CONSERVATION AGRICULTURE
COTTON FOR SMALLHOLDER FARMERS

Experiences from Paraguay

Dirk Lange and Ken Moriya

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FOREWORD

Inappropriate agricultural cultivation systems are one of the main reasons for the increasing poverty and food insecurity faced by smallholders in most parts of rural regions in developing countries. Additionally, unsustainable agricultural practices lead to an exhaustion and depletion of the natural forest and soil resources, which result in an increase in the area suffering from desertification and a reduction in biodiversity, along with its well known negative impacts at a national and global level. Cotton is particularly in focus through its conventional production systems, which result in negative impacts to humans and the environment. Nevertheless, it is one of the most important income resources for smallholder farmers.

Conservation Agriculture (CA) helping to compensate for these problems by combining increased agricultural production and natural resource management. CA has proved to be an important technique that contributes towards a more sustainable rural development. The use of agricultural conservation practices in many parts of the world has proven to minimize soil erosion, enhance the biodiversity and reduce the emissions of CO₂, helping to mitigate climate change. Moreover, smallholder families have attained a more secured livelihood and improved their income through higher yields achieved by practicing CA. Therefore, CA contributes towards reaching the "Millennium Goal".

Today, CA is practiced on almost 90 million hectares worldwide; however, most of this area is covered by mechanized medium and large scale farms, as a result of the slow adoption rate amongst smallholdings. Countries such as Paraguay indicate an increasing importance of CA for smallholdings. Paraguay is the world leader in terms of the total area, in percentage, under CA. Medium and large scale farms as well as thousands of smallholders practice this technique that results in improved incomes and labour savings being reinvested in an intensification and diversification of their production; cotton plays an important role within these enhanced conditions.

The present study was carried out under the joint cooperation between the Food and Agriculture Organization of the United Nations (FAO) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ); Germany. Its purpose is to demonstrate the practical experiences with CA cotton at the smallholder level currently existing in Paraguay, while at the same time showing the potential of this agricultural technique. To this very day, the experiences with CA cotton production at a smallholder farmer level have hardly ever been documented.

This study, however, which was carried out with the support of the Paraguayan Ministry of Agriculture and Livestock as well as other national institutions, shows that the implementation and expansion of CA cotton can only be achieved through cooperation and partnership between international and national organisations and institutions.

We would like to invite all readers to adopt and practise Conservation Agriculture. If you have any questions, please feel free to contact us at the addresses of FAO, GTZ or the Paraguayan partners indicated. We wish you a pleasant and enlightening reading through this study.

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<tbody>
<tr>
<td>BCP</td>
<td>Banco Central de Paraguay</td>
</tr>
<tr>
<td>Bt</td>
<td>Bacillus thuringiensis</td>
</tr>
<tr>
<td>CA</td>
<td>Conservation Agriculture</td>
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<tr>
<td>CADELPA</td>
<td>Cámara Algodonera del Paraguay</td>
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<tr>
<td>CIRAD</td>
<td>Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement, Francia</td>
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<td>DEAg</td>
<td>Dirección de Extensión Agraria</td>
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<td>DIA</td>
<td>Dirección de Investigación Agrícola</td>
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<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<td>GMCC</td>
<td>Green manure cover crops</td>
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<td>GTZ</td>
<td>Gesellschaft für Technische Zusammenarbeit, Germany</td>
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<tr>
<td>IAN</td>
<td>Instituto Agronómico Nacional</td>
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<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>MAG</td>
<td>Ministerio de Agricultura y Ganadería, Paraguay</td>
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<tr>
<td>PNMCRS</td>
<td>Programa Nacional de Manejo, Conservación y Recuperación de Suelos</td>
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<tr>
<td>TFT</td>
<td>Training for Transformation</td>
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SUMMARY AND CONCLUSION

This report documents the findings of a study into the experiences of Conservation Agriculture (CA) cotton on smallholder farms in Paraguay. This investigation was carried out between the months of August and October 2003, with an additional two visits on smallholders’ farms in December 2003 and early February 2004. The regions visited are located in East-Paraguay, since CA cotton is grown there on small farms. The results are from in-depth interviews with smallholder farmers, extension agents and researchers from the Paraguayan Ministry of Agriculture and Livestock (MAG). This study was funded by the Food and Agriculture Organization of the United Nations (FAO) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Germany.

Cotton is one of the most important and widely grown cash crops, both for sophisticated high input farmers and resource poor smallholder farmers in developing countries. It is grown in different ecological regions and farming systems. Under Conventional Tillage systems, particularly monocropping systems, the disturbance of soil has led to the destruction of soil structure and faster mineralization of soil organic matter leading to reduced soil fertility, soil loss and desertification in many developing countries. This is a severe problem, particularly in cotton, since it is an extremely income orientated crop and the lower productivity of the degraded soils leads to income problems for many smallholder farmers worldwide.

Contrary to the problems caused by the Conventional Tillage systems, CA systems seek an improved use of soils and crops with reduced soil disturbance and the maintenance of crop residues on the soil surface in order to minimize damage to the environment. This is achieved through no mechanical soil disturbance or direct seeding, crop rotation, the use of green manure cover crops (gmcc) and a permanent soil cover. Undoubtedly, CA cotton is the solution to the constraints of cotton production under conventional cultivation as mentioned above; nevertheless, the experience of CA cotton is still limited and, in most cases, reduced to medium and large scale mechanized farming systems, mainly from Australia and the USA. Many of these examples come from farming systems that do not always include all of the CA principles in their systems, occasionally using seeds treated with Bacillus thuringiensis (Bt-cotton). No experience on smallholder farmers’ cotton under CA was identified prior to starting the field work for this report.

Paraguay has the highest percentage (60) of CA area worldwide. This area is mainly made up of medium and large scale farming systems, mainly producing soybean, but also includes smallholder farming systems to a certain extent. The smallholder farmers’ experience has been documented, e.g. by Florentin et al., Derpsch, Florentin & Moriya, Sorrenson and Dietze. Sorrenson indicated the first experiences with CA cotton in 1998. Since there were no CA cotton experiences documented worldwide, it seemed interesting to carry out a research in Paraguay in order to identify and describe existing experiences of CA cotton by smallholder farmers.

The results documented in this report show clearly that cotton is successfully grown in Paraguay’s CA smallholdings. The most important conclusion is that cotton is always part of a complete crop rotation and never practised under a monocropping system. It has been found that the crop should be used only every three years in the same area in order to break the life cycle of most pests. Thereby, all CA elements are used, which means that even after harvest the cotton residues are left on the ground for decomposition and are never burned. Further advantages were found in a labour reduction of up to 50%, an increase in yields on an average of 20-30%, peaking at 100% when compared to conventional cultivation, and less weed and pest incidence. The later was not scientifically confirmed, but the smallholders emphasised that they use less pesticides. This is to be expected, because CA systems experience an increase of beneficial insects as a result of crop rotation and mulch systems. Only in one case could a clear statement be made, where the cotton aphid almost disappeared as a result of the soil cover provided by a preceding gmcc being of a light colour and thus repelling the aphids.
The decrease in labour requirement is mainly related to the fact that no ploughing and harrowing are practised, less weeding is necessary, and cotton residues are not gathered and burned. An example of less weed incidence is that burr grass, which used to be a severe problem in conventional cultivation, almost disappeared. The increase in the cotton yields can be derived from the fact that plants grow much higher and stronger under CA systems. This can be related to a higher soil fertility and a decompacted soil, which result in a better developed root system, enhancing the capacity of absorbing water and nutrients, even from deeper horizons.

For the crop rotation, the smallholders mostly used maize, because it acts as both a food and cash crop. Other crops used are cassava, soybean, cowpea, wheat, sesame and tobacco. As a gmcc, the smallholders use the locally common ones, such as black oats, sometimes combined with white lupine, oil radish, pigeon pea, garden pea or velvetbean, which is the most popular amongst all gmcc, also combined with maize. As an exceptional experience some smallholders used weeds as a gmcc; although this provides a reduced yield when compared to other gmcc (about 50%), this mechanism provides an improved management of the upcoming weeds.

In the final section, the study has included a recommendation on how to integrate cotton into a CA system provided by the National Programme of Soil Management, Conservation and Recovery (PNMCRS) of the MAG.
1. INTRODUCTION

Cotton (*Gossypium hirsutum*) is a deep rooted woody perennial, usually cultivated as an annual crop. It is one of the most important and widely grown cash crops, both for sophisticated high input farmers and resource poor smallholder farmers in developing countries. Due to its considerable drought tolerance, it is grown in different ecological regions and farming systems.

Under Conventional Tillage systems, especially monocropping systems, the disturbance of soil has led to the destruction of soil structure and faster mineralization of soil organic matter leading to reduced soil fertility, soil loss and desertification in many developing countries. This is a severe problem, particularly in cotton since it is a highly income orientated crop, and the lower productivity of the degraded soils leads to income problems for many smallholder farmers worldwide. Additionally, the overuse of insecticides and pesticides has led to human and environmental damage, e.g. water pollution. Cotton is planted on 2.5% of the world’s agriculturally productive land, over which nearly 22.5% of all insecticides and almost 10% of all pesticides are used (Woodburn 1995).

Contrary to the problems caused by the Conventional Tillage systems, Conservation Agriculture (CA) systems seek an improved use of soils and crops with reduced soil disturbance and maintain the crop residues on the soil surface in order to minimize damage to the environment (FAO 2002a, 2).

The principles of CA are:

- no mechanical soil disturbance - direct seeding;
- crop rotation;
- green manure cover crops (gmcc) for releasing additional nutrients to the soil; and
- permanent soil cover through the rest of preceding crops and gmcc.

Advantages of CA are widely documented and include economic benefits (e.g. through higher yield), risk reduction (e.g. through diversification), labour reduction (through less work and workload) and a reduced use of pesticides. It can be argued that CA cotton could be a solution to the constraints of cotton production under conventional cultivation as mentioned above. Nevertheless, the experience of CA cotton is still limited and, in most cases, reduced to medium and large scale mechanized farming systems, mainly in Australia and the USA. Some of these examples also come from farming systems not always including all of the CA principles in their systems, occasionally using seeds treated with *Bacillus thuringiensis* (Bt-cotton). No experience on smallholder farmers’ cotton under CA was identified prior to starting the field work for this report.

Paraguay has the highest percentage (60) of CA area worldwide (Derpsch 2004). This area is made up principally of medium and large scale farming systems, mainly producing soybean, but also includes smallholder farming systems to a certain extent. The smallholder farmers experience is documented, e.g. by Florentin et al., Derpsch, Florentin & Moriya, Sorrenson and Dietze. Sorrenson indicated the first experiences with CA cotton in 1998, but only the yield increase and the labour saving aspects were mentioned. After contacting the PNMCRS from the MAG in June 2003, the existence and experience of CA cotton on smallholdings was confirmed. Since there were no CA cotton experiences documented worldwide, it seemed interesting to carry out this research in Paraguay in order to identify and describe existing experience of CA cotton by smallholder farmers.

The report is divided in two main parts. The first part covers the technical experience with CA cotton on smallholdings. Herein, the cotton varieties, the seeding and the harvesting process of CA cotton on smallholdings are described; this includes the growing of the cotton plant. Furthermore, the principles of CA, such as crop rotation and gmcc, and their influence on CA cotton are presented. Based on existing experiences, it continues with the description of problems related to weed and pest infestation and diseases in CA cotton. Lastly, the yield of CA cotton is indicated, but only as a tendency, since the impact of the growing conditions and other variables are too influential for final conclusions.

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1. It was only during the investigation/writing of this report that two other examples were found: one from Madagascar and the other from Cameroon (both CIRAD Projects). In these examples, cotton is mentioned briefly and results/experience are not described in detail.
Consequently, the CA cotton yield is compared with the country’s average.

The second part, subdivided into two parts, contains a brief recommendation for the starting process of CA cotton. The first explains the framework required to start with CA cotton, e.g. the selection of smallholder farmers to work with, the extension service and machinery required. The second is a description for the actual management of cotton in a CA system. Here, a recommendation for starting in summer and winter is indicated. It is not to be understood as a blueprint, since no two fields, farms, farmers and growing conditions are the same.

1.1 BACKGROUND

1.1.1 Cotton: A smallholder farmers living in Paraguay

There are approximately 318,800 families producing in the agricultural sector, of which 268,300 of these are smallholdings, representing 84% of all Paraguayan farmers. The most important crops, produced by smallholder farmers, are: maize, cassava, sugarcane, cowpea, peanuts and cotton. They are grown as food, fodder or cash crops, or all of these at the same time (like in the case of maize). Amongst these crops, cotton is traditionally the most important cash crop. It is grown without irrigation and generates most of the income for smallholdings; however, its importance has declined since the beginning of the 1990’s, as can be observed in Table 1, showing the cotton area and production in tones per year.

The decrease in area and production is related to the increasing degradation of soils and low world market prices. While in 1993 the production per hectare was at 1,790 t, in the year 2002 cotton yielded only 903 t/ha (BCP 2003b, Table 6).

The decline of the importance of cotton in Paraguay is also visible in the diminishing percentage of the share in export. At the beginning of the 1990s, the export of cotton made up to 55% of all agrarian products. In the year 2001 this decreased to just 15.4%. Once being the most important export crop, it lost the leading role to soybean

Despite this, cotton is still the most important cash crop for small farms in Paraguay. About 100,000 smallholders planted 133,123 hectares (out of 161,000 hectares), or 82.6% of the total cotton area during the 2002/03 season. This is equivalent to 88.5% of all cotton farmers or 37% of all small farms countrywide, and 31% of all farms in the country. In fact, even amongst bigger farmers, cotton is sown on less than 5 ha, which means that 97.8% of all cotton is seeded on plots smaller than 5 ha, and 80% is seeded on plots of 2 ha or less (MAG 2004). The largest areas where cotton is grown are in the Departments of Caaguazú, Caazapá, Canindeyu, San Pedro, Guairá, Alto Paraná and Itapúa (see Figure 1).

The climate in Paraguay is favourable for agriculture; annual rainfall reaches 1,700mm per year where cotton is mostly planted. The continental, mainly subtropical climate generates high mean annual temperatures from 19.8°C in the southeast up to 25.9°C in the northern area.

Table 1. Cotton area and cotton production in Paraguay from 1990 to 2003

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<tbody>
<tr>
<td><strong>Cotton area (ha x 1000)</strong></td>
<td>509</td>
<td>404</td>
<td>437</td>
<td>235</td>
<td>381</td>
<td>332</td>
<td>307</td>
<td>111</td>
<td>202</td>
<td>166</td>
<td>185</td>
<td>298</td>
<td>170</td>
<td>169</td>
</tr>
<tr>
<td><strong>Cotton production (t x 1000)</strong></td>
<td>642</td>
<td>631</td>
<td>391</td>
<td>421</td>
<td>380</td>
<td>461</td>
<td>330</td>
<td>139</td>
<td>222</td>
<td>202</td>
<td>247</td>
<td>294</td>
<td>153</td>
<td>172</td>
</tr>
</tbody>
</table>

Source: Banco Central de Paraguay (2003a), 65.

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2 This change in export importance comes mainly from the increasing soybean area and production. Nevertheless, decreasing cotton importance is also due to low production.

3 The numbers are taken form the MAG survey 2002/03. The percentages are calculations by the author.
of Bahía Negra. Two main seasons distinguished; a mild winter where frosts occur only occasionally and a hot, moist summer when in most parts of the country the rainfall rate is significantly higher than in wintertime (Glatzle; Stosiek, 2001). This allows two agricultural cycles, one in summer and one in winter, which is ideal for CA.

1.1.2 Conservation Agriculture in Paraguay

The first experience with permanent CA in Paraguay dates from 1983. It was in the Japanese colony of Yguazu, Alto Paraná Department, where the first farmer, Akinobu Fukami, started with CA. Nine years later all of the farmers of the Cooperative in Yguazu practiced CA, indicating a slow spread of the technique. In the same year, 1992, it is estimated that 20,000 ha were under CA. The next year, the MAG together with GTZ, initiated a process of adoption and extension of CA countrywide. It focused first on medium and large scale mechanized farmers, but in 1998, when the CA area reached about 500,000 ha, smallholder farmers were included in the project (Derpsch 2004).

Today, Paraguay has the largest area in percentage (approx. 1,400,000 ha or 60%) under Conservation Agriculture worldwide (Derpsch 2004). It is estimated that 90% of soybean, which is the most important cash and export crop in Paraguay, is seeded under mechanized CA; other important CA crops are maize, wheat and sunflower. However, the spread of CA on smaller farms is still limited, such that experience with CA on small farms has existed only since the early 1990s. In all departments of East-Paraguay some 4,500 smallholder farmers are practicing CA permanently (Magín Meza, pers. com.). As opposed to the medium and large scale farms, on smallholder farms all of the cash, fodder and food crops cultivated are part of the CA system.

1.2 THE STUDY

1.2.1 Objectives

The objective was to document the CA cotton knowledge and existing experience in Paraguay. A description of the seeding practices at a smallholder level was elaborated. Special emphasis was given to the integration of cotton into smallholder farmer’s crop rotations under CA and the gmcc used. Additionally, the seeding and harvesting techniques in relation to gmcc and residue management were documented. The occurrence and management of weed and pest problems were also considered.

1.2.2 Methodology

The investigation was carried out from August to October 2003, as well as two visits, on smallholders’ farms, in December 2003 and early February 2004. The sites visited were located in East-Paraguay, since CA cotton is only grown there on small farms, and included the different soil conditions existing in East-Paraguay. The results of the experience gained with smallholder farmers CA cotton are described in this report. The study does not have a scientific approach, but is rather orientated towards the smallholder farmers’ practical experience.

The methodology employed consisted in carrying out in-depth and informal interviews with

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4 Sorrenson, et al. referring to these experiences, documented the economic benefits of CA for smallholder farmers in the year 1998.

5 98% of the population lives in East-Paraguay, although, it consists of only 40% of the country’s area.
smallholders. A questionnaire was elaborated, reviewed by the local experts, and served as a guideline for the interviews. The interview partners were identified by the PNMCRS, i.e. smallholder farmers and extension agents, which helped to elaborate a Workplan. The interviews were always carried out together with the local extension agent. This was necessary for translating the local language, Guaraní.

During the interviews with the smallholder farmers, the cropping history was rebuilt, starting with the crop rotation for cotton, including the cotton varieties, followed by the gmcc systems used. Then the appearance of weeds, pests and diseases was assessed, including their management. Based on this, a comparison between the working process under CA and the Conventional System was elaborated in order to identify possible labour reduction. Finally, the farmers’ yields were reconstituted, which was, in some cases, difficult.

In addition, interviews were held with representatives of two public research institutions, Dirección de Investigación Agraria (DIA) and Investigación Agraria Nacional (IAN), both MAG dependencies, and the extension agents of the PNMCRS.

2. EXPERIENCE OF COTTON ON SMALL FARMS WITH CONSERVATION AGRICULTURE

2.1 INTRODUCTION

In the following chapter the experience of CA cotton by smallholder farmers will be described. Here, different elements such as seeding techniques, plant growth, crop rotation, cover crops, weeds, pests and diseases, and the lint yield are explained.

2.2 VARIETIES

A very important decision a cotton farmer makes each growing season is the cotton variety. Each variety has certain characteristics. The first criterion to consider, when selecting a cotton variety, is yield potential. The second criterion is yield stability, which means that, averaged over years, yield is less affected by different climatic conditions. Cotton growers also have to consider good fibre quality, because this translates into higher net returns. Nevertheless, varieties used in a developing country (like Paraguay) depend merely on the commodity prices, availability in the different regions/villages, and the offers made by middlemen.

Cotton varieties are of national and international origin. The farmers visited used mainly the national variety IAN 338, followed by Guazuncho (Argentina), Coodetec 401 (Brazil) and Delta Pine (different types). In addition, the varieties of Golondrina, Reva P279 (both national), INTA Pora (Argentina) and IPR (Brazil) were found. IAN 338 was distributed by the MAG, and consequently the most frequently used. The MAG guaranteed that the seeds were treated with fungicides and insecticides for their protection.

There has been no difference in the use of the varieties mentioned between CA and the Conventional Tillage system. No cases of Bt-cotton have been seen nor heard of under either of the agricultural systems.
2.3 GROWING TECHNIQUES AND LABOUR REQUIREMENT

2.3.1 Seeding, harvesting process and equipment

The cotton season in Paraguay is from September to May of the following year. The seeding process begins usually mid-September in the north-western region of East-Paraguay and ends in early November in the south-east of the country. The harvest takes place from January to the beginning of May.

Before the actual seeding of CA cotton starts, the farmer’s plot is prepared. The difference between CA and the Conventional Tillage system is that preceding gmcc and weeds are crushed and bent over with a knife roller, instead of burning and incorporating the residues and weeds into the soil. In some cases of more vigorous gmcc, such as pigeon pea (*Cajanus cajan*), a machete is used to slash the plant before passing the knife roller. If necessary, due to the knife roller not completely killing off the gmcc or weeds and these begin to grow back again, a herbicide can then be used to finish off the job. This management of the gmcc provides a mulch layer, which protects the soil (against rain, wind and sun), retains soil moisture and provides nutrients for the following cotton crop.

The smallholding farmer seeds the cotton about 30 days after managing the gmcc and after a rainfall (which enhances the seeding conditions of the soil and growing conditions for the seeds), always through the mulch layer with a jab-planter, which on average takes 1 day/ha. The distance between cotton plants is 30 – 40cm per plant, with two seeds per hole, and 85 – 100 cm between seeding rows/slots (equalling 6 plants per square meter) (see Photo 1). On the one hand, the farmers emphasized that under CA cotton they seed closer between the plants and rows/slots; on the other hand, the official recommendation for conventional cotton does not differ from the reported seeding distances of the CA cotton.

In general, if chemical fertilizer is used, it is applied at the same time as the seeding occurs (most jab-planters have containers for fertilizers), but in some cases fertilizer is applied after the planting process. The use of chemical fertilizer depends on the soil quality, financial capabilities and the accessibility by the smallholder farmer. If a farmer practices CA for many years, the soil fertility is usually high enough and chemical fertilizer is not necessary. Whilst taking into account that the chemical fertilizer is quite expensive, smallholder farmers generally tend to not use them. Nevertheless, examples in Paraguay show that some farmers use 50 – 150 kg/ha NPK. Sometimes lime (on average 1.000 kg/ha) and urea are also added.

On a few farms a subsoiler or chisel is used before the cotton seeding takes place. In this case, the basic idea is to shatter plough pans and hard or compacted soil layers. After passing the subsoiler/chisel, the cotton is sown. It has to be kept in mind that this operation should only be carried out if necessary, since the whole concept of CA is based on not moving the soil. The subsoiler/chisel, therefore, is used only for adopting CA or during a transition phase. Farmers, using the subsoiler/chisel, reported quick results for their crop growth and yield.

The cotton harvesting is always handpicked; in general it is carried out by family members, but occasionally additional labour is employed. The difference in the CA cotton harvest process is that, after the harvest, the cotton stubble is

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6 N.B. In some cases the herbicide is applied before passing a knife roller.
7 For the characteristics and benefits of gmcc see 2.6
8 The soil quality is increased in CA. Therefore the use of chemical fertilizers is only recommendable in the first years and only for increasing soil fertility. In later years the replacement of some chemical elements in the soil (mostly P), under certain conditions, and in moderate amounts, is acceptable.
9 Sometimes financed by international projects.
pulled out and left on the ground for decomposition (see Photo 2), whereas under the conventional tillage system the cotton residues are burned. The advantages of leaving the cotton stubble on the ground are, for example:

- N fertilizer recovery;
- biological activity and nutrient cycling;
- activity of the soil microbial biomass; or
- Carbon sequestration.

Therefore, the burning of cotton stubble and crop residues by CA farmers has not been reported.

2.3.2 Labour reduction

As shown in the preceding subchapter, CA cotton does not require labour for the gathering and burning of cotton residues or even for ploughing/harrowing. Other labour saving advantages are: reduced weeding activities, reduced application of insecticides and time reduction for seeding. The calculation of working days in Table 2 presents a typical example from a smallholder farmer in Naumby, Caazapá, East Paraguay.

The example shows clearly that up to a 50% reduction in labour requirement can be achieved, as can be seen in the previous Table and which has been reported by the smallholders as one of the big advantages of CA cotton, by simply eliminating many of the activities carried out under the conventional system. This helps smallholder farmers direct their time to other activities such as the diversification of crop production, processing of agricultural products, agroforestry, bee keeping, small animals, or community work, education, and capacity building, amongst others. In addition, smallholder farmers emphasized that they now have recreational time. It must be mentioned that CA not only reduces the number of hours of work, but that the workload is also considerably lighter and cheaper, which result in the overall improvement of work quality. It is also important to mention that the elimination of activities such as the burning of crop residues, that contribute to overall CO₂ emissions, and deep ploughing, that degrades soil structure, actively contribute to environmental conservation.

Table 2. Comparison of labour requirement for 1ha of cotton in Conventional Tillage and Conservation Agriculture

<table>
<thead>
<tr>
<th>Conventional Tillage</th>
<th>Conservation Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cleaning and burning</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>1 - 2 ploughings</strong></td>
<td>4 days</td>
</tr>
<tr>
<td><strong>Harrowing</strong></td>
<td>3 days</td>
</tr>
<tr>
<td><strong>Seeding</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>1st weeding (animal)</strong></td>
<td>2 days</td>
</tr>
<tr>
<td><strong>2nd weeding (manual)</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>3rd weeding (animal)</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>4th weeding (manual)</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>5th weeding (animal)</strong></td>
<td>2 days</td>
</tr>
<tr>
<td><strong>Harrowing</strong></td>
<td>5 days</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>35 days</td>
</tr>
</tbody>
</table>

1/ The small farmer did not use a subsoiler, otherwise an additional day should be calculated. The application of insecticides has been left out of the calculation since the appearance of pests differs from year to year and a difference between CA and Conventional Tillage in general has still not been quantified (see 2.7).
2.4 THE GROWING AND DEVELOPMENT PROCESS OF THE PLANT

One of the CA advantages is an improvement in the soil condition. This is achieved by a good crop rotation and the adoption of gmcc, including a diversification in the rotation of both. The effects on soil properties are:

- **biologically**: more organic matter, micro- and macrofauna;
- **physically**: water infiltration and storage, temperature stability, larger porosity, increased density; and
- **chemically**: more nutrients and less acidity.

The smallholder farmers interviewed mentioned that cotton roots grow twice as deep as under the Conventional Tillage system; they also grow straighter (see Photo 3) since they do not encounter compacted soil layers (or ploughing pans) (see Photo 4). Therefore, the whole root system is better developed, enhancing the capacity of absorbing water and nutrients, even from deeper horizons.

Due to favourable soil conditions and enhanced absorption of nutrients and water by the roots, the CA cotton plant reaches a greater height, develops more branches and leaves, and is more vigorous. The bigger leaves, on the one hand, enhance the capacity of the plant to form more chlorophyll and through this increase the photosynthetic activities. On the other hand, the bigger leaves provide more shade and through this suppress upcoming weeds. Additionally, the bolls grow bigger and open up better, which makes them easier to harvest. This was emphasized by the farmers and researchers interviewed. Another advantage is that the cotton bolls, which open on three different branch levels at different times, are more equally developed compared to the Conventional Tillage system.

Photo 4. CA cotton root in a soil, which has been under CA for 11 years (Edelira, Dept. Itapúa)

The actual growing advantage of CA cotton occurs after 60 days. This is due to many reasons; firstly, even after 60 days the decomposing cover crop steadily releases nutrients into the soil and the plant root has a stable nutrient access, which follows the Nutrient Access Concept of Soil Fertility by Roland Bunch (Bunch 2001, 15). On the contrary, under a Conventional Tillage system the organic matter of the preceding plants (crops and weeds) are incorporated into the soil, and most of the nutrients are released, through oxidation and lixiviation, within the first 60 days. Secondly, the soil temperature is more stable through the cover crop, which enhances the nutrient absorption of the cotton plant (FAO 2002c, 18). Thirdly, under good CA, the soil moisture is maintained through better water infiltration and storage, and the plant suffers less from water deficiency. In addition to this, CA cotton suffers less competition from weeds (see 2.7).

There is no special classification of CA cotton in Paraguay by the National Chamber of Cotton (CADELPA); nevertheless, the farmers pointed out that the fibre is cleaner, especially with those cultivated on clay soils. In the case of heavy rainfalls in non-CA systems, the clay soil which splashes onto the cotton bolls becomes attached to the cotton fibre. An exact description of the
change in CA cotton fibre quality, micronas, lint, linters or length of fibre could not be given by researchers or extension agents. It also depends on the cotton variety selected and the growing conditions, such as climate and rainfall. Nevertheless, through the enhanced growing conditions, an improved fibre quality can be assumed.

2.5 CROP ROTATIONS AND INTERCROPPING

2.5.1 Crop rotation

Crop rotation is not a new concept in agricultural production. Benefits include improved soil productivity, pest management and enhanced risk management with greater enterprise diversity. Crop rotation can provide a more diversified plant residue to the soil than monocropping systems, thus improving organic matter, tilth and water-holding capacity. By alternating between the different types of root systems of the various crops, more of the soil profile is used for crop production. In addition, rotating crops forms part of Integrated Pest Management (IPM) strategies, while disrupting life cycles of many insect pests and pathogens. Increasing plant diversity also may encourage biodiversity of beneficial insects, fungi and bacteria. These advantages are reached by two processes: 1st plant growth and 2nd decomposition. It is during the latter that nutrients such as N, P, and K are returned to the soil.

For the most part, the decision of which crop precedes or follows in a crop rotation depends on whether it is to be used as a cash, food or fodder crop. Nevertheless, it is important that the chosen crop complements the preceding and following gmcc and crop. In addition to this, the farmer has to pay attention to the soil conditions, as some crops might not produce well in poorer soils. Technically, there are no limits to using a gmcc, instead of a crop, for crop rotation, but this has no economic benefits on a short term basis if the gmcc seeds cannot be sold in the market. Finally, the more diversified the crop rotation is, the better and more sustainable the medium and long term results will be.

The experience of the smallholder farmers confirmed that cotton should be seeded in a crop rotation, sowing cotton every 3 years. A pause of two years between cotton in the same plot is recommendable to break the life cycles of some pests (see 2.7). Exceptionally, a 2 year rotation is practised when the smallholder depends on the income, but only if chemical fertilizer is used or the soil condition is favourable. Additionally, in a crop rotation experiment in Choré, Department San Pedro, the monocropping of cotton resulted in lower yields than with crop rotation (Florentin et al. 2001, 63). For these reasons, the crop rotation proves to be essential for CA cotton. During the research carried out for this report, no example of monocropped CA cotton has been found on small farms.

The examples from the smallholder farmers showed that the selected crop rotation depends firstly on commodity prices of crops, and secondly on its multiple purpose use (for food, cash and fodder crop). For these reasons, maize (*Zea mays L.*) is widely used for CA cotton crop rotations, in all regions of the country visited (see Photo 5).

The majority of the farmers emphasized that maize is the best crop to be sown before cotton. In most cases maize is associated with velvetbean (*Mucuna pruriens = Stizolobium cinerum*), because it provides additional nutrients and a very dense soil cover (see 2.6). The crop rotation with maize is favourable, because decomposed maize contains a high quantity of nutrients (high organic matter) for cotton plants. In particular, the stems decompose slowly, providing a mulch layer for a longer period of time (see Photo 6) and, therefore, guaranteeing a stable access of nutrients.
Other crops used by the farmers are: cassava (*Manihot esculenta* Crantz), soybean (*Glycine max* L. *Men*), cowpea (*Vigna unguiculata*), wheat (*Triticum aestivum*), sesame (*Sesamum indicum*), tobacco (*Nicotiana tabacum* L.)(see Photo 7), garden bean (*Phaseolus vulgaris* L.) or garden pea (*Pisum sativum* L.). A general recommendation cannot be given as to which of these crops provides best results, because many of them are unique cases. However, all legumes, such as soybean, are enhancing the cotton growth due to their ability of fixing nitrogen. An alternative farm practice shows that the preceding crop (cassava) can be associated with a gmcc legume (in this case dwarf mucuna *Mucuna pruriens = Stizolobium deeringianum Bort.*).

A crop that is not recommended for preceding cotton is groundnut, because it relies on the same nutrients as cotton. Due to this reason, it is seeded only in very fertile soils - with higher yield results. In spite of this, it has been observed on CA fields that peanuts sown after the cotton crop have a pest control effect (pers. com. M. Meza).

### 2.5.2 Intercropping of Conservation Agriculture cotton

The interviewed extension agents mentioned that very few experiences of CA cotton intercropping exist. In general, the problem is that an associated crop is, for example, a competitor for nutrients, water, light and space. The use of gmcc as a soil cover avoids weed appearance and provides extra nutrients, which are other reasons for not intercropping. The few existing experiences come from smallholder farmers, who were willing to experiment.

CA Cotton has been intercropped under agroforestry systems, between trees no older than three years, and with mate tea (*Ilex paraguariensis*). The latter is the only case found during the research for this report, where a farmer in Edelira, Department Itapúa, seeded CA cotton into mate tea during the 2003/04 season (see Photo 8). However, the result was not available.
for this report, because the smallholder had not yet harvested.

A second case was found in the Sorrenson report from 1998 where a smallholder farmer from Edelira, Itapúa, seeded cowpea and pumpkin into cotton: due to the fact that his soil fertility was very high, it was possible to attain a yield increase. In a third case mentioned by an extension agent, cowpea or maize was sown into cotton, but only in spots where the cotton failed to germinate (pers. com. M. Meza). This had positive effects on the suppression of weeds and pests; for instance, cowpea attracts cotton aphids, which reduces the aphid damage to cotton plants; however, an influence on cotton yield could not be proven.

2.6 GREEN MANURE COVER CROPS (GMCC)

The use of gmcc has a variety of tasks: in terms of soil cover, it protects against soil erosion and reflects sunlight, reduces evaporation, stabilizes soil temperature, suppresses weeds, breaks the life cycles of pests, and provides a habitat for beneficial insects. In addition, their decomposing residues provide nutrients for the following crop, increase soil structure (less soil compaction) and increase the level of soil organic matter (Florentin et al. 2001, 15).

Nevertheless, it is difficult to convince farmers to work with gmcc. For poor farmers, spending money and labour on a gmcc that will only offer soil improvement is a difficult concept to explain, since such improvements normally take a couple of seasons to have a visible impact on main crop yields. Therefore, gmcc also have a better chance of being adopted if they can fill an otherwise empty space in a farming system and not occupy land that could otherwise be used for a food or cash crop. As a solution to these constraints, it is recommendable that the smallholders produce gmcc seeds, in order to sell them (short term economic benefits) and to have less production costs (i.e. costs for the gmcc used in the following season).

If the smallholder farmer can be convinced, the decision of selecting the best gmcc can be a difficult one. This would depend merely on the soil conditions, the preceding and following crop, and the availability of and accessibility to gmcc seeds. In East-Paraguay gmcc are seeded in summer and winter. As winter gmcc, they are usually associated with a crop such as velvetbean or jack bean; the velvetbean is sown 70 to 90 days after the germination of the main crop (in November/December). When the gmcc is sown alone, this is carried out in October. The winter gmcc are sown directly after the harvest of the main crop (in April or May) without adding fertilizers, but its management depends on the gmcc. In general, the gmcc are crushed and bent over with a knife roller 2–3 weeks before the seeding of cotton. The knife roller stresses the gmcc plant and provides the needed soil cover. If the farmer is comfortable, has access and financial resources, he can then spray a herbicide. This should only be practised when it is necessary due to the re-growth of gmcc or the appearance of new weeds. In Paraguay Glyphosate is the most popular herbicide, which is also seen on small farms. Smallholders use 2-3 l/ha if no weeds are on the plot and 3-4 l/ha in case of weed infestation. If the smallholder farmer does not use herbicides, which is strongly desirable, he passes the knife roller several times and cleans the plot manually (by weeding). An exception to this procedure is in the case of a stronger gmcc such as pigeon pea. These are slashed with a machete prior to passing the knife roller.

The experience gained in East-Paraguay shows that there are different gmcc used with CA cotton. The most common gmcc, typically employed as a summer gmcc, is velvetbean in association with maize (see 2.5). Another very popular gmcc, typical used as a winter gmcc, is black oats (Avena strigosa), sometimes associated with white lupine (Lupinus albus L.). Other gmcc are: pigeon pea (Cajanus cajan), garden pea (Pisum sativum L. var. sativum), oil radish (Raphanus sativus var. oleiferus), different varieties of vetches (Vicia spp) or Italian ryegrass (Lolium multiflorum Lam). In unique

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11 In the eastern departments, in large scale CA, it is quiet common to fertilize the gmcc so that the following crop enhances the use of the nutrients.
12 The amount depends on the years of CA. Some farmers who practise CA only for a few years use up to 4 litres. This also depends on the experience in the use of herbicides. There are some farmers who spray only the big leaved gmcc.
13 It is not recommended to seed oil radish alone as a preceding gmcc; because it has an allelopathic effect. During its decomposition it releases substances which have a negative effect on the cotton’s root development. Oil radish combined with other winter gmcc such as black oats does not harm the cotton growth. Additionally, the roots of oil radish behave like a natural subsoiler, because they are the pivot type.
cases jackbean (Canavalia ensiformis L.DC), lablab bean (Lab lab purpureus L. Sweet), leucaena (Leucaena leucocephala (Lamk.) De Wit) or sunnhemp (Crotalaria juncea L., in dryer condition) have been used.

The most common gmcc, as mentioned, is velvetbean. Firstly, it is easy to manage, because it dies with an upcoming frost in winter without spraying an herbicide- or by slashing it with a machete and a passing a knife roller several times. Secondly, the velvetbean is able to fix up to 150 kg of nitrogen per hectare. Thirdly, it provides a very dense mulch layer (see Photo 9) at the beginning of the cotton cycle, while suppressing weeds, and producing up to 35 tonnes of organic matter per hectare (McGrath 2001).

The second most frequently used gmcc, after velvetbean, is black oats (broadcasted and worked in with a knife roller) in association with white lupine (seeded with a jab-planter). In any case, the black oats are used for the soil cover while the white lupine, which decomposes at a higher rate than black oats, is used for the fixation and provision of N. One example was found in the Department of San Pedro where white lupine is seeded only into the future cotton seeding bed, in order to enhance the access of the cotton root to N.

In poorer soils, the most popular gmcc is pigeon pea; as a legume it provides nitrogen, provides a very dense mulch layer (see Photo 10) and adds up to 14 t/ha of organic matter to soils. It is very vigorous and resists frost and drought.

Photo 10. Soil cover with pigeon pea (San Rafael, Dept. Caazapá)

In the Colonia Ñanemaiteí, Dept. of Caaguazú, two cases of weeds being used as gmcc were observed. This was practiced as a result of the farmers not having gmcc seeds, not affording to buy them, or these not being available in the market. The farmers were content with results, but stated that other gmcc result better, because they provide more nutrients. In another case, a smallholder farmer from the same region experimented by associating weeds with cassava, maize and velvetbean as gmcc and crops before seeding cotton (see Photo 11). This combination provides a very dense mulch layer, even shortly before the harvest, because the residues of maize and cassava decompose slowly.

2.7 WEEDS, PESTS AND DESEASES

The appearance of weeds and pests in CA is one of the greatest concerns. This is reflected by the fact that cotton is planted on 2.5% of the world’s agriculturally productive land, and that on this land 22.5% of all insecticides and almost 10% of all pesticides are used (Woodburn 1995). However, the loss of harvest as a result of pests and diseases oscillate between 35 and 50%. Cotton is one of the most spray-intensive crops, despite the fact that these pesticides cause health problems and environmental damages, e.g. water pollution, from the excessive and inexpert use of chemical substances. In a 1985 survey in Mexico,
Photo 11. CA cotton over a mulch of weeds, maize and velvetbean (Nanemaiteí, Dept. Caaguazú)

Photo 12. Weeding with hand-how (azada) in CA cotton (Caaguazú, Dept. Caaguazú)

cotton small farmers stated that 47% of their costs are related to pesticides (Rosenkranz, Castelló, 1993); not including the costs for their medical treatment.

2.7.1 Weeds

In the general opinion, the weed infestation in CA can only be countered with heavy use of herbicides. However, the experience obtained throughout the years shows that the appearance of weeds decreased with a good crop rotation and introduction of gmcc (Kliwer 2003, 1). This concludes that the farmers do not necessarily have to use herbicides (which are very expensive for them) for cleaning their fields. Moreover, smallholder farmers in Paraguay mainly used herbicides (Glyphosate) for killing gmcc before seeding, and not for weeding.

The experiences of the smallholdings in East-Paraguay show that the appearance of weeds in CA cotton decreased. This was confirmed by the farmer’s working days for weeding, specifically in terms of frequency and effort (see Table 2, 2.3.2). The farmers emphasized that work is easier and that they now only have to clean small spots within the fields. For the most part, they use a hand-how (azada) (see Photo 12) for small leaved weeds and pull out the big leaved weeds by hand. The explanation for the reduction of weeding days is that gmcc suppress weeds as a soil cover. In addition to that, the CA cotton plant develops bigger leaves, which provide more shade to the ground

Another important observation is that some weeds disappear such as in the case of burr grass (Cenchrus echinatus). The latter used to be a problem, especially during harvest. This made it necessary to harvest very carefully in order to not get injured with the thorns (see Photo 13). An explanation for the burr grass decrease is that the soil fertility has changed.

However, some weeds appeared in higher concentrations under CA cotton, particularly the

bigger leaved ones. Some cases are virginia dayflower (Commelina virginica), painted spurge (Euphorbia heterophylla L.) and beggar ticks (Bidens pilosa), the latter is an indictor of fertile soils. In any case, none of these weeds were considered as a severe problem.

2.7.2 Pests

As mentioned before, pesticides make up a considerable proportion of the costs of cotton farmers; insecticides particularly contribute to a larger share of these costs. The cases of pests damaging the cotton plant are diverse. Pests are, especially in the case of CA cotton, a problem if

10 Allopathic effects could not be determined.
practiced under a monocropping system, as a result of the cotton residues remaining on the ground for decomposition. Many of the pests survive in these cotton residues (e.g. bolls, branches, stems) and attack the following cotton plant (especially in the case of cotton borer). Therefore, it is recommended to have a two year break between cotton seasons on the same plot. A crop rotation is compulsory.

In Paraguay the following pests cause the most severe damage:
- Boll weevil (Anthonomus grandis);
- American bollworm (Helicoverpa armigera);
- Cotton bollworm (Helicoverpa zea);
- Pink bollworm (Pectinophora gossypiella);
- Cotton aphid (Aphis gossypii Glover); and
- Cotton borer (Eutinobothrus brasiliensis).

The appearance of pests could not be quantified. The smallholder farmers mentioned that the appearance depends on natural appearance cycles and differ from year to year. In addition, they stated that the pest problem depends on the neighbouring farmers and their infestation by pests. It is likely that the pests migrate into the CA cotton if the plot is adjacent to a conventional cotton field.

In general, smallholder farmers emphasized that they need to apply fewer insecticides (50% less), which has to be seen as an indicator of decreasing pest attack. An explanation for this is an increase of beneficial insects as a result of crop rotation and mulch systems (Altieri and Nicholls, 1999). Another reason is that, through a crop rotation, the life cycles of the pests are disrupted. Furthermore, smallholder farmers combined the pest management strategies by using bio-insecticides (for Boll weevil, Cotton aphid or American cotton bollworm), traps (e.g. Boll Weevil Attract and Control Tube – BWACT), and by rotating insecticides. Many farmers also monitored the pests and applied the insecticides only when necessary. These are the same strategies used under IPM, which has to be included in CA cotton.16

A clear advantage of CA cotton has been observed in the case of the cotton aphid, which almost disappeared. On an experiment held on two cotton plots of two adjacent smallholdings in Caaguazú (one under CA and one under Conventional Tillage), the cotton aphid infested the neighbouring CA cotton plants only after 40 days. The explanation given was that the soil cover of the preceding gmcc (velvetbean) and crop (maize) reflected the sunlight. Since the cotton aphid lives on the underside of leaves (see Photo 14), the yellow colour of the soil cover has a repellent effect.

The same effects have been observed with other gmcc of light colours (black oats and Italian ryegrass). Only after the residues changed to a darker colour and decomposed did the aphids begin to appear in CA cotton fields; but by that time no damage was reported.

16 The reason, why CA smallholdings from Paraguay used IPM strategies, is that they have good technical assistance. In one case a smallholder farmer from Yegros, Caazapá, had even participated in an FAO IPM workshop in Zimbabwe.
2.7.3 Nematodes and Diseases

Nematodes are generally a problem in the sandier soils of East-Paraguay. The only effect that can be reported is that nematodes disappear after many years of CA, mainly in plots where gmcc, such as velvetbean, canavalia and pigeon pea have been used, where no soil tillage has been practiced, and where crop rotation is implemented.

2.8 THE YIELDS OF CONSERVATION AGRICULTURE COTTON

In the preceding paragraphs numerous advantages of CA cotton are given. Next to the enhanced growing conditions, is the decreased infestation with pest and weeds (an important criterion influencing cotton yields). Nevertheless, CA cotton yield depends on diverse factors:

- Cotton variety;
- Seeding date;
- Number of years under CA;
- Soil type and fertility;
- Utilization of chemical fertilizer (NPK), urea, lime;
- Pest infestation;
- Used gmcc;
- Crop rotation; or
- Climatic conditions (rainfall, droughts, temperature).

The first reference of yield growth in CA cotton is given in the 1998 Sorrenson report on smallholder farmers' economics; two farmers from Edelira had a yield increase of 25% and 60% respectively. These farmers practised CA for 5 years. Cotton entered, like any other crop, in their farming system for the diversification of income. A second example is given by Causarano (2000) where the cotton yield increased up to 70%. Nevertheless, no scientific research was carried out on yield comparison for this report; this is due to the fact that, for an exact comparison, one year's research would not have been representative. In addition, the examples identified of CA cotton are from too many different farm types and conditions. The factors are as diverse as mentioned above and could sometimes not be reconstituted. For instance, the climatic conditions in the years concerned could not be determined for each of the different regions. Therefore, yields given here have to be seen as indicators; there is no comparison made in the crop rotation and in gmcc. Nevertheless, as an orientation, the yield/ha of cotton in Paraguay, from the years 1998 to 2003, is presented in Table 3.

The yield increase in CA cotton is on average by 20 to 30%; under very fertile soil conditions, yields can increase by 100% (sometimes including applications of chemical fertilizers). This is either compared to the country's average or to their yield before the introduction of CA. In absolute numbers, some long year CA systems can obtain cotton yields of up to 3,000 kg/ha. (pers. com. M. Meza). The experiences of all smallholder farmers visited show that they have higher yields than the country average, but that growth rates of cotton yields decrease with the years; in some years these were even less than the previous year as a result the reasons mentioned above (climate, delayed seeding, early seeding, low quality cotton variety, etc.), which are just as complex and diverse as the farmers themselves and their smallholdings visited during this study.

A good example of increasing yields comes from the smallholder farmer Mr. Diomedes Rojas (Dept. Caaguazú). It indicates that he continuously improved his CA cotton yield. During the first period of 1997/98, he harvested 1,800 kg/ha, during the second period 1999/2000 his yield reached 2,200 kg/ha, and in the third period 2002/2003 he harvested 2,700 kg. In comparison, his neighbours under conventional cotton systems harvested the countries average for each year (see Table 3).

Table 3. Cotton area and yield/ha in Paraguay from 1998 to 2003

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton area in ha</td>
<td>202,000</td>
<td>166,000</td>
<td>185,000</td>
<td>297,865</td>
<td>169,671</td>
<td>170,000</td>
</tr>
<tr>
<td>Cotton yield in kg/ha</td>
<td>1,100</td>
<td>1,217</td>
<td>1,266</td>
<td>989</td>
<td>903</td>
<td>1,086</td>
</tr>
</tbody>
</table>

Source: Banco Central de Paraguay (2003a), 79
3 HOW TO BEGIN WITH CONSERVATION AGRICULTURE COTTON ON A SMALLHOLDER FARMER LEVEL - THE RECOMMENDED START IN PARAGUAY

3.1 INTRODUCTION

The start of CA cotton has two parts, a technical process and the necessary framework. Therefore, a possible strategy for both parts shall briefly be given in this chapter. It is to be understood as a guideline, since no two fields, farms and farmers are the same. This is not to be understood as a “path to follow step-by-step” or blueprint, but must be adjusted and adapted to the local conditions.

3.2 CHANGING A FARMING SYSTEM – WHAT IT TAKES TO IMPLEMENT CONSERVATION AGRICULTURE

Before starting the actual technical introduction of CA cotton, the necessary framework has to be determined. This could begin with the elaboration of a plan for the introduction and for the transition phase. A key role in this is the selection and training/capacity building of extension agents, who later identify, contact, assist and guide (as facilitators) the smallholders during the first years of CA. Their work will be essential until the smallholder farmers gain confidence and feel comfortable with upcoming problems. The extension agents need to “speak” the local language, not only in the sense of the language itself, but also in a sense of regional and social characteristics. The training of the extension agents should include an item on the adequate use of pesticides; an IPM course should be included at this stage. The focus for the future work is to educate the smallholder farmers in terms of which situations chemicals are suitable and that they should be used only if necessary and after all other options have been exhausted.

Afterwards, a selection of the (pilot) region and the participating (pilot) smallholder farmers must be carried out. Usually, there are farmers who are sensitive to their problems and are willing to change their cultivation system, perhaps already seeking solutions. These “volunteer farmers” are usually the “easiest” farmers to work with. During the selection of the farmers, social leaders have to be contacted and, where possible, ideally included in the process. The social leaders work also as local multipliers and through this, social constraints can be identified and worked upon. The local extension service needs to select the smallholder farmers and form a group of farmers, e.g. in order to decrease the costs for suitable machinery at the beginning of the process and to encounter social barriers, which has to be expected with this radical change of the farming system, and must be overcome by a change in the mentality of the farmers. In any case, these farmers are the examples to work with in the future. One must keep in mind that the experience in Paraguay has shown that the adoption of CA, as well as any other technologies introduced into the household framework, is made easier when the wife is convinced of the advantages of CA.

Once the decision on the participating farmers has been made, there are other limitations to deal with. The most common is the cost of CA equipment. However, this has not been a great obstacle to innovative farmers. They have met the challenge by modifying their existing equipment, reducing the cost to a minimum. On the other hand, costs can be covered by international cooperation projects or by financing through micro-credits.

The next decision to be made is the access to gmcc. At this time, a future market for gmcc seeds should also be identified or developed (since it increases the attraction of gmcc for having short term economical benefits), keeping in mind that the farmer should always produce his/her own gmcc seeds. The absence of a gmcc market is a mayor setback in many regions and a hurdle in the diffusion of CA! Another focus early on in the process should be the diversification of production (e.g. agroforestry). This is, of course, a market driven decision. Nevertheless, this is a key point in terms of the sustainability of the process, due to diversification risk reduction being achieved.

While working on these issues, the national/local agriculture research institutions should be included in the process. The orientation towards

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17 In Paraguay it is now common to form Comities of 10 to 20 farmers.
18 A whole set of CA machines in Paraguay costs approximately US$ 3,500 for group of 10-12 farmes.
19 For examples see Florentin et al. 2001, FAO 2002a or Lange and Meza 2004.
Conservation Agriculture Cotton for Smallholder Farmers. Experiences from Paraguay

Farmer demands and solutions to their problems often requires a restructuring of these institutions, but has been proved to have a vital role in the process\(^\text{20}\).

As a constraint, there are always smallholder farmers who are not sensitive to their main problems, are not willing to change their farming systems, do not know how to change technically, or are simply afraid of changes and therefore resist these. This last point is certainly a key-point in agricultural extension and at the same time it proved to be another vital criterion for the slow spreading of CA amongst smallholders. Normally, the effort of reaching and convincing these farmers is time and energy consuming. Nevertheless, these farmers should be included and introduced slowly to CA through existing extension approaches. It is recommended to use the examples of the pilot farmers or pilot farmer groups to interest the “hesitators”. Therefore, the pilot farmer group should always try and include the local social leaders, who are recognized in the local hierarchies. Another possibility is to use the experience from international organizations from other countries and international projects on how to work with “hesitators”; however, these experiences must be adapted to local conditions in order to have a greater impact.

The establishment of demonstration fields on the pilot farms is key to the development of good practices\(^\text{21}\). These “doubting farmers” could then be invited for visits (e.g. farm days), or receive training offered by other farmers (approaches include e.g. Train and Visit, Farmer to Farmer)\(^\text{22}\), which could initiate the introduction to CA.

A Participative Extension Approach (PEA) can be an entrance point to reach (resisting) farmers. Whatever approach is chosen, the most critical points are trust and reliability to the implementing persons, which can be achieved by speaking the “local language” and by creating ownership within the farmers’ community.

3.3 THE TRANSITION TO CONSERVATION AGRICULTURE COTTON

For starting CA cotton, the soil needs to have at least medium fertility. The decision of whether the soil fertility is sufficient can only be determined through a soil analysis. In many poorer countries, like Paraguay, a soil analysis encounters financial and infrastructural problems. It is therefore recommended, firstly, to use only the land were the last cotton yield reached at least 1,500 kg/ha and/or, secondly, use bio-indicators, such as the presence of certain weeds (in Paraguay beggar ticks are used) for the determination of the soil fertility.

It is not recommended to seed cotton in poor soils, because the cotton plant requires high quantities of nutrients and, therefore, its cultivation would not be profitable (due to low yields). However, after the implementation of a soil recovery plan of at least 3 years, using Conservation Agriculture, with gmcc (pigeon pea followed by velvetbean, associated with maize in the case of Paraguay), crop rotation and chemical fertilizer, cotton can be seeded again with responding yields; this has been experienced in the Department of Paraguari, East-Paraguay (Florentin et al. 2001, 59).

If these obstacles are met, two recommendations proposed by the PNMCRS of the MAG exist for the implementation of CA cotton in Paraguay; one for winter and one for summer.

Summer\(^\text{23}\):

1\(^{st}\) year
- start with the seeding of maize in September/October
- 90 days after the germination of maize, the seeding of velvetbean occurs - if necessary a manual weeding beforehand
- harvest of maize approx. 40 days after the seeding of velvetbean
- let the velvetbean grow over the maize towards its cycle end

\(^{20}\) In Paraguay, the results of the DIA on the Campo Experimental Choré (San Pedro) were included in the daily work of the extension service.

\(^{21}\) At the same time, this prevents the “expert–example-effect”, which means that the new technique only works on experts/ researcher fields.

\(^{22}\) The farmers or local leaders could receive a Training for Transformation (TFT) course.

\(^{23}\) Keeping in mind that this cycle has to be adjusted to the local conditions, e.g. availability of gmcc seeds, and suited to the farmer’s capabilities.
• harvest seeds of velvetbean (for next plot, season or for sale)

• if frost occurs (aprox. July) velvetbean dies naturally

• if no frost occurs, pass knife roller over the residues of maize and velvetbean or spray herbicide at the end of its life cycle

• if regrowth occurs, slash (with machete) the velvetbean

• preparing of cotton seedbed with subsoiler or chisel

2nd year

• seeding of cotton (with jab-planter) after a first rainfall in September/October

• management of cotton as usual

• harvest of cotton followed by the broadcast of black oat before or after a rainfall

• manual weeding or passing of a harrower (animal traction) in order to improve contact between black oat and the soil

• pull out cotton plants to avoid re-growth of the crop

• seeding of white lupine (with jab-planter) immediately afterwards

• passing of knife roller in September

• herbicide application or passing of knife roller again (if gmcc stand up again or if new weeds appear)

• seeding of cassava associated with a legume (e.g. jack bean, dwarf mucuna)

• management of cassava and gmcc as usual (not forgetting the harvest of gmcc seeds)

3rd year

• repeat cycle

Winter 2nd:

1st year

• seeding of Italian ryegrass or black oat (or a combination of these two) in April/May

• manual weeding or passing of a harrower (animal traction) in order to improve contact between gmcc and the soil

• harvest seeds of gmcc before passing knife roller

• spray herbicides or pass knife roller again (aprox. 30 days before seeding of cotton)

• preparing of cotton seedbed with subsoiler or chisel

• seeding of cotton in September/October after first rainfall

• management of cotton as usual

• harvest the cotton

2nd year

• broadcast of black oat and oil radish seeds

• manual weeding or passing of a harrower (animal traction) in order to improve contact between black oat and the soil

• pass knife roller to crush and bend over cotton residues and to work-in the seeds of black oat and oil radish into the soil

• pull out the plants to avoid regrowth

• seeding of white lupine (with jab-planter) immediately afterwards

• in September pass knife roller (not forgetting to harvest gmcc seeds)

• spray herbicide or pass knife roller again (if plants stand up again or if new weeds appear)

• seeding of maize

26 Keeping in mind that this cycle has to be adjusted to the local conditions, e.g. availability of gmcc seeds, and suited to the farmer’s capabilities.
• seeding of jackbean 30 days after germination of maize
• management and harvest of maize as usual

3rd year
• management of jackbean as usual
• in September harvest seeds of jack bean
• management with machete or only knife roller, 10 to 15 days before seeding of cassava
• seeding of cassava associated with garden bean or cowpea
• management of cassava and gmcc as usual (not forgetting the harvest of gmcc seeds)

4th year
• repeat cycle
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APPENDICES

Questionnaire: Conservation Agriculture
Cotton for smallholder farmers - 2003

Which cotton variety was used?

Technical
1. Seeding distance between plants and rows?
2. How may plants per square meter? Difference to CC?
3. During what time of the year do you fertilize?
4. How much fertilizer did you apply per ha?
5. What was the yield (kg/ha) under CA and CC, respectively?
6. Did the cotton bolls open better than under CC?
7. Was the fibre cleaner, longer, bigger?
8. How did the plant change? Was it taller, did it present more leaves, more branches, more fruit, deeper roots?

Comparison of the growing and production processes on a hectare
1. How was the production process under CC?
2. How is the production process under CA?

Crop rotation
1. Which crops are used for the rotation (before and after)?
2. Which work best?
3. Which do not work?
4. Which crops are used for intercropping?

GMCC for cotton
1. Which gmcc are used on the farm?
2. Which ones work better?
3. Which ones do not work?
4. During what time of the year are the gmcc seeded?
5. How and when is the management of the gmcc carried out?
6. Which gmcc is used in association with cotton?

Weeds, diseases, and pests
1. Which weeds are the most frequent occurring and how are they controlled? Compared to CC?
2. What products are used for weed management?
3. What volume of these products is applied per ha? Compared to CC?
4. During what time of the year are they applied?
5. Which are the most frequently occurring pests? Compared to CC?
6. What products are used for pest control?
7. What volumes are used per ha?
8. Were these vectors for diseases and if so, how were they managed?
9. What products are used for disease control?
10. Which volumes are used per ha?
11. Did any of the pests present any form of resistance to chemicals?
12. Were fewer chemicals used than before?
13. Do you know other methods of pest control?
14. Which ones?
15. Any chemical rest and what are the problems caused by them?
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