification system.

machete (Figure 5), and repeated and continuous tilling - soil fertility has decreased and, in consequence, crop production has gone down (Figures 6 and 7).

Clay soils, in spite of having a natural fertility superior to that of sandy soils, show the same tendency to degrade over the years when managed in a conventional system.

FIGURE 2
Profile of sandy soil (red-yellow podzolic), predominant in the Central and Northern region of Eastern Paraguay.

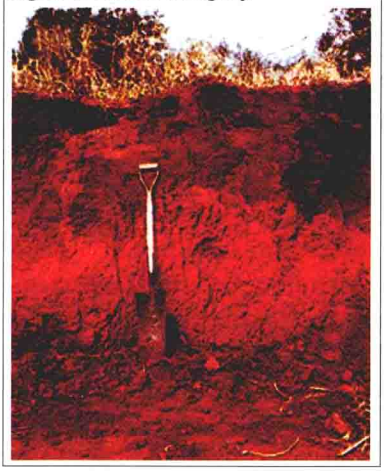
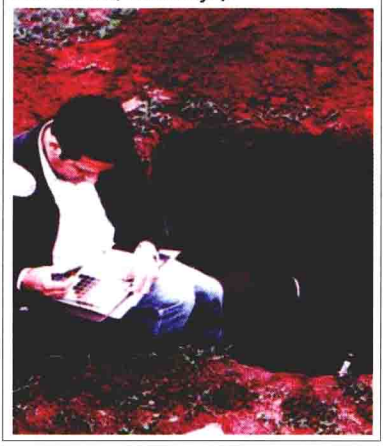


FIGURE 3
Profile of clay soil (clay alfisol) that is predominant along the margin of the Paraná River (Departments of Itapúa, Alto Paraná, Canindeyu).



Traditional systems of tillage and the burning of plant residues impoverish the soil and the people who cultivate it.

FIGURE 4
In Paraguay there are occasional frosts that affect some green manure/cover crops that are more sensitive, such as the grey-seeded mucuna (foreground), while others such as lablab (background) are less affected.

FIGURE 5
The employment of labor to cut weeds in traditional cropping systems increases production costs.

2.3 AGRICULTURAL SYSTEMS

The majority of small farms in Paraguay have 5 to 20 ha (54%), a lesser proportion correspond to farms of 1 to 5 ha (37%) and scarcely 9% of farms have less than 1ha (National Farm Census, 1991). These proportions, with some variation, could be extended to the Eastern Region.

Agricultural systems are characterized as being not intensive; they utilize almost exclusively spring-summer crops, and are managed manually or in a way that is semi-mechanized (with animal traction). Land is generally not utilized during the fall-winter period, and weeds are left to grow freely until the start of the next agricultural season. The principal crops for home use are corn, cassava, cowpeas, peanuts, and sweet potato. The most important annual cash crops are cotton, corn, and cassava. In some regions, other crops grown commercially are sugar cane, soybeans, tobacco, yerba mate (Ilex paraguariensis), Phaseolus beans, sesame, peas, and others.

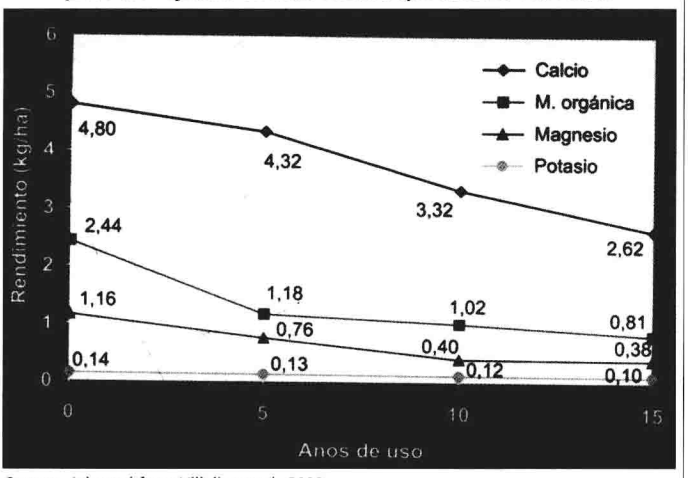
Production systems on small farms in Paraguay's Eastern Region are quite diverse and complex. However, at the present time it is possible to identify zones that are similar with respect to climate, soil texture, and fertility. These zones can be used as recommendation units, to introduce production systems with common strategies for soil use and management. Three principal zones stand out, which are:

1) Zone of moderately fertile sandy soils (7 to 10 years of use) with an average organic matter content of 1.2%, found principally in the Departments of San Pedro, Caaguazú, Concepción, and Caazapá.
2) Zone of very degraded sandy soils (over 15 years of use) with less than 1% organic matter, generally compacted (hardpan at a depth of 10 to 15 cm), found principally in the Departments of Paraguarí, Central, Cordillera, and Guairá.
3) Zone of clay soils with moderate to high fertility (organic matter from 2 to 3%), found principally in the Departments of Alto Paraná and Itapúa, where the somewhat colder and rainier climate of the Eastern Region occurs.

The definition of soil management recommendations by zones having similar characteristics presents the following advantages: it rationalizes the application of financial and human resources, reduces operational costs in the implementation of common practices, promotes sectoral and institutional integration, encourages participation in group discussion, stimulates the organization of farmers, and more. However, **in order to zonify the recommendations, it should also be taken into consideration that:**

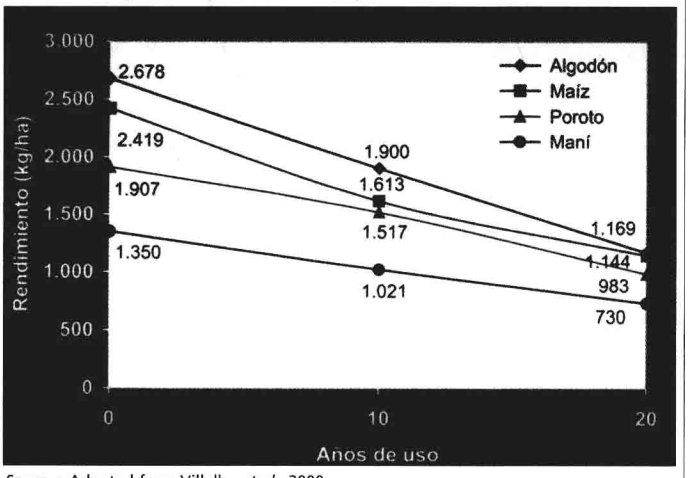
- Transition zones exist, with soil and climatic characteristics that are intermediate to those already considered, such as in the Departments of Misiones, Ñeembucú, Canindeyú, part of Caazapá, and part of Guairá. Alternative production systems should be adapted for each situation.
- The production systems identified could occur anywhere in the Eastern Region of Paraguay, not exclusively in the regions mentioned.

FIGURE 6
Evolution of fertility level in sandy soils according to years of use, in production systems on small farms. Department of San Pedro.



Source: Adapted from Villalba *et al.*, 2000.

FIGURE 7
Evolution of crop yield with years of soil use of sandy soil, in production systems on small farms. Department of San Pedro.



Source: Adapted from Villalba *et al.*, 2000.

CHAPTER 3
Green manure/cover crops (GMCCs)

In this publication, the green manures referred to are always utilized in Conservation Agriculture.

3.1 OBJECTIVES AND BENEFITS OF GREEN MANURE/COVER CROPS

Green manure/cover crops (GMCCs) are plants that are grown in order to provide soil cover and to improve the physical, chemical, and biological characteristics of soil. GMCCs may be sown independently or in association with crops.

In general, green manure/cover crops are used to pursue the following **objectives:**

- Provide soil cover for No-Tillage (reduces water evaporation and soil temperature, and increases water infiltration).
- Protect soil from erosion.
- Reduce weed infestation.
- Add biomass to soil (in order to accumulate soil organic matter, add and recycle nutrients, feed soil life).
- Improve soil structure.
- Promote biological soil preparation (Figures 8 and 9).
- Reduce pest and disease infestation.

By carrying out these functions, green manure/cover crops offer the following **benefits:**

- Increase economic return (when adequately chosen).
- Reduce need to use herbicides and pesticides.
- Increase yield and improve quality of the following crops.
- Prevent soil erosion.
- Conserve soil humidity.

FIGURE 8
Jack bean, after being flattened with a knife-roller, leaves the ground free of weeds and decompacted. The bar penetrates easily.

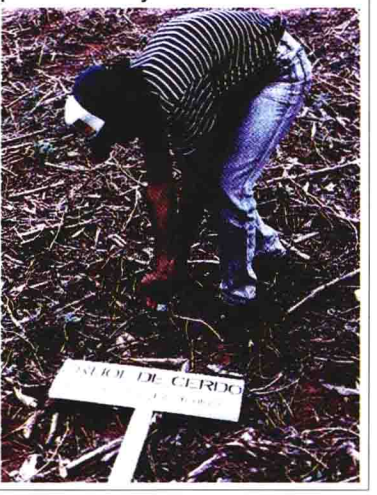


FIGURE 9
In fields without green manure/cover crops (in winter fallow), weeds proliferate and soil remains compacted. The bar penetrates with difficulty.