ADOPTION OF CONSERVATION AGRICULTURE

Adoption of Conservation Agriculture Technologies: Constraints and Opportunities*

THEODOR FRIEDRICH[1] and AMIR KASSAM[2]
Plant Production and Protection Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy

Abstract:
Conservation Agriculture in its different local adaptations is practiced for more than 3 decades and has reached nearly every part of the world. Wherever it has been adopted it has proven the benefits usually claimed in its favour. Therefore the question arises: if CA is so good, why is it not spreading like wildfire? Equal to many other good and proven agricultural production practices, the adoption of CA needs a primer before it can start moving on its own.

A number of constraints lie between the theory and a full scale adoption. These constraints come in different categories, such as intellectual and knowledge, social, financial, technical, infrastructural and last but not least policy.

At the same time, these constraints have provided a basis for meeting a number of actual opportunities which are facilitating change, namely:

- Crisis and emergencies, such as the soaring food prices, which makes people more receptive to opportunities for change.
- Increasing environmental concerns and pressures regarding the sustainability of production processes and the natural resource base, which is increasingly putting agriculture under pressure.
- Rising input and energy costs, calling for improved input use efficiency and productivity.
- Challenges of climate change for which CA holds promising adaptation and mitigation options.

The paper discusses the challenges and opportunities to adoption of CA principles and practices and the options to harness opportunities for overcoming the challenges.

Key Words: Conservation Agriculture, Technology Adoption

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[1] Theodor.Friedrich@fao.org [2] kassamamir@aol.com

INTRODUCTION

Conservation Agriculture (CA) is, to those who know it, the best bet for a sustainable and productive agriculture. People refer to CA as a win-win agricultural production system and it is successfully applied on more than 100 million hectares in so many different agro-ecosystems and cropping systems that the reason and justification for soil tillage should become weaker and weaker. Already in the 1940s Edward Faulkner in his revolutionary "Ploughman's Folly" stated that 'no *one has ever advanced a scientific reason for ploughing'*. Wherever CA has been adopted it has proven its benefits. The cases where CA did not perform as expected can usually be related to mistakes or shortcuts in the management of the system, but not to any inherent failures in the system. Yet the question arises: if CA is so good, why is it not spreading like wildfire? The simple answer is that the answer is not that simple. CA is knowledge intensive and a complex system to learn. It cannot be reduced to a simple standard technology and especially for pioneers and early adopters there are many hurdles in the way before the full benefits of CA can be reaped. This explains, why in all cases where CA has been or is currently in a process of successful adoption, this process follows an S-curve with a slow to very slow start, leading then into exponential growth, and slowing down towards a plateau level, which is most likely above 90% adoption. Since so far only about 6-7 % of the world cropland is farmed under conservation agriculture it can be postulated that in most countries CA is introduced as an "unknown" new concept and that neither the knowledge nor the other elements of an enabling environment for the adoption of CA in the country exist. This is the condition, which presents most of the constraints to adoption. Only in very few occasions, as was the case with the southern parts of Brazil in the 1970s, the problems with conventional tillage-based farming practices become so severe that spontaneous adoption occurs despite these constraints. In that case it was the uncontrollable water erosion combined with extremely poor profit margins for farmers. Obviously the reasons to change from one cropping system to another vary according to location, but in most cases erosion problems, climatic problems (drought) and unfavourable profit margins are the most important motivations for farmers to adopt CA.

As the adoption advances, the constraints decline, explaining the exponential uptake after some years. The duration of this slow early adoption before it turns into the exponential growth can be influenced mainly through supportive policies for services and related regulations.

CONSTRAINTS TO CA ADOPTION

Farmers in a country or region, where CA is not practiced, face a number of problems which make adoption difficult. These problems are of diverse nature, such as intellectual, social, biophysical and technical, financial, infrastructural and policy. Most farmers are facing several of these problems, if not all, at the same time to the effect that only very few bold pioneer farmers adopt CA. Farmers are not in the position to start with a blank sheet and to weigh objectively the merits and disadvantages of CA against conventional tillage farming. In all cases CA is the new unknown concept, while the default condition for more than 90% of the world's farmers is the conventional tillage-based practice which has worked for them so far.

Intellectual Constraints to Adoption

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. 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).

CA has actually two intellectual barriers to overcome: the first is that CA concept and principals are counterintuitive and contradict the common tillage-based farming experience, which has worked for generations and which often has created cultural values and rural traditions; the second is the lack of experiential knowledge about CA and the mechanism to acquire it..

Soil tillage, and particularly the plough, has in most countries become part of the culture of crop production. Ploughing, cultivation and tillage are often synonyms for growing a crop.

Cropland is called “arable” land which is Latin for “ploughable” land. The plough has been part of the very early developments of agriculture and has the character of a brand symbol for what is ‘correct’. It is therefore difficult for people to accept that all of a sudden the plough is dangerous and that a crop can grow without tilling the land. Overcoming this “mental compaction” is often much more difficult than actually physically starting with no-till farming (Landers 2001). Unless a person has seen it happen, it is very difficult to imagine a soil becoming softer and better structured without being tilled.

The second intellectual impediment to adoption is simply the lack of sufficient experiential knowledge about it at all and the means of acquiring it. Globally some 7% of the agricultural land is under CA. The adoption is concentrated in some few countries, eventually reaching adoption levels beyond 50%, while in the rest of the world the adoption is at levels below 2%. This explains that most people have never seen a CA system in practice. Since it is also not yet represented in any labels or certification schemes or has any direct relevance to consumers, CA hardly appears in the media. CA is also not included in university curricula even in good agricultural universities. This explains that, despite having an adoption level more than twice that of organic farming, the public knowledge about CA is much lower than about organic farming. Even most agricultural professionals and many farmers have never heard about CA, and if they have, they have only vague ideas. Permanent no-tillage farming and CA are often simply not known and therefore not on the screen as an option for farmers.

For actual adoption of CA the farmer would not only need to know about CA elements in general, she/he would need to know the details on how to implement CA elements under the specific conditions of an individual farm. This knowledge is generally not available as a standard technology package off-the-shelf. Worse, CA is a complex and management intensive farming concept in which crop management has to be planned ahead and is mostly proactive and not reactive, as in the standard tillage-based systems. Problems of soil compaction or uneven surface in tillage-based systems are corrected with tillage, in no-till systems they have to be prevented from occurring from the start. Weed and pest management in conventional tillage systems is often based on chemical or mechanical control as response to the incidence, while in CA the incidence of weeds and other pests is reduced by forward planning of crop rotations. This increased complexity requires a degree of experience and knowledge, which has to be acquired and learned. For early adopters this learning process and experiential knowledge has therefore involved a lot of trial and error until sufficient local experience and knowledge is accumulated to make the adoption easier. However, the solutions to these practical problems are best developed by the farmers themselves and not by scientists. Usually farmer's own adaptive "research and development" process leads to quicker and more applicable results than the so called 'Green Revolution' approach of leaving the development of a standard technology package "ready for adoption" to the scientific community.

To effectively cope with the diverse agro-ecological and socio-economic conditions of farming environments when considering system level alternatives and changes, *flexible* approaches to on-farm testing and dissemination are required. This is particularly so when knowledge-intensive, integrated practices involving the simultaneous management of several elements are being introduced as is the case with CA, and the elements concerned cannot be reduced to standardised technology package intended for wide applicability (Stoop *et al.* 2008). The same accounts for other complex and management intensive concepts, such as integrated pest management (IPM), which has been successfully introduced by FAO through a network of Farmer Field Schools (FFS) first in Asia. (van den Berg and Jiggins, 2007) and more recently in Africa. Another more recent example is the System of Rice Intensification (SRI) with similar levels of complexity and need for local adaptation paired with the problem of being counterintuitive (Stoop *et al.* 2008).

Thus, a relatively large variation in the implementation and performance of CA practices in farmers' fields is an obvious and logical consequence of this dissemination approach, partly also because the new balances and equilibria as well as full benefits that such practices are expected to offer take time to establish. Therefore, economic assessments and adoption studies based on aggregated results over relatively short periods of time will further contribute to biased and/or pre-mature, generalised conclusions with regards to production potentials, agronomic feasibility and future prospects.

Social Constraints to Adoption

Farming communities in the developing regions are mostly conservative and risk averse. Any farmer doing something fundamentally different from the others will therefore risk being excluded from the community. Only very strong and individually minded characters would take that step, which leads to social isolation and sometimes even to mocking. Even if those individuals have visible success, the aversion created in the community and the peer pressure can result in other farmers not following. The pressure can be so bad that the community gets jealous of the success and instead of also adopting it, it leads to boycott including using 'black magic' and placing bad spells on the fields. For adoption of CA it is therefore not enough to find any progressive farmer who will prove the concept to work, but the farmer must have a socially important role, and be respected and integrated in the community. Ideally the community should be involved from the very beginning to avoid this kind of antagonism.

Other problems can be traditional land tenure systems, where there is no individual ownership of land, which lowers the incentives of farmers to invest in the long term improvement of soil health and productivity. Also communal grazing rights, which often include the right to graze on crop residues or cover crops after the harvest of the main crop, create conflicts which make it difficult for the uptake of CA practices. These problems can be real impediments to the adoption of CA and conflicts arising, for example, from alternative uses of crop residues as mulch or animal feed cannot be solved by orders or directives. Even physical protective structures such as fences might not be the optimal solution, if they work against the traditional social values of the respective cultures. Much more important in the process is that the entire community first understands the issues and the changes and benefits involved in adopting CA and jointly looks for solutions.

Biophysical and Technical Constraints to Adoption

Although the concept of CA is universally applicable, this does not mean that the techniques and practices for every condition are readily available. In most cases the actual CA practice has to be developed locally, depending on the specific farming situation and agro-ecological conditions. Especially the crop rotations, selections of cover crops, issues of integration of crop and livestock have to be discovered and decided upon by the farmers in each location. A diversity of problems arises, very often around weed management, residue management, equipment handling and settings, planting parameters like timing and depth, which all have to be discovered new. This creates the problem that extension agents and advisors in the beginning, when CA is newly introduced in a region, cannot give specific advice on practices, but have to develop these practices together with the farmers. On the other side such an approach, if correctly applied, is much quicker and more sustainable than the development of specific practices by scientists, since it uses the immense pool of experience and innovation potential of the farmers' community. In this way some cover crops have been developed from weeds, or practices such as growing paddy rice or potatoes under no-till in CA have been developed by farmers without the scientists even thinking of proposing such innovations.

Another technical constraint is the simple unavailability of certain technologies or inputs, apart from the financial or other constraints. In many countries where farmers start with CA there are no seeds available for cover crops. Also the availability of equipment, especially no-till direct seeding equipment, often is a problem. By now there are technologies available for most situations, somewhere in the world. However, in a specific location farmers might not be aware of these technologies or they simply have no way to access them. This is were usually external support such as knowledge sharing or eventually even the introduction of specific technologies, such as direct seeding equipment, is required.

Financial Constraints to Adoption

Although the profitability of CA is usually higher than for conventional farming practice there are still financial hurdles to adoption, depending of the availability of capital to invest into this change of production system. These constraints exist at all farm size levels, though obviously to different degrees and for different purposes. Changing a production system to CA is a long term investment. In many cases the rationale for the change is the degradation of the natural resources, especially of soil and water, as a result of the previous tillage-based agriculture. In order to start with CA and to successfully create favourable conditions for the soil life and health to return, some initial investment into the land might be necessary, such as breaking existing compactions by ripping, correction of soil pH or extreme nutrient deficiencies, levelling and shaping of the soil surface for the cropping system foreseen under CA. Especially for small subsistence farmers the capital for this kind of investment is not available. In addition to this, the farmer needs new equipment, while most of the existing equipment is becoming obsolete and will most likely not find an attractive second hand market for.. The larger the farmer, the more important is this hurdle, since a no-till seed drill for example is considerably more expensive than a conventional one. This conflict between the potential improved profit margin on one side and the very concrete and actual investment requirements on the other side often leads to the fact that farmers decide not to change to CA, even though they are convinced about the benefits.

The provision of credit facilities for these cases is one solution, but sometimes also the availability of contractor services or technical advice on how to adapt and modify existing equipment as a low cost intermediate solution to start can help. The modification of existing equipment has, for example in Brazil and in Kazakhstan, provided an entry point for some farmers to start with CA and then, after benefiting from the higher profitability, making the investment into proper equipment at a later stage. Especially for small farmers the home made solutions for simple CA farm tools are an important element for CA adoption in Paraguay (Lange and Meza, 2004).

Infrastructural Constraints to Adoption

As with any agricultural production system, CA also requires certain exogenous inputs to achieve intensive production levels. CA is capable of improving the soil and crop growth conditions for production and the efficiency of the natural resource and input use, but it is not a 'perpetual motion' process which would allow crop intensification from endogenous resources. If CA is therefore meant to sustainably intensify agricultural production, a suitable market and service infrastructure must be in place to provide inputs and to allow the processing and marketing of the produce. Without any external inputs, CA systems will still perform better than conventional tillage-based methods, but this will be at a much reduced level. Some of the inputs like the types of fertilizers will differ only marginally from the requirements of conventional tillage-based farming. Other inputs, however, such as herbicides, seeds for cover- and rotational crops and especially equipment for direct seeding, planting and residue management are often completely different to the traditionally used ones and have to be introduced to the markets. This requires not only a good input supply infrastructure, but also a proactive attitude of the supply sector, such as dealers and manufacturers. Otherwise a chicken-and-egg situation is created where the supply sector does not offer certain inputs because there is no market for them, but the farmers are also not demanding the items because they are not being offered. This deadlock often requires some external intervention mostly in stimulating the demand, but also in assisting the supply sector in making inputs commercially available. This includes, besides the collaboration with the farming sector, a close collaboration with the commercial input supply sector and some supportive policies.

Policy Constraints to Adoption

Adoption of CA can take place spontaneously, but it usually takes a very long time until it reaches significant levels. Adequate policies can shorten the adoption process considerably, mainly by removing the constraints mentioned previously. This can be through information and training campaigns, suitable legislations and regulatory frameworks, research and development, incentive and credit programmes. However, in most cases policy makers are also not aware about CA and many of the actually existing policies work against the adoption of CA. Typical examples are commodity related subsidies, which reduce the incentives of farmers to apply diversified crop rotations, mandatory prescription for soil tillage by law, or the lack of coordination between different sectors in the government. There are cases where countries have legislation in place which supports CA as part of the programme for sustainable agriculture. If those countries, within the same Ministry of Agriculture, have then also a programme to modernize and mechanize agriculture, it usually happens that the first items introduced under such a mechanization programme are tractors with ploughs or disk harrows. This does not only give the wrong signal, but it works directly against the introduction and promotion of CA, while at the same time an opportunity is missed to introduce the tractors with no-till seeders instead of the plough, helping in this way to overcome this technology constraint. Countries, with their own agricultural machinery manufacturing sector, also often apply high import taxes on agricultural machinery to protect their own industry. This industry often has no suitable equipment for CA available in the short term, but due to the high import taxes the importation of equipment from abroad is made impossible to the farmers who wish to adopt CA. In other cases the import tax for raw material might be so high that the local manufacturing of CA equipment becomes unfeasible. In all those cases regulations have to be revised even beyond the influence of the Ministry of Agriculture, which often proves very difficult. Policymakers and legislators must be made aware of CA and its ramifications to avoid such contradictory policies.

Where farmers do not only farm their own land, but rent land from others, there are additional problems with the introduction of CA: the building up of soil organic matter under CA is an investment into soil fertility and carbon stocks, which so far is not recognized by policy makers, but increasingly acknowledged by other farmers. Farmers who still plough know that by ploughing up these lands the mineralization of the organic matter acts as a source of plant nutrients, allowing them to "mine" these lands with reduced fertilizer costs. This allows them to pay higher rent for CA land than the CA farmer is able to do. Such cases can be observed in "developing" African countries as well as in "developed" European ones. To avoid this some policy instruments are required to hold the land owner responsible for maintaining the soil fertility and the carbon stock in the soil, which in absence of agricultural carbon markets is difficult to achieve.

OPPORTUNITIES FOR CA ADOPTION

Fortunately, besides the constraints to adoption, there are many opportunities which facilitate the change to CA. The higher the pressure on farmers and the bigger the problems for them to carry on with their business, the easier it is to introduce a change. Farmers that are still complacent with their situation are reluctant to change.

Crisis and Emergencies

The crisis of the soaring food prices in 2007/08 has brought the importance of food as a global policy issue to the attention of everyone. Food security has been newly discussed and countries have begun to revisit their food self-sufficiency policies. Also, other emergencies, in particular those related to natural disasters such as floods and droughts are mobilizing relief funds. There is an increasing awareness that these relief funds should not only be used to replace the losses, but also be used as an investment into the rehabilitation towards more resilient agricultural production systems. In this way more and more FAO emergency rehabilitation projects are introducing CA practices into their operations with growing success, particularly in Southern and Eastern Africa and in the DPR Korea. There is obviously a problem in this, since ideally the introduction of CA should be accompanied over several years to achieve uptake and sustainability, while emergency projects are only of short duration of maximum one year. However, even if farmers would revert back to conventional tillage farming after the intervention they would not have lost, but gained some new insights. In reality there is a growing awareness about CA in many of these countries in crisis so that besides the emergency intervention the respective Ministries of Agriculture can carry on promoting CA practices. On the other side the frequency of natural disasters seems to increase and in most countries the emergency rehabilitation projects return year after year following similar events. This allows in practice the support of CA programmes over a longer time period and positive developments have been seen in this way. Obviously the project implementation has to make sure that the capacity building component is well enough established to allow for long term sustainability. This makes this kind of emergency projects more complex than the usual input distribution ones.

Increasing Environmental Concerns

Increasing environmental concerns regarding the sustainability of modern farming is putting agriculture under pressure to reform. Regulations regarding soil conservation or water quality, as for example the new EU Water Framework Directive, make it difficult for conventional tillage-based farmers to comply with the new maximum residue levels in ground or surface waters. If those threshold values would be consequently followed up, farmers would have to revert to no-till farming, which significantly reduces the water contamination levels with chemical substances from agricultural soils (Bassi 2000, Saturnino and Landers 2002). In the past the consumer interest was very much focussed on food safety resulting in growing markets for organic food. More recently the focus seems to shift to environmental issues, including biodiversity and water resources, and consumers start to become concerned with the environmental footprint of agricultural production and its sustainability. While recognizing that production levels have to increase and cannot go down, agricultural production will have to be combined increasingly with the delivery of environmental services to become sustainable and acceptable. This is a major opportunity for CA, since it is so far the best available concept for combining high intensive production with long term sustainability of the environment and the resource base. Accordingly, the reform of the UN Food and Agriculture Organization in 2008 came to the formulation of new strategic goals, with the first one being "Sustainable Intensification of Crop Production", facilitating the promotion of CA as a fundamental element in support of this strategic goal (FAO 2008a).

Rising Input and Energy Costs

The increasing costs of agricultural inputs, namely fuel and nitrogen fertilizer, both closely linked to energy costs, are the strongest direct arguments for farmers to reduce or do away with their tillage practices. However, most farmers will realize that reducing the tillage alone will not bring the desired effects and might not even work out in the long term. If correctly advised they will adopt other elements to make no-till farming sustainable, and ending up in CA-based cropping systems. While the adoption of no-till will reduce more than anything else the fuel costs for tillage, it might lead to other problems and even to increased requirements for nitrogen fertilizer and other agrochemicals. The combination with crop rotations and mulch cover however has a positive effect such that the input use becomes more efficient and optimised. Yields increase without additional inputs and in the long term even with significantly reduced inputs (Saturnino and Landers 2002). In most of the cases of CA adoption the immediate impact has been that of a reduction in production costs resulting in increased farm income, even if the yield levels would not increase or even decline in the beginning (Hickmann 2006, Lange 2005). The full adoption of CA will result in an overall reduction of the energy inputs in the system (Doets *et al.* 2000) which should be reflected in the energy costs.

Challenges of Climate Change

Climate change is an increasing challenge for agriculture. For conservation agriculture, however, it is also an opportunity, since it can respond to climate change in two ways, harnessing policy support for the further up-scaling of CA.

As a no-tillage cropping system CA holds opportunities for climate change mitigation through carbon sequestration in the soil. By reducing the mineralization of soil organic matter and hence the losses of carbon dioxide from soils through no-tillage, and by adding additional organic matter with soil residues and providing a balanced C-N ratio with crop rotations including legumes, CA contains the essential elements needed for a crop production protocol to qualify for carbon sequestration in agricultural soils. In addition the emissions from fuel are also reduced under CA. If some other complementary practices are applied, avoiding soil compactions for example with controlled traffic systems and avoiding anaerobic conditions in soils through adequate water, irrigation and drainage management, also the nitrous oxide and methane emissions can be reduced compared to conventional tillage-based agricultural practices. In this way CA can contribute to mitigating climate change. This can be harnessed with payment schemes for environmental services, such as carbon markets or emission reduction payments, which could help to promote the adoption of CA.

At the same time CA systems serve for climate change adaptation and as such should be part of national climate change adaptation plans since CA, being resilient to drought stress, reduces the yield variability over time (Tebrügge 2000) thus improving food security. The increased soil organic matter facilitates increased and better water storage in the soil. The mulch cover and the minimum soil disturbance reduces water losses from the soil and the better rooting system of the crops facilitates access to soil water from deeper soil horizons resulting in an overall water saving of about 30 % compared to conventional tillage-based systems (Bot and Benites 2005). This together helps crops to survive drought spells. In addition, run-off losses of excess surface water are avoided through far better infiltration rates of water into the soil, providing a replenishment of the groundwater aquifers and a more steady flow of rivers and wells even in the dryer months of the year. The increased infiltration capacity of soils under CA also helps to reduce the surface runoff and associated soil erosion as well as the flooding created by the water downstream in watersheds. No-tilled soils with an intact vertical macro pore structure and a good mulch cover can withstand even heavy tropical rainstorms of over 100 mm per hour, with a significantly reduced amount of surface runoff (Saturnino and Landers 2002). This can be instrumental for the reduction of flood risks as a climate change adaptation strategy (DBU 2002).

CONCLUDING REMARKS

Despite the obvious productivity, economic, environmental and social advantages and benefits of CA, adoption does not happen spontaneously. There are good reasons for individual farmers not to adopt CA in her/his specific farm situation. The origin of the hurdles ranges from intellectual, social, financial, biophysical and technical, infrastructural to policy issues. Knowing the respective bottlenecks and problems allows developing strategies to overcome them. Crisis and emergency situations, which seem to become more frequent under a climate change scenario, and the political pressures for more sustainable use of natural resources and protection of the environment on the one hand and for improving and eventually reaching food security on the other provide opportunities to harness these pressures for supporting the adoption and spread of CA and for helping to overcome the existing hurdles to adoption. In this way, the increasing challenges faced around the world, from the recent sudden global crisis caused by soaring food prices, high energy and input costs, increasing environmental concerns to issues of climate change facilitate the justification for policy makers to introduce supportive policies and institutional services, even including direct payments to farmers for environmental services from agricultural land use, which could be linked to the introduction of sustainable farming methods such as CA. In this way the actual global challenges are providing at the same time opportunities to accelerate the adoption process of CA and to shorten the initial slow uptake phase.

A diverse group of international stakeholders, interested in accelerating the mainstreaming of CA, recommended at a meeting held at FAO in July 2008 the creation of a global cluster or network of interconnected *Communities of Practices (CoPs)*(FAO 2008b). They proposed the formation of a small interim Facilitating Group, coordinated by FAO, to oversee the creation of a global network of CoPs, to firm up the agenda for action and to manage related tasks. A Listserve has been established to serve as a communication platform to facilitate the operations of this international network of CA-CoPs.

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