Direct sowing through a cover of crop residues, avoiding ploughing and minimising soil disturbance: soybean grown under CA in Brazil. Photo: Sally Bunning

Planting concepts and harvesting good results

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In large parts of Latin America, Asia, Eurasia and Africa soil tillage by plough or hoe is the main cause of land degradation leading to stagnating or even declining production levels and increasing production costs. It causes the soil to become more dense and compacted, the organic matter content to be reduced and water runoff and soil erosion to increase. It also leads to droughts becoming more severe and the soil becoming less fertile and less responsive to fertiliser.

In the early seventies, farmers in Paraná, Southern Brazil, recognised that continuing soil erosion and declining crop yields were forcing them to abandon their land and move into a marginal existence. Their first attempt at changing this trend was to rigorously adopt conventional terracing systems. The mixed and often disappointing results led them to tackle the problem of erosion at its source, considering the direct impact of rainfall on the bare soil. They abandoned the plough, broke their compacted soils, introduced cover crops, stopped the burning of crop residues and developed cutting rollers to turn crop residues and cover crops into mulch. This mulch layer eliminated rainfall impact on the soil, reduced the speed and quantity of runoff and virtually eliminated soil erosion. It also significantly increased soil fertility and yields, and reduced the labour and cost of land preparation (Hercilio de Freitas 2000, see also ILEIA Newsletter Vol.11, No.3, pp.16-17).

This was in the early nineties, at the beginning of the Zero-Tillage (ZT) movement in Latin America. At that time '*conservation*'-, '*reduced*'-, '*no*'- or '*zero*'-tillage or '*direct planting'* in combination with herbicides was already being practised by commercial farmers, mainly in the USA. But it was only after ZT was combined with cover crops and crop rotation, adapted to tropical conditions, and improved herbicides and special equipment were developed, also for small farmers, that the tremendous benefits of this approach were widely appreciated and it spread faster.

At present, ZT is being practised on about 60 million ha, mostly in Latin and North America. In Latin America, particularly in Brazil, Argentina and Paraguay, some 25 million hectares have been converted to ZT in the past ten years. As the approach has become far more comprehensive than simply ZT, it is now being referred to as Conservation Agriculture (CA) by FAO and other organisations (see also LEISA Magazine Vol.17, No.3, p.22).

In Latin America, farmers, their organisations and networks took the lead in the development of CA. Government support was initially limited as ZT was not an officially recognised technology and researchers, extension agents, trainers and policy makers were reluctant to accept new ideas. Now, all this has changed and CA is developing fast due to effective collaboration between farmers, private enterprise, research and extension. CA has long passed the stage that it was only suitable for grain crops, like maize, beans and soy. Now, crops like sugarcane, cassava, tobacco, onion, tomato, cabbage and lettuce are all successfully grown under CA.

CA also fits into an increasing number of cropping conditions of large and small farmers in the humid and dry tropical, semi-tropical and temperate climate zones in Latin America, Africa, Eurasia and Asia. The FAO is playing an important facilitating role in promoting and further developing CA, among others, by its field projects, by actively supporting regional CA networks and by providing information on CA through its publications and web site. This article provides an overview of principles, practices, potentials, constraints and methodologies. The articles on p. 10 and 11 present two FAO-supported cases of CA in Honduras and El Salvador. The article on p. 13 discusses the perspectives of CA in Africa. Previous issues of LEISA Magazine have presented approaches similar to CA: New Kekulam zero tillage rice farming in Sri Lanka (Vol.13,No.3,pp.20-21); traditional mulch farming in Burkina Faso (Vol.15, No.2&3, p 37), traditional shifting cultivation and analog agroforestry (Vol.16, No.3); the Rice Wheat Consortium approach to CA in India and Pakistan(Vol.16, No.4, pp.8-10). Other cases can be found in (García-Torres, Benites and Martínez-Vilela 2001).

General principles of CA

Three technical principles are crucial in CA:

- ***No mechanical soil disturbance*** *– direct seeding or planting*
- ***Permanent soil cover*** *– particularly with the use of crop residues and cover crops*
- ***Judicious choice of crop rotations*** *– multiple cropping, agroforestry and animal integration*

The permanent soil cover provided by growing crops, crop residues or mulch not only protects the soil from the physical impact of rain and wind, but also stabilises the soil moisture and temperature in the surface layers. This zone thus becomes a favourable habitat for a number of organisms, including plant roots, worms, insects and microorganisms such as fungi and bacteria. This soil life uses the organic matter from the soil cover, recycling it into humus and nutrients, and contributes to the physical stabilisation of the soil structure, allowing air and water infiltration and storage. This process, which can be called "biological tillage", strongly enhances soil and water conservation and soil fertility. Mechanical tillage is avoided in order to maintain soil life and soil structure, and to reduce mineralisation of soil organic matter. A varied crop rotation is important to avoid pest and disease problems, improve soil conditions and make full use of the entire soil profile and the synergetic and complementary interactions between different plant species. Green manure/ cover crop species (leguminous and non-leguminous) that are part of the crop rotation are essential in building up the soil organic matter content. The soil cover also provides new habitats for natural enemies of pest and disease organisms. It provides a physical barrier to weeds and releases allelopathic substances that reduce weed germination. Thus a healthy soil which offers optimal physical, chemical and biological conditions for the growth and reproduction of plants is created.

Box 1. Key features of CA systems

- No ploughing, disking or seed bed preparation
- Green manure / cover crops are integrated into the cropping system
- Crop, weed and cover crop residues applied as mulch protect the soil permanently
- Direct seeding or planting
- No burning of crop residues or fallow vegetation
- No uncontrolled grazing
- Nutrient cycling through the biomass in and above the soil
- Surface application of lime and fertilisers
- Specialised equipment for seeding and mulch management
- Continuous use of cropland
- Crop rotations and cover crops are used to maximise biological controls

Specific practices

Many traditional shifting cultivation systems follow the above principles of slash and mulch. Uncontrolled burning (slash and burn) and grazing, however, works against these principles. There are no blueprints for the development of new CA systems and the general principles and key features (see box 1) have to be adapted to each specific agro-ecological, socio-economic and cultural context. The success of such a new system depends entirely on the creativity and flexibility of its practitioners in developing management practices suited to their particular situation and needs. Traditional practices and species, which are adapted to the local context, but abandoned due to reasons of low productivity, are often re-introduced with good results. Agrochemicals are not excluded, but low or decreasing quantities are used efficiently. CA often includes Integrated Soil Fertility Management (ISFM), Integrated Pest Management (IPM), Integrated Weed Management (IWM), agroforestry and crop/livestock integration, for which the three principles provide an excellent basis. The integration of trees and livestock into the system is especially important. CA can come close to or be completely organic.

Benefits are many

Permanent vegetative soil cover ***strongly prevents soil erosion*** and reduces the need for other soil and water conservation measures, bunding, terracing, etc. The increased soil organic matter content allows more water and nutrients to be stored in the soil profile, so ***more soil moisture and nutrients are available for plant growth***. The excess water filtrates to deeper soil layers, ***recharging groundwater supplies*** and reducing floods and sedimentation of waterways downstream. The water conserving effect of the soil cover and the increased organic matter result in an ***economisation of irrigation water***, as is shown in table 1.

With time, the accumulation of soil organic matter and the increased activity of soil micro-organisms lead to ***higher efficiency of organic and inorganic fertilisers*** and thus allow lower application rates. This saves costs and increases the profitability of in-organic fertilisers, thereby making them affordable to more farmers.

Increased soil moisture and soil fertility favours root penetration and development, which in turn ***boosts biomass production and crop yields***. CA is a successful strategy for ***ecological intensification,*** among others ***of shifting cultivation and slash and burn systems,*** which can evolve into permanent agroforestry systems, while burning is abandoned.

CA allows ***early and timely planting*** due to the absence of tiresome land preparation activities. The effects of the soil cover result in an agricultural system that is ***less vulnerable to drought, heavy rainfalls or other natural disasters.***

Also ***the risk, scale and frequency of weed, pest and disease infestation are reduced considerably***. Where chemical pesticides or herbicides are applied in CA, the amount needed often decreases with time as farmers gain skills and new ecological balances are established. Compared to conventional tillage, ***the use of chemical pesticides and herbicides is less*** in CA.

The improved workability of the soil and less agronomic activities during the production cycle ***reduce the labour requirement substantially*** (see table 4, p.12). This is especially important for those who rely only on family labour and in areas where labour is becoming a constraint because of deaths and diseases. The reduction in the on-farm labour requirement allows ***farmers*** to ***diversify their activities***, including processing of agricultural products, and thus improve their incomes. Besides the reduction in

Table 1. Economy of irrigation water through soil cover (Pereira, 2001).

Percentage of soil cover	0	50	75	100
Water requirement ($m^3\ ha^{-1}$)	2660	2470	2090	1900
Reduction in water requirement (%)	0	7	21	29
Number of times irrigated during season	14	13	11	10
Number of days in between irrigation	6	6	8	9

Table 2. Increase in yield and farm income (in monetary units; CA=Conservation Agriculture)

	Conventional Agriculture	CA Year 1	CA Years 2-4	CA Years 4-6	Year 6 and onwards
Gross output	2000	1800	2200	2300	2400
Total variable costs	1400	1300	1200	1100	1000
Gross Margin	600	500	1000	1200	1400
Total fixed costs	200	200	200	200	200
Net farm income	**400**	**300**	**800**	**1000**	**1200**

(FAO, in print. Conservation Agriculture. What you should know about... economic aspects of Conservation Agriculture. Training module. AGLL. FAO Rome.)

labour, the ***cost for land operations and maintenance of tools and equipment are also reduced***. Even where mechanical traction is used, CA leads to ***considerable savings in the use of fossil energy***. As CA also strongly contributes to carbon sequestration due to the increase of biomass in and on the soil, it could when applied at large scale, provide ***a major contribution in controlling global warming.***

All this contributes to ***increased and more stable yields and revenues*** (***up to double or even triple)*** which build up during a period of 2-6 years. Diversification of agricultural production also plays a role in ***improving the farmer's livelihood: less risks, increased income, improved diet, etc.***

CA provides a truly sustainable production system, not only conserving but also enhancing the natural resource base and ***increasing biodiversity*** without sacrificing yields at high production levels. Therefore CA is a major opportunity that can be exploited for achieving many objectives of the international conventions on combatting desertification, on biodiversity and on climate change.

Constraints and challenges

Conversion from conventional tillage to CA is not simple and poses many constraints that need to be resolved, demanding time, effort and money. It may include costs for purchasing specialised equipment and agrochemicals, possible temporary income decreases until the new dynamics are established, and a learning process by the farmer to acquire higher management skills. For many (small) farmers, a general lack of financial resources and lack of access to equipment, chemical inputs or green manure seeds can be serious limiting factors.

Tenure may also be a constraint in situations where most of the land is collectively managed and where land is accessible to multiple users often having contradictory interests in terms of land use, for example pastoralists and farmers. Farmers who have insecure tenure may be reluctant to adopt CA even though they see the benefits, because improving the soil productivity increases the risk of losing the land to more powerful persons in the society. This is a major problem for landless persons and female heads of households.

Pest, disease, weed or soil fertility problems could occur in the transition stage when the system has not yet stabilised ecologically. This may require the use of chemical pesticides, herbicides or fertilisers for which money could be a constraint. In moist areas for example, a major issue raised by the permanent soil cover could be pest and disease management. The crop cover may harbour small animals such as rats or snakes. In drier areas, the lack of biomass due to water or nutrient shortages and other uses of the biomass (livestock feeding, cooking) is often a major issue. Where population density is low and agriculture is marginal, availability and the cost of equipment and agrochemicals is a constraint. Social and cultural acceptability may also be a problem where CA differs substantially from the indigenous or conventional system.

Before starting with CA, it may be necessary to eliminate some major effects of degradation, such as compacted soil layers, plant nutrient deficiencies or heavy weed infestation. Subsoiling of compacted and degraded soils can, due to higher water infiltration, result in immediate yield increases of up to 30%, but may be too costly for small farmers.

Conversion from conventional tillage to CA calls for a drastic change of thinking. CA is based on agro-ecological processes and systems which require farmers to think in terms of ecological concepts such as soil as a living system, plant communities, nutrient flows, pest – predator and animal – crop – soil relations, etc. If farmers are unable to radically change their thinking and vision on farming, they will not succeed in making CA work effectively. This is not only true for farmers but also for technicians, extensionists and scientists.

Farmers who depend on their local resources may have a lot of traditional / indigenous knowledge that fits with CA. Often, extensionists and researchers find it difficult to accept indigenous knowledge and learn from and with farmers. For them, shifting to the concept of CA and a participatory way of working means a tremendous change. The resistance to change of researchers, academics and advisors can be much greater than that of farmers.

Box 2. "Friends of the Land" clubs in Brazil

In Brazil, the main obstacles for farmers in the adoption of Zero Tillage were the lack of knowledge, information and technical support. These obstacles were overcome through the activities of "Clubes Amigos da Terra" (CATs), non-profit, non-commercial and non-political farmer organisations. The operational basis of the CATs is farmer-to-farmer exchanges of experiences on a monthly basis and organisation of promotional events, such as field days and debates. CATs also organise on-farm research and pilot projects with the support of other organisations. An important factor for success has been the assistance which medium and large farmers, through individual CATs and the Brazilian Federation for Direct Planting, have provided to small farmers wishing to adopt ZT. Private sector support was fundamental to the expansion of ZT as well. In South Brazil, where ZT by small farmers is well developed, there are more than ten manufacturers specialising in ZT machinery for small farmers. Both in South Brazil and Paraguay, ZT systems that eliminate the need for herbicides have been developed, especially for small farmers.

Recently, the Landcare movement in South Africa adopted an approach similar to CAT in Brazil, advocating the establishment of local Landcare Groups which would conduct situation analysis, broaden their strategic understanding with a visioning process of CA, and then undertake participatory land use planning.

Farmer groups crucial for CA

Access to information, cover crop seeds, equipment, training and technical support is a prerequisite for successful conversion to CA. In addition, financial support, especially for small farmers, is often a major requirement to catalyse the conversion process. But, one of the lessons learned from Brazil is that new technologies spread fast only when farmers feel the need to change their practices and when they take the lead in technology adaptation and innovation. Simple extension of the message, even coupled with demonstration, usually will not suffice. Also, successful improvement of land husbandry depends not just on the motivations, skills and knowledge of individual farmers. The formation of farmer groups and associations or, even better, building on existing and active groups for testing and adaptation to local contexts and learning from shared experiences is crucial for CA to take off. In Brazil such groups have become action groups, transmitting the new ideas and technologies from farmer to farmer, stimulating and supporting members to make the change (see Box 2). In addition they have also become important local pressure groups, managing to obtain improvements at institutional and political level.

Strategies for conversion to CA

Specific conversion strategies are needed to make conversion to CA attractive and affordable to farmers. In Latin America, building up soil organic matter content in the soil with intercropped green manure / cover crops (associated with the normal cash or subsistence crops) over a period

Box 3. Principal mechanisms for mass conversion to CA

- farmer-to-farmer exchange
- extension activities
- commercial and NGO-sponsored events
- small farmer pilot projects
- technical assistance/promotion activities of private sector
- private and co-operative technical assistance
- NGO/government/private-sector publications
- press and television reports
- small financial inducements

of one to three years before moving to ZT is the strategy followed by most farmers. In this way the conversion takes place without loss in productivity, while costs (for tillage and equipment) already drop considerably (Rolando Bunch, Fallow Net email discussion on CA).

Farmers may have their own specific reasons for wanting to change their farming practices. These reasons can vary from community to community and from one social group to another within a community. This calls organisations working with farmers to offer specific entry points. Saving labour, increasing yield, reducing costs, drought proofing, improving health or the livelihood system in general can be appropriate entry points to start CA. It must be the farmers themselves who decide on trying out or transferring to CA and which entry point is most important for them. They should also decide on the use of external inputs: choosing between herbicides and mechanical weeding, and using fertilisers and lime to correct initial soil imbalances. Good information on potential benefits, opportunities and constraints is a prerequisite for farmers in making their choice.

Finding the right approach of facilitating a farmer-driven participatory conversion and technology development process while ensuring the communication of a very straight-forward technical message is challenging. It requires the support of convinced and capable extension workers and researchers. Often, low-cost or ecological options can be found for adaptation to the local context and resolving conversion problems, for example weed control with hand tools, cover crops and crop rotations; use of manure and biological nitrogen fixation; home-made "soups" for disease control; compost starters etc. (Barber 1999). Sometimes new innovations are needed.

CA started in many countries as a farmer-driven adaptation of a production system. But researchers and extension workers from both public and private sectors have played an important facilitating role in reaching a critical mass of farmers and generating knowledge and adaptations to the system as a whole or to equipment in particular. In addition the process has drawn sectors together and allowed the development of coherent integrated strategies and approaches (see Box 3) addressing crops, livestock, land and water resources, as well as infrastructure, marketing, education etc.

Involving the private sector

The large-scale shift to CA in Brazil and Argentina was possible among others due to close collaboration between innovative farmers and the private sector to develop and disseminate appropriate equipment. CA is challenging the existing private sector companies and local craftsmen/artisans to support the transition to CA systems. In particular, the testing, manufacturing and provision through local markets of required tools and implements. The same applies for cover crop seeds and associated herbicides plus spraying equipment, in case chemical weed management is chosen (see Box 4).

Exchange and networking

Access to information is very important in reaching a critical mass of CA practitioners, both within a country and between countries and organisations. Part of the information can be made available in the form of selected case study material describing CA experiences under different conditions. Researchers can gather in-country information on, for instance, validation of different cover crop species and testing and adapting of hand and animal drawn equipment.

The transfer of the concepts, principles and technologies of CA needs network interchange within and between countries, so as to facilitate sharing of known solutions to problems identified during the continual learning process. Such networks can accelerate the advancement of knowledge and techniques being steadily accumulated by both national institutions and community groups in their efforts to reverse land degradation on a global scale. For this purpose several regional networks -RELACO, ACT, SACAN and ECAN- have been founded in Latin America, Africa, South Asia and Central Asia (see Websites p.30) respectively.

Policy support

CA will only spread rapidly and widely when and where government policies, services and infrastructure facilitate the conversion to these systems. Policy support is needed to adjust legislation and to provide an enabling environment to meet the requirements and facilitate the initiatives of local groups and land users. This means an appropriate policy and institutional framework and the provision of incentives (pricing, markets, land reform, security, etc.). Existing incentives and subsidies should not jeopardise the implementation of the system. New incentive measures may be needed to encourage CA uptake, including the identification and multiplication of seeds and supply of equipment through public and private sector involvement. Financial support alone cannot boost a CA programme. It is essential to make the general public, decision and opinion makers aware of the social benefits of the adoption of these practices in order to gain the government's support for natural resource management initiatives of farmers.

Finally, international organisations such as World Bank and FAO, and OECD countries in their own right, should encourage a vigorous international and regional media campaign emphasising the importance and relevance of CA as an entry point to the process of rural poverty alleviation, food security, and environmental protection. Development of CA can only be achieved by integrated action at farm, community, national and international levels.

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Box 4. Development of equipment for CA in small farms

Even in 1990, there were few small farmers working with CA in Brazil. Although the general principles were broadly applicable, the planting technology for manual and animal traction had not been developed. It was pioneer research and small manufacturing firms, which resolved the problems of adapting the planting technology in direct collaboration with farmers. Equipment for direct seeding in mulch (e.g. jab planter or animal driven direct seeders), management of vegetative cover (e.g. knife rollers and slashers), spraying of herbicides (e.g. adapted knapsack sprayer) and mini-tractors were thus developed for small farmers (see illustrations on cover, p.3,13,14). Collective purchase and use of such equipment was stimulated, as CA allows for greater flexibility in the time of sowing.