ETAG European Technology Assessment Group
ITAS · DBT · viWTA · POST · Rathenau

Annex 2

Case study
Conservation Agriculture

Final Report
Agricultural Technologies for
Developing Countries

STOA Project "Agricultural Technologies for Developing Countries"

April 2009

European Technology Assessment Group
- Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe
- Danish Board of Technology (DBT), Copenhagen
- Flemish Institute for Science and Technology Assessment (viWTA), Brussels
- Parliamentary Office of Science and Technology (POST), London
- Rathenau Institute, The Hague

STOA Project "Agricultural Technologies for Developing Countries"

CONSERVATION AGRICULTURE (CA)

December 2008

Paper prepared by

Theodor Friedrich
Amir Kassam
Francis Shaxson

Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Rome
Italy

Content

EXECUTIVE SUMMARY

CHARACTERISTICS OF CONSERVATION AGRICULTURE (CA)

The objective of this paper is to provide an overview of the characteristics of CA, its development, current relevance and global distribution, the restricting framing conditions, its potential for improvements in productivity and sustainability, its relevance to small scale farmers, the favourable settings for the promotion of CA in the developing regions, and areas of action for the future.

Definition of CA

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.

CA is characterized by three principles which are linked to each other in a mutually reinforcing manner, namely:

1. Continuous no- or minimal mechanical soil disturbance (i.e., direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil);
2. Permanent organic-matter soil cover, especially by crop residues and cover crops; and
3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops, including legumes.

Translation of CA Principles into Technologies and Farmer Practices

CA systems utilize soils for the production of crops with the aim of reducing to a minimum the excessive mixing of the soil that is characteristic of tillage-based farming, and maintaining crop residues on the soil surface to minimize damage to the environment, and deploy diverse crop rotations and associations for enhancing soil and crop health, for producing more biomass of higher quality, for integrated insect pest, disease and weed control, for improved nutrient uptake, and for biological soil tillage.

As a consequence, CA:

- Provides and maintain an optimum environment of the root-zone to maximum possible depth.
- Ensures that water enters the soil so that (a) plants never, or for the shortest time possible, suffer water stress that will limit the expression of their potential growth; and so that (b) residual water passes down to groundwater and stream flow, not over the surface as runoff.

- Favours beneficial biological activity in the soil in order to (a) maintain and rebuild soil architecture; (b) compete with potential *in situ* soil pathogens; (c) contribute to soil organic matter and various grades of humus; (d) contribute to capture, retention, chelation and slow release of plant nutrients.
- Avoids physical or chemical damage to roots that disrupts their effective functioning or limits their maximum potential for nutrient uptake.

In tropical and subtropical areas, the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid. The type and number of land preparation operations determine the quantity of residues left on the soil surface.

It is therefore important to choose land preparation practices that protect the natural resources base and at the same time improve productivity and reduce production costs. Zero till or no-till practices are those activities in which the seeds are placed into the soil with the least soil disturbance possible. That means planting and sowing into the residues of previous crops and weeds.

CA can be practiced in all size of farms and ecologies. Machinery, tools and equipment have been developed to cater for three levels of power usage: manual power; animal traction; and motorized equipment. The success of CA depends on the effective management of operations dealing with: (a) land preparation, (b) cover crops and weeds; (c) direct seeding (d) and harvest and residues.

Involved Knowledge: Integrating CA Principles into Production Practices

At the production level, CA cannot be reduced to a simple standard technology package because of the diversity and variability in agro-ecological and socio-economic conditions that are associated with farming in general and with less favourable areas and smallholders in particular. Thus, the interactions between the possible recommended technological components and the location-specific conditions of farming must be taken into account adequately. Consequently, the standardised “best bet” production technologies approach tend to be of limited relevance and value for many farmers because CA practices tend to be knowledge intensive and farmers themselves must become involved in fine-tuning the transformation and application of the principles into site specific and farm-specific practices.

International Cooperation

International cooperation has become stronger in the recent years as illustrated by the biennial process of the World Congress on CA, as well as increasing numbers of regional workshops. An international multi-stakeholder meeting organized by the UK Tropical Agriculture Association (TAA) and hosted by Newcastle University in March 2007 was followed by a larger meeting hosted by FAO with technical support from TAA. The outcome of the latter meeting has been the emergence of the concept of ‘Community of Practice’ (CoP) within development communities to formalize and strengthen the connections among like-minded persons who work in a variety of circumstances and seek collectively to improve both knowledge and practice of CA.

Potential Advantages from CA

Potential for CA systems in the 21st century agriculture development is based on the large amount of field based evidence from all continents regarding the role of CA systems in raining productivity and income, improving livelihoods and reducing production costs, increasing resilience of production, contributing climate change adaptation and mitigation, and enhancing water resources, and protecting ecosystem services and environment.

In the case of CA the benefits can be grouped as:

- Economic benefits that improve production efficiency.
- Agronomic benefits that improve soil productivity.
- Environmental and social benefits that protect the soil and make agriculture more sustainable.

CA as farming concept and a set of practices has a wide range of compatibility and complementarity with other resource conserving approaches and technologies, and applicability in rainfed and irrigated farming systems, including ‘organic’ farming. It is suitable for different crop types such as grain crops including rice, roots and tubers, vegetables, perennials, and agroforestry systems.

CURRENT RELEVANCE OF CA AND BASIC DATA ON USE WORLDWIDE

Global Area and Regional Distribution

Worldwide, there are now almost 100 million hectares of arable crops which are grown each year without tillage in CA systems. The total area under CA is still very small (about 6-7%) relative to areas farmed using tillage.

No-till agriculture in the modern sense originated in the USA in the 1950s, and from this time until 2007 the USA has always had the biggest area under no-till in the world. But it is interesting to note that, in the USA, no-till accounts for only 22.6% of all cropland hectares, as compared with the Southern Cone of Latin America where no-till becomes the majority agricultural system with 60% of the surface. Canada shows the fourth biggest area under no-till with 12.5 million ha. CA exists in Europe but it is not really widely spread. In Australia CA has been widely and quickly embraced by farmers.

Asian and African countries have begun to take up CA practices only in the last 10-15 years, but have already acquired many useful lessons with respect to adapting the principles of CA to a vast diversity of conditions and constraints. Among the most encouraging experiences has been the CA work developed in dry environments such as Tunisia and Kazakhstan.

CA is practiced in all climate zones of the world where annual and perennial crops can be grown, from the tropics and subtropics to the temperate regions. CA concept and principles are applicable to any size farm (large land holdings, commercial farmers, medium scale farmers, small scale farmers) subject to availability of equipment.

RESTRICTING FRAMING CONDITIONS

The initial and primary restriction to adoption of CA is the assumption that tillage is essential for agricultural production. Subsequent hindrances to its adoption include, variously, those of intellectual, social, technical, environmental and political characteristics. Key restrictions with mainstreaming CA systems relate to problems with up-scaling which is largely based on the: lack of knowledge; lack of expertise; lack of inputs (especially equipment), inadequate financial resources and infrastructure, and poor policy support.

Financial resources: quantum of finance available, the availability of credit,.
Input availability: Unavailability of inputs may be a problem.
Land tenure and diminished farm size
Availability of markets: compounded for farmers by transport costs.
Restrictions arising from poor infrastructure: physical and service infrastructure (extension services)
Lack of policy support: and political commitment.
Institutional restrictions: including research.
Restrictions of the part of non-farmers: Restrictions on the part of non-farmers include lack of knowledge, and negative prejudices.
Restrictions among farmers: Restrictions to adoption of CA among farmers themselves may include resistance to change, and the fear of ridicule.
Ecological restrictions: Ecological restrictions may be imposed by climatic conditions, together with land characteristics.

TECHNICAL POTENTIALS FOR IMPROVEMENT

Conventional, tillage-based ways of treating soils has resulted in damage to their inherent productive capacity and their biologically-based sustainability as favourable rooting environments. CA is aimed at self-sustaining improvements of the overall health of the soil/plant ecosystem, and provides a more benign and beneficial alternative.

By avoiding tillage, the loss-rate of CO_2 from soil to atmosphere is greatly reduced; permanent cover of mulch materials both sustains the soil biota, raises soils' retention/release capacity for water and plant nutrients, and protects the surface from extremes of rainfall and temperature; rotations limit pest build-up, favour nutrient-cycling in the soil, and increase levels of soil organic matter at different depths. In these ways CA improves and sustains soil health on land already in good condition, can regenerate land in poor condition, and favours the self-repeating sustainability of soil processes. As such it furthers the aims of a number of international Conventions on .e.g. combating desertification, loss of bio-diversity, and climate-change effects.

RELEVANCE, AVAILABILITY AND EFFECTS FOR SMALL-SCALE FARMERS

Chances, Risks, Failures and Discouragements

Land degradation is not so much consequent on poverty *per se* as it is on failure or inability to apply what is already known about the functioning of such systems. Even those rural poor who cannot fully meet their basic needs can benefit from application of CA's principles. They cite: reduction in labour to produce greater crop yields per unit area; improvement in family members' health due to being able to include vegetables in the diet; reduction or elimination of periods of hunger during the year; greater food security; chances to make off-farm sales of surplus produce. These benefits were initiated with near-nil investment through altered usage of already-available materials and energy, and then provided extra cash for re-investment in the enterprise next season. Where some resources were scarce relative to the land area,their concentration in limited proportions of the farm, as opposed to spread thinly everywhere, ensured at least some crop plants were advantaged and matured fully.

There are growing risks to continuing with tillage agriculture, but entrenched insistence on its continuation (as by powerful voices of some input- and equipment-makers) could jeopardise firm encouragement and support by governments of CA's spread. Interested farmers risk becoming disillusioned if adequate practical advice, equipment or inputs are not available.

Desirable or Necessary Changes in Farming Conditions

A government needs to make firm and sustained commitment to encouragement and support of CA, expressed in policies which are consistent and mutually-reinforcing across the spectrum of government responsibilities and, as necessary, sufficiently flexible to accommodate variability in local characteristics. Facilitation should include tapered financial and logistical support as appropriate and necessary, for the number of years needed for farmers to have made the changeover and become familiar with the functioning of CA. Formal recognition should be given to the public goods value of environmental benefits generated by adoption of CA. The education system, from first grade to post-graduate, should be permeated with understanding of well-managed CA as an optimum expression of sustainable productive agriculture.

SETTINGS FOR THE PROMOTION AND SUSTAINABILITY OF CA SYSTEMS IN THE DEVELOPING REGIONS

Regional Experiences with the Promotion and Sustainability of CA

A variety of CA cases are available from the three developing regions. Ample evidence now exists of the successes of CA under many diverse agro-ecological conditions to justify a major investment of human and financial resources in catalysing a shift, whenever and wherever conditions permit it, from tillage-based production systems to those based on minimal soil disturbance, organic residue retention, and crop rotations and combinations. This will lead to large and demonstrable savings in machinery and energy use and in carbon emissions, a rise in soil organic matter content and biotic activity, reduced carbon emissions, less erosion, increased crop water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the apparent increased volatility in weather associated with climate change. It will cut production costs, lead to more reliable harvests and reduce risks especially for small landholders.

It is useful to recall that in Latin America CA was initially designed by farmers and by farmer organizations in the southern state of Paraná in Brazil. The very good environmental and economic performances of CA systems eventually led to the implementation of supporting policies and to a fast and wide adoption of this system. Subsequently, public research and extension system joined in the effort. Even private companies like cooperatives, agro-industries, hydroelectric companies and small rural industries have been involved in CA expansion. This multi-stakeholder strategy has been really efficient and successful, as CA is now reaching 60% of the total agricultural surface at national level.

In Asia, where most national economies are transition and there is growing effective demand for food and agricultural products, much of the promotion work is being done through the normal extension services with backing from the public sector research organizations. There is also collaboration with international research.

In Africa, what appears to work are those efforts such as Farmer Field School (FFS) that reply on participatory approaches to learning and adaptation at the grassroots level, and farmer-discovery processes at on-farm benchmark sites that enable farmers themselves to decide how to put concepts and principles. In several cases the international assistance arriving for recovery after natural disasters and emergencies could in Africa successfully be harnessed to introduce CA.

AREAS AND OPTIONS FOR ACTION

Focus on CA Technology Development, Adaptation and Introduction

Technologies that can help put CA principles into practice are mostly available. However, their local adaptations to specific cropping systems and cultures across diverse agro-ecological and socio-economic situations are most important. In many places, the introduction of CA technologies and practices will be from scratch, calling for mechanisms such as FFS that would enable empowering farmers through phased learning and discovery processes.

Collective knowledge and experience must be shared in introducing CA approaches to new countries and in supporting the accelerated adaptation and uptake of CA practices in countries in which they have already been introduced.

Agronomic strategies for CA aim at harnessing the abundant and diverse life forms that exist within soils to enhance their long term productivity. They include various combinations of:

- minimal or zero tillage;
- continuous soil cover often including green manure and cover crops;
- crop rotations, sequences and combinations;
- non-inversion weed control, including the use of allelopathy and smother crops;
- crop-livestock integration in farming systems;
- increase in biomass inputs to soil systems;
- optimization between organic and inorganic nutrient amendments;
- ecosystem-based and integrated management methods to control weeds, pests and diseases;

- erosion control infrastructure where needed;

Organizational strategies include:

- participatory, farmer-centered research and development;
- greater assumption of responsibilities for agricultural innovation by farmer organizations;
- capacity building within such organizations;
- engaging scientific expertise for understanding of below-ground processes;
- incentives and certification of sustainable agriculture practices to recognize societal benefits; and
- establishment of a network of Communities of Practice (CoPs) bringing together diverse stakeholders around the world to give concerted support.

Summaries of critical issues, goals for what might be done about them, and proposed actions that could be considered in the three broad stakeholder areas are set out in the full report.

The participants in the FAO workshop in July 2008 proposed establishing a number of interconnected CoPs that can further the objectives of CA as discussed above. Participants also decided to establish and sustain a *multi-stakeholder knowledge management system* that will be suited to the needs of diverse users, and in particular of farmers who can benefit from more appropriate and effective CA practices.

Focus on European Cooperation Policy on CA, and Framing Conditions for CA in the EU

European agricultural development policy for sustainable production in Europe and in the developing regions should have a clear approach to sustainable farming which in tropical conditions is not possible with tillage-based agriculture; hence all development activities dealing with crop production intensification should be assessed for their compatibility with CA. Environmental management custodian schemes in Europe do not promote the principles and practices of CA. This is because CA practices do not attract special rewards in the single farm payments to European farmers. On the contrary, commodity related subsidies or payment for set aside land work against the adoption of CA. Thus environmental costs arising from the negative impacts from intensive agriculture in Europe continue to be externalised and shifted to the society at large. Consequently, the degradation of soil, biodiversity and environment continue largely unabated.

It is perfectly feasible to meet food security needs in Europe and in the developing regions at lower economic and environmental costs through CA systems but the transformation to such systems will require effective political will and commitment. Currently, these policy provisions are lacking in Europe.

The proposed Soil Framework Directive, resulting from the Soil Thematic Strategy, for example, would have facilitated national policies in support of CA. Unfortunately it was not adopted. However, the new EU Water Framework Directive includes permissible levels for pollutants in water such as nitrates, phosphates or pesticides, which even with conservation tillage methods cannot be reached and only under permanent no-till systems (CA) the erosion and leaching of agrochemicals into surface and subsurface water bodies can be reduced to a level compatible with the new directive.

Within Europe there is an increasing concern about the sustainability of farming and organizations promoting CA in Europe, such as ECAF. CA principles, knowledge, skills and practices as well as the associated learning and dissemination processes are of a ‘public goods’ nature and are effective in reducing purchased exogenous input requirements while enhancing the natural endogenous biotic and ecological productivity enhancing processes. European governments and European Commission will have to take responsibility of promoting the transformation through the EU’s Common Agricultural Policy (CAP) which has been generally rather effective in managing agricultural change over the past several decades.

CONSERVATION AGRICULTURE (CA)

> *"No one has ever advanced a scientific reason for plowing."*
> *"There is simply no need for plowing in the first instance. And most of the operations that customarily follow the plowing are entirely unnecessary, if the land has not been plowed."*
> *"There is nothing wrong with our soil, except our interference."*
> *"It can be said with considerable truth that the use of the plow has actually destroyed the productiveness of our soils."*
>
> Edward Faulkner
> From Plowman's Folly (1943)
> Quoted in Goddard *et al.* (2008)

1. CHARACTERISTICS OF CONSERVATION AGRICULTURE (CA)

1.1 Definition of CA

Based on broad consensus across diverse stakeholders, CA is currently defined by the UN Food and Agriculture Organization (FAO) as follows:

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.

1.2 The Key Elements of CA: The Three pillars

CA is characterized by three principles which are linked to each other in a mutually reinforcing manner, namely:

4. Continuous no- or minimal mechanical soil disturbance (i.e., direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil);
5. Permanent organic-matter soil cover, especially by crop residues and cover crops; and
6. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops, including legumes.

These three principles are also often referred to as the three basic pillars of CA that combine to form a robust ecological foundation for sustainable intensification of primary production with which secondary production of livestock can be integrated successfully. The three pillars are elaborated in the following sections.

1.2.1 Continuous no- or minimal mechanical soil disturbance

For over 2000 years farmers have believed that they must plough the land to get a good crop, associating soil tillage with increased fertility which can occur in the short run due to mineralization and break down of organic matter as a consequence of soil tillage. But the more often the land is ploughed, the faster it loses crucial organic matter and the biotic activity it supports. As organic matter content falls, soils become capped and less porous, losing their ability to absorb and retain water – and this has two bad effects: first, there is less water to support crop growth and the biological activity that is so important for productivity, and second, more water accumulates and moves across the land surface, causing floods and erosion. Thus, the loss of organic matter leads to loss in plant nutrients as well as soil structure and biological life. These degradation processes due to tillage are dramatic in the tropics due to higher temperatures and rainfall intensities, but can be noticed all over the world. Mechanization of soil tillage, allowing higher working depths and speeds and the use of certain implements like ploughs, disk harrows and rotary cultivators have particularly detrimental effects on soil structure. Excessive tillage of agricultural soils may result in short term increases in fertility due to release of plant nutrients, but it will degrade soils in the medium and longer term. Structural degradation, loss of organic matter, erosion and falling biodiversity are all to be expected from tillage

The soil degradation which occurs as a result of tillage can be reversed by minimizing soil disturbance, and this led to movements promoting no-till or zero-tillage, particularly in southern Brazil, North America, New Zealand and Australia. Over the last two decades the technologies that permit successful no-till farming, allowing crop residues to produce a layer of mulch over time and seeds to be drilled directly into the mulched stubble, have been improved and adapted for nearly all farm sizes, soils, crop types, and climatic zones. Experience is still being gained with this alternative approach to agriculture and FAO has supported the process for many years.

1.2.2 Permanent soil cover, especially by crop residues and cover crops

In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer protects the soil from the physical impact of rain and wind but it also stabilizes the soil moisture and temperature in the surface layers. Thus this zone becomes a habitat for a number of organisms, from larger insects down to soil borne fungi and bacteria. These organisms macerate the mulch, incorporate and mix it with the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure and its porosity. At the same time this soil organic matter provides a buffer function for water and nutrients. Larger components of the soil fauna, such as earthworms, provide a soil structuring effect producing very stable soil aggregates as well as uninterrupted macropores leading from the soil surface down to the subsoil and allowing rapid water infiltration in case of heavy rainfall events. Keeping the soil covered and planting through the mulch protects the soil and improves the growing environment for the crop.

This process carried out by the living component of a soil or the soil biota, the edaphon, can be regarded as "**biological tillage**". However, biological tillage is not compatible with mechanical tillage becasue with increased mechanical tillage the biological soil structuring processes are destroyed and disappear. Certain operations such as mould board ploughing or disc-ploughing have a stronger impact on soil life than others as for example chisel ploughs. Most tillage operations are, however, targeted at loosening the soil which inevitably increases its oxygen content leading in turn to the oxidation and mineralization of the soil organic matter. This inevitably leads to a reduction of soil organic matter which is the substrate for soil life and biological processes. Thus, agriculture with minimal or no mechanical tillage is only possible when soil organisms are allowed to take over the task of tilling the soil. This, however, leads to other implications regarding the use of chemical farm inputs. Synthetic pesticides and mineral fertilizer have to be used in a way that does not harm soil life.

1.2.3 Diversified crop rotations or plant associations, including legumes

As the primary objective of agriculture is the production of crops upon which secondary production depends, changes in the management of pests (insects, diseases and weeds) become necessary with CA. Burning plant residues and ploughing the soil is mainly considered necessary for phytosanitary reasons: to control insect pests, diseases and weeds. In a system with minimal mechanical tillage based on mulch cover and biological tillage, alternatives have to be developed to control pests. Integrated Pest Management (IPM) based largely on natural control of pests becomes mandatory so that soil biological life is not poisoned. One important element to achieve this is diversified crop rotations and associations that interrupt the infection chain between subsequent crops and make full use of the physical and chemical interactions between different plant species. Synthetic chemical pesticides, particularly herbicides, are helpful and may be necessary in the first years in the case of larger holdings operating under a labour shortage but have to be used with great care to reduce the negative impacts on soil life. Compared to intensive tillage-based farming systems with high inputs of agrochemicals, the use of synthetic pesticides and mineral fertilizer tends to decline in CA to a level significantly below that of the original level to the extent that a new balance between the organisms of the farm-ecosystem, insect pests and beneficial organisms, crops and weeds, becomes established and the farmer learns to manage the new cropping system. Burning crop and weed residues destroys an important source of plant nutrients and soil improvement potential. The phytosanitary motives for burning and ploughing can be better achieved by IPM practices that also include crop rotations and associations to minimize the need for synthetic pesticides and herbicides. In an undisturbed ecosystem an equilibrium between beneficial and pest organisms tends to develop, reducing over time the need for chemical control.

Another key contribution of diversified crop rotation is the possibility of incorporating high biomass legumes in the cropping system that fix nitrogen from the atmosphere and enrich the soil nutrient pool. In CA systems with livestock, legumes such as *Mucuna* offer an excellent source of protein rich feed. Together with crop health aspects of rotations and biological nitrogen fixation, diversified rotations in arable systems and crop associations in perennial systems allow crops of different root morphology to help with the process of biological tillage as described in the previous section and as biological pump for nutrients.

1.2.4 Synergy effects and benefits

CA, understood in the way elaborated as above, provides a number of advantages on global, regional, local and farm level:

- It provides a sustainable production system, not only conserving but also enhancing the natural resource base and increasing the variety of soil biota, fauna and flora (including wild life) in the agricultural production systems without sacrificing yields at the high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro- as well as macro level.
- No-till fields act as a sink for CO_2 and CA applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying CA practice could eventually be rewarded with carbon credits.
- Soil tillage is, among all farming operations, the single most energy consuming and thus, in mechanized agriculture, an air-polluting operation. By not tilling the soil, farmers can save between 30 and 40% of time and labour, and in mechanized agriculture, fossil fuels, as compared to tillage-based cropping.
- Soils under CA have very high water infiltration capacities, reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water, reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of CA that natural springs that had dried up many years earlier, started to flow again. The high potential benefit of a massive adoption of CA on global water balances and water supplies is not yet fully recognized.
- CA is not low output agriculture but delivers yields that are comparable or greater than those obtained with modern tillage-based intensive agriculture, but in a sustainable way. Yields tend to increase over the years with a simultaneous decrease in yield variations.
- For the farmer, CA is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting, and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.

Disadvantages of CA in the short term might be the high initial costs of specialized planting equipment and the completely new dynamics of a CA system, requiring high management skills and a learning process by the farmer. Long term experience with CA all over the world has shown that CA does not present more problems or less problems, but rather different problems to a farmer, all of them capable of being resolved. Particularly in Brazil the area under CA is now growing exponentially, having already exceeded the 25 million hectare mark. Also, in North and South America the concept is widely adopted (see Section 2.2).

1.3 Translation of CA Principles into Technologies and Farmer Practices

CA systems utilize soils for the production of crops with the aim of reducing to a minimum the excessive mixing of the soil that is characteristic of tillage-based farming, and maintaining crop residues on the soil surface to minimize damage to the environment, and deploy diverse crop rotations and associations for enhancing soil and crop health, for producing more biomass of higher quality, for integrated insect pest, disease and weed control, for improved nutrient uptake, and for biological soil tillage.

As a consequence, CA will:

- Provide and maintain an optimum environment of the root-zone to maximum possible depth. Roots are able to function effectively and without restrictions to capture high amounts of plant nutrients and water.
- Ensure that water enters the soil so that (a) plants never, or for the shortest time possible, suffer water stress that will limit the expression of their potential growth; and so that (b) residual water passes down to groundwater and stream flow, not over the surface as runoff.
- Favour beneficial biological activity in the soil in order to (a) maintain and rebuild soil architecture; (b) compete with potential *in situ* soil pathogens; (c) contribute to soil organic matter and various grades of humus; (d) contribute to capture, retention, chelation and slow release of plant nutrients.
- Avoid physical or chemical damage to roots that disrupts their effective functioning or limits their maximum potential for nutrient uptake.

1.3.1 Technologies and practices related to the principle of minimal or no soil disturbance

This principle of minimal or no soil disturbance calls for the practice of direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil. Direct seeding in CA systems involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as being synonymous with the terms: no-till farming, zero-tillage or zero-till, no-tillage or direct drilling, etc. Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (wheat and barley for example). The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are kept at the absolute minimum possible. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil is visible on the surface.

Land preparation for seeding or planting under no-till system involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch layer. Crop residues are retained either completely or by a suitable amount to guarantee the complete soil cover, and fertilizer and amendments are either broadcast on the soil surface or applied during seeding.

1.3.2 Technologies and practices related to the principle of permanent soil cover

Soil cover can be achieved by crop residues or cover crops. It is preferably produced *in situ* and only in exceptional cases carried to the field. Crop residues have to be distributed evenly and managed in a way to facilitate subsequent planting. Options depend on the planting technology and are leaving residues standing anchored in the soil, cutting them or chopping them into small pieces. Cover crops need to be managed before planting the main crop. This can be done manually or with animal or tractor power. The important point is that the soil is always kept covered. The means to achieve soil cover include the following practices:

- Use of appropriate/improved seeds for high yields as well as high residue production and good root development.

- Integrated management and reduced competition with livestock or other uses e.g., through increased forage and fodder crops in the rotation.
- Use of various cover crops, especially multi-purpose crops, like nitrogen-fixing, soil-porosity-restoring, pest repellent, etc.
- Optimization of crop rotations in spatial, timing and economic terms.
- "Targeted" use of herbicides for controlling cover crop and weed development.

1.3.3 Technologies and practices related to the principle of diverse crop rotations and associations, including N-fixing legumes

In CA systems, the rotation of crops is not only necessary to offer a diverse "diet" to the soil micro organisms, but as the crops root at different soil depths, they are capable of exploring different soil layers for nutrients. Plant nutrients that have been leached to deeper soil layers and that are no longer available, can be "recycled" to upper soil layers by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carry over of crop-specific pests and diseases from one crop to the next via crop residues. The means to achieve effective crop rotations and associations include the following practices:

- Designing and implementing crop rotations and associations in space and time according to the various objectives: food and fodder production (grain, leaf, stalks); residue production; pest and weed control; nutrient uptake and biological subsurface mixing/cultivation, etc.
- Using appropriate/improved seeds for high yields as well as high residue production from above-ground and below-ground parts, taking into account the prevailing soil and climate conditions.

Crop rotations in CA are ideally designed in a way that some crop is growing throughout the entire vegetation period without any fallow period. This enhances the biomass production and carbon sequestration and at the same time leaves no opportunities for weeds to develop and spread.

1.4 Machinery, Tools and Equipment for CA Systems

In tropical and subtropical areas, the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid. The type and number of land preparation operations determine the quantity of residues left on the soil surface. For example, ploughing leaves less than 15% residues intact on the surface whereas direct seeding leaves between 60 and 95%.

It is therefore important to choose land preparation practices that protect the natural resources base and at the same time improve productivity and reduce production costs. In CA systems, land preparation practices are reduced to almost zero. Zero till or no-till practices are those activities in which the seeds are placed into the soil with the least soil disturbance possible. That means planting and sowing into the residues of previous crops and weeds. Therefore, farmers, extensionists and researchers have been developing not only instruments and equipment to seed into the residues, but also tools and implements to manage the crop residues and fallow vegetation, and weeds.

CA can be practiced in all size of farms and ecologies. Machinery, tools and equipment have been developed to cater for three levels of power usage: manual power; animal traction; and motorized equipment. The success of CA depends on the effective management of operations dealing with: (a) land preparation, (b) cover crops and weeds; (c) direct seeding (d) and harvest and residues. Details of machinery, tools and equipment for these operations are provided at the FAO CA website and are summarized below.

1.4.1 Land preparation

Hand tillage

Hoes and spades in different shapes and weights are the tools used for hand-tillage operations. However, under CA systems there is no general tillage anymore and farmers use direct seeding (e.g., jab planters) to plant the crop. With this the main bottleneck of labour availability for land preparation is eliminated. Tillage tools might still be necessary for some specialized operations even under CA, such as reshaping beds or maintaining irrigation ditches.

Chisels and subsoilers

Chisels or rippers are sharply pointed, metal tines that can be attached to the ordinary plough beam (Moeller, 1997). Usually, farmers who want to avoid ploughing in minimum or reduced land preparation activities use chisels which can also be used to break up plough pans or other impermeable soil layers, like crusts.

The subsoiler is used to break up hard or compacted soil layers, with the aim of improving water infiltration and root penetration. For animal traction, it can be attached to the ordinary plough beam. It can also be used to break up dry soil. The point works beneath the compacted layer and can be used up to soil depths of 25-60 cm. With animal traction the maximum working depth of a chisel is around 30 cm. For this reason real subsoiling is not possible with animals, but shallow compacted soil strata can be broken using adequately shaped chisels.

1.4.2 Cover crop, residue and weed management

The objective of cover crop, residue and weed management is to prepare the area for planting the subsequent commercial crop and to manage the weeds so that they cannot interfere with the crop development. In CA systems, this management facilitates the penetration of direct seeding equipment into the soil and into a favourable environment for seed germination, without obstructing the implement.

It is desirable that the residues form a good soil cover that protects the soil for quite some time against the impacts of rainfall and that liberates allelopathic chemicals to suppress the germination of weeds. The release of these chemicals should be slow and gradual until the commercial crop is able to compete with the weeds. One of the factors influencing the release of allelopathic chemicals is the decomposition of organic matter.

Residue and cover crop management can be done either mechanically or chemically, or a combination of the two, depending on the possibilities of the farmer; the topography (sloping or flat land); the degree of weed infestation; and the stage of development of the cover crop.

Mechanical management
Residue management for land preparation in CA starts at harvest time. Stubble length and residue distribution have an influence on the subsequent planting operations and other activities. Anchored and standing residues are easier to handle for most no-till seeders and planters, particularly disk based ones, than cut and lying residues. Lying long residues are easier for disks, chopped residues easier for chisel furrow openers. Even distribution is required generally.

Mechanical management of residues and cover crops can be done by using machetes, knives or sickles, knife rollers or chopping rollers, crushers, mowers, spreaders etc. or any similar implement depending on the power source.

Chemical management
Chemical management of fallow vegetation or cover crops is done by spraying herbicides. Herbicides are applied to desiccate or "cold-burn" the vegetative cover and thus facilitate the subsequent planting of the commercial crop. This practice is normally carried out when the cover crop is not yet in the full flowering or milky growth stage, and it is necessary to sow the next crop, or when it is too late to use the knife roller. Besides the commonly used tractor sprayers, different types of sprayers and equipment for herbicide application on small scale farms have been developed depending on the power source, such as knapsack sprayers, sprayers on wheels with sprayer pump, boom sprayers, weed wipers).

Even if only herbicides of low toxicity are being used, the application of agrochemicals always requires maximum care and knowledgeable operators. The sprayers used must not leak and must be in good working condition, the nozzles regularly cleaned and replaced. Operators should be trained in calibration and handling of sprayers to make sure that a maximum result is achieved with a minimum of herbicides.

1.4.3 Direct seeding

Direct seeding in CA systems is performed with different equipment depending on the power sources, and includes: planting stick or hand hoe; manual direct seeding; animal traction and single-axle tractor drawn planters; and direct seeding with tractors.

Planting stick or hand hoe
Direct seeding is practiced in a lot of places in the tropical world, although the terminology is not used as such. Seeding or planting in large parts of Africa is done by using a hand hoe. The hand hoe used for planting purposes usually differs from the one used for tillage and weeding in that the blade is thin and narrow.

Manual direct seeder or hand jab planter
In order to speed up the process of planting, hand jab planters (or *matracas* in Portuguese) have been developed. It is a hand-held tool that allows the farmer to plant from a standing position and

faster than with other hand tools (average 2 days per hectare). One of the modifications to the planter is a second hopper, opposite the seed hopper, for fertilizer. This allows the farmer to fertilize and plant at the same time. If the jab planter is provided with a second hopper to apply fertilizer and seeds in one operation, it has two separate delivery tubes and points to make sure the seed and fertilizer are not deposited too close to each other.

Animal traction and single-axle-tractor drawn planters

Direct seeding implements for animal traction and single-axle-tractors have been designed to manage residues on the soil surface and at the same time to place the seeds and possibly fertilizer in the soil. Therefore direct seeders have following working elements:

- A disc to cut through the surface mulch and open a slot in the soil.
- A furrow opener to place the fertilizer - often a chisel point.
- A furrow opener to place the seed - either a chisel or a double disc.
- Wheels to control the planting depth and eventually close and press the seed row.

For seed metering most modern animal traction planters now use standard discs designed for tractor planters, which can cope with the speed of any draught animal.

For many years, most scientists have thought that the best cover for seeds is loose soil. This thinking has evolved from situations with tilled seedbeds. However, especially under dry conditions, it can be observed that seeds under mulch cover germinate better than those covered by loose soil. Since under tilled conditions (loose soil) the macropore system in the vicinity of the seeds is completely destroyed the soil moisture equilibrium and the capillarity is disturbed. In undisturbed soil, the soil humidity equilibrium is intact providing optimal exchange of moisture between soil particles and pores. This allows the capillary supply of soil water to the soil surface while reducing the evaporation loss with the mulch cover. In CA, soil moisture loss takes place in the slot, and depending on the type of slot more or less moisture is lost. Further details of the relative moisture-conserving benefits of the different types of slot can be found in Baker *et al.* (1996).

Surface residues are an important resource for promoting seedling emergence from dry soils and it is possible to obtain more effective seedling emergence from a dry soil by direct seeding than by tillage, provided the correct technique and equipment are used. The animal traction prototype seeders were originally made to plant one row at a time, but planters are now manufactured that can seed more rows. Multi-row versions might even provide an operator's seat.

Direct seeding equipment for tractors

No till planters or seeders have either all or some of the following components:

- Hoppers for seed and, if applicable, for fertilizer with the respective metering mechanisms and delivery tubes.
- Row cleaner, if necessary, to remove excess mulch from the plant row.
- Cutting disc to cut through residue cover.
- Furrow opener for fertilizer.
- Furrow opener for seeds.
- Seed press wheel.

- Furrow closing wheel (often in combination with depth control).

Different crops and seeds require different ways of seeding or planting. The two major types are:

1. Seed drill: the seed is planted in a continuous band into the crop row. This method is usually used for small grain crops like cereals. The seed is metered with feed rollers of different designs; either positioned one for each seed line and gravity fed or centrally with pneumatic distribution of the seed to the lines. The machines for this type of seeding are usually called seed drill or seeder.
2. Precision planting: single seeds, or a predetermined number of seeds, are placed at an equal predetermined distance within the row. This method is usually used for row crops like maize, beans, cotton, sunflower etc. The number of seeds per planting hole and the distance between each planting location is determined by seed plates which have cells or chambers to meter the seed. The metering can either be mechanical or pneumatic, where the air is either as vacuum or as pressurized air used to select the number of seeds per position.

There are some modern no-till planters which incorporate both options in one machine, the seed drill and the row-crop precision planter. The farmer only has to equip the seed-drill-cum-planter with the desired number of furrow openers and connects them to the respective metering mechanism.

Already a lot of manufacturers of zero tillage equipment have posted their products together with information on the Internet. Information about CA equipment and suppliers is available online in an FAO CA Technology Database, which is accessible through: http://www.fao.org/ag/catd/index.jsp

The database provides information on different models of CA equipment for manual use, animal and mechanized traction. Technical, agronomic and commercial information for direct planters and seed drills, rippers, equipment for residue handling and specially developed sprayers can be viewed from this site. Complete addresses are provided, including links directly to webpages of the manufacturers.

1.5 Involved Knowledge: Integrating CA Principles into Production Practices

It is clear from the above description of the CA concepts, principles and practices that CA is a different paradigm for managing sustainable production intensification in which multiple objectives are managed simultaneously such that the results are economically, socially and environmentally beneficial for the producers and for the society.

At the production level, CA cannot be reduced to a simple standard technology package because of the diversity and variability in agro-ecological and socio-economic conditions that are associated with farming in general and with less favourable areas and smallholders in particular. Thus, the interactions between the possible recommended technological components and the location-specific conditions of farming must be taken into account adequately. Consequently, the standardised “best bet” production technologies approach tend to be of limited relevance and value for many farmers because CA practices tend to be knowledge intensive and farmers themselves must become involved in fine-tuning the transformation and application of the principles into site specific and farm-specific practices. In all this, local and indigenous knowledge is important in optimising the available resources for production intensification and environmental management. At the high tech level, precision farming allows the fine tuning of the practice with the variations in the land resource characteristics and landform combined with an accurate control and monitoring of farm operations for overall efficiency savings.

With CA systems which espouse to emulate nature as much as possible and use natural ecosystem processes and biological and mechanical methods in the management of nutrients, pests including weeds, and water etc, forward planning is of the essence. For example, CA permits early planting due to direct seeding, and therefore early harvest. This allows a cover crop to be fitted into the cropping system which provides a source residue, fodder and biological nitrogen. For effective weed management, timing of different crops and the use of mechanical methods of control must be planned well ahead of time. Thus, CA practices are knowledge intensive production practices and offer productivity, economic and environmental improvements of considerable potential benefit to large groups of farmers. CA requires farmers to be alert and innovative in formulating and implementing optimal solutions. In the case where CA practices are being introduced to achieve system level transformation, participatory approach to learning, adaptation and uptake work well as for example with Farmer Field Schools (FFS).

1.6 Key Actors and International Cooperation

At the national level, key actors in the promotion of the practice of CA in the developing regions range from farmer and producer organizations such as APDC and FEBRAPDP in Brazil and AAPRESID in Argentina GKB in Germany, AIGACoS in Italy, WANTFA in Western Australia and SANTFA in South Australia, MZTRA in Canada, CASA in the USA, APAD in France, to state or national research organizations such as IAPAR, EMBRAPA in Brazil, KARI in Kenya, INERA in Burkina Faso, CTRC in China and INIA in Uruguay. There are national NGOs such as TAFA in Madagascar, PACA in India, Kilimo Trust in East Africa, TAA in the UK who are dedicated to promoting CA through advocacy and awareness and there is an overlap between promoting NGOs and no-till farmer organizations, since many of them cover both sectors.

At the regional level and international level, there are large networks that promote research and extension activities such as WASWC internationally, RELACO in Latin America, ACT Network in Africa, ECAF in Europe and CAAPAS in South America. For example ECAF is made up of a group of European scientists, technicians and farmers interested in the adoption of CA practices. At present 14 national associations from the following countries belong to ECAF: Germany (GKB), Belgium (BARACA), Denmark (FRDK), Slovakia (SNTC), Spain (AEAC.SV), France (APAD), Finland (FINCA), United Kingdom (SMI), Greece (HACA), Hungary (TMME), Italy (AIGACoS), Ireland (CAIR), Portugal (APOSOLO) and Switzerland (SNT).

FAO has been active in capacity building and technical assistance in all developing regions, and has organized regional and international meetings on the role of CA in sustainable production intensification. FAO in collaboration with national and regional organizations and donor agencies sponsor the World Congress on CA every two years. International research organizations such as the CGIAR Centres (e.g., ICARDA, ICRISAT, CIMMYT, IWMI and the Rice-Wheat Consortium) have increasingly become more active in research on CA systems, and GFAR and regional research organizations such as FARA, APAARI, FORAGRO, ACSAD are beginning to direct greater attention to promoting research on CA.

Recently, multi-stakeholder international initiatives such as KASSA funded by European Commission and the World Bank-led IAASTD process have promoted knowledge sharing and awareness of the role of CA systems in sustainable agriculture. Some donor agencies, such as the World Bank, IFAD, Bill & Melinda Gates Foundation, Ford Foundation, Gatsby Foundation, have begun to give serious attention to supporting research and development programmes to promote CA for sustainable production intensification. The World Bank Report 2008 on Agriculture for Development highlights CA systems as development priority to be promoted in the future. Similarly, there is growing interest in the private sector including from machinery and agro-chemical companies to promote CA.

International cooperation has become stronger in the recent years as illustrated by the biennial process of the World Congress on CA, as well as increasing numbers of regional workshops. An international multi-stakeholder meeting organized by TAA and hosted by Newcastle University in March 2007 was followed by a larger meeting hosted by FAO with technical support from TAA (FAO 2008a, 2008b). The outcome of the latter meeting has been the emergence of the concept of ‘Community of Practice’ (CoP) within development communities to formalize and strengthen the connections among like-minded persons who work in a variety of circumstances and seek collectively to improve both knowledge and practice of CA. The participants in this consultation proposed establishing a number of interconnected CoPs, facilitated by FAO, that can further the objectives of CA. More details on CA-CoPs are provided in Section 7.

1.7 Potential Advantages from CA

Potential for CA systems in the 21st century agriculture development is based on the large amount of field based evidence from all continents regarding the role of CA systems in raining productivity and income, improving livelihoods and reducing production costs (economic), increasing resilience of production (local and national food security), contributing climate change adaptation and mitigation, and enhancing water resources, and protecting ecosystem services and environment. Some of these advantages are elaborated in the following sections.

To be widely adopted, all new technology needs to have benefits and advantages that attract a broad group of farmers who understand the differences between what they are doing and what they need. In the case of CA these benefits can be grouped as:

- Economic benefits that improve production efficiency.
- Agronomic benefits that improve soil productivity.
- Environmental and social benefits that protect the soil and make agriculture more sustainable.

Economic benefits:
Three major economic benefits can result from CA adoption:

- Time saving and thus reduction in labour requirement.
- Reduction of costs, e.g., fuel, machinery operating costs and maintenance, as well as a reduced labour cost.
- Higher efficiency in the sense of more output for a lower input.

The positive impact of CA on the distribution of labour during the production cycle and, even more important, the reduction in labour requirement are the main reasons for farmers in Latin America to adopt CA, especially for farmers who rely fully on family labour. Manual labour for soil preparation is back-breaking and unnecessary. Should the supply of labour be reduced, through sickness or migration, then the tillage based system can quickly become unsustainable.

Agronomic benefits:
Adopting CA leads to improvement of soil health and productivity:

- Organic matter increase.
- In-soil water conservation.
- Improvement of soil structure, and thus rooting zone.

The constant addition of crop residues leads to an increase in the organic matter content of the soil. In the beginning this is limited to the top layer of the soil, but with time this will extend to deeper soil layers. Organic matter plays an important role in the soil: fertilizer use efficiency, water holding capacity, soil aggregation, rooting environment and nutrient retention, all depend on organic matter. A better rooting environment leads also to a better and healthier crop establishment.

Environmental benefits:
Environmental benefits that result from adoption of CA include:

- Reduction in soil erosion, and thus of road, dam and hydroelectric power plant maintenance costs.
- Improvement of water resources in quality and quantity.
- Improvement of air quality.
- Biodiversity increase.
- Carbon sequestration and GHG emission reduction.

Residues on the soil surface reduce the splash-effect of the raindrops, and once the energy of the raindrops has dissipated the drops proceed to the soil without any harmful effect. This results in higher infiltration and reduced runoff, leading to less erosion. The residues also form a physical barrier that reduces the speed of water and wind over the surface. Reduction of wind speed reduces evaporation of soil moisture.

Soil erosion is reduced close to, or even below, the regeneration rate of the soil. CA even adds to the system due to the accumulation of organic matter. Soil erosion fills surface water reservoirs with sediment, reducing water storage capacity. Sediment in surface water increases wear and tear in hydroelectric installations and pumping devices, which result in higher maintenance costs and necessitates earlier replacement.

More water infiltrates into the soil with CA rather than running off the soil surface. Streams are then fed more by subsurface flow than by surface runoff. Thus, surface water is cleaner and more closely resembles groundwater in CA than in areas where intensive tillage and accompanying erosion and runoff predominate. Greater infiltration should reduce flooding, by causing more water storage in soil and slow release to streams. Infiltration also recharges groundwater, and thus increasing well supplies and revitalizing dried up springs.

Sediment and dissolved organic matter in surface water must be removed from drinking water supplies. Less sediment loss and less soil particles in suspension, lead to a reduced cost for water treatment. Since water infiltrates in CA through macropores and does not percolate through the soil matrix leaching of soil nutrients and chemicals is also reduced resulting in cleaner ground water.

One aspect of conventional agriculture is its ability to change the landscape. The destruction of the vegetative cover affects the plants, animals and micro-organisms. Some profit from the change and turn into pests. However, most organisms are negatively affected and either they disappear completely or their numbers are drastically reduced. With the conservation of soil cover in CA a habitat is created for a number of species that feed on pests, which in turn attracts more insects, birds and other animals. The rotation of crops and cover crops restrains the loss of genetic biodiversity, which is favoured with mono-cropping.

Systems which are based on high crop residue addition and no tillage, accumulate more carbon in the soil, compared to the loss into the atmosphere resulting from plough-based tillage. During the first years of implementing CA the organic matter content of the soil is increased through the decomposition of roots and the contribution of vegetative residues on the surface. This organic material is decomposed slowly, and much of it is incorporated into the soil profile, thus the liberation of carbon to the atmosphere also occurs slowly. In the total balance, carbon is sequestered in the soil, and turns the soil into a net sink of carbon. This could have profound consequences in the fight to reduce green house gas emissions into the atmosphere and thereby help to forestall the calamitous impacts of global warming.

1.8 Key Restrictions with CA: The Unutilized Potentials

Key restrictions with mainstreaming CA systems relate to problems with up-scaling which is largely based on the: lack of knowledge; lack of expertise; lack of inputs (especially equipment), inadequate financial resources and infrastructure, and poor policy support. These and other restrictions are elaborated in more detail in Section 3.

The most important limitation in all areas where CA is practiced is the initial lack of knowledge. There is no blueprint available for CA, as all agro-ecosystems are different. A particularly important gap is the frequent dearth of information on locally adapted cover crops that produce high amounts of biomass under the prevailing conditions. The success or failure of CA depends greatly on the flexibility and creativity of the practitioners and extension and research services of a region. Trial and error, both by official institutes and the farmers themselves, is often the only reliable source of information.

However, as CA is gaining momentum rapidly in certain regions, there now exist networks of farmer organizations and groups of interested people who exchange information and experiences on cover crops, tools and equipment and other techniques used in CA. Initial nervousness about switching from plough-based farming to CA can be ameliorated by forming farmer groups to exchange ideas and gain knowledge from more experienced practitioners.

As CA under certain socio-economic circumstance partly relies on the use of herbicides, at least during the initial stage of adoption, some people worry that adoption of CA will increase herbicide use and that in turn will lead to increased contamination of water by herbicides. In fact, field experience and scientific evidence has shown that herbicide use tends to decline over time as the soil cover practices prevent weed emergence.

Reductions in leaching of pesticides under CA might be caused by greater microbial activity degrading pesticides faster or by increased organic matter adsorbing the pesticides.

1.9 Interrelation with Other Production Systems and Practices

CA as farming concept and a set of practices has a wide range of compatibility and complementarity with other resource conserving approaches and technologies, and applicability in rainfed and irrigated farming systems, including ‘organic’ farming. It is suitable for different crop types such as grain crops including rice, roots and tubers, vegetables, perennials, and agroforestry systems, and CA combines well with IPM practices. However, CA does not have any compatibility with continuous monocultures and heavy tillage-based farming.

Being a knowledge-intensive concept, CA requires a greater intensity of engagement by the producers in the management of the different aspects of CA practices. As such, CA lends itself to participatory approaches to learning and adaptation by farmers, including small resource poor farmers. Farmer Field Schools in particular have shown to work well in training and capacity building of farmers with CA principles and practices.

1.9.1 Irrigated farming

Principles and practices involved with CA systems apply to both rainfed systems and irrigated systems. In the case of irrigated rice, systems of production that avoid or minimize soil disturbance can work well with CA. This is beginning to occur in DPR Korea, South Asia and Egypt where wheat-rice-legume rotations are widespread. Given that irrigated rice under the SRI system does not require anaerobic conditions, and therefore does away with flooding, it would appear that SRI practices can combine well with CA, involving direct seeding or transplanting, an increased recycling of crop residues and nutrients, encouraging soil biota and root systems to capture greater nutrient efficiencies, and reducing crop water requirement. More research and farmer participatory testing is required to integrate SRI with CA. Surface irrigation systems require special attention to residue management, but as all other irrigation systems they likewise benefit from water savings under CA.

1.9.2 Organic farming

CA has many features in common with organic farming, although the latter does not permit the use of synthetic materials such as commercial mineral fertilizers etc. Where organic farming is tillage-based, application of the three CA principles would enhance productivity and resilience of organic production systems and offer economic and environmental benefits that have been described earlier. Indeed, one exciting future opportunity that can be harnessed is the integration of compatible CA practices into organic farming. CA-based organic farming would lead to greater soil health and productivity, increased efficiency of use of organic matter, and reduction in use of energy. Organic CA farming is already practiced in some cases as in the USA, Brazil and Germany.

1.9.3 Integrated Pest Management Practices

IPM practices have proved to be successful for managing crop health with minimal or no use of synthetic pesticides in the case of insect pests and diseases. Similarly, IPM for weed control based on mainly mechanical and biological control has shown to be relevant and compatible with CA practices, including for small producers. Indeed, a system in which CA and IPM are integrated offers opportunities to combine production practices that can simultaneously enhance soil health as well as crop health. This is a solid ecological foundation for sustainable production intensification. FAO has initiatives in place in West Africa on Integrated Production and Pest Management (IPPM) in which farmers are empowered through FFS process to manage the integration of IPM and CA practices for sustainable production intensification. IPPM approach to intensification allows the possibility of strengthening crop-livestock integration because of the greater biomass and livestock feed availability following adoption of CA as described in the next section.

1.9.4 Livestock interactions

One major feature of CA is its capacity to increase biomass production which can form a sound basis for integrating livestock into the system, or strengthening the existing links with livestock production. This is well described in Landers (2007), as detailed in the following sections.

Farming systems that successfully integrate crop and livestock enterprises stand to gain many benefits that can have a direct impact on whole farm production. Ruminant animals are especially desirable due to their ability to convert forages, browse and crop residues high in cellulose to useful food and fibre products. Such animals provide for: system diversification; recycling of nutrients; soil enhancing rotation crops; power and transportation; and act as biological "savings accounts" for farmers during periods of stress. Nevertheless, even with the potential for synergies, if the system is managed to favour excessively either crops or livestock, synergies are lost and detrimental effects may result.

Failure to consider the livestock component as part of the agricultural system creates an immediate conflict because system resources must be used to support the animal enterprise. For example, a 410 kg cow will have a daily dry matter maintenance intake of roughly 1.5-2% of body weight. The daily requirement amounts to 8.2 kg or about 3.0 tons annually. This gives some idea of the magnitude of the annual biomass requirement but does not address the specific animal nutrient needs or a strategy for utilization. Nutrient demand to carry out productive functions such as work, reproduction and growth will require more from the system. Not only do intake requirements increase to 2.5-3% of body weight but also the nutritive requirements of the ration are considerably higher than for maintenance. Animals that are maintained in poor body condition or are incapable of reproduction are of little or no value to the enterprise or the system in general.

There are, however, situations where conflicts between crop residues and cover crops required for CA and the demand from the livestock sector, are difficult to withstand. The exact nature of the conflict between crop and livestock production depends on the production system involved. It may be due to:

- Excessive residue consumption by livestock kept by farmers. Livestock may or may not have access to communal grazing land. If tenure is secure and livestock do not depend on communal land, it may be possible to solve conflict through technical changes in production system.
- Excessive residue consumption by livestock owned by pastoralists (and sometimes by farmers). This situation is more complex because crop producers/mixed farmers face different problems from those of pastoralists.

Competition for crop residues

CA practices require a critical level of crop residues and cover crops to maintain or enhance soil chemical, physical and biological properties and prevent land degradation. In many areas of the world, crops and livestock compete for the same resources, and require proper management to meet CA objectives. Synergistic integration of crops and livestock offers numerous advantages.

Farming systems that successfully integrate crop and livestock enterprises stand to gain synergies that directly impact production and agro-ecological efficiencies. Sánchez (1995) has reviewed the case for the integration of livestock (mainly ruminants) with perennial crops. Some advantages listed include: diversification of income through animal products (milk, meat, fibre, hides, and manure), weed control, soil erosion control, increased yield of main crop, and income during the "start-up" period for tree crops.

Competition for crop residues and cover crops between livestock and in situ recycling represents a widespread and serious threat to realizing the benefits of CA. Traditionally, crop residues have been used for multiple purposes, i.e. fuel, building materials, mulch, feed and bedding, most of which conflict with their use for soil improvement. Among these, livestock related use (feed and bedding) is probably the most widespread in developing countries.

The removal of crop residues for or by livestock, either through grazing or cut and carry, is a common practice in most crop-livestock systems. In many cases residue removal by animals is excessive, leaving insufficient vegetation for soil enhancement and conservation purposes, and compromising the sustainability of the systems. Furthermore, in some systems these residues may have a greater long-term value as soil amendments, because many crop residues have very low feed value, often not meeting animal maintenance requirements. On the other hand, livestock are an important part of production in mixed farming systems and in the absence of alternative feed sources; farmers are usually unwilling to abandon this critically important one.

It is necessary to understand the root cause for such practices, as they usually involve socio-economic or cultural issues. Examples of the successful integration of livestock with cropping systems exist and these case studies can serve as the basis for a concentrated effort to search for possible solutions to this important problem.

Complementary feeding strategies

In traditional mixed farming areas the use of the crop residues can be a strong initial deterrent for the smooth change towards CA. If livestock is accustomed to feed on crop residues, a conflict of interest can be created when crop residues need to be kept for soil protection or for organic matter accumulation.

In this case, there are various alternative solutions whose viability would depend on the particular conditions of each location. The following are some of these options:

- Estimation of the amount of crop residues needed for soil protection and enrichment and the balance can then be used for animal feeding (direct controlled grazing or cut-and-carry).
- Establishment of double purpose cover crops (soil protection and forage) within the crop rotation cycle.
- Establishment of plots of permanent forages for direct grazing or for cut-and-carry.
- Planting of hedgerows for forage production with prunings
- Reduction of herd size by culling out animals no longer needed for animal traction.
- Temporary displacement of animals to other areas.

Establishment of alternative and complementary forage sources (legumes, grasses and tree fodder), strategic application of inorganic fertilizers and manure, conservation of surplus forage, supplementation, treatment of crop residues, controlled grazing, zero, or combinations of these, must be flexible enough to adjust to the needs of each farming situation.

On steep land, the use of living contour erosion barriers consisting of grasses and/or leguminous trees that can serve as livestock feed is an efficient strategy if the species selected are palatable feeds as well as effective erosion barriers (Barber, 1996).

Legumes are particularly important in mixed farming systems because of their role in nitrogen cycling and as sources of protein for human and animal nutrition (Devendra, *et al.*, 2001). Nevertheless, when land is limited, farmers are reluctant to take land out of crop production to establish forages. However, CA often allows the use of time within the vegetation period for forage production, which can otherwise not be used due to the time spent on tillage and land preparation.

The ability to conserve and transfer forage from periods of surplus to periods of deficit appears to be a logical approach to efficient production. Nevertheless, the humid tropics bring special challenges to the practice of forage conservation (hay & silage) due to frequent rains and high humidity during the season(s) when surplus forages are available for conservation. This technology is rarely adopted by small farmers who see it as a costly process requiring machinery and infrastructure that is unavailable to them (Quiroz *et al.*, 1997). However, simple methods have been developed which are suitable for small scale farmers in the semi-arid tropics (IIRR & ACT, 2005).

In combination with other strategies, it would seem worthwhile to develop forage conservation methods appropriate for small and medium-sized farms. Cereal residues contain high concentrations of cell wall material and associated lignin. These constituents reduce the value of residues as livestock feeds. Possibilities exist through treatment to modify these constituents rendering them more nutritious. For example, ammonification of cereal residues with urea treatment (Pezo *et al.*, 2000) can significantly increase their crude protein concentrations, digestibility, intake and, consequently, animal performance. The adoption of these technologies by small farmers has been limited because some of these materials require access to specialized equipment, appropriate technical assistance, credit, or consistent supply of affordable inputs.

Where fodder is being cut and carried to confined livestock, the amount of residual field vegetation can be precisely controlled. If crop stubble is grazed, the herder must maintain control over the animals such that the needed residual is maintained. This can be done by controlling the grazing time permitted in a given area and by allowing animals to express selective defoliation of edible plant fractions. In cut and carry systems, non-edible parts can be returned either as such or as part of compost prepared by mixing with animal excreta. According to Sain and Barreto (1996) farmers in Guaymango, El Salvador who allow grazing of crop residue, restrict consumption to about 50 percent of the total amount available. As average residue yields of the maize/sorghum system are near 10 t/ha, the amount left (about 5 t/ha) is well above the 3.5 t/ha threshold reported by Barber (1996)

The appropriate management of bovines is key for productivity improvements of grain production and even for livestock itself, by improving the sources and quality of feed, and indirectly, the soil. In order to achieve this, the following practices are emphasized:

1. **Not over-stocking**, but keeping a number of animals according to land availability and forage production capacity, balancing production and consumption of biomass during the year. This will avoid overgrazing and will maintain adequate soil coverage.
2. **Increase the intensity of land use** by the establishment of fenced areas, for the production of grasses and legumes for cutting, for grazing, for silage and for hay, and for corrals.
3. **To control grazing**, with rest periods which allow pasture recovery. The investment for pasture division and rotational grazing faces two major obstacles: the high fencing costs and current socio-economic situation of farmers, many of whom do not even have enough land to keep their own animals and graze them along road sides, empty lots or lands "borrowed" from neighbours.

1.9.5 Agroforestry and related systems

CA works well for agroforestry and related systems in which crops are combined with woody perennials in the production system. This is particularly because the minimal or no soil disturbance means that roots of tress are not damaged by tillage, plus the system benefits from all the other advantages of CA including the enhancement of soil health and productivity. In fact, several tree crop systems in the developing and developed regions already practice some form of

CA, but these systems can be further enhanced with improved crop associations including legumes, and integration with livestock. Alley cropping has been one innovation in this area that is beginning to offer productivity, economic and environmental benefits to producers who are able to take advantage.

1.9.6 Genetically Modified Organisms (GMO)

In some countries, such as Argentina, Brazil and the USA there has been a significant increase of no-till agriculture combined with the use of GMOs, particularly herbicide resistant varieties. This has led, especially in the US to the impression that herbicide resistant GMOs are an integral component and essential requirement of no-till farming, and of CA systems. This is not the case, since no-till farming and CA have been practiced long before the existence of GMOs. The rapid expansion of no-till with the GMOs resulted from the fact that, with this technology, farming and crop management apparently become extremely easy. Most of these types of cases grow only one crop (soya or maize) in continuous monoculture, and the use of no-till plus herbicide as post emergence weed management reduces the production costs significantly. However, this technology is not sustainable in the long-term, and leads to herbicide resistance, pest and disease problems, environmental and human health deterioration, and other difficulties, and certainly does not offer the benefits offered by CA. In the longer term the farmers applying this way of no-till farming either convert to proper CA, integrating crop rotations and cover crops and reducing the necessity for post emergence weed control, or revert back to periodic tillage. The no-till farmers organizations dedicated to Conservation Agriculture in the above mentioned countries discourage this way of farming. Since the herbicide resistant GMOs focus on no-till farming systems, there is an area of overlap with CA, so that such GMOs are used in CA in some cases, but CA is not dependent on GMOs or herbicide resistant varieties. A clear distinction is here necessary between no-till as stand alone technology and CA as integrated no-till system. Other types of GMOs such as those that are resistant to insect pests (e.g., Bt cotton) or to diseases, or to abiotic stresses such as drought and salinity are fully compatible with CA practices and these GMOs can be used in CA systems where national policy permit their use.

2. CURRENT RELEVANCE OF CA AND BASIC DATA ON USE WORLDWIDE

In the absence of CA certification systems no official reporting mechanisms for CA exist. No-till area, on the other side, is reported in some countries as an option for tillage in agricultural census. Where they exist, CA organizations keep records of CA adoption in their countries. But regular long-term reporting in this way only exists in few cases, mainly in the southern Latin America. For the global CA reporting, as done for the World Congresses on Conservation Agriculture or for the FAO database and hence for the purpose of this report, the reporting is done through networking with stakeholder groups and individual validation of the figures, using official reports, organization reports and personal knowledge and judgments of national champions. To come closer to realistic CA adoption figures, the reported no-till area is reduced to “permanent” no-till with a minimum time span between tillage operations of not less than 5 years. This excludes periodic or seasonal no-till areas, which is the majority of the no-till areas in the USA.

These figures are then further judged with the local stakeholders to determine the percentage of this long term no-till complying with CA as defined under section 1.2. In the light of this the given overall figures in Table 1 and Figure 1 appear to be a fair estimate of the CA adoption area around the world. In fact, they are probably conservative, because they include only figures from countries where contact persons exist and figures have been reported. There are still many unknown areas, mostly in Africa, but also in Russia, where CA is known to be applied but no reliable data could be obtained.

2.1 Global Area and Regional Distribution

CA and other similar systems for intensive farming that lead to the progressive build-up of soil organic matter have been successfully tested and applied by farmers in many parts of the world over the past 40 years. Though these systems vary in the technologies applied across countries, climates, soils and crop types, their common features are that they enable farmers to create conditions favourable to biotic activity in the soil through:

(a) maintaining, to the extent that local conditions allow, a year-round cover over the soil provided by the current crop, including specially introduced cover crops and intercrops and/or the mulch provided by retained residues from the previous crop;

(b) minimising soil disturbance by tillage, eliminating tillage altogether once the soil has been brought to good condition, and

(c) diversifying crop rotations, sequences and combinations, adapted to local socio-economic and environmental conditions, which contribute to maintaining biodiversity above and in the soil, and help avoid build-up of pest populations within the spectrum of soil inhabitants.

Although much of the CA development to date has been associated with rainfed arable crops, farmers can apply the same principles to increase the sustainability of irrigated systems, including those in semi-arid areas. CA systems can also be tailored for orchard and vine crops with the direct sowing of field crops, cover crops and pastures beneath or between rows, giving permanent cover and improved soil aeration and biodiversity[1]. Functional CA systems do not replace but should be integrated with current good land husbandry practices.

Because of the benefits that CA systems generate in terms of yield, sustainability of land use, incomes, timeliness of cropping practices, ease of farming and eco-system services (see section 1.8), the area under CA systems has been growing exponentially, largely as a result of the initiative of farmers and their organizations (Figure 1). It is estimated that, worldwide, there are now almost 100 million hectares of arable crops which are grown each year without tillage in CA systems. Except in a few countries, however, these approaches to sustainable farming have not been "mainstreamed" in agricultural development programmes or backed by suitable policies and institutional support, and the total area under CA is still very small (about 6-7%) relative to areas farmed using tillage.

2.2 Area with CA in Developed Countries

---

[1] The common constraint, given by farmers, to practising this latter type of inter-cropping is competition for soil water between trees and crops. However, careful selection of deep rooting tree species and shallow rooting annuals resolves this.

No-till agriculture in the modern sense originated in the USA in the 1950s, and from this time until 2007 the USA has always had the biggest area under no-till in the world. In 2008 Brazil overtook the USA for the first time. But it is interesting to note that, in the USA, no-till accounts for only 22.6% of all cropland hectares. Conventional agriculture with tillage remains majority even if CA is a valid option for farmers, as compared with the Southern Cone of Latin America where no-till becomes the majority agricultural system with 60% of the surface. Another interesting point about adopters in the USA is that only about 10 - 12% of the total area under no-till is being permanently not tilled (CTIC, 2005). This occasional tillage prevents the system from reaching its optimum balance, as the soil is disturbed from time to time. Research has shown that it takes more than 20 years of continuous no-till to reap the full benefits of the system. Farmers that practice rotational tillage, i.e., plough or till their soils occasionally, will never experience the full benefits of the system (Derpsch, 2005).

Canada shows the fourth biggest area under no-till with 12.5 million ha.

CA exists in Europe but it is not really widely spread, as the land surface under no-till systems does not exceed 2% of the agricultural land. Since 1999 ECAF is promoting CA. The adoption is slow but visible in Spain, France, Switzerland and Finland, with some few farmers proving the concept to work also in Germany, UK and Italy.

In Australia CA has been widely and quickly embraced by farmers. It has improved weed control, time of sowing, given drought tolerance and has enabled dry regions to use water most efficiently (Crabtree, 2004). But inappropriate seeding machines, which move the mulch too much, and sheep that graze crop residues, are leading to an insufficient soil cover. So efforts have to be done to improve the practices and so the sustainability of no-till systems.

2.3 Area with CA in Developing Countries

Amongst developing countries, Brazil has the longest experience in CA and since 1972 many useful "lessons learned" originate from there and from neighbouring Argentina and Paraguay. Their experiences have contributed to a better understanding of the long-term biophysical and environmental effects of CA application. They have also set important precedents for the engagement of farmers as principal actors in the development and adaptation of new technologies. Farmers in many other countries in Asia and Africa have also gained valuable but more recent experience on how to adapt the principles of CA to their own conditions.

Brazil took the initiative when herbicides (Paraquat/Diquat) and direct-drilling equipment became available in the US, and it became clear that conventional ploughing was leading to a severe environmental and economic crisis for farmers in southern Brazil. Progressive and wealthy farmers led the way, some travelling to the USA to learn about their soil conservation and management systems and to purchase direct-drilling equipment. Next, "common interest groups" were formed initially amongst large-scale farmers and later with small-scale farmers. CA has emerged mainly as a result of farmer innovation together with problem-solving support from input supply companies, state and federal research and extension organizations, universities, as well as long-term funding commitments from international donors such as the World Bank and

GTZ. However the momentum for innovation and adoption has been, and still is, principally with farmers and their organizations.

Apart from enabling their land to be cropped more intensively without risk of degradation, CA attracted Brazilian farmers because it increased crop yields (at least 10-25%), greatly reduced surface runoff and soil erosion, and cut tractor use, resulting in big savings in fuel and production costs (see Section 1.8). Such benefits explain why today, South American farmers practice zero tillage CA on a continuous basis, year after year, on about 47 million hectares.

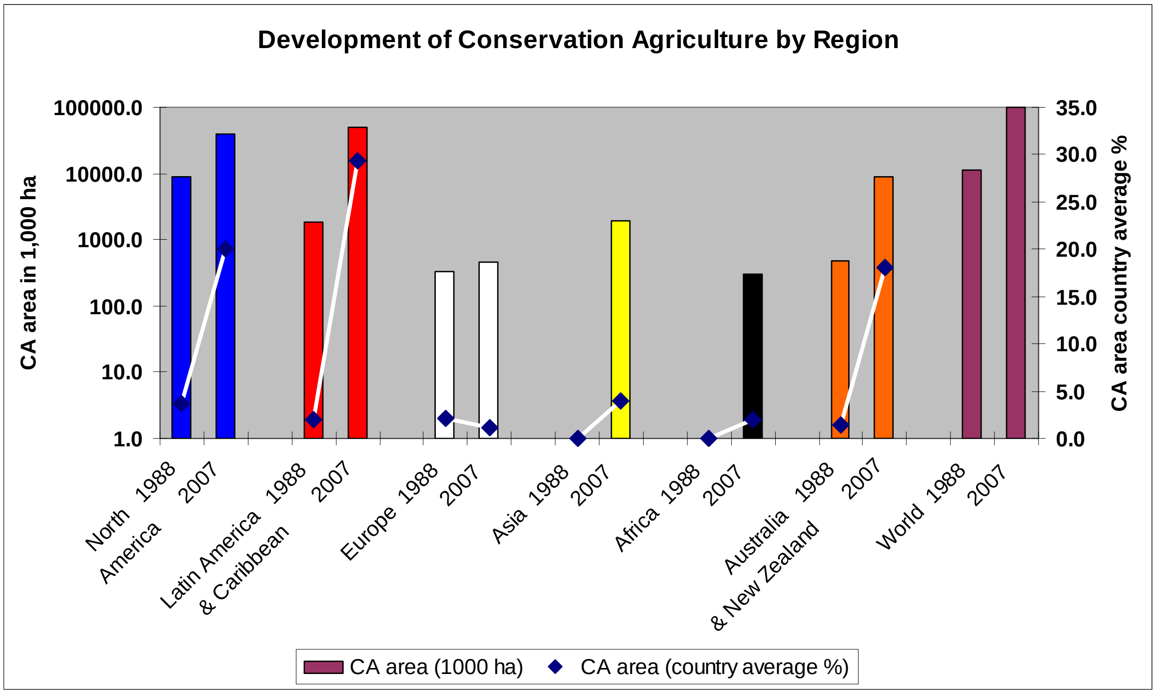


Figure 1: Development of Conservation Agriculture over the last 20 years by world region in total area (ha) and as average percentage across the adopting countries of the respective region (from FAO, 2008a)

The main crops grown under CA include soybean, maize, wheat, sunflower, canola as well as cassava, potato and a number of horticultural and cover crops. CA practices are also being applied to perennial crops and to tree crops. Soil cover is achieved by growing cash crops and cover crops either in association or sequentially. Main cover crops include oats, oilseed-radish, rye, lupins, vetches, *Mucuna* (velvet bean) and pigeon peas, depending on the scale of farms. In some cases, especially amongst small-scale farmers, herbicide use can be reduced by direct-drilling seed into a cover crop that has been flattened using a knife roller. Specialized no-till equipment has been developed in Brazil and the Americas, including tractor-mounted, animal drawn and hand tools (including jab planters). These are being exported to Africa and Asia and being adapted there for local use and manufacture.

For their part, Asian and African countries have begun to take up CA practices only in the last 10-15 years, but have already acquired many useful lessons with respect to adapting the principles of CA to a vast diversity of conditions and constraints. Among the most encouraging experiences has been the CA work developed in dry environments such as Tunisia and Kazakhstan where highly innovative adaptations have been made to the very demanding low winter temperatures and low and unpredictable rainfall. In DPR Korea, the introduction of CA has made it possible to grow two successive crops (rice maize or soya as summer crop, winter wheat or spring barley as winter crop) within the same year, through direct drilling of the second crop into the stubble of the first. The feasibility of growing potatoes under zero tillage has also been demonstrated in Korea.

Innovative participatory approaches are being used in Africa to develop supply-chains for producing CA equipment targeted at small holders. Similarly, participatory learning approaches such as those based on the principles of FFS are being encouraged to strengthen farmers' understanding of the principles underlying CA and how these can be adapted to local situations.

The corresponding programmes recognize the need to adapt systems to the very varied agro-ecosystems of the regions, to the extreme shortage of land faced by many farmers and to the competing demands for crop residues for livestock and fuel – problems that are particularly pronounced amongst small-scale farmers in arid and Mediterranean regions.

CA is spreading in many areas of Africa and particularly in eastern and southern Africa, where it is promoted by FAO and the African Conservation Tillage Network. Building on indigenous and scientific knowledge and innovative equipment design from Latin America, farmers in at least 14 countries are now practicing CA (in Kenya, Uganda, Tanzania, Zambia, Swaziland, Sudan, Madagascar, South Africa, Zimbabwe, Mozambique, Ghana, Burkina Faso, Morocco and Tunisia). In Zambia alone, between 70 000 and 100 000 smallholder farmers are practicing CA (Rumley and Ong, 2007). In the specific context of Africa (where the majority of farmers are resource-poor and rely on less than 1 ha, and there is food insecurity, degradation of soil fertility, drought and irregular rains, shortage of human power for agricultural labour) CA systems are very relevant for addressing the old as well as new challenges of climate change, high energy costs, environmental degradation, no sustainable intensification paradigm other than the standardized tillage-based "green revolution" types relying on the inefficient use of purchased inputs of agro-chemicals. In Africa CA should respond to growing food demand by increasing food production while reducing negative effects on the environment and energy costs, and develop locally adapted technologies that are consistent with CA principles. (Kueneman *et al.*, 2007)

While large numbers of small-scale farmers – in Paraguay, China and various African countries – have taken up CA, experience indicates that adoption tends to be at a much slower pace than amongst larger-scale farmers. With food security among their major objectives, many small-scale farmers are hesitant to invest scarce labour, land, seed and fertilizer in cover crops that do not result in something to eat or to sell. They also suffer from restricted access to relevant knowledge as well as to inputs or credit. As a result, there is an increasing recognition of the need to encourage farmers to move towards full adoption of CA at their own pace, testing out promising approaches initially on small areas of their farms and progressively expanding as their confidence in the results develops.

The largest areas under CA nowadays are in the major grain exporting countries (USA, Brazil, Argentina, Canada, Australia) (Table 1). CA is being taken up rapidly in a number of Asian countries (DPR Korea, China, Kazakhstan). In Central Asia, a fast development of CA can be observed in the last 5 years in Kazakhstan and the neighbouring Russian areas. Kazakhstan now has 3.5 million ha under reduced tillage, and of this 1.2 million ha are "real" CA with permanent no-till and rotation. China has equally a dynamic development of CA. It started 10 years ago with research, then the adoption increased during the last few years and the technology had been extended to rice production system. Now about 1.3 million ha are under CA in China. In India and the Indo Gangetic plains, in the wheat-rice cropping system, there is large adoption of no-till wheat with more than 4 million ha, but only marginal adoption of permanent no-till systems and full CA.

2.4 Global Distribution of CA across Climate Zones

CA is practiced in all climate zones of the world where annual and perennial crops can be grown, from the tropics and subtropics to the temperate regions. Functional examples exist in the tropics and sub-tropics (summer rainfall) in the moist (sub-humid) and dry savanna and the humid forest environments in Latin America (e.g., Brazil, Colombia, Venezuela, Argentina, Bolivia, Chile, Mexico, Paraguay, Uruguay), Africa (e.g., Kenya, Tanzania, Zimbabwe, Zambia, Swaziland, South Africa, Madagascar, Zambia, Ghana), Asia (e.g., India, Pakistan, China), northern Australia and USA. In the African tropical Sahel zone, CA is practiced in the form '*zai*' pits which involve concentrating available nutrients and moisture supply around and close to the plants or trees.

In the subtropics, CA is practiced in the winter rainfall areas with Mediterranean-type environments in Latin America (e.g., Chile, Argentina), in Africa (Tunisia, Morocco), Asia (Syria, Kazakhstan), and in California, USA. In the temperate regions, CA is practiced in Latin America (e.g., Chile, Argentina), Asia (e.g., DPR Korea, China), North America (USA, Canada) and Europe (e.g., Spain, France).

2.5 Distribution of CA Across Farm Types

CA concept and principles are applicable to any size farm (large land holdings, commercial farmers, medium scale farmers, small scale farmers) subject to availability of equipment. In Latin America, Africa and Asia, it has been shown to work in large, medium and small farms. However, the area of CA comprises mainly of large farms which, under labour shortage situations, can capture the economies of scale with the use of CA machinery and equipment.

In 2002, it was estimated that of the total area under CA, only a small proportion (about 450,000 ha) was practiced on small farmers by around 200,000 farmers. This is because only few countries (e.g., Brazil) have seriously invested in research and developed technologies to suit small farmers. Brazil is also among the few countries that manufacture equipment for small farmers (one or two-row seeding machines, sprayers, knife rollers, fertiliser and lime spreaders for animal traction, hand jab planters etc).

Table 1: Conservation Agriculture adoption by country over the last 20 years in ha and in percent of total arable land (source: FAO AQUASTAT 2008 and FAO, 2008a)

Conservation Agriculture area in 1,000 [ha]				
	1988-1991	1993-1996	1998-2001	2003-2007
Argentina	500.0	3,950.1	15,000.8	19,719.4
CA area (%)	1.8	13.9	51.5	66.8
Australia	400.0			9,000.0
CA area (%)	0.8			18.1
Bolivia				550.0
CA area (%)				16.9
Brazil	1,350.0	8,847.0	18,744.5	25,501.7
CA area (%)	2.3	13.5	28.2	38.3
Canada	1,951.2	4,591.8	8,823.5	13,480.8
CA area (%)	3.8	8.8	16.9	25.9
Chile				120.0
CA area (%)				5.2
China				100.0
CA area (%)				0.1
Colombia				102.0
CA area (%)				2.8
France	50.0			150.0
CA area (%)	0.3			0.8
Kazakhstan				1,790.6
CA area (%)				8.0
Mexico				22.8
CA area (%)				0.1
New Zealand	75.0			
CA area (%)	2.0			
Paraguay		200.0	1,200.0	2,094.0
CA area (%)		7.4	33.4	48.7
South Africa				300.0
CA area (%)				1.9
Spain				300.0
CA area (%)				1.6
United Kingdom	275.0			
CA area (%)	3.9			
United States of America	6,839.2	17,361.0	21,124.6	25,252.4
CA area (%)	3.7	9.6	11.8	14.3
Uruguay			753.5	1,082.3
CA area (%)			53.4	76.7
Venezuela (Bolivarian Republic of)				300.0
CA area (%)				8.7
World total	11,440.3	34,949.9	65,646.9	**99,866.0**

However, in 2005, according to FEBRAPDP, the Federation of No-Till Farmers of Brazil, there were about 500,000 to 600,000 ha of no-till being adopted by small farmers with animal traction. This corresponds to some 100,000 farmers using no-till practice in Brazil. Also, in Paraguay the number of small farmers adopting CA practices has grown rapidly recently. It was estimated that in 2005, some 12,000 farmers were using no-till on about 30,000 ha. Another region with a large number of small farmers who have adopted no-till technology is the Indo-Gangetic Plains. Here a few hundred thousand farmers are using the technology on an estimated 2 million ha.

It is estimated that CA will grow at a much slower pace in smallholder farming systems than in mechanized medium and large scale systems. The most important reasons for this are too little research and development, inadequate extension efforts, and funding shortages allocated for this target group worldwide. Another important reason is the logistics of how to reach a greater number of small farmers in remote areas, with shrinking budgets for extension services. While mass media strategies can work well with well-educated medium and large farmers, individual assistance over a period of time is necessary when working with small-scale subsistence farmers. Lately, learning and extension systems based on the FFS approach is showing promising results particularly in Africa

3. RESTRICTING FRAMING CONDITIONS

To gain fullest effects of Conservation Agriculture it is necessary convert thinking from the commonly-held view that tillage is essential for agriculture to be productive and successful. This is not yet generally the case, and continuing to think thus – at any level from farmer to policy-maker – constricts the perception of what is wrong with the tillage paradigm and of how desired benefits can be gained with the CA paradigm. To continue with tillage is to damage the capacity of the soil to renew itself and thereby achieve a dynamic self-sustainability through the interactions of the soil biota and the increasing organic matter.

The failure to change the way of thinking is perhaps the first and most severe frame-restriction of all, because it could maintain the present primacy of tillage: one season of tillage could, by oxidation of carbon to carbon dioxide, negate the whole of one or more season's worth of carbon capture and retention. The following quote from Lal *et al.* (2004) captures the growing sentiments regarding CA: "Implementing a program to increase soil organic carbon requires that governments mandate no-till agriculture or provide financial incentives to farmers. Aid programs should place far greater emphasis on subsidizing and providing technical and other assistance for soil restoration. As an option that wins globally and locally, adoption of no-till farming deserves attention now."

3.1 Restrictions to Adoption of CA

The successful spread of CA, however significant the potential benefits may be, requires that a number of constraints – including the widespread perception amongst farmers that inversion tillage is an essential part of crop production processes – have to be overcome. These constraints include (FAO, 2008a):

- **The mind-set of the plough**. The plough has become the symbol of agriculture and many, including farmers, extension agents, researchers, university professors and politicians have difficulty in accepting that agriculture is possible without tillage.
- **Competition for crop residues.** Most small-holder farmers manage mixed crop/livestock systems and rely on crop residues for animal feed and often fuel. CA systems need to incorporate components that provide for animal feed while at the same time enabling adequate soil surface residue cover. There is room to turn this constraint into an advantage through diversifying and enriching the crop rotations and linking CA and intensive livestock production.

- **Social issues.** Communal grazing rights often apply in rural communities making it difficult for farmers to decide unilaterally that they will keep residues on their fields. Changes in communal and local policies may be required to allow for residue retention. Fire protection may also be necessary.
- **Weed control**. The principal function of tillage is supposed to be weed control and so, when tillage stops, weed control becomes a major factor. In many cases controlling the weeds present at seeding time has been achieved with herbicides, especially the wide-spectrum "glyphosate". However, for farmers who do not have access to herbicides or the equipment to apply them, or want to engage in organic farming, manual weed control can be difficult and very time-consuming in the first years of practicing a CA system if no specific technical advice is provided how to adapt to this new condition. After a few years of good weed control and use of cover crops, weed populations decline and become more manageable under CA, even without using herbicides.
- **Fertility amendments.** The success of CA depends on adequate residue cover. In very infertile and degraded soils sufficient fertility amendments must be applied to overcome shortages of specific soil nutrients which might be limiting to the build up of both of soil life and of plants. This serves to increase production not only of the economic portion of the crop but also of the residues/cover crops.
- **Soil rehabilitation.** Severely compacted or very uneven land would require investments into sub-soiling to break the compaction and leveling to prepare the soil surface for the future crops. These are often costly operations, which only need to be done once, but they do have to be done before starting with CA.
- **Market linkages.** Poor linkages may limit farmer access to fertilizer and other inputs for well managed crops.
- **Knowledge intensity.** CA is a knowledge intensive system and farmers, extension agents and researchers need to obtain, share and integrate new knowledge into their practices. Small-holder farmers are often poorly linked to knowledge and information systems, and even extension personnel in many developing countries may have little access to new information.
- **Land tenure.** Farmers that do not have secure access to land may be reticent to invest the time and effort in conserving and improving the land when this may not provide them with longer term benefits.
- **Equipment.** Small-scale equipment for seeding crops without tillage is not readily available in many areas. Suitable equipment needs to be introduced, tested and adapted and local manufacture stimulated where possible. This is a particular problem of CA, since without adequate equipment the performance of the system is not satisfactory, while commercial suppliers will not stock or offer this kind of equipment without a visible and strong market asking for it.
- **Excess soil water**. Soil structuring processes in CA depend on soil life, which needs oxygen. As such CA is not well adapted to situations with poor drainage and extremely high water tables with waterlogging. However, permanent raised beds which ensure that part of the root system is in aerobic conditions offer a possible solution. In general these conditions require even for tillage based agriculture some drainage to produce well.
- **Time.** The principles of CA need to be adapted to local biophysical conditions and farmer circumstances. This takes time, and massive short-term uptake of CA is difficult – a problem for politicians looking for short-term impact.

- **Policies.** Often the policies and procedures of governments and international institutions tend to favour short-term approaches to stimulating agricultural output and keeping consumer prices low, rather than encouraging sustainable land management and the creation of conditions in which farmers are rewarded with adequate livelihood prospects, including compensation for ecosystem services. Even if favourable long term policies support sustainable agriculture, the ramifications are often not fully understood and different policy sectors have conflicting policies in place.

The above constraints tend to be most severe amongst small-scale farmers who already face many risks to their livelihoods. In some countries attempts to introduce CA have failed, not necessarily because the three CA principles have proven inappropriate but because the process of adaptation and promotion has not been suited to local socio-economic realities or been mainstreamed into farm extension programmes and general policies supported by strong cases of local CA successes.

However, even after it is agreed that a change towards Conservation Agriculture is desirable, there are a number of restrictions to its achievement on the ground (see Friedrich and Kassam, 2009). These restrictions act as framing conditions for adoption of CA and some of them are elaborated in the following sections, namely:

- Lack of financial resources
- Unavailability of inputs
- Land rights and diminishing farm size
- Availability of markets
- Inadequate Infrastructure
- Poor policy support
- Institutional weaknesses
- Restrictions on the part of non-farmers
- Restrictions among farmers
- Ecological restrictions

Any of the above restrictions in different combinations can hinder the adoption of CA practices. Overcoming each restriction creates a necessary condition for change but all restrictions must be removed or ameliorated in order to create a sufficient condition for up-scaling the adoption of CA practices.

3.2 Financial Resources

A key restriction in the change process is the insufficiency of financial resources at the farm and government level to support the change-over from tillage system to CA.

At farm level

Expenditures of money are required during the initial phase of undoing the soil problems of the past so as to get the soil into a condition on which improvements can be built. Tillage induced hard-pans at or beneath the soil surface need breaking up. While this can be done most laboriously by hand with hoes, mattocks, *jembes* etc., it is more easily achieved with a chisel of some kind, and the power to do its work, whether provided by animals or by tractors of various sizes. But lack of finance to hire such animals and/or equipment can cause significant delay in getting started in CA (except on a very small scale) as would unavailability of lines of credit for the purpose.

Poverty-stricken small farmers with only small plots of land (e.g., ½ hectare or less) may be unable to get credit at all. Commercial mechanised farms may be able to get bank credit more easily, or from input-providers, or may be in a position not to need credit.

Lack of even small amounts of money to buy services, inputs and/or equipment can have proportionately greater negative impact on the small resource-poor farmer than it would on a farmer with more resources and credit-worthiness.

A further restricting factor can be the high cost of credit for capital and/or seasonal crop-establishment expenses, which could dissuade prudent farmers from taking it.

Alternatively credit at acceptable rates might not be available to fund actions which are unfamiliar to the lender, who might consider them too risky at normal rates of interest.

At government level

From its own funds alone, a government might be unable to offer additional support to the development of CA. Particularly damaging would be a lack of commitment to assist farmers during the change-over period, to cover some of the risks and uncertainties they encounter, until the stage of farmers' confidence in CA's advantages had been reached. Progress of CA could collapse if some farmers' livelihoods continued to be degraded by tillage agriculture even as the public benefits of CA were beginning to be perceived and appreciated.

The short-term 'project' approach to piloting CA is not suitable for testing and disseminating CA practices whose benefits may not be felt immediately by the farmer. Generally, a medium to longer-term view must drive any transformation planning and integration of CA elements into farmer practice using participatory learning approaches. Top down approaches to dissemination do not work with CA practices as farmers must be directly engaged in testing and discovery process.

3.3 Input Availability

3.3.1 Unavailability of inputs

Unavailability of required inputs can be a significant restriction on progress of CA. There may be potential suppliers in locations that can be reached by farmers, but farmers will be frustrated if these do not stock required inputs – either because they do not yet perceive sufficient demand to get them from wholesale suppliers, or because the required inputs are not readily obtainable in the region/country. This applies particularly to seeds of improved varieties of preferred crops and cover-crops; fertiliser materials of formulations appropriate to the local soil conditions and crops; appropriate veterinary products for maintaining animal health; herbicides for control of the particular spectrum of weeds; and others.

Inputs are needed in the right quantity and at the time required. If the materials are in stock, but their prices are too high relative to the amount of money a farmer has, the materials would effectively be as inaccessible as if they were not in stock.

If there is little or no commercial farming in a region with a large preponderance of resource-poor farmers, the latter may find it difficult to obtain the required materials which their interest in CA may have indicated, because of lack of demand from those able to purchase them**.** In this case it is actually beneficial to link the introduction of CA for small farmers with a programme also directed towards commercial farmers, who would easier create specific demand to channel inputs into a region. In this way the introduction of CA into smallholder farming in Brazil was a subsequent movement following the adoption of larger farms in the region. Similar examples exist in Africa, where commercial CA farmers facilitate the adoption of CA for small farmers around their farm through the provision of inputs and services.

3.3.2 Unavailability of reliable equipment

It is generally not desirable for a farmer to attempt to use existing farm equipment and expect it to do well the jobs for which it was not designed.

Problems exist if: (a) the equipment is not available in the country; (b) even if the equipment could be imported into the country the potential stockists do not think there was sufficient demand to be commercially worthwhile; (c) the equipment is imported and available in-country, the retailers have them in stock, but the price is too high for farmers to pay; (d) locally-made equipment of the right type is available and at an acceptable price, but the quality is too poor to sustain the severity of use to which it is put. It has been noted that, if a new piece of unknown equipment fails in its intended use in the new system, the farmer is more likely to blame the system than to blame the piece of equipment. This could have the adverse effect of causing the farmer perhaps to abandon further progress in CA, revert to old ways, and pass negative messages to his friends and neighbours.

A further restriction would arise if the equipment was entirely satisfactory in work until some part got broken, but the standard of engineering etc. in nearby repair shops proved to be insufficiently competent to mend it.

3.4 Land Tenure and Diminishing Farm Size

3.4.1 Insecure land rights

If farmers do not have secure rights to the use and produce of their farmland (as in the case of renting land, sharecropping etc.) there is the likelihood that the farmer would be unwilling to invest time, effort and money into improving it if/when the owner might decide to take it back and profit himself from the benefits of the other’s work. This could prove to be a severe disincentive and dampener of enthusiasm for adopting CA. This potential problem is widespread in many parts of Africa.

Another problem relating to the efficacy of soil cover, by crop residues and/or cover crops/green manures as a specific CA feature, is that posed by communal grazing of individuals' fields after harvest. This has the double effect of both compacting the soil surface layer and eating-off the residues which otherwise would be a protective cover and a substrate for biotic activity in the soil. Some (inadequate) counterbalancing benefit may be expected from the manure which is deposited during the process.

3.4.2 Diminishing farm sizes

Local conventions on inheritance of farmland (as in a country with a rising human population, e.g., Kenya) can result in continual subdivisions of the land into smaller and smaller parcels distributed between family members. Each parcel eventually may become so small that it cannot support the farmer himself/herself and any family. The result may be that they, as rural poor, may abandon farming and migrate to the city and become part of the urban poor. This problem cannot be avoided by adopting CA methodology, but at least CA has the capacity to put off that day by producing more per unit area under CA than previously. Thus, because of soil improvement by CA methods, a given number of people can be sustained for longer than would otherwise have been the case. A number of case studies of very poor small farmers attest to this reality (see Section 4 below). As farm sizes diminish, in systems using tillage-agriculture the chances of the land being from time to time put into a type of crop solely to restore its condition becomes ever less likely.

3.5 Availability of Markets

3.5.1 Problems of marketing

Where there is commercial farming already established, there are likely to be suitable markets for the produce. However, where there are large numbers of small resource-poor farmers practising what is effectively subsistence farming, with little to sell outside (or even within) their local communities there are unlikely to be relatively sophisticated markets within reasonable distance of each other among such farming communities.

If there are few markets, and difficulty in reaching them, the farmers lose out because they cannot easily take advantage of the often close relationship between product-marketing infrastructure and input-supply infrastructure plus credit, in well-organised markets.

Prices received by farmers for their produce may be low because the market for some/all the products are depressed or because middlemen take off proportionately-large commissions to transact on the farmers' behalf.

This is a problem of any agricultural development, not only of CA. However, the urgency of transforming agriculture to more-sustainable systems is so great that poor marketing arrangements can be seen as a potentially-severe impediment to the rate of CA's adoption and development. Without market access and moving from subsistence to a market oriented production it will be difficult to improve rural livelihoods even with CA.

3.5.2 Lack of group strength

If farmers produce little for sale, and they continue in their conventional ways of agriculture, with static or falling yields, there is little or no incentive to form common-interest groups, as can occur with the change to CA. Without a supporting group, they individually have little or no bargaining power with middlemen or in the markets which they may attend.

3.6 Restrictions Arising from Poor Infrastructure

3.6.1 Poor roads infrastructure

The relatively large distances to market to be covered in such areas are a hindrance to innovation and diversification in cropping systems because of the costs to farmers (particularly the resource-poor) involved in taking part in marketing. This is made worse if roads are of poor quality, badly maintained and/or subject to damage by runoff or flooding which takes long to repair. Poor roads also inhibit farmers' production of saleable perishable produce such as vegetables and fruits, because of damage during transport, and the decline in freshness suffered over the time taken to cover long distances.

3.6.2 Insufficient rural electricity

In areas of poor farming, producing little money return, and often without access to expanded knowledge and/or finance, it is unlikely that there is incentive to connect such areas to the national or regional electricity grid, because farm-families may be unable or unwilling to pay the energy bills. Electrical energy for domestic lighting, and providing power in workshops, can be provided by diesel generators, but again the cost of motors and fuel may inhibit uptake.

In areas where there are possibilities of irrigation and of sales of the produce – fresh or dry – the lack of widespread electrical connections to irrigation pumps can hinder progress in raising income of farms which are benefiting from improved soil conditions under CA.

3.6.3 Insufficient or inadequately-trained rural advisory staff

CA principles and practices are knowledge-intensive, and they cannot be transferred to farmers in a linear manner used to disseminate standard simple technology. Extension training and knowledge base of scientists is often not adequate to allow them to engage effectively with farmers in testing and adapting CA practices into prevailing production systems.

Thus, in areas with CA beginning to be embraced by a growing number of farmers, an insufficiency of relevant knowledge and skills may be related to a scarcity in numbers of field staff relative to the number of farmers to be served. They may have too little knowledge of CA among them to be able adequately to assist and guide the farmers during the early stages. Such staff need to be able to impart knowledge, organise and run meetings effectively, act as 'Yellow Pages' concerning how to access particular information, arrange technical visits between farmers in different places (including formal Study Tours). Such a deficiency can seriously slow development of CA by being unable to satisfy keen farmers' requirements for knowledge and assistance to feed their skills and capacity for innovation.

3.7 Lack of Policy Support

3.7.1 Lack of political emphasis on CA

In general it has been observed that issues like soil health and soil productivity, unless they result in catastrophic dimensions of erosion, do not inspire or attract policy makers. They might take note about concerns of soil degradation but then move over to the next agenda item.

Those who are content to maintain the *status quo* of tillage agriculture, and seeing no reason to change it, would be unlikely to be public champions for promoting CA as its environmentally-preferable successor. Particularly sectors which are gaining from tillage- based agriculture and might lose out under CA are even likely to militate against a wider adoption of CA. This is the case with the tractor industry and most likely in the long term with the agrochemical industry, both sectors with potentially considerable political influence.

Without a government's high-level political commitment to favouring spread of CA, it will suffer from insufficient back-up of positive support to the pioneer farmers who begin the changeover, such that increases in interest could falter or fail, for which some of the reasons are outlined above.

3.7.2 Problems with political manoeuvering

With change in the chosen party of government, new policies may be developed for the sake of emphasising the difference between the new government and its predecessor rather than to carry forward aspects of good prior programmes.

Some politicians favour short-term projects which could provide quick electoral advantages more than longer-term programs with deeper and lasting vision. Short-term-ism militates against anticipated support being of sufficiently long duration to complete the transition from conventional tillage agriculture to proven CA.

Favouritism and nepotism may have the effect of having important vacant posts relating to CA diverted to politicians' personal favourites rather than to suitably-qualified persons. Travel funds for technical purposes e.g., overseas study tours may be provided to those who then make use of them for other purposes (e.g., shopping), thus limiting the number of opportunities for technical staff to gain relevant knowledge of other countries' agricultural experiences.

Some policies' positive effects may become distorted due to corrupting influences, for instance, the 'cornering' of a market, e.g., monopolising a transport network for personal gain rather than the public good.

A politician may make high-sounding speeches for burnishing his/her public image, but fail to ensure follow-on action. Political insincerity about the need to finance – or to finance for long enough - worthwhile projects and programmes which have been accepted – can be damaging to the development of CA. It leads to lack of trust in the political persons and to the disappointment of those whom it was planned to benefit.

3.8 Institutional Restrictions

Even in the face of looming problems posed by complexities of climate change effects and its interactions with increasing demands for production from the land, a number of governments are not yet fully enthused by the possibilities of CA. The global and national urgencies are such that it is not appropriate just to let the adoption of CA takes its own course, even though Brazilian experience shows that this can occur – though more slowly than it would have done if there had been stronger and subject-specific backing. The effectiveness of such backup will depend on coherence of purpose and approach between the different agencies of government involved in encouraging the spread of CA.

3.8.1 Hindrances within government.

Institutions (e.g., Government. departments) are normally arranged in ways conformable with, and dedicated to, only maintaining the current ways of doing things, inappropriate though that might be.

Ways of tackling certain problems - e.g., soil erosion – are usually based on time-honoured convention more than they could be on active observation, feedback, and adjustment by the agency with responsibility for technical matters of land use and conservation.

There are sometimes rivalries between, or clashing objectives of, different Ministries, Departments, or agencies within Government, which do not have adequate inter-communication (e.g., as between Agriculture and Local Government regarding the improvement of inappropriate byelaws; or between Agriculture as Veterinary Departments as to which has main responsibility for animal husbandry).

Often there is found to be inadequate ‘horizontal’ coherence between related Departmental policies - e.g., between those on environment vs. agriculture vs. water supplies vs. human health.

There may be found inadequate ‘vertical’ coherence between decision-making at HQ and necessities at regional/local levels. This may be so especially in matters of keeping field staff (at the interface with farmers) up-to-date with information and motivation (e.g., study-trips outside their areas to see different situations and provide opportunities to discuss with others). An example is a tendency to make apparently arbitrary decisions about postings of field staff from one place to another, without due consideration of the need for consistency and continuity of linkages with farmers.

3.8.2 Unfocussed research, and need for relevant research

There is generally little participatory, farmer-centred research and development. Despite requests for solutions to specific problems raised by farmers and/or field staff (e.g., for refinements for better adaptation of CA principles to local conditions); there may be unwillingness to alter emphases in research and/or advisory programmes to address them.

Key aspects still requiring greater attention under different ecological and socio-economic situations include:

- Weed control and integrated weed management.
- Integrated pest management in CA systems.
- Integration of integrated pest (including weeds) management with CA.
- Economically viable crop rotations and diversification of production.
- Plant nutrition and nutrient management under CA conditions with respect not only to grain or economic yields alone but also generation of plant biomass usable to raise organic-matter levels in the soil to maintain soil health and access to a balanced supply of nutrients (see Section 3.8.3).
- Development of effective CA in the semi-arid to arid zones in the tropics, sub-tropics and temperate climates in view of their characteristic environmental limiting factors.
- The integration of livestock and mixed cropping into CA on small and medium holdings.

Research is sometimes undertaken and reported without regard to the need for results to complement each other in the actual field situations in which they are applied: e.g., "…best developments in weed-control research were not being incorporated into the [soil] fertility research, and the best results from the crop rotation research were not being incorporated into the tillage-systems research program" (Gan et al., 2008).

3.8.3 Inadequate research on nutrient management in CA systems

Research on Integrated Soil Fertility Management (ISFM) and Integrated Natural Resources Management (INRM) approaches of various types and nomenclature have been in vogue in recent years in certain sections of the scientific community. Generally, such approaches are focused more on meeting crop nutrient needs in terms of a simple nutrient balance accounting rather than managing soil health and land productive capacity as is the case with CA systems. Also, most of the work that is couched under the rubric of ISFM or INRM over the past 15 years or so has been institutionally geared towards tillage-based systems which have many unsustainable elements, regardless of farm size or the level of agricultural development. Unless the concepts of soil health and function are explicitly incorporated into ISFM or INRM approaches at the research institutional level, sustainability goals and means will remain only accidentally connected, and sustainable crop intensification will be difficult to achieve particularly by resource poor farmers (see Kassam and Friedrich, 2009).

CA systems have within them their own particular sets of ISFM or INRM processes and concepts that combine and optimize the use of organic with inorganic inputs integrating temporal and spatial dimensions with soil, nutrient, water, soil biota, biomass dimension, all geared to enhancing crop and system outputs and productivities but in environmentally responsible manner. There is empirical evidence to show that CA-based ISFM or INRM processes can work because of the underpinnings of soil health and function (Shaxson *et al.*, 2008).

Focusing on soil fertility but without defining the tillage and cropping system, as often proposed by ISFM or INRM approaches, is only a partial answer to enhancing and maintaining soil health and productivity in support of sustainable production intensification, livelihood and the environment. Over the past two decades or so, empirical evidence from the field has clearly shown that healthy agricultural soils constitute biologically active *soil systems within landscapes* in which both the soil resources and the landscape must operate with plants in an integrated manner to support the various desired goods and services (e.g., food, feed, feedstock, biological raw material for industry, livelihood, environmental services, etc) provided by agricultural land use.

CA systems aim at enhancing soil health and function as a precursor to sustainable production intensification. Nutrient management in CA must be formulated within this framework of soil health (Shaxson *et al*., 2008; Kassam and Friedrich, 2009). Thus, nutrient management strategies in CA systems would need to attend to the following four general aspects simultaneously, namely that:

> (i) the *biological processes* of the soil are enhanced and protected so that all the soil biota and microorganisms are privileged and that soil organic matter and soil porosity are built up and maintained;
> (ii) there is adequate *biomass production and biological nitrogen fixation* for keeping soil energy and nutrient stocks sufficient to support higher levels of biological activity, and for covering the soil;
> (iii) there is an adequate *access to all nutrients* by plant roots in the soil, from natural and synthetic sources, to meet crop needs; and
> (iv) the *soil acidity* is kept within acceptable range for all key soil chemical and biological processes to function effectively.

Consequently, research on successful nutrient management strategies as part of any ISFM or INRM approach must pay close attention to issues of soil health management which means managing the microscopic integrity of the soil-plant system particularly as mediated by soil living biota, soil organic matter, soil physico-chemical properties, available soil nutrients, adapted germplasm as well as to managing the macroscopic dimensions of landscapes, socioeconomics and policy. Given that CA principles and practices offer substantial benefits to all types of farmers in most agro-ecological and socio-economic situations, CA-based IFSM and INRM approaches to nutrient management and production intensification would be more effective for farmer-based innovation systems and learning processes such as those promoted through FFS networks (Kassam and Friedrich, 2009).

3.8.4 Gaps between governmental and non-governmental organizations.

A lack of effective liaison between government agencies and the private sector in providing support for the development of CA can result in government agencies failing to enlist the specialist technical assistance which may be available within relevant commercial enterprises. It could also result in the private sector being unaware of new commercial opportunities emerging from the development and spread of CA among both large and small farmers.

Many well-meaning NGOs do useful work in the field, but often without reference to one another's approaches and results, or without a mutual melding of approaches among themselves and between them and government agencies.

3.9 Restrictions on the Part of Non-Farmers

Preconceptions, hidden assumptions, prejudices, misapprehensions - particularly about (a) CA and (b) small farmers – inhibit acceptance by non-farm agriculturists (and others) of the potentials offered by CA. Some examples are given in the following sections.

3.9.1 Pervasive hidden assumptions

A dogmatic unwillingness/inability to accept that there may be other valid ways of perceiving the causes of a particular problem, or an uncommon outcome, etc. than one's own view alone, can prove a hindrance to progress in seeing the potentials of CA in any situation.

Fixation on the 'tillage paradigm' for crop production inhibits giving serious consideration to CA as a better alternative. The assumption that new technologies will minimise/remove all the problems of tillage agriculture inhibits consideration of the nature and causes of unsustainability of tillage agriculture.

Common assumptions that small resource-poor farmers are 'irrational,' 'ignorant', 'stupid' limits thinking and action about how best to engage with them, encourage and assist them to achieve better livelihoods, more effectively and rapidly. Not understanding small farmers' attitudes to risk, and in particular, their strategies for risk aversion, limits appreciation of their skills in survival.

The incorrect assumption that runoff and soil erosion are inevitable accompaniments of farming limits thinking and action to discover why, and what could be done about it. The common assumption that low soil fertility is mainly a problem of soil chemistry and applied mineral fertilizers hinders consideration of what else might be involved, and its relative significance.

New technologies that lead to immediate fast adoption often show obvious advantages resulting in fast acceptance and enthusiasm. In many cases this enthusiasm cools down, once the new technology is known and the downsides become visible. With CA it is just the opposite way: it contradicts so much of the knowledge a farmer has learned and been told that the benefits offered by CA are not obvious in the beginning. However, once the step-wise adoption begins, CA improves its performance over time. The more experience producers have with CA, the more convinced and positive is their opinion about it.

3.9.2 Misapprehensions

Inadequate knowledge about CA perpetuates the belief that 'Conservation Tillage', 'Minimum Tillage', or 'Zero-tillage' without adequate mulch-cover can have as much beneficial effect as CA with permanent complete soil cover on the soil.

The less practical experience people have with CA, the more critical and negative is their attitude towards it. A study carried out with European and American no-till farmers and agricultural experts came to similar conclusions. It was found that the experts, mostly without practical experience in CA, anticipated many problems for its adoption. In their perception actually the problems exceeded the benefits leading to an overall negative attitude. Farmers, however, who were actually practicing CA and had experience with the system, had an overall positive perception with the benefits clearly dominating and the problems being manageable (Tebrügge and Böhrnsen, 2000).

Building public awareness of CA and its practitioners is necessary to dispel such misapprehensions

3.10 Restrictions among Farmers

3.10.1 Resistance to change and fear of ridicule

"It is not part of our culture to do things differently". Particular agricultural practices may be strongly ingrained in a long-standing community, especially if the majority have little contact with outside sources of relevant information.

Among the farming community, there may be fear of a novel altered activity which could destabilize part or all of a common or traditional system of farming that has served reliably, at least for survival, over the generations to the present (we only meet the survivors).

Fear of ridicule by neighbours/peers can be a strong deterrent if a farmer seen to be trying something out of the ordinary in his farming. Thus, it is useful in such cases to ensure group and community involvement in the change process, to provide a sense of solidarity and purpose in common.

3.10.2 Range of perceptions

Within a farm-family, and/or among the wider community, there will likely be different perceptions of same item, situation or proposal, on the part of women, men, and children. One may want to innovate, another to be more cautious. A start in CA might therefore be delayed until a majority view in its favour emerges.

Motivations vary between farmers – e.g., from sheer survival on the one hand, to chiefly a profit motive on the other. Each would need to perceive a different ranking of the potential benefits of CA's various positive effects.

Where the local tradition is that the cattle and other animals of the local community are entitled to graze on all harvested fields as well as on common lands, there are likely to be conflicting views between traditionalists and those who would start CA on their croplands.

3.10.3 Insufficient persuasive evidence

If clear evidence of one or more benefits of CA cannot be provided and/or experienced, farmers are unlikely to begin to participate in moves to introduce CA.

If neighbours or outsiders (e.g., advisers, researchers) have not provided to a farmer first-hand experience of an innovation, other approaches may not have any more success.

"Strategies for the implementation of no-tillage should carefully consider that the results of various diffusion investigations show that most individuals do not evaluate an innovation on the basis of scientific studies of its consequences, although such objectives are not entirely irrelevant, especially to the first individuals who adopt. Instead most people depend mainly on a subjective evaluation of an innovation that is conveyed to them by other individuals like themselves who have previously adopted the innovation. This dependence on the communicated experience of near-peers suggests that the heart of the diffusion process is the modelling and imitation by potential adopters of their network partners who have adopted previously." (Rogers, 1983).

There is, as yet, not enough formal analysis of the monetary and non-monetary aspects of technical and agronomic improvements resulting from CA, which could provide further evidence to the unconvinced that CA is 'a good bet'.

3.11 Ecological Restrictions

Climatic conditions in the region
Annual expectations of distribution of rainfall, temperature variations, wind, evaporative demand, all impose basic limitations to what systems of agriculture and management (crops with or without livestock) are feasible and thus the preference and experience of the farmers. In particular places, some of these factors (especially rainfall) may be limiting to how much biomass could be produced per year which could be used as a complete mulch of organic matter. Rainfall amount, variability, and reliability at the particular site, as affected locally by e.g., local hills/mountains and altitude -- producing more rain on one side and rain-shadow on the other -- also exert limitations.

Soil type
Limitations on use may be imposed by unsatisfactory proportions of sand, silt and clay at different depths, because they affect (a) soil-structure's fragility/strength and compactibility; (b) permeability of subsoil (relative to rates of percolation through and below rooting-depth; (c) depth to root-limiting physical layer; (e) nature of limiting material; (f) potentially-limiting nutrient deficiencies in relation to composition of parent material of the soil. However, over the longer-term some of the soil differences, particularly below the top soil, become less significant in an agronomic sense as a protective living mulched horizon is formed at the soil surface.

Slope
Steep slopes restrict ease of management up/down-slope and cross-slope, as well as the speed and erosivity of any runoff that may occur. However, with CA much steeper slopes can be made

agriculturally productive than with tillage farming, as runoff and erosion is avoided and infiltration rates are high in CA systems.

Severity of past soil erosion
Past misuse of the land may have resulted in a severely-eroded topsoil layer which limits productivity, and indicates the difficulties of remediation before CA can have fullest effect. How severely dissected the land is by erosion-gullies also restricts options for use and their management.

Wetness
If the water-table is near the surface, this limits the choice, rooting-depth and success of dryland crops in the rotation.

3.12 Addressing the Restrictions

The key issue related to the above-discussed restrictions were considered by an international soil health workshop held at FAO in Rome in July 2008 and addressed in a *Framework for Action* (FAO, 2008a), identifying options to accelerate the participatory adaptation and large-scale uptake, wherever appropriate, of CA systems in forms fitted to the diversity of local conditions and constraints. In these ways it would be possible to safeguard the world's capacity to produce a sustainable supply of food and other farm products for its future population, while at the same time providing farmers with sustainable livelihoods

It was agreed by the workshop delegates that this acceleration will require nothing short of a revolution in the way farmers, their advisers, scientists and those who influence farming policies think about, decide and act regarding soil and crop management. The main focus of this Framework is, therefore, on defining the processes needed to induce and support this paradigm shift. The potential for improvement through the paradigm shift is discussed in Section 4, and their relevance, availability and effects for small-scale farmers are discussed in Section 5.

4. TECHNICAL POTENTIALS FOR IMPROVEMENTS

There are two overall approaches to agriculture: conventional tillage and CA.

Conventional tillage agriculture is characterised by fields without a permanent cover of organic matter. There is a tendency towards monoculture rather than rotations which restore the underlying health of the soil. The nutrients chiefly come from externally applied fertilisers, and pest control is primarily through the use of chemicals.

CA does not use tillage, resulting in fully-covered field surfaces all year round. Diverse crops are grown, including cover crops, and pest control primarily occurs via biological means such as natural predators. Mulch is a key component of conservation agriculture, contributing protection to the soil surface, improving soil porosity which makes water more readily available, and providing a source of energy and nutrients to the soil biota.

The basic premise of CA – by contrast with conventional tillage agriculture – is that no matter how good are the technologies which are added to the soil to improve agricultural outputs, those technologies will not enable plants to reach their full genetic potential unless they can contribute to sustained improvements in the soil ecosystem's overall health and its ability to provide a good rooting environment. A characteristic of CA is that it focuses on the health of the soil/plant ecosystem as the source of soil productivity and other key benefits. In doing this it integrates the different disciplines which conventional tillage sees as separate.

The ways soils have most commonly been treated by the large majority of both large and small farmers up to the present have resulted in losses of productive potential and of biologically-based sustainability. The loss of sustainability is not widely recognised, and tillage agriculture has, to date, offered no way forwards to deal with this decline in soils' productive capacity. There is an intention to '*switch to modern farming practices* (Kaumbutho and Kienzle, 2007*)* – but what does this mean? What should constitute modern farming practices – high cost tillage agriculture which has relied in land becoming less and less fit for purpose across the tropics (a possible risk even in the UK, see Chamberlain, 2008) and which relies on a constant need for external inputs such as water and fertiliser? Or, the more benign alternative paradigm of CA?

Before going further, it is worth noting that not everyone shares the same perception of the problems:

4.1 Problems Addressed

4.1.1 Differing perceptions

International and national level perceptions:
At international and national levels, agriculture is now being presented as the main rural development tool, e.g., "….reforms are essential for Kenya to shift from subsistence to market production and to ensure that agriculture will again become the main engine of economic growth while eliminating hunger and poverty" (Kaumbutho and Kienzle, 2007). Governments' intentions are based on wanting economic expansion, food security, environmental improvements etc., and economic 'levers' are being used to achieve it, on the assumption that small farmers can be cajoled into farm improvements for national reasons, and in so doing gain some benefits for themselves. To date this has not been a markedly successful strategy.

Perceptions at community level:
Community level concerns relate to broad issues such as food supplies, water supplies, and local/municipal budgets – problems not commonly linked jointly with farming activities. In particular, communities will be concerned with more-frequent shortages of locally-produced foods and higher purchase-prices of foodstuffs etc. in the market, because of scarcities. A key concern is also more-frequent damage to infrastructure by flood-waters which are beyond bridges' designed capacity and which result in washed out roads. Flooding may also be deeper and more frequent yet river-flow may be more erratic accompanied by a falling water-table, declining yields from of wells and of boreholes unless they are deepened. Eroded sediment from these floods chokes roads, channels, public spaces and harbours. Water supplies are increasingly polluted by sediment, agro-chemicals and biological pathogens; and require more and expensive treatment to make it of fit quality for domestic use. Municipalities' budgets are often stretched or diverted by the need for this additional repair work.

Perceptions at farm-family level:
Different farmers, according to their circumstances, are primarily motivated by different combinations of profitability and livelihood security. This affects what each considers to be an appropriate ranking of his/her priorities, but the list comprises:

- Increased incidence of weeds, pests, diseases.
- Soil quality declines: it is harder to get a good tilth for planting seeds and more energy is needed to get the soil into the supposed required condition.
- Crops show drought's effects sooner, and for longer than formerly expected.
- Declining cover to soil by sparser crop plants, which results in surface crusting and runoff, representing loss of potential water for crops.
- Erosion of soil, seeds and fertiliser, representing loss of topsoil's multiple characteristics, and wastage of expensive energy and inputs.
- Increasing food-insecurity.

On the one hand falling productivity results in less output per unit of input – (such as effort, fuel, seeds) and this is made worse by rises in input prices. On the other hand, farmers need increasing inputs to produce a unit of output, and this is made worse by unfavourable weather conditions. The net result is falling profitability, calculated as the difference between income and costs.

Changing perceptions
"Tillage agriculture has been the norm for hundreds of years. A change to the new production system without tillage requires a radical mental change…… This applies not only to farmers but to researchers, extension agents and politicians as well. Mindset is probably the biggest obstacle to no-till adoption in most parts of the world" (Derpsch, 2008a). However, Baker *et al.* (2007) report that farmers have said that CA "puts the fun back into farming".

4.1.2 Reduced productive capacity of agricultural soils

The decline in productivity results from on-farm ecosystems (which include both plants and soil-inhabiting biota), losing their capacity to revive themselves on a recurring basis. Such productivity decline is caused by techniques which result in the soil being exhausted by over-use more quickly than it can regenerate itself. This is a direct effect of tillage for two reasons. First, tillage damages the soil's naturally-occurring physical structure which results in a loss of porosity and water-holding capacity. Second, tillage causes excessively-rapid oxidation of organic matter and this reduces its positive physical and chemical benefits for plant growth.

The net causes of this productivity decline can be seen in the following areas: water availability at the farm level and landscape scale, soil fertility decline, soil erosion, soil compaction, loss of biodiversity.

(i) *Water availability at the farm level*: At the farm level, rainwater does not necessarily penetrate impermeable soils, because of crusting or compaction. Crusting results in surface run-off, and compaction (a) reduces the size of the soil pores so that the plant roots are hindered in penetrating to depth, and (b) results in quicker water-saturation of the uppermost layers, with consequent surface runoff. Even when water is able to penetrate soil, however, it may well be held at tensions which make it unavailable to plants. For example, although a clay soil may hold a great deal of water, the small size of the pores between the soil particles means that the surface tension of the water is too great for the plants to extract it. Thus the effects of drought stress will be seen earlier than if the plants were grown on a soil in better condition.

(ii) *Water availability at the landscape level:* If water does not permeate the soil, then underground water sources are not recharged. Water which runs off the surface will run quickly down slopes and effectively be 'lost' for use by plants. Water which penetrates down to the groundwater moves very much more slowly before it emerges again in springs and rivers. The balance between these two processes affects river flow, groundwater availability, the severity of floods and the duration and volume of dry season stream flow. It also affects the quality of water in the aquifers and thence in rivers, lakes and other water bodies.

(iii) *Soil productivity decline:* Conventional tillage generally needs to use more inputs per unit of output to maintain yield levels, making it increasingly difficult to maintain an economic yield from farming. Among the reasons for this loss in productivity are:

- Loss of soil porosity impedes not only the movement of water but also of root-respiration gases (O_2, CO_2);
- Soil compaction reduces the extent of root exploration;
- The accumulation of organic matter below ground is sharply reduced. This reduces the soils' capacity to capture, retain and slowly release plant nutrients throughout the growth period. Sporadic applications of fertiliser are an inefficient use of the resource as the rate of release of nutrients does not match the rate of their requirements by the growing plants (Bunch, 2008).
- Plants become less resilient to adverse weather conditions because:
  - There is less plant-available water;
  - There is less of slow-released nutrients from the diminished soil organic matter;

(iv) *Soil erosion*: Caused by wind or water, soil erosion can result in the loss of topsoil, seeds and any fertilisers that have been applied. Erosion may become so severe that it is impossible to easily work the field surface, and farmers may need to entirely replant and re-fertilise the damaged area – involving further waste of energy and other resources.

(v) *Soil compaction*: This is caused by repetitive pressure on the soil – by feet, by hand-held implements such as hoes, and by large-scale equipment such as disc ploughs and traffic of heavy machinery. The severity and extent of soil compaction worldwide is not widely comprehended, but it contributes to inefficient use of water (see above) and a higher amount of tillage energy to achieve the same result.

(vi) *Loss of biodiversity:* Farming systems with inadequate rotation give rise to far simpler soil ecosystems than occur under more varied cropping patterns. As this occurs, there will be fewer species whose role it is to break down organic matter into its constituent materials such as nutrients. These simplified soil ecosystems also offer plants less resilience against pests and diseases.

4.1.3 Falling profitability of farming

As organic matter declines, responses to external additions of nutrients become less effective over the lifetime of the crop and uptake is also limited by drought-induced water-stress in the plants. Yields thus become less stable from year to year than under a regular climatic regime, and swings are worse if climate becomes more aggressive. As soil becomes less suitable as a rooting medium, the costs of maintaining the benefit:cost ratio (an expression of the ratio between yields and inputs) rises. This in turn reduces the margin between costs and income from level yields. Thus in terms of output per unit of input (energy, chemicals, seeds) the efficiency of their use declines, and the farm becomes less economic (Shepherd, 1992).

In commercial tillage-agriculture farmers can purchase equipment and energy (in fuels) to attempt to simulate optimum soil conditions. They can purchase chemical formulations of plant nutrients but not the slow-release capacity which resides in the characteristics of biotically-transformed organic matter. Neither this added energy or the added nutrients produce satisfactory simulations, and the rising costs involved in trying to maintain the soil condition are superficially hidden within the broader economics of the farming enterprise. As soil's physical condition and the biotic characteristics of its health declines, the costs of any attempts at remediation rise under the tillage-agriculture paradigm.

4.1.4 Poor adaptation to climate change

Climate change due to global warming shows tendencies to make weather swings more extreme. For example, more-intense rainstorms may occur from which larger proportions of incident rainfall run off the soil surface rapidly, especially if the soil is in poor physical condition. This runoff accumulates along stream-lines and rivers into rising floods downstream. Also, hotter drought periods, which increase evapotranspiration rates from vegetation, hasten the exhaustion of soil-water. Its unavailability to plants then induces stress and the visible severity of effects of drought. Thus at the same time as climate change induces more extreme weather swings, soils are becoming less able to counter those effects. Conservation agriculture has been widely demonstrated to reverse the decline in soil conditions and increase resilience of crops by diminishing onset of stress conditions. CA addresses the problems associated with drought and flood by generating a net increase in organic matter, enhancing the self-recuperative activity of soil biota and the associated improvements in soil porosity.

4.2 Technical Organisational Solutions

4.2.1 CA as a fundamental change in the agricultural production system.

Conservation agriculture is a means of reproducing plants and water recurrently and sustainably from landscapes and the soils which cover them. It does this by favouring improvements in the condition of soils as rooting environments. CA is not a single technology, but one or more of a range of technologies that are based on one or more of the three main *c*onservation agriculture principles):

- Reducing the intensity of tillage, or elliminating it altogether.

- Covering the soil surface adequately – if possible completely and continuously throughout the year.
- Diversifying crop rotations, which should include leguminous plants (Triomphe et al., 2007).

CA functions best when all three key features are adequately combined together in the field: (a) permanent complete cover of organic materials such as crop residues, on the soil surface; (b) minimal disturbance of the soil once it has been brought to good condition, with seeding/planting made through the mulch cover; (c) crop rotations/sequences which include N-fixing legumes. It is significantly different from conventional tillage agriculture in that, ideally:

- It avoids tillage once already-damaged soil has been brought to good physical condition prior to initiating the CA system.
- It maintains a mulch cover of organic matter on the soil surface at all times, for providing both protection to the surface and substrate for the organisms beneath.
- It specifically uses sequences of different crops and cover-crops in multi-year rotations;
- It relies on nitrogen-fixing legumes to provide a significant proportion of that plant nutrient - which is needed for biomass production of crops and cover-crops.

CA also relies on liberating other plant nutrients through biological transformations of organic matter. This can be augmented as necessary by suitable artificial fertilizers in cases of specific nutrient deficiencies; but organic matter also provides micronutrients that may not available ‘from the bag’.

CA can retain and mimic the soil’s original desirable characteristics (‘forest-floor conditions’) on land being first opened for agricultural use. Throughout the transformation to agricultural production CA can sustain the health of long-opened land which is already in good condition; and it can regenerate that in poor condition (Doran and Zeiss, 2000). CA is a powerful tool for promoting soil – and thus agricultural - sustainability.

The above mentioned multiple effects of CA when fully applied together are illustrated in Table 2.

By contrast with conventional tillage agriculture, CA can reverse the loss of organic matter, improve and maintain soil porosity and thus prolong the availability of plant-available soil water in times of drought. It can also reduce pest and disease incidence by biological means, raise agro-ecological diversity, favour biological nitrogen fixation, and result in both raised and better-stabilised yields accompanied by lowered costs of production. Furthermore, CA is a major opportunity that can be explored that can be exploited for achieving many objectives of the International Conventions on combating desertification, loss of biodiversity, and climate change (Benites *et al*., (2002).

Table 2: Effects of CA components fully applied together

CA COMPONENT ► TO ACHIEVE ▼	MULCH COVER (crop residues cover-crops, green manures)	NO TILLAGE (minimal or no soil disturbance)	LEGUMES (as crops for fixing nitrogen and supplying plant nutrients)	CROP ROTATION (for several beneficial purposes)
Simulate optimum ‘forest-floor’ conditions	√	√		
Reduce evaporative loss of moisture from soil surface	√			
Reduce evaporative loss from soil upper soil layers	√	√		
Minimise oxidation of soil organic matter, CO_2 loss		√		
Minimise compactive impacts by intense rainfall, passage of feet, machinery	√			
Minimise temperature fluctuations at soil surface	√			
Provide regular supply of organic matter as substrate for soil organisms’ activity	√			
Increase, maintain nitrogen levels in root-zone	√		√	√
Increase CEC of root-zone	√		√	√
Maximise rain infiltration, minimise runoff.	√			
Minimise soil loss in runoff, wind	√			
Permit, maintain natural layering of soil horizons by actions of soil biota	√	√		
Minimise weeds	√	√		√
Increase rate of biomass production	√	√	√	√
Speed soil-porosity’s recuperation by soil biota	√	√	√	√
Reduce labour input		√		
Reduce fuel-energy input		√		
Recycle nutrients	√			
Reduce pest-pressure of pathogens				√
Re-build damaged soil conditions and	√	√	√	√

Interdependence of the macroscopic benefits from CA and the microscopic features of the soil it has improved:

It is important to recognise that the improvements seen at **macro-scale** (e.g., yields, erosion-avoidance, water supplies and farm profitability), are underlain and driven by essential features and processes happening at **micro-scale** in the soil itself.

“Widespread adoption of CA has been demonstrated to be capable of producing “large and demonstrable savings in machinery and energy use, and in carbon emissions, a rise in soil organic matter content and biotic activity, less erosion, increased crop-water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the apparently increased volatility in weather associated with climate change. It will cut production costs, lead to more reliable harvests and reduce risks especially for small landholders. … ”(FAO, 2008a).

CA as the fundamental basis of soil system ‘sustainability’:
The key feature of a sustainable soil ecosystem is the repetitive biotic actions on organic matter in suitably-porous soil. This occurs under CA’s conditions of management which continually maintain the organisms’ living conditions, including soil aeration. This means that under CA, soils become *potentially self-sustainable*. Activities which damage this capacity for self-sustainability by, for example tillage and/or compaction, therefore prejudice future profitability, environmental integrity and ongoing productive capacity.

4.2.2 The importance of involving the farmers

CA principles can be applied in many forms of agricultural practice. Because CA comprises several principle-based technologies rather than a single, prescriptive approach, farmers can choose the tools they judge to be most appropriate for them. Assisting farmers to improve the husbandry of land with CA must start with a thorough understanding of the present situation, of which the farmers themselves have the most detailed knowledge (FAO, 2001a). Therefore from the outset *they* must be the deciders of what is to happen. Farmers must be the principal point of focus, rather than the focus being on the land on its own, as they make the ongoing decisions about how the land will be used and managed. In spite of the fact that projects and field teams may tend to focus on technical issues within CA such as tillage, cover crops, weed control and implements at the field scale, sufficient attention needs also to be given to non-technical issues, such as rural finance, marketing and value-chain development, organizational or policy issues.

Though the principles of CA remain the same in all situations, how they can be best applied depends on how individual farm families make decisions. This depends on how each farm family responds to specific combinations of:

- Environmental conditions, such as
    - temperature regime and variations
    - rainfall expectations
    - soil types and condition, and historical trends in productivity;
- Farmers’ resource-availability, including:
    - land area;
    - availability and types of finance;
    - sources of farm-energy, such as manual/animal-power/fuel-powered machinery;
    - skills and knowledge

    - assessments of risks.
- Production system
    - Type of farming system (crops/livestock/mixed) and whether the system is rainfed or irrigated;
- Market opportunities and transport availability
- Support, encouragement, guidance, from
    - farmer groups;
    - formal 'extension' programmes;
    - policies, laws.

Farmers can be ingenious in problem-solving, and if they pick up information about CA from friends and other acquaintances, they may well innovate and adapt the method to their own conditions. Because of its flexibility and multiple options, CA is a system that can trigger the innovative creativity of farmers.

4.2.3 Importance of farmers' organizations

Farmers tend to believe their trusted peers more than their formal advisers when discussing the advantages and disadvantages of a new technique, approach, or tool. Making it easy for them to interchange ideas and experiences will help strengthen their own linkages and reinforce recommendations.

Interested farmers may have already coalesced into informal groups with common interests. Such groups can form the basis for Farmer Field Schools (FFS), with guidance from well-trained advisory staff, for purposes of regular experimenting and 'learning by doing'. Farmer groups, which may also form themselves into Associations, Federations, and/or Co-operatives, derive confidence from mutual support and exchange, from training together, from working together to reach goals such as joint actions towards environmental improvements. On the one hand, small informal groups of farmers may evolve and develop into co-operatives and larger bodies. On the other hand, if such bodies already exist, they may embrace the CA ethic and actions, and draw in new members. Such groups and organisations also develop bargaining power with buyers and sellers, traders, transport agencies, and others: and this benefits all the members of the group. If sufficiently well-organised, they may be able effectively to pressure government for necessary reforms to aid the CA cause. The development of such groups can then become a powerful means of encouraging others to join, and benefit from, the movement towards getting CA established among increasing numbers of farmers and across ever-larger areas of land.

4.2.4 Role of scientists and extension/advisory agents

Appropriate roles for scientists in support of CA are: (a) to respond to unsolved technical problems, (e.g., cover crops for different situations); (b) explore new potentials and possibilities based on what is already known and observed; (c) clarify basic soil conditions re the significance of organic-matter's effects and related interactions with respect to soil productivity and its changes over time under different treatments; (d) 'blue-sky' exploratory research with possible relevance to CA. These lines may be at odds with the conception that fancy new techniques are the main route to solving old problems.

Advisory staff may need to be trained as facilitators of knowledge-expansion and information-exchange, of problem-solving, as travel-agents for study visits and interchanges, and of linkages between farmers and their groups with service-providers, and with government. They can bring in knowledge from outside, act as ‘Yellow Pages’ sources of information, as guides to introduction of helpers.

There is always a need for good linkages and feed-back loops to be developed and maintained, in both directions, between researchers, advisory/facilitating staff, and farmers, so that all sides can remain well-informed about needs of the farmers, results of research, and of possibilities to be explored.

4.2.5 Importance of policy support for rapid up-scaling: the example of Kazakhstan

The capacity of CA specifically to address the improvement of sustainability – through its biological components – should spur innovative thinking and action at government levels in the search to revitalise agriculture on all degraded lands of any degree, where increasing expenditures are required just to maintain yields at a level average. While farmers would adopt CA due to its benefits, there are certain hurdles which keep farmers from doing this step or which slow down the adoption process considerably. Government policies play an important role for the adoption process. Uncoordinated policies between government sectors, for example making access to new equipment impossible or expensive, or crop-related subsidies work against the adoption of CA, while supportive policies can accelerate the adoption process dramatically. A good example for this is Kazakhstan.

CA has been promoted in Kazakhstan for some time by CIMMYT and FAO which introduced Conservation Agriculture through a project from 2002 to 2004. CA has had an explosive development in recent years as a result of farmers taking keen interest, enabling and facilitating government policies, and an active input supply sector. While the total CA area in the country in 2004 was below 1000 ha, it grew until 2007 to 600,000 ha and in 2008 to 1.3 million ha, placing Kazakhstan in only 4 years among the top ten CA adopting countries in the world. Besides a general policy support for CA, which encouraged public and private extension services to take up this message, the government provided initial subsidies for locally produced herbicides to decrease the initial costs and credit lines for purchasing no-till seeding equipment to overcome problem of capital availability for investment. Further, the country was open for importation of no-till seeding equipment, despite having one of the main seed drill manufacturing facilities from the Soviet times (see also Section 4.4.2 and Figure. 2 below).

4.3 Important Differentiations

4.3.1 By global regions, major cultivation conditions and farming systems

CA production systems are experiencing increasing interest in most countries around the world. There are only few countries where No-tillage is not practiced by at least some farmers and where there are no local research results on the technology available. CA has expanded to soils and climates earlier thought inadequate for practicing No-tillage successfully. It is now being practiced by farmers from the artic circle (e.g., Finland) and over the tropics (e.g., Kenya, Uganda) to about 50º latitude South (e.g., Malvinas/Falkland Islands); from sea level in several countries of the world to 3000 m altitude (e.g., Bolivia, Colombia); from extremely dry conditions with 250 mm a year (e.g., Western Australia), to extremely rainy areas with 2000 mm a year (e.g., Brazil) or 3000 mm a year (e.g., Chile). No-till farming is practiced on all kind of farm sizes from half hectare (e.g., China, Zambia, Tanzania) to hundreds of hectares in many countries of the world, to many thousands of hectares (e.g., Australia, Brazil, USA, Kazakhstan). CA is practiced on soils that vary from 90% sand (e.g., Australia), to 80% clay (e.g., Brazil's Oxisols and Alfisols). Soils with high clay content in Brazil are extremely sticky but this has not been a hindrance to adoption of no-till and other CA practices when appropriate equipment was available. Soils which are extremely sensitive to crusting do not present this problem under CA because the mulch cover and the soil biological processes avoid the formation of crusts. CA has even allowed expansion of agriculture to soils considered marginal in terms of rainfall or fertility (e.g., Australia, Argentina). All crops can be grown adequately under CA and to the authors knowledge there has not yet been found a single crop that would not grow under this system, including root crops. Equally CA is applicable not only to rainfed agriculture, but it can also be adapted to all irrigation practices, including furrow and flood irrigation, to agroforestry and plantation systems and also crop-livestock systems (see Sections 1.10 and 4.3.2). In the case of irrigated systems, special care for the residue management is required and in case of the furrow irrigation systems the bed-and-furrow arrangements are established as permanent beds on which all rotation crops, including rice and other cereals, are grown.

The wide range of conditions where CA is working successfully all around the world, its economic, social and environmental advantages as well as the recognition as a truly sustainable farming system should ensure the expansion of this technology to areas where adoption is still small as soon as the barriers for its adoption have been overcome. The main barriers to its adoption continue to be: knowledge on how to do it (know how), mindset (tradition, prejudice), inadequate policies as commodity based subsidies (EU, US), availability of adequate machines (many countries of the world) and availability of suitable herbicides to facilitate weed management (especially in developing countries) (see Section 3). These barriers must be overcome not only by farmers but also by researchers, extension workers, university professors, politicians and all stakeholders involved in the farming industry if a greater adoption is aimed to be achieved. The widespread adoption of CA under a great range of different conditions on more than a 100 million ha world wide shows that the system can be made to work and function it is only a matter of a firm determination to do so, after recognizing the superiority of this system in relation to unsustainable intensive tillage practices.

4.3.2 By specific cropping systems

This section only covers a selection of some cropping systems which at first glance do not seem to fit into the CA system, while the standard rainfed grain crop systems appear the easiest way to apply CA.

Irrigated systems: For irrigated systems CA carries the additional advantage of shorter turnover times between subsequent crops and reduced water consumption, reducing irrigation costs and increasing efficiency. For technical irrigation systems, be it drip, micro or sprinkler irrigation, CA carries the advantage that major parts of the irrigation system can be buried in the soil without the danger of being damaged by tillage operations. Surface irrigation systems require some care in the residue handling, stubble length and water management to avoid movement of the residues with the irrigation water. For furrow irrigation permanent bed systems have been successfully adopted in several countries, such as Mexico, Bangladesh, Pakistan and others. A major advantage of CA in irrigated farming is the reduction of the salinity problems especially in arid areas. The permanent mulch cover avoids the evaporation of water which on bare soil leads to the accumulation of salts on the soil surface. In addition to this act the organic acids of the decomposing mulch to reduce the pH values at the soil surface facilitating germination of the crops. These effects could even be observed under extreme conditions, for example in the Aral Sea area with an annual rainfall of about 100 mm and extremely saline irrigation water.

Irrigated Wetland Rice: Irrigated rice was long time considered a stable sustainable system, where the puddling of the soil, i.e., the total destruction of the structural integrity of the soil and a permanent flooding was considered necessary. In many Asian countries the water consumption of paddy rice growing is becoming increasingly unsustainable. Under a CA system the rice would equally be grown without any tillage and puddling. The rice is be directly seeded with no-till seeders or transplanted into the soaked but untilled soil. The conventional hardpan under the rice paddies, which avoids water seepage, is disappearing, allowing better root growth. This requires changes in the water management. The rice is not anymore permanently flooded, but just irrigated according to the needs. Weed management is changed as well and counts on residue cover instead of standing water. The effect is a better root development of the rice leading to higher yields, equally higher yields of any other crops grown in rotation with the rice, lower water consumption and a reduction of the green house gas emissions from rice. This system of rice growing is already successfully applied by farmers in China and DPR Korea.

Root and tuber crops and other crops growing under the soil: All root crops develop, like other crops, better in undisturbed well structured soil. Crops like sugar beet or cassava are more regularly shaped and have less soil sticking to them at harvest time. Those crops multiplied by seeds are seeded with normal precision no-till planters. Others, like cassava, are just buried in a planting hole or slot. The main problem for this kind of crop is not the seeding and planting, but the harvest with low soil movement. Preferable are techniques which pull the crop out of the soil, which are available for most root crops, including crops like peanuts. Eventually under difficult soil conditions a cutting blade is required which passes through the soil under the root crop to facilitate the pulling with minimum soil disturbance. Other tuber crops like potatoes can be grown completely on top of the soil without any necessity to disturb soil for the harvest. To avoid greening of the potatoes the crop is covered with a thick mulch cover or a black plastic. This technique is successfully applied in DPR Korea by several potato farms.

Shifting agriculture: This system, also referred to as bush fallow rotation or slash and burn, is based on the clearing of land to prepare a cultivation plot and subsequently abandoning this to re-growth and eventual natural reforestation. It is a stable form of agriculture under low population-density regimes, but rising population density decreases re-growth time available for forests and leads to this system becoming unsustainable. Some shifting agriculture has evolved into sophisticated agroforestry management systems while in others it continues to be practiced in response to poor land tenure policies. Shifting cultivation can be adapted to CA, changing from slash and burn systems to slash and mulch systems.

Agroforestry: Agroforesty systems involve the growing of woody perennials and annual crops together in a sustainable manner in most ecologies, and it is increasingly practiced in degraded areas with perennial legumes. The practice brings environmental benefits through soil protection and efficiency of utilization of water and soil nutrients. It also creates a wider diversity of environments for wildlife and other fauna. Local knowledge concerning utility of native species could be mixed with scientific information to develop future agroforestry farming systems. A particular advantage of CA in agroforestry systems is the better compatibility with tree and field crops since the tree roots cannot be caught by ploughs or deeper-reaching tillage implements.

Agropastoral systems: These represent a variety of systems suited to resource-poor or degraded areas and can impact severely on the resource base through overgrazing. Under these conditions the integration of crops in so called “crop-livestock” systems is successfully applied in Brazil and Argentina to recover degraded pasture lands with a rotation into no-till field crops for a couple of years. No-till cropping allows not only the inclusion of pasture or forage crops into the rotation where under traditional tillage-based systems the time would be too short to grow any additional crop, but they also allow integrating into the crop rotation areas which are considered permanent pasture and not suitable for “arable” farming, for example due to erosion risks.

Plantation systems: These include crops such as tea, coffee, cocoa, oil palm, timber and rubber, or olives, vineyards, fruit orchards. These plantation-based systems all benefit equally from CA principles. Using cover crops as soil cover and mulch improves the microclimate, water balance, soil fertility and can also help with pest and disease control.

4.4 Achievable Effects

4.4.1 Higher productive capacity of soils

As an effect of CA, the productive potential of soil rises because of improved interactions between the four factors of productivity: (a) hydric: more water available; (b) biotic: more organisms, organic matter and its transformation products; (c) chemical: raised CEC gives better capture, release of inherent and applied nutrients: greater control/release of nutrients; (d) physical: better characteristics of porosity for root growth, movement of water and root-respiration gases.

No-till, or a reduced proportion of the area needing tillage (e.g., planting basins, or ‘zai/tassa’), requires less input of energy per unit area, per unit output, and lower depreciation-rates of equipment than formerly. It involves lower production costs, thereby increasing the profit margin, at the same time as lessening emissions from burning of tractor-fuel.

4.4.2 Higher yields and incomes

The combination of features which raises productive potential makes the soil a better environment than before for the development and functioning of crop-plants’ roots. Improvements in the soil’s porosity has two major positive effects: (a) a greater proportion of the incident rainfall enters to the soil; (b) the better distribution of pore-spaces of optimum sizes results in a greater proportion of the received water being held at plant-available tensions. Either or both together mean that, after the onset of a rainless period, the plants can continue growth towards harvest - for longer than would previously been the case - before the soil water is exhausted. In addition, increased quantities of soil organic matter result in improved availability, and duration of their release into the soil water, of needed plant nutrients – both those within the organic matter and those applied 'from the bag'. Thus the availability of both water and plant nutrients is extended together. Under these conditions, plants have a better environment in which to express their genetic potentials, whether they have been genetically-engineered or not.

"Machinery and fuel costs are the most important cost item for larger producers and so the impact of CA on these expenditure items is critical. Most analyses suggest that CA reduces the machinery costs. Zero or minimum tillage means that farmers can use a smaller tractor and make fewer passes over the field. This also results in a lower fuel and repair costs. However, this simple view masks some complexities in making a fair comparison. For example, farmers may see CA as a complement to rather than as a full substitute for their existing practices. If they only partially switch to CA (some fields or in some years), then their machinery costs may rise as they must now provide for two cultivation systems, or they may simply use their existing machinery inefficiently in their CA fields". (FAO, 2001b)

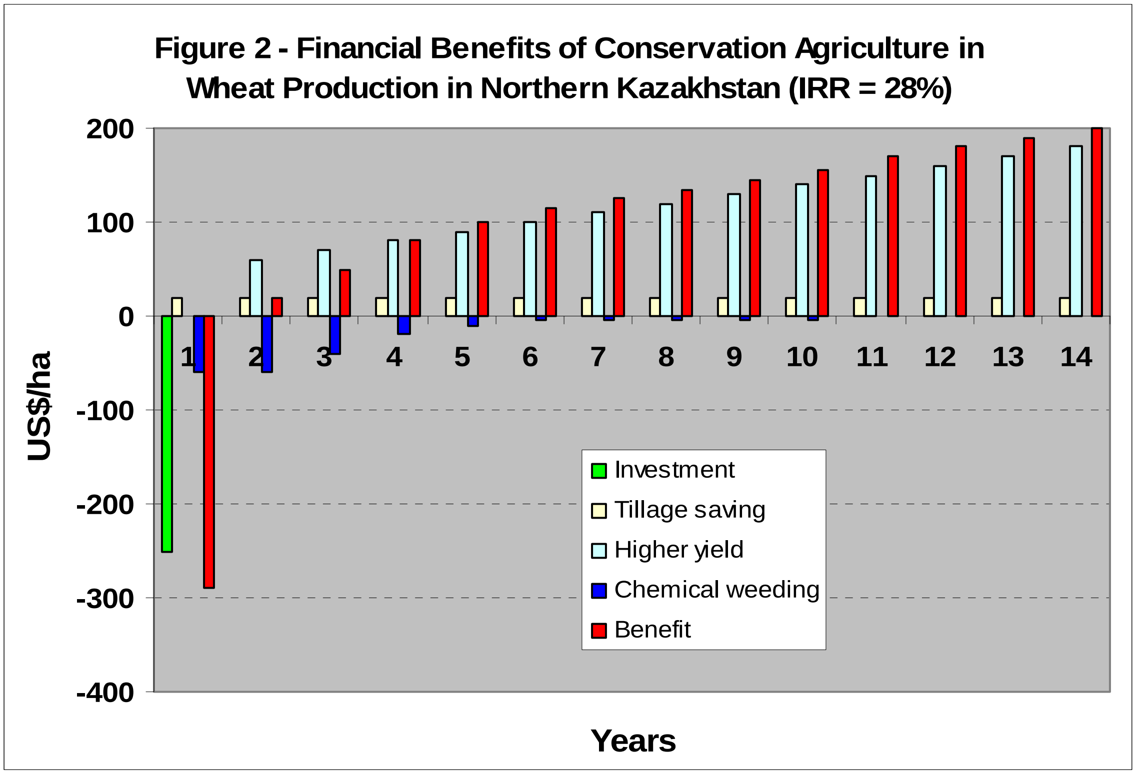
Better soil protection by mulch cover minimises both runoff volumes and the scouring of topsoil carrying with it seeds and fertilizers. Such losses represent unnecessary cost, wasted rainwater and wasted energy. Their avoidance increases the margin between profits and costs, which formerly, under tillage agriculture, were accepted as 'normal' expenses to be anticipated.

Systems are less vulnerable to pests, diseases, drought effects because better soil conditions include also greater biotic diversity of potential predators on pests and diseases, while crop rotations break pest build-ups. Here, much of the cost of avoiding or controlling significant attacks is diminished because of it being undertaken by natural predators.

As a result, the financial benefits for farmers in Latin America who have adopted CA have been striking. However, these take time to fully materialize. Sorrenson (1997) compared the financial profitability of CA on 18 medium and large-sized farms with conventional practice in two regions of Paraguay over ten years. He found that by the tenth year net farm income had risen from the CA farms from under US$10,000 to over US$30,000, while on conventional farms net farm income fell and even turned negative. Medium and large-scale farmers have experienced:

- Less soil erosion, improvements in soil structure and an increase in organic matter content, crop yields and cropping intensities.
- Reduced time between harvesting and sowing crops, allowing more crops to be grown over a 12-month period.
- Decreased tractor hours, farm labour, machinery costs, fertilizer, insecticide, fungicide and herbicide, and cost savings from reduced contour terracing and replanting of crops following heavy rains.
- Lower risks on a whole-farm basis of higher and more stable yields and diversification into her cash crop"(FAO staff, 2001a).

Such effects are cumulative over space/area, and accumulate over time from degraded condition to improved stabilised condition, with yields and income rising over time, as in this example of large-scale wheat production under CA in Kazakhstan Figure 2 shows the development of wheat yields and financial benefits after changing from conventional tillage to Conservation Agriculture on mechanised farms in northern Kazakhstan, IRR=28% (Fileccia, 2008).



Thus, farmers should turn away from the struggle to reach the highest yield. Instead they should struggle for the highest economic yield (Derpsch, see Section 6.2). Figure 2 indicates that CA can achieve that goal. Further, in Paraguay, yields under conventional tillage declined 5-15 percent over a period of ten years, while yields from zero-tillage [CA] increased 5-15 percent. Over the same period, fertilizer and herbicide inputs dropped by an average of 30-50 percent. In Brazil, over a 17-year period, maize and soybean yields increased by 86 and 56 percent, respectively, while fertilizer inputs for these crops fell by 30 and 50 percent, respectively. In addition, soil erosion in Brazil decreased from 3.4-8.0 t/ha under conventional tillage to 0.4 t/ha under no-till, and water loss fell from approximately 990 to 170 t/ha (Derpsch, 2008a).

4.4.3 Climate change adaptation and less vulnerability

Less vulnerability to effects of drought, less erosion, lower soil temperatures, represents a managed adaptation to climate-change's effects of, for example, more intense rainstorms, increased daily ranges of temperatures, and more severe periods of drought.

Good mulch cover provides 'buffering' of temperatures at soil surface which otherwise are capable of harming plant tissue at the soil/atmosphere interface, thus minimising a potential cause of limitation of yields. By protecting the soil surface from direct impact by high-energy raindrops, it prevents surface-sealing and thus maintains soil's infiltration-capacity.

4.4.4 Reduced greenhouse gas emissions

No-till farming also, and most importantly, reduces the unnecessarily-rapid oxidation of organic matter to CO_2 which is induced by tillage. Together with addition of mulch as a result of saving crop residues *in situ*, there is a reversal from net loss to net gain of carbon in the soil, and the commencement of long-term processes of carbon sequestration.

Making use of crop residues represents retention of much of the atmospheric C captured by the plants. Some becomes transformed to soil organic matter of which part is resistant to quick breakdown, (though still with useful attributes in soil), and represents net C-accumulation in soil, eventually leading to C-sequestration. Tillage however results in rapid oxidation to CO2 and loss to the atmosphere. Expanded across a wide area, CA has potential to slow/reverse rate of emissions of CO2 and other 'greenhouse' gases by agriculture.

With CA, reduced use of tractors and other powered farm equipment results in lesser emissions of exhaust gases.

Studies in southern Brazil show an increase in carbon in the soil under conservation agriculture. The different cover-crops show significant effects on the organic carbon level for two depths (0-5cm and 5-5cm). The means of all cover crops presented greater values for soil organic carbon than fallow at both depths (Calegari and Alexander, 1998). During the initial years until the establishment of the cropping system the increase in total organic carbon content was restricted to only the surface layers of the soil (0-2.5 cm) (Testa *et al*., 1992). With time, this effect reached deeper soil layers (2-5 – 7.5 cm). Castro Filho *et al.* (1998) found a 29 percent increase of soil organic carbon in no-tillage compared to conventional tillage in the surface 0-10 cm of the soil, irrespective of cropping system.

According to Testa *et al.* (1992), compared to the fallow-maize cropping system which was taken as a reference, soil carbon content increased by 47 percent in the maize-lablab system, and by 116 percent in the maize-castor bean system. In systems where nitrogen was applied as a fertilizer the carbon contents increased even more. Baker *et al.* (1996) found that crop rotation systems in CA accumulated about 11 t/ha of carbon in the topsoil (0-17.5 cm) after nine years. Under conventional tillage agriculture and with monoculture systems the carbon liberation into the atmosphere was about 1.8 t/ha per year of CO_2" (FAO, 2001a).

CA systems can also help reduce the emissions for other relevant green house gases, such as methane and nitrous oxides, if combined with other complementary techniques. Both methane and nitrous oxide emissions result from poorly aerated soils, for example from permanently flooded rice paddies or from severely compacted soils. CA improves the internal drainage of soils and the aeration and avoids anaerobic areas in the soil profile, provided soil compactions through heavy machinery traffic are avoided and the irrigation water management is adequate. Technical solutions are available for both.

4.4.4 Better ecosystem functioning and services

Greater quantities of cleaner water and increased biological nitrogen fixation:

CA’s benefits derive from improved soil conditions – air-space, water, nutrition – in the volume explored by plants’ roots. The improvement in the porosity of the soil is effected by the actions of the soil biota – such as microscopic bacteria, fungi, small insects, worms etc. - which are present in the soil. The mulch on the surface both protects against the compacting effects of heavy rain, damps-down wide temperature fluctuations, and provides energy and nutrients to the organisms below as well.

When the effects seen on a square meter of a field surface are reproduced across enough farms in a contiguous micro-catchment in a landscape, and beyond, the ecosystem services provided – such as clean water, sequestration of carbon, avoidance of erosion and runoff - become more apparent. The benefits of more water infiltrating into the ground beyond the depth of plant roots is perceptible in terms of more-regular streamflow from groundwater through the year, and/or more reliable yields from wells, boreholes. The benefits of carbon-capture become apparent in terms of the darkening colour and more crumbly ‘feel’ of the soil, accompanied by improvements in crop-growth. plus less erosion and hence less deposition of sediment downstream in streambeds, blocking bridges etc.

Legumes in CA rotations provide increased *in-situ* availability of nitrogen, as the essential plant nutrient for producing biomass, diminishing the need for large amounts of applied nitrogenous fertilizers.

Wider society gains in a number of ways from the actions of those who embrace CA, whether large or small farmers, among them:

- much-diminished erosion and runoff,
- less downstream sedimentation and flood-damage to infrastructure;
- better recharge of groundwater, more regular streamflow throughout the year, and the drying of wells and boreholes less frequent.
- cleaner civic water supplies with reduced costs of treatment for urban/domestic use;
- increased stability of food supplies due to greater resilience of crops in the face of climatic drought;
- better nutrition and health of rural populations, with less call on health services;

Protection and better use of agro-biodiversity

This addition of soil organic carbon also clearly represents the incremental development of the soil from the surface downwards, by contrast with its depletion under tillage agriculture.

In CA systems, the mixtures, sequences and rotations of crops encourages agro-biodiversity because each crop will attract different overlapping spectra of micro-organisms. The optimisation of the populations, range of species and effects of the soil-inhabiting biota is encouraged by the recycling of crop residues and other organic matter which provides the substrate for their metabolism. Rotations of crops inhibit the build-up of pest- and disease-species by interrupting life-cycles, making them more vulnerable to natural predator species.

Above-ground the same crop mixtures, sequences and rotations provide mixed habitats for insects, mammals, birds, without undue mechanical disturbance during the year.

Under CA, increased bio-diversity from both soil organisms' proliferation as well as from the wider range of crops favours a broader range of insect pollinators

4.5 Necessary Steps for Introduction of CA and Transformation of Tillage Systems

4.5.1 Technology development and adaptation

It is desirable, from the outset, that there should be favourable attitude by Governments and other agencies towards CA, preferably accompanied by an active commitment to removal of the restraints to adoption and development which have already been indicated in Chapter 3 above, and are further elaborated in Section 7.

The key message is that Research programmes and activities need to do more to address the real-life problems of farmers, and to include farmers in the design and implementation of programmes relevant to their needs. New technical knowledge may become less important than identifying and addressing the central factors inhibiting improved land husbandry -- which may be economic, social, infrastructural or market-related. Government organizations need to serve their farmer clients in more interdisciplinary and participatory way, jointly focussing on particular groups, problems or areas rather than planning from above or executing technical programmes independently of one another (FAO, 2001b).

4.5.2 Building up a nucleus of knowledge and learning system in the farming, extension and scientist community

The Latin American experience with CA has shown (FAO, 2001b) that by providing institutional and financial support, government has played a crucial role in creating incentives for adoption. The studies also point to the importance of credit availability for the purchase of new no-till machinery. Smallholders have been a special target as they lack the capacity to raise funds and retrain on their own. The World Bank reiterated these observations in its review of a project in Brazil promoting sustainable agriculture, modern forms of land management, and soil and water conservation. It considered rural extension to be a pivotal element in the project. In addition, monetary incentives were highly successful in motivating group formation among farmers, leading to an increase in cooperation and social capital. It recognized rapid paybacks and government financial incentives and support as key influences on adoption.

Elsewhere, CA plus the FFS approach to assisting and informing small and larger farmers creates a form of insert into national and regional development which can underlie and enrich 'watershed management' as a concept for sustainable improvement of landscapes and livelihoods.

Sustainable forms of agriculture must be maintained in all ecosystems many of which are vulnerable under ever-changing economic conditions, and there fore must be constantly monitored by the farmers themselves, supported by appropriate technical and policy changes. Most importantly, a nucleus of practical knowledge and learning system should be built up in the farming, extension and research community and this knowledge and learning system should always be put out and demonstrated to stakeholders as evidence of relevance and feasibility, and used for hands-on training students, researchers, extension agents and farmers as well as sensitizing institution leaders and decision-makers.

Demonstration areas: Once initial 'benchmark' demonstrations of CA have been established among interested farmers themselves, it will become important to catch the interest of other potential supporters. For this reason it will be desirable to work with innovative farmers who are prepared to describe and share their experiences with a wider range of people, beyond the farming community. Such demonstrations would need to be clearly visible (e.g., alongside public roads) and easy of access to people from e.g., commercial organisations, different branches of Government, potential financiers who might assist broader expansion, and others.

Staff training: Key to success of FFS and other guidance of farmers in CA is that those advising farmers and other should be fully conversant with the ethos, changed mind-set, agro-ecologic and socio-economic principles, and modes of application of CA. It will be appropriate to set up dedicated training courses for this purpose at the outset, to generate a commonality of understanding among the trainees. On this they can base understanding of what they encounter among farmers and in the field, and provide consistent information. The training institution should maintain close links with the fieldwork and experiences to gain feedback and make appropriate adjustments to the programme for the refining of future courses.

Field days and study-visits: As already noted, much relevant experience is passed from farmer to farmer in conversation, on the basis of their own experiences and appraisals of recommendations and trials. Field days enable many farmers to get together to see new things and exchange views. Specifically-arranged study visits to unfamiliar areas within their own country, and/or different countries and among farmers in very different circumstances, can be powerful means of engendering new ideas and observing and discussing novel techniques. On return home, these may become the focus of further innovation and experimentation by the farmers.

Participatory and interdisciplinary learning process: For the development of CA in the field, intercommunication between farmers, researchers and advisers about progress and problems needs to develop active feedback loops, with information, requests, responses and results passing between all the parties involved. In this way a nucleus of information in common can be developed within and between the farming, advisory and scientist communities.

A participatory and interdisciplinary process should be the basis for the analysis of socio-economic and agro-ecological factors which determine problems at farming system level and the methodology to identify technical solutions, which can be managed by farmers. This has certain implications for policy-makers. On the one hand, an assumption that CA will spread on its own in some desirable fashion is not appropriate. On the other hand, a uniform policy prescription to fit many locations is not realistic either, whether it consists of direct interventions or more indirect incentives stemming from research and development, or some mix of both. Designing successful policies to promote CA is likely to start with a thorough understanding of farm-level conditions. This understanding needs to include management objectives, attitudes to risk, willingness to make trade-offs between stewardship and profits. The next step is the careful design of location-sensitive location-sensitive programmes that draw on a range of policy tools. Flexibility is likely to be a key element in policy design to promote CA.

A type of research which is seldom undertaken, but which can pay dividends for in good interactions between farmers and those who would advise them is that of 'Operational Research'. It is aimed at investigating, in the field, and with farmers, how improved practices (whether defined by researchers and/or by farmers) actually have their effects in the field, and how farmers perceive and manage them. Farmers and researchers become partners in such investigations, to the mutual benefit of both. Other criteria of success than profit alone, many of which may be suggested by farm-families themselves, become part of the 'stock-in-trade' of such collaborative teams.

4.5.3 Financing and enabling the initial stages

An effective sequence of initial interventions for promoting the transformation towards CA systems could be as follows:

1. Identify what are the limiting factors to farmers making improvements to their livelihoods (which may not always primarily be financial) to catch their attention. Falling soil productivity may well be at the base of the cited problem.
2. Identification of factors limiting crop yields (beyond just 'fertilizer') and what could be done to alleviate these.
3. Identify one or more farmers already undertaking CA and demonstrating it's agronomic, financial and/or livelihood benefits, and set up study visits.
4. Or: set up demonstration for researchers and advisory staff ['extensionists'] and farmers' groups leaders, to catch their interest.
5. Initiate 'learning by doing' e.g., through FFS network or other participatory forms of investigation and learning. Gain insight into what farmers know already and how they would tackle the apparent problems in the light of new knowledge introduced.
6. Determine what are optimum means of achieving CA's benefits for different situations of farm size, resource-endowments, through on-station and on-farm research and benchmark demonstration, observation, FFS etc and Field Days on farms already attempting CA. Record-keeping, analysis and feedback loops, Operational Research, are all important
7. Importing suitable samples of equipment (e.g., jab planters, direct seeders, knife rollers, walking tractors, etc.) to be able to demonstrate their use at the beginning.
8. Interact with any already-established farmers' groups, e.g., co-ops, to gain interest and support.

It must be assumed that, as a minimum, a sufficient budget is available to cover, among others, costs of staff salaries and training-costs, travel costs, transport, equipment purchase, publications, and (b) permission is given for field staff to work on CA.

Risks attend any changeover from one way of making a livelihood to another. All farmers, large or small, with and without resources, will be subject to such risks, though in different ways and to different degrees, and will make their own decisions on how best to minimise or avoid them. In recommending that governments give fullest support, at all levels, to Conservation Agriculture, it is assumed that this will also include whatever may be necessary to reduce and ameliorate any extra risks to farmers arising from the process of change during the transition period – until the new system of CA has become safely and appropriately established. Such assistance to farmers could be appropriately in the form of sharing costs of any additional start-up credit, of purchase of suitable equipment, of extra insurance premiums (for perceived greater risks attending an unfamiliar set of procedures), etc. This matter is further discussed in the next Section 5.

Having made a commitment, it is also important for a government to make a policy that will ensure that sufficient and appropriate support to farmers' efforts be provided and maintained, to share costs and risks taken by small farmers during the period of changeover from tillage agriculture to that of CA. This period might be up to say five years in each instance of uptake, covering the time from initial awareness-raising to farmers and their groupings having developed full confidence in their capacity to manage their own development and attainments. Because uptake would not all occur at the same time, such assistance would necessarily be on a 'rolling' basis.

A corollary of the above is that arrangements should be made in advance of the timetabled cessation of a donors' financing to maintain continuity of support to farmers at the required, or a planned and diminishing, level of staffing, transport, finance.

As mentioned above, the period of changeover from tillage agriculture to a reduced/minimal/no-tillage form of production needs to have provision made for responding to needs that can be anticipated. This is likely to include differing degrees of cost-sharing for inputs, equipment, travel etc. for fixed durations from uptake, as a form of minimising the increased risks which could arise during the alterations in crop-production methods and management. The need for credit can be foreseen, and suitable arrangements made, whether with a banking system, or maybe 'merry-go-round' loans made out of a group's own regular savings. Foreseeable needs may also include that of ensuring the availability of CA-specific equipment for farmers' use from government or commercially operated equipment pools until such time as farmers have been able to evaluate, and perhaps improve such equipment and decide to purchase their own items. Lack of availability of such equipment at critical times for the farmers who need them has been found to be a strong disincentive to making further progress with CA because of loss of timeliness or precision then prejudices expectations of yield.

Sufficient finance should be available in budgets for study tours, field days and other opportunities for farmers to meet each other and discuss CA matters of mutual interest. This has been found to be a potent way of stimulating exchange of information and innovations.

4.5.4 Mobilize input supply sector to service this new developing market

With keen farmers grouping together into Associations etc. (see above), potential suppliers of inputs and technical advice will become aware of potential commercial opportunities, and can be encouraged to join, and provide supplies to, the team of people spearheaded by the farmers themselves. Usually some 'kick start' is necessary to break the deadlock of farmers not adopting because of lack of available technologies and the commercial sector not offering these technologies for lack of market demand. Policies facilitating procurement with credit lines, promoting technologies with technical extension programmes and introducing supportive tax and tariff policies are important for building up the long term commercial development of suitable input supplies for CA.

Arrangements for marketing the crops and for selling farm inputs require attention at the time of beginning the CA revolution in a country where these may not work adequately well. Markets may exist already, but they may be inaccessible or be attractive to farmers because of poor roads, high transport costs, 'rigged' pricing, etc. This has implications for improving the bringing-together of suppliers and purchasers to work as a team together with government field staff and others in responding to farmers' needs and requirements.

4.5.5 Sensitise policy-makers

Both the field demonstrations and technical discussions generated by the growing spread of CA methods and successes, as told by farmers and others, will also make government department heads, policy-makers, institutional leaders and others aware of benefits, and of the desirability of backing the initiatives. It is important that policy makers come to a full understanding of the implication of the CA system. This makes it easier for them to justify supportive policies, which in the end are beneficial not only for the farming community but for everyone and hence for the policy makers and their reputation. On the other hand it is important for policy makers to think in long term developments and in integrated approaches, even across sectors and ministries. Import taxes on equipment or certain mechanization policies can counteract for example policies for sustainable agriculture if not coordinated well.

As Pieri *et al.* (2002) put it: "The rules to be designed need to be based on real-life experiences demonstrating the positive environmental and socio-economic impact of conservation agriculture, which can be confirmed by testimonies of farmers and extensionists, as thus being measurable and visible results".

"For the transition to more sustainable agricultural and other land use systems to occur, governments must facilitate the process with an appropriate range and mix of policy instruments and measures… It makes sense to take a planning horizon of five to ten years, within which to consider the likely impact of various policy measures".

"It is…important for decision-makers to understand that the supportive environment created by favourable institutional and policy conditions will accelerate the process of change towards sustainable economic and social development with measurable effects. These favourable conditions are also critical to scale-up success NT [=CA] pilot projects".

5. RELEVANCE, AVAILABILITY AND EFFECTS FOR SMALL-SCALE FARMERS

5.1 Chances

5.1.1 Livelihoods

'Small farmers' covers a wide range, from those with many resources on mechanised smallholdings down to those with very small patches of land and virtually no resources except their own manual labour for any farming activity. Points made in Sections 3 and 4 mainly refer to both large and small farmers. It is not only larger mechanised farmers but also the resource-poor farmers who can benefit from using the basic principles of CA to improve their soils and begin to diminish their poverty, improve their livelihoods, and join those who began CA with a greater endowment of resources.

Some realities of rural poverty:
Many of the world's small farmers are poor and getting poorer -- as land productivity degrades, as population rises, as farms get smaller, and as disease – e.g., HIV/AIDS - diminishes both the number and the energy of family members available for farm work, which then becomes the task of the very old and very young who remain. A commonly-recurring theme in descriptions of rural poverty in tropical countries is that the farm-families are unable to meet basic needs such as food, clothing, housing, health, and education for the children. This view may not necessarily shared by district decision-makers or leaders, who may view poverty from the perspective of possessions or cash. Where this is the case, the divergence of opinions is not encouraging for dialogues between the two groups. In surveys of poverty in Kenya, communities stressed that efforts and resources for relieving poverty should come from 'inside', and that they wished that government and other agencies would provide an environment which was supportive of their own efforts, rather than taking a prescriptive approach (Nyamwaya, 1997).

A characteristic which does always feature prominently in the literature on poverty is population pressure and 'land-hunger'. There is little land of good quality onto which farmers, large or small, can spread. In general, 'spare' land has either become severely degraded already or, if brought into cultivation, is likely to become so and is likely to degrade faster under tillage agriculture than land of better characteristics under the same treatment. For those of an expanding population who remain on the land, the tendency is therefore for farm sizes to become smaller over time, reducing the area available to a family from which enough food and other essentials can be generated. The problem is worsened if the productive capacity of land already in use is also falling over time.

Examples of CA's potential for alleviating rural poverty:
Conservation Agriculture's potentials have already been described, and have shown themselves capable of improving the livelihoods of farmers already with some resources, such as money and equipment. How can the resource-deficient rural poor of a nation also gain equivalent benefits? Three extended examples below serve to illustrate the possibilities, which derive primarily from the improvement in soil conditions:

Mrs. Margaret Ogola, 72 years old and a Mariwa Farmer Field School member, started conservation agriculture in October 2004 on a half acre (quarter hectare). She could not cultivate all her five acres, mostly bushland, because of her age and financial constraints. She had been farming conventionally for 15 years and could get scarcely more than one bag of maize. She slashed the weeds in her plot with a machete (*panga*), and planted maize by pitting. For two consecutive seasons she had harvested nothing because of drought. In September 2005, she planted maize and lablab with the animal-drawn mulch planter. The lablab established good cover and she had no weed problem. She harvested 11 bags of maize. She cut and left the maize stovers. The lablab continued to grow. On March 2006, she slashed the cover crop. She also increased her cultivated acreage to one acre by slashing bushes and planted maize and lablab using the animal-drawn mulch planter. She uprooted the few weeds by hand. She expects to harvest not less than 24 bags of maize. She says the weed population has gone down and her soil fertility has improved because of the lablab. Despite her age, she now finds farming easy, since less labour is required to prepare land and to weed. She intends to go full blast and use conservation agriculture on her five-acre plot because the maize yield has increased. The money she will get from selling maize will help her hire labour to clear the remaining bush land and to buy supplies (Mwangi *et al.*, 2007).

Mama Temu planted maize intercropped with pigeon pea in 2005. In July she cut the maize tops after maturity to reduce shade on the pigeon pea. She harvested the maize in August. In September, pigeon pea beans were harvested and the plants were left for the whole year into 2006. She formed an improved fallow or rotation system on her land. She also managed to reduce weeding and increase water retention. The next pigeon pea harvest will be this September. Pigeon peas give good soil cover because it has a dense canopy. She plans to plant maize in the following season. This way farmers keep harvesting pigeon pea, and it forms a canopy for soil cover and suppresses weeds (Maguzu *et al.*, 2007).

Up until 1999, in the Kakamega District of Western Kenya, *Anna* worked her 0.1 ha smallholding and was responsible for feeding her children. To do this, she was using three strategies:

- Subsistence production of maize, though this provided only 20 % of the family needs;
- Renting-in land: but theft of the crops from fields far from the house often resulted in no produce for the family
- Casual labour @ Ksh.50 per day.

The family frequently experienced hunger, and she could seldom afford to buy vegetables at the local market.

In 1999 Anna learned from staff of the Association for Better Land Husbandry, an NGO in Kenya, how to make vegetable beds suitable for production using the principles of CA. She made seven beds totalling 48 sq m, near the house, using compost and grass-straw mulch cover above loosened soil. She also planted 8 banana stems using the same principles of soil improvement with mulching. She concentrated on raising the productive capacity of her small '*shamba*', and the results turned her life around. The CA processes rebuilt soil structure and markedly increased yields. As a result, she is now able to provide here own vegetables – kales, spinach, pumpkins, cowpeas, onions, and others – to improve the family diet, and has sufficient also to sell from the farm, bringing in Ksh. 200-300 every week. She was so impressed with the results, that in 2000 she expanded the area under CA into her maize patch. The maize yield doubled, and she extended the system further into the maize-patch. The family thenceforward has not experienced hunger. She was also able to give up casual labour for other people, and she no longer has to beg for money from her husband. She reported that every day her self-confidence grew (Hamilton, 2003).

Similar experiences were recorded in a survey of individual small farmers groups (90 individuals, 9 NGOs, and 41 Self-help groups, all on un-mechanised farms) across 11 Districts Kenya in 1996. CA systems had been applied on smallholder kitchen-gardens and maize plots. The results suggested that CA farming is the only land-use system which can meet two requirements – that it should raise the standard of living and be sustainable – thus alleviating food-security concerns.

The results showed, among those interviewed, that self-sufficiency in maize rose from 22% to 43% of farmers; the experience of hunger was reduced from 57% to 24 % of farmers, and the proportion of households buying vegetables reduced from 85% of farmers to 11 %, and increased the numbers selling vegetables to 77% of farmers. The families noted improvements in diet and in general health. Cash income had increased. It was noted that the number of people who adopted the CA techniques as a result of farmer-to-farmer comments nearly doubled over a three-year period. The results, astonishing their neighbours, instilled great pride in the CA farmers (Hamilton, 2003).

CA in non-ideal conditions:

Many farmers are in situations where optimum conditions of CA cannot be met immediately or maybe even at all. Nevertheless, what CA aims to achieve provides a goal towards which to aspire, even if it cannot be fully reached. The limitations, possibilities and practicalities of each individual situation suggest how best to start, using both knowledge and creativity to overcome difficulties on the way. Plant growth and water movement are governed by the same principles in every situation. The resources of the farm family and the characteristics of the specific location determine how their improvement might be undertaken.

If resources are scarce, it is cost-effective to concentrate them onto limited proportions of the total area of a field, etc., for example:

- If water is limiting, it could be appropriate to concentrate it into suitably-sized and -spaced basins, so as to wet limited areas (e.g., ‘*zai*’ or ‘*tassa*’ to sufficient depth for good rooting of a small number of plants. Wetting a larger expanse to a shallower depth would provide insufficient water for the total number of plants to produce a harvestable crop.
- The volume of material available for mulching may be so sparse that it would be ineffective as either protection and/or as a sufficient substrate for the soil biota if spread across the whole field surface. In this case partial success could be achieved by applying it in strips or in localised patches across the field (preferably a permanent position for each). Weed control and reducing surface compaction in the bare strips would have to be undertaken by cutting rather than by tillage. The results would not be as satisfactory as if a full cover and no tillage could be achieved, but some improvements could be expected beneath the mulched strips.
- If there is a problem in maintaining cover from year to year because local custom assumes the community’s rights to graze any fields after harvest, alternatives could include:
    - fencing-off proportions of the area, on which the increased biomass produced by CA during the rains makes up for the loss of part of the grazing area; or, for example:
    - reaching accord with the community as to the usefulness of an agreed proportion of the crop residues etc for protecting the land surface and contributing to better grass and fodder production, and the usefulness of the remaining proportion for animal-feed.

In drier parts of Zambia, early preparation of planting basins, in-row furrows, etc. for water-capture is recommended. By using this method in support of CA farming, it facilitates early planting with the first rains, at which time the plants also get the advantage of the ‘nitrogen-flush’ in the soil which occurs at that time. For those adopting CA techniques, this moves the whole farming calendar forwards, meaning that farmers plant, weed and harvest early, and attain food security earlier in the dry season (Baudron *et al.*, 2007).

Farmers in many countries have noted that the soil becomes darker-coloured under CA, the topsoil deeper and less stony at the surface, and no longer suffers from soil erosion. Family incomes have improved, and family quarrels are much reduced. Because of higher yields on the farm, even though the area has not increased, overall output is higher than before (Nyende *et al*., 2007).

The lesser labour demand on small resource-poor farmers is of particular benefit to those suffering from HIV/AIDS. In Kenya, for example, some districts are severely affected and death rates are high, and household labour availability is diminishing. Large numbers of rural people are affected by HIV/AIDS, which diminishes their energy and their capacity to work their fields. CA, with its more secure crop-yields and lesser demands for energy to produce them, is a boon to HIV sufferers, because with manual jab-planters they are still able to plant, to produce food, to prolong their lives, and thus also reduce the number of orphans (Kaumbutho and Kienzle, 2007).

CA on non-mechanised small farms:
CA can be attractive to smallholder farmers. However, embarking on CA on a small un-mechanised farm may involve some different considerations from those facing larger farmers. Smallholders generally use few bought inputs, often because they cannot afford them. The availability of credit to help with CA's increased need for purchased inputs (such as herbicide, or farm equipment, etc) is therefore important. If at present they normally hire land-preparation equipment, then a switch to CA should be relatively easy as there are no implications for investing in machinery: costs in the short term would be much the same as long-term costs on embarking on CA (FAO, 2001a).

CA based on the appreciation of need to improve soil health as basis for regular production of plants and water from landscapes can simultaneously raise productivity, be conservation-effective, and provide sustainability. Its advantages can benefit small-scale farmers – whose motivations are often (initially at least) focussed on need for e.g., food security, cash for school fees, health services and other basics – as well as large-scale farmers who may often be motivated more by raising income via cost-saving.

The effects of soil degradation on crop yields is seen most clearly on the fields of poverty-stricken small farmers, where the poverty of the soil is generally not masked by the previous application of fertilizers. For small farmers such as these, CA is probably one of the few viable farming practices if the number of people relying on relief food aid is not to increase. Positive experiences with CA among such farmers indicate that it is not poverty *per se* which has the main cause of land degradation, but rather that they have been poorly served with appropriate advice as to the optimum means of both tackling it and of preventing it in future.

Near-nil investment, and follow-through:
By improving the soil – in the above cases by breaking any subsurface hard-pan and adding organic matter – the farmers were able to improve their livelihoods with an initial 'near-nil investment'. The Association for Better Land Husbandry, an NGO which initiated this work,

followed-through with the farmers' groups that developed. At interactive meetings between farmers and field staff of ABLH and of the Ministry of Agriculture, farmers were requesting provision of demand-led services (Muraguri, 2000), such as:

- Market intelligence and linkages,
- Training, seminars a field-days, and sponsorship to attend them,
- Farm inputs: seeds, simple irrigation kits, credit;
- Transportation to the market – especially for perishable produce;
- Technology and demonstrations: irrigation; micro-scale food processing; transportation (push-carts, [bicycle]-taxis); water-harvesting techniques;
- New farming methods.
- Group-formation skills.

If poverty-stricken farmers can begin and then follow-through the process of their own improvement, those with more resources should also be able to improve their situation, building from small beginnings and re-investing the benefits.

Indications of CA's potentials for improving livelihoods of small farmers who already have some resources:
Farmers with somewhat larger holdings and/or more resources may be able to further reduce the input of their own energy needed to achieve closer realisation of the three key aspects of CA by purchasing appropriate equipment, which may be manually operated (e.g., jab-planters, knapsack sprayers) or powered by animals or small tractors (e.g., rippers, no-till seeders, see Sections 1 and 4).

Evidence of successful introduction of CA by small scale farmers in Ghana, Paraguay, Southern Brazil:
Ghana – Land is prepared by slashing the existing vegetation with a 'machete' and allowing regrowth up to 30 cm. Then a glyphosate-based herbicide is applied at low volume, after which the vegetation dries (but is not burned-off), providing a mulch. After 7-10 days the farmer plants the crop (generally maize) through the mulch with a dibbler or planting-stick, which is the only disturbance of the soil – here called 'minimum tillage'. Benefits and costs of this type of CA practice , when contrasted with the former 'slash-and-burn' method, were analysed. The results showed that this 'minimum tillage' method resulted in more than twice the yield of maize and of monetary gross margin, as shown in Table 3 (Boahen *et al.*, 2007).

Paraguay -- Savings in labour, increase in net farm income and uptake of CA are presented in Tables 4a, 4b and 4c respectively (Derpsch, 2008a).There are several reasons why adoption has been so rapid in Paraguay. First, CA techniques gave efficient and economic erosion control, and no-tillage reduced the drudgery of farm work. The widespread use of green manure and cover crops improved the soil's organic matter content whilst simultaneously giving greater weed suppression. Importantly, however, No-till/CA was the only conservation agriculture technology being recommended, meaning that messages were consistent and positive with no contradictions. Publications with practical information were widely available, as were the results of economic studies that were done on the systems. Aggressive farmer-to-farmer extension gave a culture of 'no secrets', and ensured that appropriate knowledge was available in the region.

Table 3: Gross margin analysis of maize production (Small farms, hand labour)

Item	Minimum tillage			Slash-and-burn		
	Quantity (t/ha)	Unit price (‘000 GHC)	Amount (‘000 GHC)	Quantity (t/ha)	Unit price (‘000 GHC)	Amount (‘000 GHC)
Costs						
Herbicide (litres)	2.0	120	240	-	-	-
Labour (work-days)	48.0	15	720	83	15	1245
Hiring of knapsack	1.0	20	20	-	-	-
Total cost			*980*			*1245*
Revenue						
Yield (kg)	1.2	15	1800	0.5	15	750
Gross margin			*820*			*-495*

However, there are still some factors which limit the spread of No-till/CA techniques in Paraguay. These include better ‘know-how’ of specific techniques. In particular, it is known that green manure and cover crops benefit N-fixation, soil loosening and nutrient recycling (for example), but more work needs to be done on the use of green manure and cover crops for cost-effective weed control. There is an urgent need for cheap no-till machinery for animal traction, to enable sowing small grains and cover crops (Derpsch, 2008b). Finally, better alliances between donors and other stakeholders (including equipment manufacturers and co-operatives) would improve the framing environment for CA, across the entire country.

Table 4a: Savings in labour by switching from conventional to No-till/CA (Small farms, some equipment)

Dept. Concepción		Dept. Caazapá	
Crop	Saving in labour	Crop	Saving in labour
Maize (red)	42 %	Maize (red)	47 %
Maize (white)	50 %	Maize (white)	65 %
Cassava	65 %	Cassava	50 %
Sesame	55 %	Peanuts	55 %
		Cotton	48 %

Table 4b: Economic analysis of seven small farms of 5-20 ha in Paraguay

Farming type	Year	Net farm income (US$)
Conventional tillage	1998	740
No-till / CA	1998	1567
No-till / CA	2003i, ii	4049, 2211

Table 4c: Uptake of CA in Paraguay after initiation of GTZ/MoA project in 1993										
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
‘000 ha	10	80	110	170	220	400	500	720	1000	1200	1300

Brazil – Successful implementation in southern Brazil is represented by information from the states of Santa Catarina and Rio Grande do Sul. In Santa Catarina state, the impact of a CA-based project, initially supported through the change-over years by World Bank financing, is reported by de Freitas (2000). The principal activities aimed at soil recuperation and livelihood improvement. The means of achieving these aims included:

- Use of green manure and cover crops;
- Management and use of animal manure;
- Protection of water sources;
- Road alignment and improvement;
- Elimination of erosion gullies;
- Forestry development

The impact of the project’s activities over seven years led to the State’s Agricultural Research and Extension organization redefining its aim as ‘knowledge, technology and extension for sustainable development in rural areas, for the benefit of society’. It also formally defined its working areas as topographic micro-catchments of the landscape. This enabled rural extensionists to consolidate their efforts, time and resources. This had a number of effects, among them:

- There was more contact with rural families, enabling them to know more about the realities of the farmers’ livelihoods.
- By interacting directly with farmers in the conservationist planning of their farms, they gained the farmers’ respect and confidence.
- There was a constant interactive process between representatives of the public sector, the private sector, and of rural communities living in the micro-catchment.

Its implementation resulted in widespread diffusion of project activities through greater participation of the main beneficiaries (small farmers) in decision-making on ‘What? How? Who? and ‘How many?’. This resulted in great stimulus to community organizations.

In Rio Grande do Sul state, the reasons for adoption of CA, resulting from a comparable project, are summarized in Table 5 (Pieri *et al.*, 2002).

Table 5: Reasons to adopt No-till farming – Rio Grande do Sul, southern Brazil (small farms, some equipment)

Reasons for adoption	Farmer approval (%)
Higher yields	35
Higher income	55
Erosion control	75
Time saving	90
Labour saving	100

Understanding the basis for adopting and adapting:
Farmers prefer that change comes 'from inside' (see above). They may modify and diversify prescribed conservation agriculture recommendations to fit their own farms' different situations. Spread of a favoured technique is seldom because farmers have evaluated it on the basis of scientific studies of its consequences. Rather, most people depend mainly on a subjective evaluation of an innovation that has been made by their neighbours/friends who have previously adopted it (Rogers, 1983).

Local innovation is one factor seen as absolutely critical to villagers becoming the 'subjects' of their own development, and to continuing this process after the end of any external assistance. Because of the high cost of providing a formal advisory service to a multitude of small farmers, techniques which 'ignite' small farmers are needed so that self-generated spread becomes a reality. Farmer Field Schools have had some success in achieving this. The 'half-life' of a particular technology among small, or any other, farmers may be as short as about 6 years, because of changes in conditions of the weather and the markets, labour availability/costs, and other mutable factors to which they respond. But the capacity to innovate is the feature of CA which will endure – particularly if it is encouraged in the early stages of adoption. Yield sustainability is a major contributor to improving farm productivity and farmers' livelihoods. The FFS approach to learning and dissemination is a means of linking farmers' own knowledge, enthusiasm and creativeness with new ideas and experiences through facilitated group discussions, learning-by-doing, study trips, and related types of interactions which lead to learning by discovery.

As Bunch and López (1995) put it: "It is the increase in yields that convinces the farmers of the value of [improving soil conditions]. More important, the increase in yields will convince farmers to continue to experiment – to continue to become involved in the development process of, by, and for themselves. In this way, farmers are motivated to become involved in a process of innovation, to search for new ideas, experiment with them, adopt those that prove useful, and share their experiences with others".

5.1.2 Chances for additional value-adding or other income-generating activities

One of the major benefit of CA for small farmers is the reduction of drudgery, labour and time spent for growing a crop. This 'labour' replacement mainly eliminates hard and badly paid work in the field, allowing farmers to invest the time into more profitable value adding activities. This is particularly important for small farmers who rely entirely on family labour, including children. In many cases it has been observed that by breaking this time bottleneck farmers can either expand their operations, or begin to keep animals, thus adding value to their crop production. Others start processing their produce to more refined consumer products, and children can return to school instead of helping out on the farm. The introduction of CA to small farmers in some parts of southern Brazil improved their livelihoods to such an extent that the migration of younger people to the urban centres could be reversed as reported in FAO (2001b):

"Sustainability through incentives: 'Paraná 12 meses' is a programme initiated by the Brazilian state of Paraná, with the World Bank, to assist farmers to spread their income over 12 months instead of the normal seasonal peaks…Some of the money available has been used to encourage and enable farmers to utilise the time saved by adopting CA to add value to their primary products. Thus, for example, instead of selling maize, wheat or soya beans, farmers are offered training courses in dairying and the raising of pigs or poultry. In addition, municipal-level training and self-sustaining market outlets have been established to enable farmers to process the products of these secondary enterprises and sell for example, cheeses, yoghurt, and confectionery. In this way, skills are developed, rural jobs created, urban drift is slowed, profits normally accruing to urban traders are retained on the farm, and even small-scale farmers can generate profits which will enable them to pass on to their heirs an enterprise of which they can be proud." (FAO, 2001b).

5.2 Risks: Failures and Discouragements

5.2.1 Perceptions of risk

In the context of looming global environmental problems, there is evidently considerable and growing risk attached to the continuation of tillage agriculture which continues to provoke land degradation though loss of cover over the soil, loss of porosity of the soil, and net loss of soil organic matter. In the face of climate change and expanding human populations, this must become a concern to all governments.

At the level of a nation's government which acknowledges this threat, it may be argued that there is still a risk attached to making a commitment to transform all of a country's 'conventional' agriculture based on tillage if there is thought to be, as yet, insufficient convincing evidence of the efficacy of conservation agriculture as the alternative. It is worth noting that there are about 100 million hectares under one or another form of CA worldwide.

The spread of CA could be at risk if resistance to changing 'traditional' methods of farming as practiced for generations, and/or cultural traditions, is strong enough to block any attempts to alter them.

At the level of a resource-poor farmer, the evidence of benefit from his/her own efforts - manually and on a small patch of land only – to increase water infiltration by soil-loosening and to raise soil organic matter by mulching with manure and/or compost entails little risk. The plants grown on such trial patches are likely to perform better than those under the 'normal' tillage regime, and indicate a reduction in risk of food insecurity rather than an increase.

Where long-term rights to the use of land have not been established, there is a risk to the land-user that any improvement to the land's condition as a result of adopting CA could result in the landlord/owner taking back the land for his/her own benefit. Farmers perceiving this risk may thereby be inhibited in developing CA on the land they work (Boahen *et al.*, 2007) (see Section 3).

5.2.2 Risks consequent on insufficient support/back-up

Such risks may be ordered according to whether they occur at an early, medium-term, or late stages of adoption of CA. Some examples follow.

Risk at early stages:
Cover crops are recommended in many situations, for accumulating mulch, for increasing N-levels in the soil, and/or for controlling weeds.

According to Kaumbutho and Kienzle (2007), “Farmers practicing conservation agriculture progressively increased their crop yield from adoption time, attaining optimum production when accumulated crop residue attained 100% cover, ensuring maximum water infiltration and the best harvest. Soil fertility and weed control also increased considerably”. In seasonally-dry areas, local custom which permits post-harvest grazing of all fields by the community’s animals poses a risk of not being able to achieve the best level of ground cover. The obverse is that, in areas with high rainfall and abundant growth of cover-crops, the density of the ‘living mulch’, if not adequately managed, poses the risk that both the planting is made more difficult and the crop itself is eventually smothered.

Unless strengthened by the encouragement of their peer-group, there is a risk that farmers starting the process of improving their land with CA may become disheartened if they have to wait one or two seasons for what they consider are worthwhile benefits to become apparent.

For an adopter of conservation-effective methods, risks may also arise as the farm agro-ecosystem begins to change. The spectrum of pests, diseases and weeds may change in the process, for the control/management of which the farmer may be unable to get appropriate advice and assistance. Such a comment applies also to the risk of not knowing of others with whom to confer, share experiences, gain confidence, discuss innovations etc. or even how to contact them. The risk is of becoming disheartened if appropriate back-up is not available.

Risk at medium-term stages:
Lack of appropriate information, and of research to generate new knowledge, or provide better understanding of ‘old’ knowledge, could put at risk the effectiveness of well-motivated advisers, such as in FFS network serving innovative farmers interested in developing CA. Common problems are those of (a) identifying appropriate cover-crops for specific situations and niches, and (b) labour-saving methods of weed control in situations where the time and effort needed for it to be successful negates other benefits of CA which has already been established on the farm.

When a small farmer spreads CA over a wider area with success, there may be difficulty in generating cash from an excess of production over household needs if there is difficulty in marketing it. The risk here is that he/she may be unable to benefit from the opportunities for potentially generating cash which a functional market system could provide.

Farmers with larger farms and/or more financial resources may not be able to expand the benefits of CA on their properties without mechanical assistance in the form of CA-specific seeders, jab-planters, harvesting equipment etc. The progress of CA, in terms of increased benefits to the farmer and/or the spread of the methods onto larger areas of land, would be at risk if it were not possible to buy appropriate equipment and if necessary get technical help in maintaining it. A similar case arises in the matter of seeds of locally-suitable cover-crops, at least until such time as farmers produce and sell such seeds among themselves.

There is a risk of stifling progress in adopting CA across larger areas if farmers desirous of purchasing such equipment and other farm inputs, but with insufficient cash, are unable to access credit at appropriate rates of interest.

There is a risk of technical staff losing credibility if they have undertaken survey work, collected samples, made economic analyses etc. and kept the results to themselves without taking the trouble to feed the resulting analyses etc. and their implications back to the host farmers.

Risk at late stages:
One of the major risks for adoption and up-scaling of CA is that this might conflict with the interests of certain influential lobby groups, particularly manufacturers of agricultural inputs which would suffer from a large scale adoption of CA, such as tractors, tillage implements and in the long term even agrochemicals. Those manufacturing industries have in some countries considerable political influence to obstruct the adoption of CA.

There needs to be collaborative involvement of and with the private sector – e.g., suppliers of inputs, equipment, and providers of transport and marketing services, including providers of credit – alongside and with government initiatives to promote and foster CA. Without it and the complementary non-governmental services they can provide, there is risk of delaying or stifling farmers enthusiasms, initiatives, inventiveness and adaptive capacities towards the optimum fulfillment of CA's potential benefits to both the farm families, to the lands they work, and the wider community and environment.

The spread of CA risks being prejudiced if successful 'pilot' projects are not suitably followed-up and reinforced over a sufficient time-period for the system and its support services to become 'entrenched'.

5.3 Desirable or Necessary Changes in Framing Conditions

Successes and failures in agriculture depend on the decisions and actions of individual farmers and how they manage the soil resource base on their farms. It is in this context that off-farm laws, policies, decisions, advice, market-prices and other forces are responded to or ignored. It is also the context in which changes in such forces aiming to favour the uptake of CA will be considered, ignored again, or be responded to and acted upon.

This means that farmers need to take a leading role in the process of introducing and implementing CA on a large scale. But to take up this role they need a supportive policy environment.

5.3.1 Supportive policies

CA has the potential to have an appreciable and widespread effect on large-scale farming as well as on the lives of large numbers of small farmers. For this to happen, however, it is important that national governments make a firm commitment to sustained promotion of the development of CA and that they continue to support its implementation. This commitment – in the form of enabling rather than prescriptive policies – would both remove existing obstacles and limiting factors, but also encourage and facilitate the adoption process, so as to bring CA into the main stream of agricultural activity.

A facilitating policy environment can be an important determinant of whether CA is adopted or not. In cases where policy has been weak or ineffective, much of the successful diffusion of CA has occurred because of support from the private sector, farmers groups or other non-governmental organisations. In some countries, existing policies have both encouraged and discouraged CA at the same time. In spite of this, successes can be seen in the green decoupling programmes in Europe, and in farmland stewardship programmes such as Australia's Landcare.

While CA can certainly spread in a limited fashion without policy support, it cannot be assumed that it does not need a supportive policy environment. However, it is unrealistic to assume that it is possible to devise a 'one size fits all' policy in support of CA: whether this comprises direct interventions, indirect incentives via research and development activities, or a mix of the two. Since the principles of CA are based on an understanding of farm-level conditions, management objectives, attitudes to risk and trade-offs between stewardship and profits, policies in support of CA need to be formulated on a similar appreciation.

The main implication of this is that most policies to support CA must be enabling and flexible, rather than unitary and prescriptive. Allowing the design of location-sensitive programmes which draw on a range of policy tools will ensure that policies are designed which both accommodate and promote the location-specific nature of CA.

However, one area where a more uniform policy may be appropriate is in the development of social capital, to promote the precursor conditions for collective action – such as the development of group extension approaches (FAO, 2001a).

Within this flexible policy framing, however, there are five other issues policymakers need to consider:

Policy coherence:

CA is compatible with existing approaches to promoting agricultural and environmental sustainability, such as watershed management. However, it is not simply a case of meshing CA principles with policies encouraging a traditional approach to agricultural production. Any policies designed to promote CA will need to be examined for their coherence with (for example) existing laws on water use, health, the use of pesticides and other chemicals, and the burning of crop residues.

A first step in creating legal rules for the protection of natural resources may be to establish a national framework whose provisions have a stimulating and motivating character and whose responsibilities are shared between the land users and the executing organizations. However, the interdisciplinary nature of CA principles means that CA policies may well cut across traditional Departmental boundaries. This means that there is a clear need to co-ordinate the adoption of a CA approach across departments to reduce the likelihood of conflicting policies being implemented. Agriculture-related incentives or subsidies must be examined to ensure that they do not jeopardise farmers' ability to adopt CA practices. Ultimately, skill levels and reward systems in the public sector may need to be adjusted so that government staff provide conservation-effective advice to all farmers, all of the time.

This could be accomplished by decentralising a CA programme to a regional capacity within the existing governmental organisation, avoiding the need to create a new entity to execute new laws or regulations.

Non-government agencies, such as international donors and NGOs, should be encouraged to adopt the same stances, so as to mesh effectively with the national priority of CA.

Policies to actively encourage knowledge sharing:
If farmers are to take the leading role in implementing CA, there will be a need for policies which encourage knowledge-sharing at all levels. Farmers, advisors and even policymakers will need to share knowledge about how CA works, who it works for, where it works (or where it doesn't work), why it works, and how well specific practices and policies can be transferred between communities, regions and countries. This could be accomplished by developing appropriate local, national and regional CA networks and task forces to facilitate capacity building and active mutual learning. Part of the mission of these networks and task forces would be to build a good shared awareness of positive opportunities and constraints for CA within existing and transitional policy environments.

Basing 'macro' policies on 'micro' understanding:
National policy needs to be framed in the full understanding of how micro-level issues – technical, socio-cultural, economic and environmental -- are significant to the broad macro-scale features of agriculture and the environment as a whole. At the farm level, micro-level changes (such as raising the OM content of the soil) give rise to macro-level effects such as increased yields and profits. In a similar way, the aggregative effects of farm-level CA activities can be seen at a landscape level in terms of groundwater recharge, and improved water quality. This has significant implications for the framing of programmes of research, of pre-service and in-service training of technical staff, and for advisory mechanisms to farmers and their groupings.

This relates as much to policy formulation as it does to the provision of technical advice. For example, a community comprising a group of small farmers may decide to develop their own local bye-laws – as for instance to regulate open grazing of post-harvest residues. Any national policy which promotes the formation of farmer groups must be supportive of these sorts of local initiatives within the national legal framework.

Policies relating to farm-level risk management:
Adopting CA may, in the short term, involve costs and risks to which farmers, especially small-scale farmers in resource-poor settings, are averse. For example, late-starting farmers in dry areas may feel that the time taken to first prepare the soil adequately for CA might delay planting to such an extent that they risk losing all the potential crop. If they need to hire oxen and equipment from other farmers, the added financial risk may seem too great for them to begin to make the transition to CA in that particular year.

If CA is to be a national priority, governments need to recognise the public goods value of the environmental benefits generated by widespread adoption of CA practices. This means that appropriate policies and incentives need to be put in place to share costs and risks.

The potential benefits arising from widespread implementation of CA are so high that it is cost-effective to provide tapered support to farmers during their change-over period. If CA becomes a national priority, then it needs a commitment from governments in the form of policies and (if necessary) legislation which make a formal undertaking to mitigate the risks associated with the transition phase.

Whether CA is adopted by large or small-scale farmers, wider society gains in a number of ways, such as:

- Reduced erosion and runoff, resulting in less downstream sedimentation and flood-damage to infrastructure;
- Better recharge of groundwater, more regular streamflow throughout the year, and better replenishment of wells and boreholes;
- Cleaner civic water supplies with reduced costs of treatment for urban/domestic use;
- Increased stability of food supplies due to greater resilience of crops in the face of climatic drought;
- Better nutrition and health among rural populations, with less call on health services.

A first step would be to classify, and where possible quantify, the benefits to society that can result from adopting CA. Information on these benefits of CA could be used to create public awareness and lobby for policy reforms that would adequately reward adopters, protect farmers against the additional short-term risks of making the transition to CA., and reward successful adopters for their effective stewardship of land and water resources

5.3.2 Institutional capacity

CA is not a static set of technologies, but a dynamic system that differs from place to place and from year to year, depending on the prevailing bio-physical and socio-economic conditions facing individual farmers. The institutions that are set up to promote and support CA need to be similarly dynamic so that they can respond to farmers' varied and changing needs. As well as policymaking departments (see above), these institutions include the research and development programmes on which much of the technical knowledge of CA is based. Whatever technological combinations are used by farmers, R&D activities must help to assure that good husbandry of crops, land and livestock (Shaxson, 2006) can occur simultaneously for the system to function well.

Both the technical and social sciences must be combined with the views and opinions of stakeholders to develop technologies and systems that can be adapted to varied conditions facing farm families adopting CA as a way of farming. This means that the diverse providers of information – and their investors – need to be involved in broad programmes to develop the science and technology for CA. Such institutions include international agencies, multi-donor programmes, NGOs, national government staff, academic institutions, commercial organisations and agribusiness. Each brings a different expertise and understanding to the table. However, unless these are tied together within a common framework of understanding of the principles and benefits of CA, their potential synergy cannot be felt. One way forward would be to develop common indicator sets to assess progress towards the environmental, economic and social benefits of CA. This would help promote CA as the sustainable alternative to tillage-based agriculture techniques, and to build a common basis for understanding the potential of CA for both large and small-scale farming communities.

5.3.3 Accessibility and affordability of required inputs

There are costs involved in making the transition from tillage-based agriculture to CA. The farming patterns which preceded a farmer's decision to switch production techniques may not have produced enough saved resources to allow him or her to accept all the potential risks associated with the change-over. Nor may it be possible for him or her to make the necessary investments in unfamiliar seeds (e.g., of cover crops) or to hire new equipment such as manual, animal-drawn or larger tractorised seeders.

Once CA has become established on a farm, its lowered costs and the higher and more stable yields then begin to generate sufficient resources to pay full commercial costs of these new inputs.

5.3.4 Knowledge, education and learning services

CA involves a fundamental change in the way we think about agricultural production and how it is related to environmental stewardship and nature. There are three implications of this. First, we need to think differently about how cognitive knowledge is spread to farm families, of all farm sizes, and to public at large. One necessary change will be to inculcate schoolchildren – and then right up through graduate and postgraduate education – of the need to go beyond tillage agriculture and to understand the importance of CA systems in all settings for sustaining the production of crops *and water* from landscapes, and for protecting the environment and biodiversity. Doing this will ensure that CA principles become the accepted norm for agriculture and environmental stewardship, whatever the scale of farming.

A second change will be to ensure that people working in specialised areas of agricultural science and policy are informed of emerging CA successes from the field and the implications and inter-relations with their specialisations. Both researchers and advisory staff need to be kept up to date with the principles of CA, its effects and results. This means having the capacity to work across the traditional science disciplines and to work closely with farming communities to understand what constitutes good land husbandry. Without compromising the quality of education in the traditional agricultural and social sciences, it would be possible to boost education and training on CA principles and benefits in universities, colleges and schools. Such training would stress the commonality of the principles of CA principles and show how they can be applied through diverse technologies and development approaches.

In addition, while the greatest impact will come from applying all three principles of CA at the same time, farmers' constrained socio-economic situations and attitude to risk may mean that what is more likely to succeed is a step-wise approach which responds to their individual conditions. This means that knowledge management systems in research and extension need to be able to operate at different scales simultaneously. They need to be able to assess the landscape-scale benefits of adopting CA whilst also providing evidence of how well CA performs in the micro-environments of individual farms and farming communities. A key function of the tertiary education system in both developed and developing countries would be to research and validate the science underpinning CA techniques.

Third, a new international Community of Practice (CoP) needs to emerge which can acquire, evaluate, share and disseminate robust evidence about the principles, practices and impacts of CA. Raising awareness of CA in government, professional organisations and the general public will help support the diverse initiatives of research, extension, advocacy and evaluation which must be in place to advance the state of the art in CA. This international CoP might devise specific encouragements for larger-scale and more advanced CA practitioners to advise and mentor those at earlier stages of adaptation and uptake. It could also monitor the results of CA projects and programmes, at all levels, and disseminate them to the international community.

7. SETTINGS FOR THE PROMOTION AND SUSTAINABILITY OF CA SYSTEMS IN THE DEVELOPING REGIONS

6.1 Regional Experiences with the Promotion and Sustainability of CA

Ample evidence now exists of the successes of CA under many diverse agro-ecological conditions to justify a major investment of human and financial resources in catalysing a shift, whenever and wherever conditions permit it, from tillage-based production systems to those based on minimal soil disturbance, organic residue retention, and crop rotations and combinations. This will lead to large and demonstrable savings in machinery and energy use and in carbon emissions, a rise in soil organic matter content and biotic activity, reduced carbon emissions, less erosion, increased crop water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the apparent increased volatility in weather associated with climate change. It will cut production costs, lead to more reliable harvests and reduce risks especially for small landholders.

It is useful to recall that in Latin America CA was initially designed by farmers and by farmer organizations in the southern state of Paraná in Brazil. The very good environmental and economic performances of CA systems eventually led to the implementation of supporting policies and to a fast and wide adoption of this system. Subsequently, public research and extension system joined in the effort, and in the southern states of Brazil CA has been promoted by public and private bodies as research, rural extension, water and fisheries services (maintained by the state government with the support of municipalities). The implementation of support to CA has always been done with a participative strategy, including the farmers in the process through exchanges within and between groups at the watershed level. Farmers contributed to find agronomic solutions (adapted cover crops and rotations) suitable with their farming systems and designed specific implements for direct seeding in collaboration with local machinery industries. Even private companies like cooperatives, agro-industries, hydroelectric companies and small rural industries have been involved in CA expansion. This multi-stakeholder strategy has been really efficient and successful, as CA is now reaching 60% of the total agricultural surface at national level, while being close to 90% in the southern states of Santa Catarina, Paraná and Rio Grande do Sul. Moreover in terms of quality of no-tillage, Brazil and the neighboring countries have really high standards. Green manure cover crops and crop rotation are widely used. Permanent no-tillage is applied on more than 90% of the whole area under this technology in Argentina, Brazil, Bolivia and Paraguay is permanently not being tilled (Derpsch, 2005).

In Asia, where most national economies are transition and there is growing effective demand for food and agricultural products, much of the promotion work is being done through the normal extension services with backing from the public sector research organizations. There is also collaboration with international research centres such as CIMMYT in Kazakhstan and India, or international development agencies such as FAO in DPR Korea and China with some spectacular impact in these countries.

In Africa, where the majority of farmers are resource-poor, relying on less than 1 ha, the prevailing food insecurity, degradation of soil fertility, drought and irregular rains, shortage of human power for agricultural labour, etc creates an environment that is not always conducive to change, particularly when public sector extension systems have largely disappeared, and research organizations are weak. What appears to work are those efforts that reply on participatory approaches to learning and adaptation at the grassroots level, and farmer-discovery processes at on-farm benchmark sites that enable farmers themselves to decide how to put concepts and principles, once learnt and understood, into practice in their production systems taking into account their existing agro-ecological and socio-economic situations as well as the characteristics of their prevailing farming systems (Kueneman *et al*., 2007). Linked to FFS networks for dissemination and scaling of CA practices, farmer-discovery benchmark sites provide an effective mechanism for stakeholder convergence, learning and innovation as well as a resource for on-farm experimentation and testing of new ideas and concepts. In several cases the international assistance arriving for recovery after natural disasters and emergencies could in Africa successfully be harnessed to introduce CA with the participatory instruments and some capacity building, making use of the receptiveness for change of farmers after an emergency situation.

The following Sections 6.2, 6.3 and 6.4 provide a variety of CA cases from the three developing regions taken from the report of the international multi-stakeholder workshop on soil health hosted by FAO in July 2008 (FAO 2008b).

6.2 CA Cases from Latin America

6.2.1 Conservation Agriculture: No-tillage including Cover Crops and Crop Rotation in Brazil (by Ademir Calegari)

After dramatic effects of soil erosion following un-planned expansion of agriculture across the country, it was found hat mechanical soil conservation practices were insufficient to control the problem. From a few hectares under no-till in the early 1970s, the spread of fully-developed CA has now spread to some 26 million ha, with 5.7 million ha in Paraná State alone. Adequate systems comprise minimal/no-tillage plus cover crops and rotations. In a non-conventional paradigm, these orderly systems have resulted in higher storage of water in the soil profile, reduced surface evaporation of water, and related hydrologic benefits, raised yields per ha of many crops, improved weed control, better efficiency of use of inputs and energy inputs, and showing themselves to be both economically feasible and ecologically sustainable. A range of cover-crops in the rotations are used to maintain soil cover, provide additional fodder, and augment organic matter, at the same time as fulfilling multiple agronomic, ecological or economic functions simultaneously. Soil organic matter levels are consistently found to be a keystone soil quality indicator, inextricably linked to other physical, chemical and biological soil quality indicators, and an indicator of sustainability. More than fifty percent of total cropped land in Brazil is now estimated to be managed under appropriate CA systems, on the lands of both large-scale and small-scale farmers. Reasons for the latter to favour CA systems include savings in time and labour, control of erosion, higher yields and greater income. The development of associations of farmers interested in CA systems has been crucial in the increase and spread of CA systems in Brazil.

6.2.2 Experiences with Conservation Agriculture/No-Till in Paraguay (by Rolf Derpsch)

CA methods for a wide range of crops have spread from about 20,000 ha in 1992 to 2.2 million ha in 2008 (65% of all agricultural land in Paraguay), among both mechanised medium and large farmers using tractor equipment, and among small-scale farmers with farms of less than 20 ha using hand labour or animal traction. CA has hade significant positive effects on soil conditions, its physical, chemical and biological conditions, resulting in increasing productivity over time; average yields have increased between 1 % and 30%. There have been beneficial effects on soil moisture through continual cover lessening evaporation from the soil surface. Small farmers have commented that they would never go back to the old system, because the reduced work-load and other benefits have improved their livelihoods. Farming sustainability has been improved through these effects and that of minimising soil erosion. Adaptation, adopting and spread of CA methods has been significantly favoured by many joint activities between the public sector, international aid agencies and the private sector. The nature and se verity of imitations which still limit he extent and rate of spread of CA in Paraguay include: limited relevant research n CA; high cost of advisory coverage of 300,000 small farmers; limited financial and personal capabilities of the Extension (advisory) service; limited support for the spread of CA among small farmers by international aid agencies in some departments. Knowledge is still the most important limiting factor in the spread of CA methods. Needed improvements include more alliances between stakeholders and donors; more research on green manure/cover crops for efficient and cost-effective weed control, N-fixation, soil loosening etc.

6.2.3 Environmental and Productive Quality Management in Conservation Agriculture in Argentina (by Santiago Lorenzatti)

There are currently an estimated 15-16 million ha of CA in Argentina. It has been found that it presents a real and concrete alternative to tillage agriculture that has proved to be more ecologically benign, maintaining yields and reducing costs without impacting adversely on the environment. Its optimum expression is seen when it includes not only no-till, rotations and cover crops but also integrated insect pest and disease management, nutrients restoration and rational and professional use of external supplies. It has been shown that the agronomic ecosystems are no longer vulnerable and productive areas have been extended without experiencing some common risks. Soil productivity has increased due to better chemical and physical aspects of fertility and more efficient water economy. It had reduced fossil fuel consumption, lessened carbon dioxide emissions due to the absence of tillage, and increased soil organic matter, favouring carbon sequestration. In this context, the farmers' organisation AAPRESID is developing an initiative to develop an Environmental and Productive Quality Management System which can offer certification. This involves the development of a Good Management Practices Protocol and the use and recoding of scientifically-based indicators that enable measuring the impact of the agriculture on the environment. The certification will be of the process, not the product. Among other aspects, it is anticipated that this will bring producers and consumers closer together, and generate new leverage for the creation and growth of new service companies.

6.3 CA Cases from Asia

6.3.1 Conservation Agriculture Development in China (by Gao Huanwen)

China is characterised by a large land area, high population, and mostly small family farms. Single crops per year are found in areas of <500 mm rainfall in the north, through double cropping on irrigated land in the central areas with rainfall 600-800 mm, and in the south, paddy fields with multiple cropping under rainfall of > 1000 mm. Studies of Conservation Tillage (sic) began in the 1970s, with human or animal power; investigations with powered equipment began in 1991. There are currently about 3.3 million ha of CT in China: 1.4 million ha in the north, using light tractors and passive seeders; 0.6 million ha in the centre, using mid-sized tractors and power-driven no-till seeders; in the south there is rice direct-seeding, no-till transplanting mainly using hand tools or animal power. It is recognised that it would be desirable to minimise soil disturbance, have cover crops, and follow rotations in all situations. However, the small size of farms, lack of sufficient appropriate equipment and, as yet, limited research and experience of managing combinations of seeds, fertilizers, water, cover crops etc. for true CA in the varied ecozones of the country, plus an extension system not yet oriented to such systems, are factors hindering CA's wider spread. It would be desirable to have an 'ecology subsidy mechanism' which encouraged farmers to make the transformation, making use of CA-dedicated research and effective oriented extension, and also offering the possibility for farmers to acquire suitable equipment initially at reduced cost. In the meantime, progress is being made in learning how, first, to reduce tillage, then to develop rotations and further increase soil cover, and move towards ideal situations step by step as different agro-ecologic and socio-economic conditions permit.

6.3.2 Improvement of Soil and Water Management in Kazakhstan: Conservation Agriculture for Wheat Production and Crop Diversification (by Murat Karabayev)

Kazakhstan has a continental climate, with hot summers and sub-zero winters, and mean annual rainfall (varying from north o south, between 400-250mm. A major crop is wheat, whose yields have generally ranged between 0.9-1.1 t/ha. Soil moisture inadequacy is a significant factor limiting yields. In addition, water and wind erosion is widespread. Concerns about drought, soil salinity and weed infestation are increasing, while decreasing soil fertility is evidenced by loss of topsoil organic matter. After initial work in 2000, the area under zero/minimal tillage and direct sowing has been rising rapidly from zero to around 600,000 ha in 2008, in both irrigated and no-irrigated conditions. Yield benefits in rainfed areas derive much from improved soil moisture conditions, related to better infiltration of water derived from both rainfall and winter snowfall. An attraction to farmers is also the reduction in costs, and the better timeliness of sowing due to reduced energy-use. In irrigated conditions, CA methodology applied on permanent raised beds has proved very efficient. Experience to date shows beneficial changes in both the physiological characteristics of individual plants and in overall yields. Good information has been amassed on the comparative economics of wheat-growing under tillage and CA systems of production. Key aspect still requiring attention include: weed control; economically viable crop rotations and diversification of production; plant nutrition under CA conditions with respect not only to grain yields alone but also generation of plant biomass usable to raise organic-matter levels in the soil; processing and marketing of newly-introduced crops; building scientific and technical capacity, teaching new technologies and agricultural methodologies, providing appropriate training courses at all levels, providing suitable consulting services, and building public awareness of these up-to-date farming systems.

6.3.3 Introduction of Conservation Agriculture Techniques in DPR Korea (by Kim Kyong Il and Kim Chol Hun)

In DPR Korea, approximately half the arable land is under paddy rice, and half under upland crops. Mean rainfall is 1000-1200 mm annually, of which some 60% falls in July and August. Winter temperatures fall below freezing, while summer temperatures average 24 degrees. The government’s fundamental agricultural policy is to provoke a revolution in seeds, crop intensification, and diversification. Since the initial convincing work on CA in 2003 on three cooperative farms, the methods have spread to another 22 farms, and thousands of hectares are at the stage of introductory CA work. The growing awareness and benefits of CA are seen as closely aligning strongly with the government’s aims to intensify cropping and make continuous improvements in soil fertility. CA techniques are being applied as: no-till paddy transplanting or no-till direct seeding with mulching; no-till upland crops with direct seeding and mulching; CA potato production (coverage with straw, not soil); maize or paddy direct seeded after green manure crops. Crop residues are retained to provide dense complete soil cover, whether planting is by hand or machine. Progressive annual increases in soil organic matter, in soil inhabiting organisms, and in available N, P and K have been recorded. Yields of main crops have increased by 10% or more, while labour, fuel and time have been saved in the process of production. Now that results and advantages of CA’s introduction are clear, it is important to raise interest among policy-makers so that they can formulate appropriate strategies for its further encouragement. Non-farm agricultural staff also should be informed of its advantages and methods, and also traditional farm machinery needs to be replaced by equipment most appropriate to the effective further spread of CA.

6.4 CA Cases from Africa

6.4.1 Assessing and Accompanying CA Development in Africa: Emerging Lessons (by Bernard Triomphe, Saidi Mkomwa and Josef Kienzle)

Due to the intrinsic complexity of CA as a technical system, and to the many aspects involved in is promotion, understanding and accompanying CA development requires making due use of appropriate conceptual considerations. Firstly, it involves innovation in the farming system, to provide local adaptation, with reference to interlinked biophysical, agronomic, soico-economic and social aspects. Linked to farmers are non-farm agriculturists involved in developing and disseminating knowledge, advising farmers, providing relevant services or shaping local or national policies. Secondly, it involves consideration of innovation pathways – the routes and time as farmers shift from current practices to CA practices. This is a better way of looking at CA than just referring to 'adoption'. Thirdly, it needs to characterise CA as farmers actually adapt, integrate and implement it, and their actual access to knowledge, advice and resources. A final consideration is how to measure CA performance and impact. A series of case-studies were undertaken across Africa in 2005-2006 having regard to these considerations. The first lesson to emerge is that the farmers do not tend to go for permanent no-tillage, but rather go for disturbing the soil periodically. This is clearly better than continuous tillage, and corresponds better with a number of farmers' objectives with regard to management under their local conditions. A second outcome is that many if not most farmers struggle to maintain adequate soil cover. Thirdly, there are good reasons on the one hand for using herbicides under certain conditions, but also other reasons for not using them. A fourth lesson is that the prevalence of a 'project' approach to piloting CA seems to be a major problem, on account of unrealistically short time-frames, discontinuities in strategies and availability of support, and limited lead-time for institutionalising a proper CA agenda into existing institutions and policies. Pre-eminence is often given to 'demonstrating' CA rather than adapting it in a participatory manner to the local context. In particular, farmers and their associations appear to play a secondary role compared with those of outsiders. Even the principles of FFS are seldom wholly adequate, if only because of its costs and its sensitivity to the qualities and skills of the facilitators. Rather than asking about "How to change farmers' mindset and convince them of the beauty of CA and what wonders it can do for their soils?" we should be asking "What type of CA should be developed, for and with what types of farmers and conditions, with what approach, at what cost with what benefits to farmers and society?". One should accept that eventual success, wherever achievable, will depend on a complex, and relatively slow process which needs to be re-invented and nurtured locally, 'on-the-go', given existing conditions, constraints and opportunities.

6.4.2 Enhancing Access to CA Knowledge and Information and Partnerships: Experiences of the African Conservation Tillage Network (ACT) (by Saidi Mkomwa and Josef Kienzle)

The ACT is a not-for-profit voluntary membership NGO with offices in Nairobi. It receives funds from many international organisations. The current membership stands at 1200 individuals and institutions from 33 countries. As the earlier 'Green Revolution' model appears to be less than satisfactory for African situations, and food prices and costs of transport rise, a new paradigm "Producing locally for local consumption' seems to be emerging. In this context, CA has the potential to enhance food security through increased and stabilised productivity of soils and crops. Building on indigenous and scientific knowledge, and using innovative equipment designs from fore-runner Brazil, CA is beginning to spread in Africa. But its more rapid spread requires better understanding of: why many farmers 'backed away' from the Green Revolution and reverted to worse conditions than before; the identification and removal of current hindrances to farmers accessing and perfecting available improved practices. ACT aims to facilitate the shift from the common ‘input-based approaches’ to those better informed by sharing up-to-date knowledge and adaptations. What is lacking is not knowledge but the will to make best use of it. ACT provides web-based support to its members by providing a wide range of information relevant to the use, development and spread of appropriate CA methodology. A reference book on CA for farmers and advisory staff, and case studies, brochures and informative leaflets are produced and distributed. ACT is involved with the World Congresses on CA, and provides learning-education and training support to FFS curriculum development and adaptation. International tailor-made workshops and training courses have provided many CA graduates scattered throughout Africa who provide a good nucleus for CA expansion. A major challenge is to accelerate and address the issue of curriculum reform at higher education levels so that agricultural colleges preferentially teach CA principles and practices vs. tillage methods. In recognising farming communities and farmers no only as producers but also as stewards/managers of broader ecosystems, emphasis is now being laced on developing human capital and potentials at the farm level. Networking farming communities can help utilise their strength of togetherness to lobby for and tap into existing resources for micro-credit, insurances and environmental services.

6.4.3 Conservation Agriculture Adoption Experiences in East Africa: The Case of Kenya and Tanzania (by Barrack Okoba and Wilfred Mariki)

From 2004, the CA-SARD Project (‘Conservation Agriculture for Sustained Rural Development’) introduced the concept of CA in rural areas of northern Tanzania and in western and central regions of Kenya, where there was evidence of widespread land degradation, low soil fertility and high soil loss due to poor cover and low organic matter levels. It has the developmental objectives of improving food security and rural livelihoods of small and medium farmers, to be approached through FFS, in which all production constraints are identified and farmers and community leaders are involved in learning about CA. The area covers approximately four agro-ecological zones, from the Upper Highlands to the Lower Midlands across which the climatic conditions correspond with altitudinal gradient in terms of rainfall (400-2200mm/yr.), temperature and soil fertility. The higher is the altitude, the higher the rainfall and the lesser the soil degradation. Through participatory assessments by practicing farmers, it is found that the net financial benefits can be higher under CA than under conventional tillage agriculture, particularly because of savings in labour/time, lesser amount and cost of fertiliser required to maintain yields, and reduced energy/fuel costs for tillage and spraying operations. 20 large-scale farmers (>100 ha) operate some aspects of CA on a total 10,000 ha of land, using not-till plus permanent soil cover, but not using crop rotations. 500 medium-scale farmers (10-50ha) covering approx. 3,000 ha combine no-tillage and crop associations and make efforts to achieve permanent soil cover, despite competition from livestock for fodder. Smallholders (2.5-10ha) cover about 20,000 ha of land parcels, under mixed cropping systems. They are using a combination of no-till and permanent soil cover using legume cover crops. Though crop rotations are hardly practiced, they have been using crop associations. Positive improvements due to the practices used have been quantified for earthworm populations, biomass and grain yields. Feedback from FFS have shown up the following challenges to the adoption of CA: (a) how to integrate livestock and mixed cropping on smallholdings; (b) unavailability or inaccessibility of CA inputs and equipment in local markets; (c) low capacity of local manufacturers of hand/animal-driven CA equipment; (d) how to develop effective CA in semi-arid to arid zones in view of their characteristic environmental limiting factors; (e) lack of supporting policies and implementing institutions.

6.4.4 Direct Drilling in Tunisia (by Moncef Ben-Hammouda, Khelifa M'hedhbi and Hatem Cheikh M'hamed)

In contrast with the conventional mode of diffusion - from small research plots on state research stations, through state development agencies, to farmers ('vertical' transfer) - a 'horizontal' approach to diffusion for spreading CA based on Direct Drilling (CA/DD) is being used in Tunisia). With assistance from CIRAD-France and FFEM/AFD, research is conducted at farm level with farmers using field layouts that can provide statistically-valid data for experiments undertaken at multiple sites and over several years, to compare CA/DD with Conventional Drilling (after tillage). First step extension of the successful research results is done by the farmer on his farm, while strongly assisted by a coordinated multi-disciplinary research team from six technical institutes. Other farmers then willing to undertake their own tests of CA/DD on a small scale are assisted by a specialised crop-production extension team from the public sector. It has been found that other, but sceptical, farmers did not wait long to test for themselves, and some farmers are now recognised by their peers as CA/DD farmer-experts, who can command a fee for their services. As elsewhere, decompaction of soil is a key first step when beginning the process. The Tunisian climate is Mediterranean, characterised by intense, sudden, irregular rainfalls, with large inter-year variability, necessitating different agronomic sequences from one year to another. CA/DD requires a permanent mulching as dry residues of a prior crop or a cover crop, and adapted agronomic sequences, different from static rotations. 'Biological tillage' by soil organisms and by deep-rooted crops becomes the means of maintaining soil porosity, contributing to the overall cost-savings provided by CA/DD. Because of the variable nature of the climate, cropping is opportunistic, using short-season varieties to take advantage of short and irregular periods of adequate soil moisture. Where CA/DD is practiced, adequate soil cover has greatly reduced erosion by wind and water, maximises water-use efficiency and protects soil organisms from direct solar radiation. As noted above, farmer-to-farmer spread of successful CA/DD techniques appears to be occurring, and once they spread more widely, it is anticipated that a state programme could be set up to diffuse the systems among small farmers also.

6.4.5 Conservation Agriculture in Swaziland (by James Breen)

The objective of the project is to provide encouragement of community based natural resource management as a basis for long-term food security amongst resource-poor farmers in Swaziland. Over the last six years, FAO's Emergency Programme in Swaziland has trained a total of around 800 farmers, plus advisory and other staff, and provided limited number of examples of CA equipment suitable for small farmers to use. This process has included a Study Tour to the Potshini Community [CA] Project in South Africa by 17 farmers and two Extension Service staff in 2005, and the selection in 2007 of 85 'Lead Farmers' to facilitate farmer-to-farmer spread There is now a demand from farmers in Shewala for expansion of CA as they recognize it as 'the most sustainable way to produce food'. Jab planters and ox-drawn direct seeders are favoured here. A Field Day was held on June 20th, 2008, attended by 90 farmers and others. Farmers are now requesting more support from NGOs and Extension to implement CA in the areas where it has been in use for some years. It fervently hoped that this work to expand the spread of CA will be given continuity by a seamless transition of funding for its extension and expansion from its

FAO/EP source – which ended in July 2008 - to new sources in the EU and Norway. The most important requirements for the successful implementation of CA in Swaziland *[and, comparably, elsewhere]* include:

(a) An agreed plan to implement CA over the next five years to be drawn up with the cooperation of all stakeholders in Swaziland, including farmers and farmer groups, Extension and Research staff, Government Mechanization Unit staff, related Government Ministries and all relevant private sector firms. This plan should build on experience gained so far in the implementation of CA and should include achievable targets and a good monitoring and evaluation system to identify and deal with field problems as they arise. (b) Active and sustained field research on CA by the Research Department comparing it with conventional agriculture. (c) Policy support to CA and active participation by all members of the National CA Task Force in the sustained promotion of CA. (d) Sustained and practical training for extension and research staff and for farmers, with constant back-up field visits. (e) Adequate supplies of quality seed of maize, sorghum, various legumes and cover crops to ensure maximum biomass yields. (f) Sufficient and affordable supplies of jab planters, ox-drawn planters (possibly on a contractor basis) and tractor-drawn planters. (g) Credit for sustainable procurement of quality, locally adapted seed and other farm inputs thus ensuring good yields. (h) An understanding with livestock owners that crop residues on CA farms will no longer be available free to their stock and that they must make alternative arrangements in this regard. (i) Large scale, sustained, practical training programme for farmers and extension workers. (j) CA to be fully integrated into curriculum at University of Swaziland. (k) Sufficient extension staff (ratio of 1:60 farmers is recommended in Zimbabwe; the ratio in Swaziland is well over 1:1000). (l) Development of well managed side-by-side demonstrations comparing CA with conventional tillage over several years. (m) Need for good farm management and timely planting, weeding and pest/disease control.

6.4.6 Sustainable Crop Intensification in Madagascar through Conservation Agriculture (by Jean-Louis Reboul)

Since 1990 an NGO (‘TAFA’) has been in collaboration with IRAD and with CIRAD/Brazil in adapting direct-seeding cropping systems to the diverse agro-climatic and agro-ecologic situations in Madagascar. This has included work on farmers’ fields among a wide range of cropping systems and degrees of farming sophistication. Effects have been observed and measured over 15 year, and have shown potentials for improving soil health and function, and people’s health. The promotion of these varied systems as a national priority was decided by the Government. The technical successes have provided a basis for AFD and CIRAD to develop an international programme in the ‘direct seeding’ cropping programmes and some countries in both Africa and Asia. All the appropriate policies and arrangements to promote adaptation, adoption and spread seem to be have been organised by the Government together with TAFA, built around an original institutional organisation – ‘The Madagascar Direct Seeding Group’ -- a National Diffusion Strategy, much training, and the recent implication of the research community. However, in spite of significant investments, the spread of these technically-validated technologies has amounted to only about 2,500 ha, on which only simple systems seem to be appropriated by the Malagasy farmers. Some hindrances have been identified: (a) insistence by donors on focussing on small farmers alone - among whom change is always slow - exacerbated by the fact of exposure of the technical advisory staff (who have little technical background in the concepts and methods and too little training) to many challenging problems they don’t know how to address; (b) complexity of the ‘perfect’ systems proposed by the scientific community; (c) little or no attention to larger commercially-oriented farmers who could show evidence of the potential benefits, nor involvement of the private sector etc. The type and extent of necessary improvements for wider and more rapid spread include: (i) Strengthening the national operational capacity through experimentation and exposure to field practice, (ii) simplification of the technology for easier understanding by the intended users, (iii) amplification and diversification of training and education activities, and specific training of a large number of Extension staff; (iv) further elaboration f the |national Diffusion Strategy to cover a wide range of users and support agencies, (v) specific assistance to individuals, (vi) support to small farmers by providing appropriate inputs and equipment; (vii) specific support to private sector operators to provide services by large mechanised units; (viii) funding of group activities to improve sustainable land management on communal lands.

7. AREAS AND OPTIONS FOR ACTION

The following sections are based on the outcome of the Rome Workshop and as reported in FAO (2008a, 2008b) and constitutes the views of a large number of CA stakeholders worldwide who have a great deal of experience with promoting the development, adaptation and introduction of CA technologies and practices. The stakeholder experience range across most agro-ecologies and socio-economic situation, for small farmers and large farmers.

Focus on CA Technology Development, Adaptation and Introduction

As highlighted in the previous sections, technologies that can help put CA principles into practice are mostly available. However, their local adaptations to specific cropping systems and cultures across diverse agro-ecological and socio-economic situations are most important. In many places, the introduction of CA technologies and practices will be from scratch, calling for mechanisms such as FFS that would enable empowering farmers through phased learning and discovery processes.

The evolving family of CA practices presents farmers and the various institutions supporting them with many productive opportunities to deal with current problems that are likely to become more stressful in the future: food and fuel price increases, labour shortages, water constraints, soil degradation, and adverse climate impacts.

The immediate **goals** of CA include increasing the productivity of land, water, labour and capital to meet human needs, while preserving the integrity of the natural ecosystems on which all life depends. Specifically, CA aims to conserve and enhance the quality of natural and human resources, while achieving greater profitability of agriculture for producers, assured supply and better-quality food for consumers, and greater and sustainable livelihood opportunities to raise standards of living broadly and equitably.

CA practices contribute to the **broader goal** of sustainable agriculture by the synergistic management of soil, water, plant and animal, labour, and soil biotic resources. While the main examples of CA summarized in Section 6 have been developed and demonstrated in the domain of field crops, CA practices are applied also to plantation crops, livestock production, agroforestry, and enrichment of soil biodiversity to capitalize upon inter-specific interactions in supportive environments above- and below-ground.

Many stakeholders are convinced of the desirability of enabling many more farmers around the world to take up CA practices, both in their own interest of securing a better livelihood and in the broader public interest of conserving the quality of agricultural lands so that they can continue to be productive. To achieve this goal, collective knowledge and experience must be shared in introducing CA approaches to new countries and in supporting the accelerated adaptation and uptake of CA practices in countries in which they have already been introduced.

Agronomic strategies for CA aim at harnessing the abundant and diverse life forms that exist within soils to enhance their long term productivity. They include various combinations of:

- minimal or zero tillage;
- continuous soil cover often including green manure and cover crops;
- crop rotations, sequences and combinations;
- non-inversion weed control, including the use of allelopathy and smother crops;
- crop-livestock integration in farming systems;
- integration of perennial plants in farming systems;
- increase in biomass inputs to soil systems;
- optimization between organic and inorganic nutrient amendments;
- ecosystem-based and integrated management methods to control weeds, pests and diseases;
- erosion control infrastructure where needed;
- methods to increase soil absorption and retention of water (*in situ* ”green water”);
- enhancement of soil biological diversity and beneficial activity.

Organizational strategies include:

- participatory, farmer-centered research and development;
- greater assumption of responsibilities for agricultural innovation by farmer organizations, including catchment groups, and individual farmers;
- capacity building within such organizations and within specialized research and extension agencies especially to support scaling up;
- engaging the best modern scientific expertise for better understanding of below-ground processes and potentials driven by roots and soil biota;
- creation of incentives and certification of sustainable agriculture practices to recognize societal benefits and encourage uptake of sustainable farming systems; and
- establishment of a network of Communities of Practice (CoPs) bringing together diverse stakeholders around the world to give concerted support for changing mindsets, expanding institutional investments, sharing knowledge and experience, and promoting best practices.

Set out below are summaries of critical issues, goals for what might be done about them, and proposed actions that could be considered in the three broad stakeholder areas as detailed in FAO (2008b): science and technology development; underpinning scaling-up of CA; and creating supportive policies, putting in place incentives and tapping resources. No attempt has been made to set priorities amongst the proposed actions, but these are expected to emerge from the further collective thinking within the proposed CoPs.

7.2 Science and Technology Development

Strategic issues

- CA is characterized by the three central principles of no-tillage, soil cover and crop rotations; but there are many specific technologies that have to be appropriately selected and combined to apply the three principles in practice in ways that are attractive to farmers in very different agro-ecological settings.
- Whatever the technology combinations, good crop, land and livestock management must be constantly assured for the system to function well.
- CA is not a static technology but a dynamic system that will differ depending on biophysical and socio-economic conditions and evolve over time. R&D programmes must respond to this need.
- The contributions of numerous branches of the technical and social sciences, economic disciplines, stakeholders and interest groups must be combined in developing technologies and systems that are adapted to varied conditions and users.[2]
- Diverse providers and investors need to be involved in science and technology development for CA, including international agencies, multi-donor programmes, NGOs, government staff, academic institutions, commercial companies and agribusiness, each bringing different expertise but achieving synergy through using common disciplines and indicator sets.

Goals

- Research and development programmes to provide a common framework of knowledge, including a set of indicators for information collection and dissemination, that (i) quantifies and demonstrates the link between CA and soil health that underpins all the other benefits (ii) compares the technical, social, economic and environmental benefits of CA to farmers and society with conventional agricultural practices, (iii) ensures continuing improvements in CA over time and (iv) allows for integration of CA into farming systems.
- Research and development to provide a platform to scale up CA from the plot level to the farm and landscape level, and to mitigate climate change and desertification.

Priority actions

- Quantify the process changes that demonstrate why CA-based systems are better and more sustainable than conventional agriculture systems, including generation of more rigorous information on the benefits to farm family livelihoods and the broader society.

---

[2] Disciplines include crop science (breeding and seed supply of both cash and cover crops, including legumes), soil science (physical, hydric, chemical and biological), crop management for dryland and irrigated conditions (rotations, beds, fertilizer), climate change (gaseous emissions and carbon), biofuel production, weed and pest control, livestock, engineering (machinery production and development), social-economic sciences (family, gender, labour, time, drudgery, alternate farm enterprises, the economics and benefits of CA uptake), as well as politics (local, regional and national policies and their implementation).

- Evaluate capital losses from soil degradation and the economic gains to be derived from CA-linked rehabilitation.
- Develop crop/soil/livestock/economic system models that integrate the effects of CA systems; extrapolate results to other regions and conditions and indicate areas that require further research and understanding.
- Prepare "Frequently Asked Questions" (FAQs) or "mythbusters" to respond to the most commonly raised questions/misunderstandings about CA.
- Study the processes of innovation and diffusion of CA practices and the dynamics of on-farm and collective decision-making with the objective of understanding if and how uptake can be accelerated.
- Deepen understanding of management options and trade-offs of crop/livestock CA systems, including the increased productivity of marginal or degraded lands.
- Improve CA machinery to move beyond expensive imported equipment and create local manufacturing capacities and markets to meet growing demand: consider the special needs of small farmers with little cash or credit to buy CA equipment.
- Set up R&D programmes to refine choices of crops and rotations within CA.
- Building on current CGIAR centre initiatives, create a set of CA observation sites worldwide in major agro-ecosystems to provide focal points for strategic long-term research, applied on-farm research, farmer adaptation and impact assessment studies, training and learning nodes.
- To aid building the CA knowledge base, where possible use common indicators and benchmarks in monitoring and evaluating trials in different regions.
- Aim for synergies of inputs/outputs and cross-cutting scenarios by promoting active inter-country and inter–agency networking for data and information sharing.

7.3 Underpinning Scaling-Up of CA

Strategic issues

- A single global strategy for up-scaling CA will not work: strategic approaches must be tailored to countries, regions or even local sites, reflecting specific technical, economic and social conditions.

- The needs, technologies and potentials for CA uptake by large- versus small-scale farmers are distinct, and must be tackled in a differential manner. Linking the learning and uptake processes of large and small farmers offers potential payoffs in speeding uptake, but effective and equitable links must be built.

- Up-scaling cannot be hastened: the pace of local adaptation and dissemination of CA principles must be compatible with the capabilities of farmers, support services and other stakeholders.

- For small-scale, risk-averse farmers especially, introducing CA will often be stimulated by providing targeted incentives, and fair cost-sharing and risk protection arrangements over several years. These may be perceived as a just compensation for the many eco-services that adoption of CA is likely to generate for the benefit of society at large.

- Wherever possible, simultaneous uptake by farmers of all three CA principles is desirable to achieve greatest impact. But a step-wise approach to the introduction of the principles may at times respond better to farmers' constrained socio-economic situations, scarce resources and perceptions of risk.
- Ensuring the availability of well-prepared advisers and facilitators is key to minimise the potential negative effects of suboptimal performance of CA systems in the early years of their introduction.

Goals

- Location- and client specific knowledge and mechanisms to be available to all categories of target farmers that empower them to understand the CA principles, support them in transition to CA in their own situations, and transmit their experience to other groups.
- Farmers and communities to be empowered to recognise which technical approaches to CA principles are appropriate to their own situations, apply them and transmit their experience and ideas to others.
- Farmers and communities who take up CA to be willing to accept the risks of change and receive full value for the wider benefits to society that they thereby generate.

Priority actions

- Build CA introduction within the context of the overall functioning and dynamics of local farming systems and their changing environment; address economics, crop-livestock interactions, gender and cultural aspects, among others - but do not over-estimate possible rates of change.
- Ensure close partnering from the start among diverse stakeholders in adapting, promoting and supporting CA uptake – e.g., farmers and their organisations, research, extension services, service/input/credit providers, government agencies, NGOs, etc.
- Ensure that farmers assume a leading role in the process, developing as appropriate local, national and regional CA networks/task forces to facilitate capacity building, sharing of knowledge and active mutual learning.
- Develop knowledge management systems at the scales required to provide stakeholders with quality evidence on the performance of CA, its impact, successes and failures, under their diverse conditions.
- Assess the specific needs of all target categories of potential CA adopters; tailor empowerment and support arrangements to their specific needs.
- Introduce CA principles pragmatically, based on understanding of realities on the ground. Start change using locally-available inputs and based on local knowledge and beliefs whenever possible.
- Demonstrate benefits of simultaneous uptake of all CA principles from the start but maintain an approach to adoption that remains flexible and compatible with farmers' willingness and capacity to implement CA.

- Pay special attention to the start-up phase of CA adaptation; unless skillfully organized and guided, failures are likely.
- Provide small-scale, risk-averse farmers with targeted incentives or cost-sharing to help them overcome a slow start up of CA, and cover the costs and risks of learning and adapting technology to their particular conditions.
- Link CA focus groups together through networks, forums and exchanges to share experiences and technologies, nationally and internationally.
- Include specific encouragements for larger-scale and more advanced CA practitioners to advise and mentor those at earlier stages of adaptation and uptake.
- Ensure adequate attention is given to supply chains for specialist inputs and equipment when they become necessary, as well as ensuring proper access to input and output markets.

7.4 Creating Supportive Policies, Putting in Place Incentives and Tapping Resources

a. Branding

Strategic issue
The basic principles of CA fully support the overall aims of sustainable agriculture. However they are often confused with other related, overlapping or complementary initiatives for changes to agricultural systems.

Goals

- The public, policy makers, agricultural scientists and farmers to be made aware that, without more attention to soil health, returns from further input intensification of agriculture will continue to decline. Uptake of CA principles is accepted as the future pathway towards sustainable and more profitable agriculture.
- CA principles support and facilitate other initiatives for sustainable agriculture and do not compete with other ‘brands’ such as Sustainable Agriculture or Eco-agriculture.

Priority actions

- Communicate that CA principles fit into the larger context of sustainable agriculture.
- Stress basic principles and understanding that there are a wide range of means of applying these principles in specific contexts.
- Engage NGOs as advocacy partners. Link into efforts that are already developing guidelines for sustainable biomass production.
- For the above, use the expanding CA knowledge bases recommended below.
- Enlist professional PR assistance.

b. Positioning

Strategic issue

Investment in CA offers a tremendous opportunity to contribute simultaneously to progress in resolving major world issues related to food security and prices, reaching MDGs, energy saving, the environment and climate change adaptation and mitigation. There are many ongoing or planned initiatives in these fields within which CA must be positioned.

Goal
A CA approach to become integrated into large scale programmes and processes related to food, the environment, climate change, poverty alleviation, national/regional programmes, including. CAADP/NEPAD, AGRA, the operations of Conferences of the Parties on biodiversity, desertification and climate change, initiatives for food security and poverty reduction initiatives (PRSP), and the programmes of producer networks, large investors and International Financing Institutions (IFIs).

Priority actions

- "Sell" CA's win-win potentials for resolving current global issues affecting agriculture and the environment – e.g., slowing climate change through reduced fossil fuel use, reduced gaseous emissions, increased carbon sequestration from residue retention and build-up of soil organic matter; reduction of the impacts on food security of seasonal weather volatility; contributions to watershed repair through reduced runoff, improvements in water quality and reduced siltation; reduction of desertification due to reduced erosion and permanent ground cover; potentials created for biofuels through sustainable use of marginal land.
- Describe potentials for impacts on such issues within large and small-scale farming systems but show how required approaches differ.
- Build awareness of positive opportunities and constraints for CA within existing and transitional policy environments.
- Publicise CA: consider launching a CA Journal, also stress use of new media forms such as cell phones, DVDs and the internet.

c. Advocacy and Capacity

Strategic issue
CA presents a paradigm change that offers the means to introduce new, beneficial systems that can raise the positive image of agriculture and farmers. However means and capacity for advocacy and change are at present inadequate.

Goals

- The advantages of CA to be understood and well known by the general public, political leaders, decision-makers and stakeholders. There is national enthusiasm and implementation capacity to advance paradigm change.
- Farmers to be seen as stewards rather than despoilers of national land and natural resources.

Priority actions

- Increase attention to agriculture sustainability issues in education and knowledge systems (see below).

- Create alliances with environmental groups (e.g., UNEP, WWF).
- Promote concepts of good environmental stewardship which can be well understood by the general public, various stakeholders and policy makers.
- Promote and acknowledge success and contributions of individual farmers and communities.
- Promote CA role in 'green water' management.
- Support and strengthen advocacy and PR by farmers and their networks to raise the positive image of farming.

d. Knowledge

Strategic issues

- Knowledge systems need to give greater prominence to the successes and potentials of CA and its central role in maintaining agricultural sustainability and profits.
- The CA paradigm scarcely features in education and training programmes, most of which continue to teach inversion tillage as central to sound agricultural practice. Funding and curriculum reforms are needed to strengthen knowledge about CA principles, practice and potentials at various levels in education, training, research and development organisations, and as part of farmer training and empowerment.

Goals

- Knowledge and evidence of the potentials and beneficial results of CA to be well known to political leaders, policy makers, donors, the private sector and farmers.
- This knowledge to have secured public support for development of enabling national and local policies, strategies and programmes to promote CA investment.

Priority actions

- Classify and where possible quantify the benefits to society that can result from different approaches to CA adoption. Create public awareness and lobby for policy reforms that will adequately reward adopters or indemnify farmers against risks of change.
- Build and transmit knowledge of CA potentials to all relevant audiences, covering both 'legs' of the issue – needs of small scale and larger farmers.
- Support increased national capacities for knowledge management.
- Within knowledge management systems, assemble experiences covering the costs and benefits of CA, livelihood and social benefits, environmental benefits, also farmer decision/making processes in CA uptake and the dynamics of system change.
- Boost education and training on CA principles and benefits in universities, colleges and schools. Emphasize strategic training/research on appropriate knowledge areas (ecosystem, farm size, socio economics) within the different scientific disciplines, stressing commonality of the CA principles but diversity of the technologies and development approaches through which CA principles are applied. At tertiary level, test/validate the science and products of CA.
- Provide fiscal incentives and use PR and the public media to move education towards better understanding of CA and to overcome entrenched beliefs in the tillage paradigm.
- Assess and respond to knowledge needs along commodity value chains.

- Use large farmers to channel information to smaller farmers. Review and synthesise CA knowledge for wider dissemination.

e. Policy and Incentives

Strategic issues
CA uptake may involve costs and risks to which farmers, especially small-scale farmers in resource poor settings, are averse. Appropriate policies and incentives must be put in place to share costs and risks and recognise the public goods value of environmental benefits generated by widespread CA adoption.

Goal
Specific enabling policies and incentives to be put in place by governments and international institutions seeking to broaden the uptake of CA and by relevant inter-governmental bodies.

Priority actions
Use or develop case studies and the knowledge necessary to justify policy change and incentives for CA uptake, including knowledge on increased agricultural output, C sequestration, reduced N_2O and CO_2 emissions, energy efficiency, cost/benefit improvements, water productivity and watershed functions. Options include to:

- Assist in the evolution of national policies and community or individual incentives geared to CA uptake in general.
- Seek specific government endorsement or recommendation of CA.
- Provide for cost sharing for adaptation, promotion and dissemination of CA technology and to encourage local manufacture of small machinery.
- Encourage international institutions and donors that support CA to adapt their funding instruments to cover the full period necessary for CA to become a permanent element of production systems.
- Develop certification criteria for CA production systems and their products, as a means of increasing value-added for CA farmers.
- Explore incentives for biomass production and carbon retention by small farmers.
- Promote closer working between government and farmers, the private sector, technology generators/disseminators, and NGOs in policy reform, and the design and application of incentives for uptake of CA.
- Create a Competitive Grant Fund for CA research and education

7.5 Next Steps: Establishing a CA Community of Practice (CA-CoP)

The next steps outlined in this section have grown out of an increasingly shared and deep understanding among persons from many countries, professions and institutional affiliations of the profoundly biological nature of agricultural systems' performance. Mechanical and chemical interventions can generally produce desirable short-term results and have enabled food production to respond successfully to an unprecedented rise in demand over the past half century. Experience and scientific evaluation, however, are showing that the technologies on which recent growth in farm output are based are less and less sustainable, as soil degradation is becoming an ever greater problem. The rapidly rising cost of petrochemical-based inputs, growing concern for human and soil health, and recognition of the links between intensive farming and climate change processes make it vital for the world's farmers to raise output using methods that do not further compromise the natural resource base for agriculture and diverse ecosystems.

Stakeholders recognise the value of joint action and wish to contribute to the emergence of greater and sustainable institutional and human capacities to:

- acquire, evaluate, share and disseminate accurate, unbiased and diverse **knowledge** about the principles, practices and impacts of CA;
- raise **understanding** in governmental circles, professional organizations and the general public of the benefits, limitations and solutions relating to CA;
- identify, share, enhance and give more ready access to multidisciplinary **expertise** on CA; and
- support diverse **initiatives** for research, extension, advocacy and evaluation of CA that can advance the state of the art and the effective application for CA.

The concept of 'Community of Practice' (CoP) has emerged within development communities to formalize and strengthen the connections among like-minded persons who work in a variety of circumstances and seek collectively to improve both knowledge and practice. The participants in the FAO workshop in July 2008 proposed establishing a number of interconnected CoPs that can further the objectives of CA as discussed above. Modalities remain to be worked out in detail, with appropriate organizational and financial support, but the outlines of such an emergent capacity can be drawn.

The premises for a CoP are:

- The improvement of both theory and practice is greater from a **continuous interaction** between researchers and practitioners than from following the previous concept of a linear process where knowledge is generated and validated separately from practice, being subsequently 'extended' to practitioners;
- There is greater productivity from having **multi-sectoral cooperation** than having a standard 'division of labour' in that different kinds of institutions (public sector, private sector, NGO, academic, grassroots, etc.) have respective comparative advantages to contribute to a collective enterprise and learn from each other; and
- There is great power in bringing together **like-minded individuals** who operate from diverse institutional bases, who are agreed on the general goal even as they contribute different ideas and values about the means for achieving this; excitement and energy as well as information can be generated from heterogeneity that is encompassed within an 'envelope' of broad agreement leading to convergence of community members' perceptions and action.

The value orientations that make a CoP effective include:

- Concomitant valuation of knowledge/theory and of practice, privileging neither one over the other;
- Respect for diversity and for differences of opinion, within the framework of some broader shared objective and concern;
- Appreciation that the world is diverse and changing, and that ongoing, iterative learning is necessary and gratifying.

Participants decided to establish and sustain a **multi-stakeholder knowledge management system** that will be suited to the needs of diverse users, and in particular of farmers who can benefit from more appropriate and effective CA practices. Such a system of CoPs, with some overarching identity and common purpose, will engage a variety of agencies, professional organizations, and publics to acquire mindsets and create programmes more supportive of CA.

Implementing the ideas sketched below will be the responsibility of a temporary Facilitating Group, representing all sets of stakeholders and acting on behalf of the participants in this consultation, operating under a charter of purpose that frames the goals and modes of operation which will be circulated to participants by email for concurrence before the Group begins its work. Nominations and volunteers for the Group were solicited from all the participants before the end of the consultation, with the consultation's conveners asked to constitute an optimally sized Group with appropriate representation across sectors, roles, world regions, and disciplines.

Tasks for the Group over the 12 month after it begins work include, but are not limited to:

- Determine the most appropriate and sustainable **organizational arrangements** for the CoP/CoPs, with **administrative support** provided from one or more international organizations that want to facilitate the purpose of the CoP/CoPs.
- Identify possible sources of **financial support**, and enter into discussions with donor agencies to secure the resources needed to operate the envisioned international initiative.

Actions that the CoP/CoPs, when organized, could embark upon could include:

- Establishment of a **multi-functional presence on the internet** that can both provide information on CA and support interactive exchanges among CoP participants. Internet access and email have opened up opportunities for rapid, low-cost and highly interactive communication that we want to utilize. It should support collaborative efforts among individuals, organizations and communities as well as assist in problem-solving and ongoing innovation. Special efforts should be made for this information and these opportunities to be made available to agricultural communities.
- Maintenance of a **register of professionals and practitioners**, from a variety of disciplines and organizations and a variety of statuses who are willing to provide knowledge and support for CA initiatives at international, national, regional or local levels.
- Development of a **network of CoPs** that provide opportunities for greater contributions -- and outputs -- from participants in the overall CA-CoP. Possible focuses of specific CoPs would be:
    - *Knowledge for CA* – research agenda and priorities available to all persons interested; documentation on CA and evaluation of CA experience; exchange of research outputs, etc.
    - *Advocacy for CA* – public and professional communication; policy dialogue with decision-makers, etc.
    - *CA Application* – field support of CA initiatives, such as training modules; cumulative experience on participatory approaches, etc.
    - *Education for CA* – curriculum improvement in primary and secondary schools; enrichment of university and professional education.

Support for these CoPs might be worked out with several different institutions which are becoming higher-level stakeholders in CA such as GFAR, CGIAR, UNEP, IFAD, international farmer organizations, and UNESCO, universities and NGOs. FAO is the international organization with the broadest interest and stake in CA and has indicated its willingness to provide the administrative support base for the overall CA-CoP.

- A first activity for the Facilitating Group would be to form task forces from among the workshop participants to draft within the next four months a short **policy paper on CA** and an **analytical paper on the costs and benefits of CA.** These papers could be used in discussions with donor agencies, international organizations, professional organizations, private sector and others.

A Listserve has been now established at FAO to serve as a communication platform to facilitate the operations of this international network of CA-CoPs.

7.6 Focus on European Cooperation Policy on CA

European agricultural development policy for sustainable production in Europe and in the developing regions should have a clear approach to sustainable farming which in tropical conditions is not possible with tillage-based agriculture; hence all development activities dealing with crop production intensification should be assessed for their compatibility with CA. The fact that there is hardly any land under CA systems in Europe reflects the true reality of how uncoordinated and lagging behind the current strategic directions for sustainable agriculture are. Environmental management custodian schemes in Europe do not promote the principles and practices of CA, and farmers have no incentives to switch from the destructive and inefficient production systems to those based on minimal or no-till systems. This is because CA practices do not attract special rewards in the single farm payments to European farmers. On the contrary, commodity related subsidies or payment for set aside land work against the adoption of CA. Thus environmental costs arising from the negative impacts from intensive agriculture in Europe continue to be externalised and shifted to the society at large. Consequently, the degradation of soil, biodiversity and environment continue largely unabated. Intensive industrial tillage-based farming in Europe contributes to release of carbon into the atmosphere which can be reduced drastically with CA, and so can frequency of floods because water infiltration rates in agricultural soils under CA are several times higher, and enough to cope with the extreme rainfall events that are on the increase due to climate change. Further, due to lower agro-chemical requirement of CA systems for a particular level of production, there is relatively far less contamination of the environment including water resources, and there is greater room to accommodate a wide range of useful agrobiodiversity and wildlife under CA than under intensive tillage agriculture.

Recent reports conclude that half of the European agricultural birds are on their way to extinction unless something serious is done to address the situation. Set-aside schemes, originally introduced to decrease over-production, still continue but this time to encourage biodiversity 'ex-situ' which will never be adequate to rehabilitate and conserve agrobiodiversity and rural wild life. This is simply because the cause of the damage lies at the heart of the tillage-based industrialised systems of farming in Europe that are based on heavy inputs of agro-chemicals rather than harnessing the biotic and ecological potentials of the land resource base. Similarly, intensive tillage has been identified as a major cause for exacerbating flooding and risks of flooding during storms because of poor rainfall infiltration characteristics of most arable soils in Europe. Tillage-based input intensive farming has many unsustainable elements and European cooperation policy within and outside Europe should now seriously aim at transforming such systems towards CA systems. Such a transformation will lead to lower energy costs and agrochemical requirements, higher total and factor productivities and rehabilitation and conservation of biodiversity and the environment. CA systems also are better adapted to climate change and contribute to climate change mitigation.

It is perfectly feasible to meet food security needs in Europe and in the developing regions at lower economic and environmental costs through CA systems but the transformation to such systems will require effective political will and commitment as well as a higher quality of strategic research and extension programmes on CA systems from the public sector research, education and extension institutions. Currently, these policy provisions are lacking in Europe and therefore cannot enable and foster effective development cooperation policies between European nations and developing nations directed towards sustainable agricultural intensification.

7.7 Focus on Framing Conditions for CA in the EU

Several initiatives in Europe have been aiming in getting closer to a policy support of CA. The proposed Soil Framework Directive, resulting from the Soil Thematic Strategy (EUC, 2006) for example, would have facilitated national policies in support of CA. Unfortunately it was not adopted, probably because of the economic damage which some key industries might anticipate from a wide adoption of CA. However, the new EU Water Framework Directive includes permissible levels for pollutants in water such as nitrates, phosphates or pesticides, which even with conservation tillage methods cannot be reached. First indications from watershed based field experiments in Saxony/Germany indicate that only under permanent no-tillage systems (CA) the erosion and leaching of these agrochemicals into surface and subsurface water bodies can be reduced to a level compatible with the new water framework directive.

Within Europe there is an increasing concern about the sustainability of farming and organizations promoting CA in Europe, such as ECAF, which has also received an EU-life project, or ECAF’s institutional members from some 14 different European countries who are becoming increasingly vocal in promoting CA as a necessary condition for truly sustainable agriculture. CA principles, knowledge, skills and practices as well as the associated learning and dissemination processes are of a ‘public goods’ nature and are effective in reducing purchased exogenous input requirements while enhancing the natural endogenous biotic and ecological productivity enhancing processes. Consequently, it is unlikely that the European private sector, particularly the input market chains that deal with agro-chemicals and machinery supply or the largely privatised research and extension service, will provide leadership in creating the enabling technical, market and policy conditions for transforming the current tillage-based systems to CA-based systems. European governments and European Commission will have to take responsibility of promoting the transformation.

EU’s Common Agricultural Policy (CAP) has been generally rather effective in managing agricultural change over the past several decades. The aim of the CAP is to provide farmers with a reasonable standard of living, consumers with quality food at fair prices and to preserve rural heritage. However, a common view is that the CAP has traditionally promoted a large expansion in agricultural production. At the same time it has allowed farmers to employ ecologically harmful ways of increasing production, such as the indiscriminate use of fertilizers and pesticides, with serious environmental consequences. However a total re-focusing of the payment scheme in 2004 now puts the environment at the centre of farming policy. This forces strict limits on the amount of nitrogenous fertilisers which can be used in vulnerable areas. Strict environmental requirements must also be observed to maintain any farm subsidy payments. The recent decoupling of farm subsidies and shift under the CAP to single farm payment scheme to remunerate farmers for providing environmental management services is a concrete example that EU governments are becoming more sensitive to environmental and land degradation in Europe, but the root causes of the degradation which is essentially the industrialised tillage-based agriculture remains largely unaddressed. This is because the decision about which system of farming to deploy is left to the farmer. The land stewardship scheme that is linked to single farm payment could potentially serve as an effective incentive lever to move European farming towards CA-based practices provided CA principles and practices are explicitly integrated into the scheme.

LITERATURE

Baker, C. J., Saxton, K.E., Ritchie, W.R. (1996): *No-Tillage Seeding: Science and Practice.* CAB International, Wallingford. 258 pp.

Baker, C.J., Saxton, K.E., Ritchie, W.R., Chamen, W.C.T., Reicosky, D.C., Ribeiro, M.F.S., Justice, S.E., Hobbs, P.R. (2007): *No-Tillage Seeding in Conservation Agriculture* – 2nd Edn. CABI and FAO, Rome. 326 pp.

Barber, R.G. (1996): *Linking the production and use of dry-season fodder to improved soil conservation practices in El Salvador*. Proyecto CENTA-FAO, GCP/ELS/004/NET, documento de campo Nº 8.

Baudron, F., Mwanza H.M., Triomphe, B., Bwalya, M. (2007): *Conservation agriculture in Zambia: a case study of Southern Province*. FAO, Rome. 28 pp.

Benites J., Vaneph S., Bot, A. (2002): Planting concepts and harvesting good results. *LEISA Magazine*, Oct. 2002, 18(3): 6-9.

Boahen, P., Dartey, B.A., Dogbe, G.D., Boadi, E. A. (2007): *Conservation Agriculture as practised in Ghana.* CIRAD and FAO, Rome 33 pp.

Bunch, R. (2008): Nutrient Quantity or Nutrient Access? A New Understanding of How to Maintain Soil Fertility in the Tropics. Unpublished paper (Pers. comm.).

Bunch, R, Lopez, G. (1995): *Soil recuperation in Central America : Sustaining Innovation after Intervention.* Gatekeeper Series no. 55. International Institute for Environment. and Development (IIED), London

Calegari, A., Alexander I., 1998: The effects of tillage and cover-crops on some chemical properties of an oxisol and summer crop yields in southwestern Paraná, Brazil. *Advances in GeoEcology*, 31: 1239-1246.

Castro Filho, C., Muzilli, O., Podanoschi, A.L. (1998): Estabilidae dos agregados e sua relacao com o teor de carbono organico num Latossolo roxo distrofico, em funcao de sistemas de plantio, rotacoes de culturas e metodos de preparo das amostras. *Revista Brasileira de Ciencia do Solo*, 22: 527-538..

Chamberlain, D. (2008): *The Farmers Club Journal,* Winter 2008. Royal Agricultural Society of England, London, pp. 14-15.

Crabtree, B. (2004): Strong Economics of no-tillage cause widespread adoption in southern Australia. *Paper presented at the First congress on Conservation Agriculture/No-till*, Dnepropetrovsk, Ukraine, 18-23 November 2004.

CTIC (2005): *CTIC National Crop Residue Management Survey 2004.* Conservation Technology Information Centre, CTIC Partners. West Lafayette, Indiana, USA.

De Freitas, V.H., (2000): *Soil Management and Conservation for Small Farms.* Soils Bulletin 77. FAO, Rome. 66pp.

Devendra, C., Sevilla, C., Pezo, D. (2001): Food-feed systems in Asia: *Review. Asian-Aust. J. Anim. Sci.* 14: 733-745.

Derpsch, R. (2005): The extent of conservation agriculture adoption worldwide: Implications and impact. In: *The Proceedings of the 3rd World Congress on Conservation Agriculture*, Nairobi, Kenya, 3-7 October 2005; ACT, Harare.

Derpsch, R. (2008a): No-Tillage and Conservation Agriculture: A Progress Report. In: *'No-Till Farming Systems'*, Goddard *et al.* (Eds.), pp. 7-39. World Association of Soil and Water Conservation (WASWC) Special Publication. No.3., WASWC, Bangkok.

Derpsch, R. (2008b): Critical Steps in No-till Adoption. In: *No-Till Farming Systems* (Goddard, T. *et al.* (Eds.), pp. 479-495. World Association of Soil and Water Conservation (WASWC) Special Publication No. 3, Bangkok.

Doran, J.W., Zeiss M.R, (2000): Soil health and sustainability: managing the biotic component of soil quality. *Applied Soil Ecology*, 15(1):3-11.

EUC (2006): *Thematic Strategy for Soil Protection,* [SEC(2006)620], [SEC(2006)1165], COM (206) 231, final 22.9.2006. Communication from the Commission of the Council, The European Parliament. The European Economic and Social Committee and the Committee of Regions, European Commission, Brussels.

FAO (2001a): *Conservation Agriculture: Case Studies in Latin America and Africa.* Soils Bulletin No. 78. FAO, Rome. 66 pp.

FAO (2001b): *The Economics of Conservation Agriculture*. FAO, Rome. 65 pp.

FAO (2008a): *Investing in Agricultural Intensification: The Role of Conservation Agriculture – A Framework for Action.* International Technical Workshop on Investing in Sustainable Crop Production: The Case for Improving Soil Health held at FAO, 22-24 July 2008. Plant Production and Protection Division, FAO, Rome. (http://www.fao.org/ag/ca/doc/proposed_framework.pdf).

FAO (2008b): *Report of the International Technical Workshop on Investing in Sustainable Crop Production: The Case for Improving Soil Health* held at FAO, 22-24 July 2008. Plant Production and Protection Division, FAO, Rome.

Fileccia, T. (2008): *Conservation Agriculture and Food Security in Kazakhstan.* Working Paper (final draft), Plant production and Protection Division, FAO, Rome.

Friedrich, T. and Kassam A.H. (2009): Adoption of Conservation Agriculture Technologies: Constraints and Opportunities. Invited Keynote Paper at the 4th World Congress on

Conservation Agriculture: *Innovations for Improving Efficiency, Equity and Environment.* 4-7 February 2009, New Delhi, ICAR.

Gan, Y., Harker, K.N., McConkey, B., Suleimanov, M. (2008): Moving Towards No-Till Practices in Northern Eurasia. In: *No-Till Farming Systems*. Goddard, T., Zoebisch, M., Gan, Y., Ellis, W., Watson, A., Sombatpanit, S. (Eds.), pp. 179-195. Special Publication No. 3, World Association of Soil and Water Conservation (WASWC), Bangkok. 544 pp.

Goddard, T., Zoebisch, M., Gan, Y., Ellis, W., Watson, A., Sombatpanit, S. (2008) (Eds.): *No-Till Farming Systems*. Special Publication No. 3. World Association of Soil and Water Conservation (WASWC). Bangkok, Thailand. 544 pp.

Hamilton, P. (2003): Goodbye to Hunger! - Effects of Conservation Agriculture Beds on Small Farmers' Livelihoods in Kenya: Conservation Farming with Near-Nil Investment. *ENABLE – Newsletter of the Association for Better Land Husbandry,* no. 16, March 2003. www.taa.org/pubdpapers/*ENABLEJune2003*

IIRR and ACT (2005): *Conservation Agriculture: A Manual for Farmers and Extension Workers in Africa.* International Institute of Rural Reconstruction (IIRR), Nairobi; African Conservation Tillage Network (ACT), Harare. 152 pp.

Kassam A.H. and Friedrich, T. (2009): Perspectives on Nutrient Management in Conservation Agriculture. Invited Keynote Paper at the 4th World Congress on Conservation Agriculture: *Innovations for Improving Efficiency, Equity and Environment.* 4-7 February 2009, New Delhi, ICAR.

Kaumbutho, P., Kienzle, J. (2007): *Conservation Agriculture as Practised in Kenya: Two Case Studies.* African Conservation Tillage Network (ACT), Centre de coopération internationale de Recherche Agronomique pour le Développement (CIRAD), FAO. 109 pp.

Kueneman, E., Kassam, A.H., Legoupil, J., Freude, B. (2007): Harnessing the agricultural productivity of the moist savannas through the dissemination of proven technologies and good agriculture practices: going to scale in Burkina Faso. *Tropical Agriculture Association Newsletter*, 27(4): 21-25.

Lal, R., Griffin, M., Apt, J., Leave, L., Morgan, M.G. (2004): Managing Soil Carbon. *Science* Vol. 304 No. 5669, 16 April 2004, p. 393.

Landers, J. (2007): *Tropical Crop-Livestock Systems in Conservation Agriculture: The Brazilian Experience.* Integrated Crop Management, Vol. 5. Plant Production and Protection Division, FAO, Rome. 92 pp.

Maguzu C. W., Ringo D., Mariki W, Owenya M., Kola F., Leseyo C. (2007): *Arumeru District.* In: Conservation agriculture as practised in Tanzania: three case studies. Shetto R., Owenya M. (Eds.). ACT/Nairobi, CIRAD/Paris, FAO/Rome.

Moeller, O. (1997): *Farmers' Tools*. Farmesa, FAO, Zimbabwe. 115 pp.

Muraguri, P. (2000): *Farmers' Voice for Demand-Led Services*. In: Identifying Private Incentives to Better Land Husbandry in the Tropics and Sub-Tropics – Summary record of the ABLH Workshop. Shaxson, T.F.(Ed.). Wye College, 28-29 March 2000'. Association For Better Land Husbandry, Tropical Agriculture. Association., UK. 15pp.

Mwangi P.K., Okelo, K. O., Apina, T. (2007): *Siaya District*. In: Conservation Agriculture as practiced in Kenya: two case studies. Kaumbutho P., Kienzle J. (Eds.). ACT/Nairobi, CIRAD/Paris, FAO/Rome.

Nyamwaya, D. (1997) (Ed.): *Coping without Coping – what poor people say about poverty in Kenya*. Human Resources Social Services Department of the Office of Vice-President and Ministry of Planning and National Development, Government of Kenya.

Nyende, P., Nyakuni, A., Opio, J.P., Odogola, W, (2007): *Conservation Agriculture: a Uganda case study*. FAO, Rome. 29 pp.

Pieri C., Evers, G., Landers, J., O'Connell P., Terry, E. (2002): *No-Till Farming for Sustainable Rural Development*. Agriculture and Rural Development Working Paper, World Bank, Washington DC. 65 pp.

Pezo, D.A., Lanting, E.F., Wong, C.C., Kerridge, P.C. (2000): Feed resources for ruminants in smallholder farming systems in South East Asia. In: W.W. Stur, P.M. Horne, J.B. Hacker and P.C. Kerridge (eds.). *Working with farmers: The key to adoption of forage technologies*. pp. 97-111. ACIAR Proceedings No. 95. ACIAR, Canberra, Australia.

Quiroz, R.A., Pezo, D.A., Rearte, D.H., F. San Martín **(**1997): Dynamics of feed resources in mixed farming systems of Latin America. In: C. Renard (ed.). *Crop Residues in Sustainable Mixed Crop/Livestock Systems*. pp. 149-180. CABI, Wallingford, U.K.

Rogers, E.M. (1983): *Diffusion of Innovations*. The Free Press, NY. 453 pp.

Rumley, R., Ong, C., (2007): Wetting Africa's Appetite: Conservation Agriculture is Rainfall into Higher Crop Yields – and Catching On. *RELMA Review Series Conservation Agriculture in Africa*, Issue 3. (http://www.relma.org/PDFs%5CIssue%203%20%20Conservation%20Agriculture.pdf).

Sánchez, M. (1995): Integration of livestock with perennial crops. *World Animal Review* 82: 50-57.

Sain, G. E., Barreto, H. J. (1996): The adoption of soil conservation technology in El Salvador: Linking Productivity and conservation. *J. Soil and Water Cons*. 51:313-321.

Shaxson, T.F., (2006): Re-thinking the Conservation of Carbon, Water and Soil: A Different Perspective. *Agronomie*, 26 (2006)1-9.

Shaxson, F., Kassam, A.H., Friedrich, T., Boddey, B., Adekunle, A. (2008): Underpinning Conservation Agriculture’s Benefits: The Roots of Soil Health and Function. *Main background document for the Workshop on Investing in Sustainable Crop Intensification: The Case for Improving Soil Health*, 22-24 July, FAO, Rome.

Shepherd, T.G. (1992): Sustainable soil and crop management and its economic implications for grain growers. In: *Proceedings of the International Conference on Sustainable Land Management* (ed. P. R. Henmriques), pp. 141-152. 17-23 November 1991, Napier, Hawkes Bay, New Zealand.

Sorrenson, W.J. (1997): *Financial and Economic Implications of No-Tillage and Crop Rotations Compared to Conventional Cropping Systems.* TCI Occasional Paper Series No. 9. FAO, Rome.

Tebrügge, F. and Böhrnsen, A. (2000): *Direktsaat-Beurteilung durch Landwirte und Experten in der EU und Nebraska*. Landtechnik 55, 1, S. 17-19.

Testa, V.M., Teixeira, L.A.J., Mielniczuk, J. (1992) Caracteristics quimicas de um Podzolico vermelho-escuro afteadas pro sistemas de culturas. *Revista Brasileira de Ciencia do Solo*,16: 107-114.

Triomphe, B., Kienzle,J., Bwalya M., Damgaard-Larsen S. (eds.) (2007): ‘*Conservation Agriculture in Africa’* series. Case Study Project Background and Method. In: ‘*Conservation Agriculture as Practiced in Kenya: Two Case Studies’* African Conservation Tillage Network (ACT), Centre de coopération internationale de Recherche Agronomique pour le Développement (CIRAD), FAO. 109 pp.

ABBREVIATIONS

AAPRESID	Associación Argentina de Productores de Siembra Directa
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands, Syria
ACT	African Conservation Tillage Network, Kenya
AEAC.SV	Associación Española de Agricultura de Conservacion. Suelos Vivios, Spain
AFD	Agence Française de Développement
FFEM	French Global Environment Facility
AGRA	Alliance for Green Revolution in Africa
AIGACoS	Associazione Italiana per la Gestone Agronomica e Conservativa del Suolo, Italy
APAD	Association pour la Promotion d'une Agriculture Durable, France
APAARI	Asia Pacific Association of Agriculture Research Institutions, Thailand
APDC	Associação de Plantio Direto no Cerrado, Brazil
APOSOLO	Associação Portuguesa de Mobilização de Conservação do Solo, Portugal
BARACA	Belgium Association in Research Application on Conservation Agriculture,
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CAAPAS	Confederación de Asociaciones Americanas por una Agricultura Sustentable
CA/DD	Conservation Agriculture based on Direct Seeding
CAIR	Conservation Agruiculture Ireland
CAP	Common Agricultural Policy
CASA	Conservation Agriculture Systems Alliance, USA
CA-SARD	Conservation Agriculture for Sustained Rural Development Project, FAO
CEC	Cation Exchange Capacity
CGIAR	Consultative Group on International Agriculture Research
CIMMYT	International Maize and Wheat Improvement Centre
CIRAD	Cenre de Coopération Internationale en Recherche Agronomique por le Developpement
CTRC	Conservation Tillage Research Centre, China
CoP	Community of Practice/Communities of Practices
ECAF	European Conservation Agriculture Federation
EMBRAPA	Brazilian Organization for Agricultural Research
EU	European Union
FAO	Food and Agriculture Organization of the United Nation
FARA	Forum for Agricultural Research in Africa
FEBRAPDP	Federation of No-Till Farmers of Brazil
FFS	Farmer Field School
FINCA	Finnish Conservation Agriculture
FORAGRO	Forum for the Americas on Agricultural Research and Technology Development
FRDK	Foreningen for reduceret jordbearbejdning i Danmark
GFAR	Global Forum for Agriculture Research, Rome
GHC	Ghanian Cedis
GHG	Green House Gases
GKB	Gesellschaft fur Konservierende Bodenbearbeitung, Germany
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit, Germany
HACA	Hellenic Association for Promotion of Conservation Agriculture, Greece
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome

IAASTD	Internation Assessment of Agricultural Knowledge, Science and Technology
IAPAR	Instituto Agronômico do Paraná, Brazil
ICARDA	International Centre for Agriculture Research in Dry Areas
ICRISAT	International Crops Institute for the Semi-Arid Tropics
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IFI	International Financing Institution
IIRR	International Institute of Rural Reconstruction
INERA	Institut National de la Recherche Agronomique, Burkina Faso
INIA	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Uruguay
INRM	Integrated Natural Resources Management
IPM	Integrated Pest Management
IPPM	Integrated Production and Pest Management
IRAD	Institut de Recherche Agricole pour le Developpement
ISFM	Integrated Soil Fertility Management
IWMI	International Water Management Institute
JICA	Japanese International Cooperation Agency
KARI	Kenya Agricultural Research Institute
KASSA	Knowledge Assessment and Sharing on Sustainable Agriculture
MDG	Millennium Development Goals
MoA	Ministry of Agriculture
MZTRA	Manitoba Zero Tillage Research Association
NEPAD	New Partnership for Africa's Development
NGO	Non Governmental Organization
NT	No-Till
PACA	Professional Alliance for Conservation Agriculture
PRSP	Poverty Reduction Strategy Paper
R&D	Research and Development
RELACO	Latin American Conservation Agriculture Network
SANTFA	South Australian No-Till Farming Association
SMI	UK Soil Management Initiative
SNT	Swiss Soil Conservation Association
SNTC	Slovak No-Till Club
SRI	System of Rice Intensification
TAA	Tropical Agriculture Association, UK
TAFA	Tany sy Fampandrosoana, Madagascar
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
TMME	Hungary Conservation Agriculture Association
WANTFA	Western Australia No-Till Farming Association
WASWC	World Association of Soil and Water Conservation
WB :	World Bank.
WWF	World Wide Fund