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L'extension de l'Agriculture de Conservation : un soutien politique et institutionnel pour l'adoption et l'implémentation

La expansión de la Agricultura de conservación: apoyo político e institucional para su adopción y práctica

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The spread of Conservation Agriculture: policy and institutional support for adoption and uptake

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Abstract. Conservation Agriculture (CA) in its many local adaptations has been practiced for more than three decades. In year 2013 it was deployed on some 155 million hectares worldwide on both large and small farms. In most cases, it has led to yield, economic and environmental benefits, and thus would appear to deserve greater policy and institutional support to accelerate opportunities for adoption and uptake. CA represents an alternate approach to the sustainable intensification of agriculture and differs fundamentally from modern approaches based largely on intensive tillage and purchased inputs that often disrupt ecosystem functions. CA incorporates a number of apparently counterintuitive and often unrecognised elements that simultaneously promote soil health, productive capacity and ecosystem services.

Important constraints appear to be preventing wider-scale adoption of CA. Experience across many countries has shown that the adoption and spread of CA requires a change in commitment and behaviour of all stakeholders. For farmers, social mechanisms that encourage experimentation, learning and adaptation to local conditions are a prerequisite. For policy-makers and institutional leaders, transformation of tillage to CA systems requires that they fully understand the large economic, social and environmental benefits that these systems offer. Such transformations call for sustained policy and institutional support that provides both incentives and 'motivations' to encourage farmers to adopt components of CA practices and improve them over time. Here, we summarise the key institutional and policy requirements. Many of these apply widely to other forms of more sustainable agriculture.

Keywords. sustainability, tillage, soil carbon, soil health, extension

1. Introduction

The first paper in this series of two on Conservation Agriculture (Kassam *et al.*, 2009) indicated that the sustainability of agricultural production and of the continuing provision of environmental services is strongly dependent on maintaining soils in a sufficiently carbon-rich condition (Pretty, 2008; Reicosky, 2008: Moebius-Clune *et al.*, 2011). CA as a production system is underpinned by a set of three interlinked principles - minimum or no mechanical soil disturbance, permanent soil organic cover, and crop diversification - that are applied simultaneously. These principles can be, and indeed are being, integrated into most rainfed and irrigated production systems to strengthen their ecological sustainability, including arable farming, horticulture, plantation agriculture, agro-forestry, organic farming, System of Rice Intensification (SRI), 'slash and mulch' rotational farming, and integrated crop-livestock systems (FAO, 2011). Thus, CA as a production system is applicable wherever plants can grow and reproduce naturally, i.e. not in deserts without irrigation, nor in poorly drained waterlogged landscapes with water ponding on the soil surface. Such excessively wet or dry conditions require different kind of interventions to make CA applicable, such as irrigation or landscape level drainage. Areas with very cold winters might require an adaptation of CA towards a higher level of soil disturbance but still within the CA definition of allowable soil disturbance, such as strip till, to allow warming up of the seed zone.

Global concerns about degradation of land resources which maintain natural ecosystems, and whose soils are the bases of agricultural systems, were clearly expressed in the World Conservation Strategy (IUCN, 1980) and the World Soil Charter (FAO, 1982), as well as later in the Millennium Ecosystem Assessment (MEA, 2005). The effective implementation of CA principles puts into practice recommendations of these and subsequent expressions of international concern such as the International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD) (McIntyre *et al*., 2008), the UK Foresight Global Food and Farming Report (Foresight, 2011) and the UK National Ecosystem Assessment (UKNEA, 2011). These concerns have subsequently intensified as the demand for agricultural produce and services rise, human populations continue to increase, consumption patterns change, land degradation continues, and fluctuations of global climatic conditions become more extreme (Pretty, 2013). As a consequence of human activities in using carbon-rich resources, levels of carbon dioxide in the atmosphere have been rising, in part due to the excess rates of oxidation of soil organic matter provoked by conventional tillage agriculture (Reicosky, 2001). While CA provides the best guarantee for carbon sequestration in soils, the level of such sequestration does depend, in addition to minimum soil disturbance, on suitable crop rotations or associations, and on the amount of the biomass from the production system that is retained as surface mulch and also is being incorporated or sequestered into the soil. Thus the overall reduction in greenhouse gas emission as a result of this would also depend on the careful observation of soil compaction and drainage problems and mineral fertilizer application rates to avoid, for example, NO_2 emissions resulting from anaerobic soil conditions.

CA as a production system has the potential to deliver on both sustainability and intensification, and its principles are widely applicable across a range of farming systems. CA is currently applied on some 155 million hectares of arable land (at 2013) across many different agro-ecosystems in all continents (Kassam *et al*., 2011, 2014; Friedrich *et al*., 2012). This paper elaborates the policy and institutional conditions that appear to be necessary to support the introduction, adoption and widespread uptake of CA at the national level.

2. Adoption and uptake of CA

Shifting from tillage-based agriculture to no-tillage CA systems removes unsustainable elements in the current tillage-based systems and replaces them with CA elements that make the production systems ecologically sustainable. The individual CA principles have been practiced by farmers for a long time (Derpsch, 2004; Montgomery, 2007) and many of the advantages arising from the individual CA practices have been known for many years. What is new and unique about the modern concept of CA is the bringing together of all three interlinked CA principles that are applied simultaneously through locally devised and tested practices as part of a production system with other good management practices, particularly: (i) use of well adapted good quality seeds; (ii) enhanced and balanced crop nutrition, based on and in support of healthy soils; (iii) integrated management of pests, diseases and weeds; and (iv) efficient water management. In many respects, this represents a fundamental operational change in agricultural production systems and to the producers.

Thus, sustainable crop production intensification based on CA is the combination of all improved practices applied in a timely and efficient manner. The approach offers farmers many possible combinations of CA-based practices to choose from and adapt, according to their local production conditions and constraints. The benefits of CA provide an indication why many farmers worldwide are adopting CA systems and why CA is receiving attention from the development and research community as well as from government, corporate and civil sectors. However, not all synergistic interactions in CA systems are fully understood nor fully recognized. In general, scientific research on CA lags behind farmers' own discoveries (Derpsch, 2004; Bolliger *et al.*, 2006; Goddard *et al.*, 2008). Similarly, knowledge and service institutions in the public and private sectors tend to be aligned to supporting conventional tillage-based systems. Further, there is limited policy experience and expertise to assist in the transformation of conventional tillage-based systems to CA systems for small and large farmers in different ecologies and national contexts (Friedrich & Kassam, 2009; Milder *et al.*, 2011; FAO, 2011).

On a few occasions, such as in southern Brazil in the 1970s-1980s (Bolliger *et al.*, 2006) problems with conventional tillage-based farming practices became so severe that spontaneous change to no-till system and its widespread evolution towards CA practices occurred (Mello & Van Raij, 2006). At the time, it was severe water erosion combined with poor profit margins that encouraged uptake (Derpsch *et al*., 1991). Similarly, it was wind erosion in the mid-west USA and the Canadian Prairies that led to the adoption of reduced tillage systems in North America (Montgomery, 2007).

Generally for early adopters there are many hurdles as is often the case with new systems requiring significant behavioural change. Further scaling up of CA practices to achieve sub-national and national impact will thus require enabling policies and institutional support (including training, access to knowledge and research) to both producers and input supply chain service providers (including equipment and machinery) (Friedrich & Kassam, 2009; FAO, 2011).

The typical adoption process for new technologies follows an 'S' curve, with a relatively slow start to adoption, possibly preceded by farmers' own trials on just parts of CA principles and/or parts of their land, leading then into fast or even exponential growth, and slowing towards a plateau (Alston *et al.*, 1995; Rogers, 1995). In some contexts, for example in Paraguay and Western Australia, this had led to complete adoption, with tillage almost completely disappearing over the past decade (Derpsch & Friedrich, 2009; Crabtree, 2010). In others, when conditions for adoption are less favourable, the initial phase of the 'S' curve can be drawn out , sometimes lasting many years such as in Brazil (Bolliger et al., 2006; Junior *et al*., 2012) or Argentina (AAPRESID, 2010). To date, some 11% of the world's arable cropland is farmed under CA (although more is farmed with reduced tillage systems). In most countries CA is being introduced as an "unknown" new concept and thus neither the agronomic knowledge base nor the policy and institutional support environment is necessarily favourable to adoption.

3. Necessary conditions for the CA adoption

CA is both management and knowledge intensive and complex to practice, requiring more planning than tillage-based systems. It cannot be reduced to a technology package, adoption requiring both change and adaptation based on experiential learning (Derpsch, 2008; Friedrich & Kassam, 2009). The following sections elaborate the *necessary conditions* for the introduction of CA and transformation of tillage-based systems. The support to foster these necessary conditions must be mobilised at the individual, group, institutional and policy levels within the private, public and civil sectors so that the behaviour patterns of all stakeholders involved in the CA innovation system are mutually reinforcing to induce the development of the *sufficient conditions*, or the enabling environment, for adoption and spread. In cases where the learning process is missing or the benefits to the farmer are not obvious, then non-adoption or disadoption can occur.

3.1 Reliable local individual and institutional champions

Wherever CA has successfully spread, there have been local champions whose own examples have encouraged adoption. Those champions are then supported by research and development groups, and private sector service providers in equipment and machinery, seeds and agrochemicals. More recently the international research community and development organizations including NGOs have shown interest in this farmer-driven adoption process, bringing the promotion and dissemination of CA to international attention. In this way, local national champions, whether individuals or institutional, are now increasingly being supported by international champions.

3.2 Dynamic institutional capacity to support CA

CA is a dynamic system in constant development and adaptation. The institutions that are set up to support CA need to be similarly dynamic so that they can respond to farmers' changing needs. As well as policy making departments, 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 CA to function well.

Biophysical, ecological, agronomic and social sciences must be aligned with the views of stakeholders to develop systems that can be adapted to varied conditions facing farm family adopter of CA. This means that self-organizing innovation networks of diverse providers of information need to be involved in broad programmes to develop the science and technology adaptation for CA (Ekboir 2003; Cernea & Kassam, 2006; Rajalahti *et al.*, 2008; World Bank, 2012). Such institutions include international agencies, multi-donor programmes, NGOs, national government staff, academic institutions, commercial organisations and agribusiness with their diverse points of view. One way to support integration would be to develop common indicator sets to assess progress towards the environmental, economic and social benefits of CA.

3.3 Engaging with farmers

Support for any production systems should be oriented towards solving farmers' problems that inhibit productivity. However, when the transformational change occurs with the adoption of CA by farmers who have only known and practiced tillage agriculture, a new challenge is created. Farmers need support to understand new concepts and principles, enable an intellectual change in mind-set, commit to a longer-term process of change in their production system, test and adapt new practices, and change equipment and machinery. In establishing different cropping systems and farm operations, they also need to manage new production input and output relationships involving crop, soil, nutrient, water, pest, and energy management practices. Thus, engaging with farmers and providing them with the necessary support is critical for successful adoption and uptake of CA.

Though the principles of CA remain the same across contexts, how they can be best applied depends on how individual farm families make decisions. This emerges from how each farm family can respond to specific combinations of environmental conditions, farmers' resource-availability, production system, market opportunities and transport availability, and support, encouragement and guidance (Wall, 2007). Farmers can be ingenious in problem-solving, and if they pick up the conceptual part of CA, they often innovate and adapt the practices to their own conditions (WOCAT, 2007; Borsy *et al.*, 2013).

3.4 The Importance of farmers' organizations

Farmers tend to believe trusted peers more than their formal advisers when discussing innovations, making it easy for them to exchange ideas and experiences helps strengthen their own linkages and reinforce recommendations (Pretty, 2003). Social capital is used as a term to describe the importance of social relationships in cultural and economic life. The term includes such concepts as the trust and solidarity that exists between people who work in groups and networks, and the use of reciprocity and exchange to build relationships in order to achieve collective and mutually beneficial outcomes. Social capital is thus seen as an important pre-requisite to the adoption of sustainable behaviours and technologies over large areas (Cernea & Kassam, 2006). Where social capital is high in formalized groups, people have the confidence to invest in collective activities, knowing that others will do so too. Farmers' participation in technology development and extension approaches has emerged as a response to such new thinking (Pretty *et al*., 2011).

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 experienced advisors, for 'learning by doing' (e.g. Mariki *et al.*, 2011). Farmer groups, which may comprise associations, clubs, co-operatives or other organizational arrangements, derive confidence from mutual support and exchange, which can accelerates innovation and adoption (e.g. Silici *et al.*, 2011; Marongwe *et al*., 2011). The fastest development of suitable technologies is usually achieved through groups of innovative and pioneer farmers who are part of a community and exchange their experiences through their networks, thus building social capital (Pretty, 2003).

Small informal groups of farmers may evolve into co-operatives and other larger bodies. 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, equipment related service providers, transport agencies, and others: and this benefits all the members of the group. If sufficiently well-organised, they may be able effectively to pressure national and local governments and institutions for necessary reforms and services, including research and extension, to aid the CA cause. The development of such groups can then become a powerful means of encouraging others to join the movement. Mentoring programmes, where experienced CA farmers assisted newcomers during the first year of adoption have resulted in immediate yield increases and significantly higher profitability during the first year of adoption compared to farmers who had to learn on their own, mainly because mistakes could be avoided (Meyer, 2009).

3.5 Providing knowledge, education and learning services

CA involves a fundamental shift in the way agricultural production is conceived and how it relates to environmental stewardship (Kassam *et al*., 2009). There is a need to think differently about how knowledge is spread to farm families, to professionals in the public and private sectors, and to society at large. One opportunity lies in educating schoolchildren – and then right up through graduate and postgraduate education – for a broader focus on ecologically-based, resource conserving agriculture based on the core CA principles in all settings for sustaining the production of crops and water from all landscapes.

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 for their disciplinary specialisations. Both researchers and advisory staff need to be kept up to date with the different ways by which the principles of CA are put into practice, their effects on the resource base and the environment, and the socio-economic outcomes. This means having the capacity to work across the traditional science disciplines and to work closely with farming communities. Recognizing the realities of CA technical education and vocational training in universities, colleges and schools will include CA principles and benefits in their curricula.

In addition, while the greatest impact will come from fully applying all three principles of CA, farmers' constrained socio-economic situations may mean that some are gradually introduced responding to the individual conditions. Thus 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 on 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 and practices.

Third, international national, regional and international networks covering all levels of development management and geographical regions are required to acquire, evaluate, share and disseminate robust evidence about the principles, practices and impacts of CA. These networks should 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 across the international community. A global communication platform for all CA community of Practice (CA-CoP) stakeholders was launched in January 2009 and is hosted by FAO (FAO, 2008). However, establishing more regional and national CA networks would assist in completing the multi-level coverage of CA stakeholders. Establishing a global network of CA farmer associations would help to facilitate exchange of information amongst farmer groups who could also provide constructive feedback into policy and input supply sector.

3.6 The need for scientists and extension agents to recognise and characterise the problems related to CA adoption and facilitate problem solving

It could be argued that what is expected of scientists and extension agents in the promotion of CA adoption may not fundamentally differ from that required for conventional farming practice. The focus should be on recognising, characterising and solving problems related to CA adoption and dissemination. However, there is a difference in that CA is relatively new and therefore problems can arise for which locally-based experience and knowledge does not exist. Thus, in support of CA scientists need to: (a) respond to unsolved technical problems (e.g. cover crops, and crop combinations for different situations), systems development in ecologies that are too dry or too wet, biomass management across competing demands ; (b) explore new potentials and possibilities based on what is already known and observed; (c) clarify basic soil conditions regarding the significance of organic-matter effects and related interactions with respect to soil productivity and its changes over time under different treatments and adapt knowledge on nutrient levels and fertilization; (d) advance knowledge about pest, disease and weed interactions under CA conditions; (e) design new mechanization concepts for CA systems including aspects such as compaction management and promotion of no-till seeders for small farmers; (f) undertake 'blue-sky' exploratory research with possible relevance to CA.

Also, too little ex-ante analyses have been carried out to better understand how specific policies will work and what impact they might have. Systems research aimed at linking and supporting change policies with potential environmental benefits that may accrue, and quantifying such relationships, is definitely a priority area for research. However, these benefits might not be equally applicable for all agro-ecosystems; important variability and system trade-offs could limit the expansion and adoption of these technologies in smallholdings. Risk coping mechanism for potential adopters and more importantly effective technical assistance are key elements for uptake of CA under difficult biophysical conditions. The competing uses for crop residues could be potentially resolved through local by-laws that reduce free access to residue grazing and promote better area and on-farm integration of crop-fodder-tree-livestock systems involving community-based approaches to the effective management of functional biomass and stocking rates. The dynamic functioning and evolution of these integrated systems and their long-term impacts on the potential productivity of agro-ecosystems also deserve a sustained research attention in the future.

Advisory staff also 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. As with any innovation system, there is a need for linkages and feed-back loops between researchers, extension staff, and farmers, so that all sides engaged in CA can remain well-informed about needs and achievements of the farmers, results of research, and of possibilities to be explored.

3.7 The need to build up a nucleus of knowledge and learning system for CA in the farming, extension and scientist community

The Latin American experience with CA has shown that, by providing institutional and financial support, government can play a crucial role in creating incentives for adoption (FAO, 2001a; Derpsch, 2004; Bolliger *et al*., 2006; Borsy *et al*., 2013). The studies also point to the importance of financing 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 (FAO, 2001b). 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, in Sub-Saharan Africa, CA plus the FFS approach to assisting and informing small and larger farmers creates a form of insert into community, sub-national and national governance and development efforts. Such collective agro-ecological efforts can implicitly or explicitly underlie and enrich 'watershed management' as a practical concept for sustainable improvement of livelihoods, landscapes and ecosystem services (Pretty, 2003; Pretty *et al*., 2011), and facilitate the reconnecting of people, land and nature (Pretty, 2002).

Sustainable forms of agriculture such as those based on CA principles, which are identifiable in biological, social, environmental and economic terms, must be maintained in all agro-ecosystems, and therefore must be supported by appropriate operational and policy changes. Most importantly, a practical knowledge and learning system for CA should be built up in the farming, extension and research community and 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. Such knowledge and learning systems are emerging in Brazil, Argentina, Alberta (Canada), Andalucia (Spain) and Western Australia (Kassam et al., 2013) and include following elements.

- *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 and capable 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 offer ease 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 participatory approaches is that the advisers and lead farmers should be fully conversant with the ethos, changed mind-set, agroecologic and socioeconomic principles, and modes of application of CA. Dedicated training courses for this purpose are needed, 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 which cover both theory and practice.

- *Field days and study-visits:* Much relevant experience is passed from farmer to farmer. 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. On return home, these may become the focus of further innovation by the farmers.

- *Participatory and interdisciplinary learning process:* For the development of CA in the field, active feedback loops for intercommunication between farmers, researchers and advisers are helpful. In this way information can be shared within and between the farming, advisory and scientist communities. A participatory 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 practical 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/or development. Designing successful policies to promote CA starts with a thorough understanding of farm-level conditions. This understanding includes farmers' management objectives, attitudes to risk, willingness to make trade-offs between stewardship and profits. The next step is the careful design of 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.
- *Operational research:* A type of research which can pay dividends for good interactions between farmers and advisors is 'Operational Research'. It is aimed at investigating, in the field, and with farmers, how improved practices and their interactions with overall systems, and *vice-versa* 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, suggested by farm-families themselves, become part of the 'stock-in-trade' of such collaborative teams. This approach is similar to the concept of multi-stakeholder innovation network performing different and vital activities to make farmer adoption work (Ekboir, 2002, 2003; Rajalahti *et al.*, 2008; World Bank, 2012)

3.8 Mobilizing input supply and output marketing sectors for CA

With farmers grouping together into associations, 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 farmers themselves. Usually some 'kick start' is necessary to break the deadlock of farmers not adopting because of lack of available technologies and equipment 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. To prevent disadoption, incentive mechanism must be clearly directed to specific adoption hurdles and must be separated from the conceptual components of CA. Whereas CA should never be promoted as blueprint technology package in the first place, production inputs such as fertilizers, if provided as incentives, can be part of the CA message.

3.9 Accessibility and affordability of required inputs and equipment

Real costs arise during 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 the farmer to accept all the potential risks associated with the change-over. Nor may it be possible for the farmer to make the necessary investments in unfamiliar seeds (e.g. of cover crops) or to hire or procure new equipment such as direct seeders. However, once CA has become established on a farm, its lowered operating costs and the generally higher and more stable yields then begin to generate sufficient resources to pay the full commercial costs of these new inputs (Bolliger *et al.*, 2006; Baig & Gamache, 2009; Crabtree, 2010; ECAF, 2012; Junior *et al.*, 2012).

CA can be used with many types of production inputs, including seeds of traditional or modern cultivars, at any level of agricultural development and farm power, manual, animal assisted or mechanised. This flexibility allows CA to target inputs (e.g. fertilizers, seeds, equipment) and using them regardless of the source which may be organic or mineral in the case of fertilizers, and GM or non-GM in the case of seeds.

3.10 Financing and enabling the initial stages

Risks attend any changeover from one way of making a livelihood to another. All farmers, regardless of size and resources, will be subject to such risks, and will make their own decisions on how best to minimise or avoid them. In recommending that governments give appropriate support at all levels to CA and other forms of sustainable intensification, 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 until a new system of CA has become 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), or as incentive payments justified by the positive environmental services expected to result from adopting CA.

However, incentives in the form of subsidies carry the risk of encouraging farmers to adopt practices and technologies they do not believe in. However, with CA, the economic benefits improve over time and in general evidence suggests that large mechanised farmers do not revert to old practices once they switch to CA (Sorrenson, 1997; Filleccia, 2009; Baig & Gamache, 2009; Lindwall & Sonntag, 2010; González-Sánchez *et al.*, 2010; Crabtree, 2010). In the case of small farmers in Sub-Saharan Africa, there have been contexts where farmers reverted to old practices once the support for inputs including advisory services became ineffective (FAO, 2008). However, during the past five years, with greater policy support and institutional attention being paid to CA by governments, national research and extension institutions, NEPAD (New Partnership for Africa's Development), international research and development agencies and donors, over 500,000 ha have been brought under CA by small farmers in Zambia, Malawi, Mozambique, Zimbabwe, Tanzania and Kenya (Friedrich *et al.*, 2012).

Zimbabwe, Zambia, Malawi and Mozambique also now include CA as a core element of their national agriculture development policy and strategies. NEPAD has integrated CA as a key element if it's agricultural development framework. In Zimbabwe and South Africa, CA is being integrated into the education system. In Zimbabwe, in response to domestic emergency, CA has been a core element in agricultural rehabilitation and development programmes that involve public-private partnerships for linking farmers with service providers including inputs. Most countries in southern Africa region have established multi-stakeholder national task forces to facilitate the promotion of CA in response to any new development opportunities that may arise.

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. This period might be up to five years in each instance of uptake to farmers having developed full confidence in managing the new system. Because uptake would not all occur at the same time, such assistance would necessarily be on a 'rolling' basis. Further to this adoption phase, extension and research need to address the specific needs of the CA farmers on a permanent basis. Such temporary support mechanisms are being successfully piloted in Spain, Germany, Italy and Switzerland (ECAF, 2012).

The period of changeover to a new system may thus require cost-sharing for inputs, equipment, and travel as a means of minimising both risks and a temporary dips in yields which could result from inexperience during the learning and adaptation phase. The need for credit can be foreseen, and suitable arrangements made, whether with a banking system or informal community savings schemes. Temporary investment might be also needed for CA-specific equipment, and its repair/modification for farmers' use from communal or commercially operated equipment pools. 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 loss of timeliness or precision then prejudices expectations of yield. Finance should be available for study tours, field days and other opportunities for farmers to meet each other and discuss CA matters of mutual interest as a potent way of stimulating innovations.

Although it is not possible to distil a generic set of guidelines that could constitute initial interventions for promoting the transformation towards CA systems, we suggest an effective sequence is 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.
2. Identification of factors limiting crop yields and what could be done to alleviate these.
3. Identify one or more farmers already undertaking CA and demonstrating its agronomic, financial and/or livelihood benefits, and set up study visits.
4. Or: set up demonstration for researchers and advisory staff and farmers' groups leaders, to catch their interest.
5. Initiate 'learning by doing' e.g., through 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 for animal or tractor power, knife rollers, walking tractors with no-till seeded attachments, etc.) to be able to demonstrate their use at the beginning.
8. Interact with any already-established farmers' groups, e.g., co-operatives, to gain interest and support.

4. Designing and implementing policy and institutional support

Adoption of CA can take place spontaneously, but where it is not supported by policy and public and private sector institutions, it usually takes a long time until it reaches significant levels as in the case of Brazil and Argentina where it took some 20 years before CA began spreading. Policy and institutional support is crucial for the introduction and accelerated adoption of CA based on all stakeholders working together for a common goal as has happened for example in Brazil, Argentina, Paraguay and more recently in western Canada and in western Australia (Derpsch, 2004; Kassam *et al.*, 2010). In essence, the role of policy and institutional support is to ensure that the above-described necessary conditions are met for the introduction and subsequent widespread adoption of CA systems in various agricultural land use sectors.

Adequate policies and institutional support can shorten the adoption process considerably, mainly by removing the constraints mentioned earlier. This can be through information and training campaigns, suitable legislations and regulatory frameworks, research and development, incentive and credit programmes. However, policy makers often are not aware of the relevance of CA as a basis for sustainable intensification and thus many 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, and yet within the same Ministry of Agriculture also have a programme to modernize and mechanize agriculture, introducing tractors typically equipped with ploughs or disk harrows. This not only gives 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 tractors with no-till seeders instead of the plough.

Countries with their own agricultural machinery manufacturing sector also often apply high import taxes on machinery to protect their own industry. This industry commonly 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. Policy makers and legislators will need to be made aware of CA and its ramifications to avoid such contradictory outcomes.

With farmers who own land but also rent other land, there are additional problems with the introduction of CA: the build-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 some developing countries in Africa as well as in industrialised countries in Europe.

To avoid this, 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. Generally, farmers with secure land tenure are more likely to take care of their land and maintain or increase the carbon stock in the soil. Mechanisms that encourage good land stewardship within a land rental situation are provided within the CAP which applies the same rules to farmers who own their land and farmers who do not (ECAF, 20102). Similarly, in Alberta, Canada, the carbon offset scheme, which is in its sixth year of compliance, encourages all farmers including those who do not own their land to adopt CA protocol to enhance soil carbon stocks for which they get paid (Haugen-Kozyra and Goddard, 2009).

Effective demand in the market and the value chains beyond production are also important in ensuring that farmers can receive an attractive return for their effort to produce safe and nutritious food and other ecosystem products using sustainable practices such as CA. Policies and institutions that encourage and enable the integration and verification of CA practices and their products into practical programmes in which farmers can receive monetary benefits for delivering certain ecosystem services have been established recently (Kassam *et al.*, 2013).

These include CA farmers in the Alberta carbon offset scheme selling carbon off-sets to industry emitting GHG (CCC, 2011); farmers participating in the Itaipu Dam *Programa Cultivando Água Boa* ('cultivating good water') in the Paraná basin III in Brazil qualifying for payments and development assistance for supplying water of good quality into the Itaipu dam (ITAPU, 2011); olive farmers in Andalucia, Spain, receiving financial and technical support for adopting CA practices to control soil erosion (Franco and Calatrava, 2006). Such schemes do help farmers to transform their tillage-based production systems to CA-based systems. Likewise it could also be argued that farmers ploughing land should pay a carbon tax similar to other emitting industries.

4.1 The need to sensitise policy-makers and institutional leaders

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 better understanding of the implications of CA. 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 constituency. 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 (Pieri *et al.,* 2002).

4.2 Formulating enabling policies

A facilitating policy environment can be an important determinant of whether CA is adopted and how fast. 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-government 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 decoupling programmes in Europe in which financial support to farmers is defined in terms of income support for environmental management (ECAF, 2012), and in farmland stewardship programmes such as Australia's Landcare (Flower *et al.*, 2008; Llewellyn *et al.,* 2009).

While CA so far has spread mostly without policy support, it would need a supportive policy environment for accelerated spread. However, there is no '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 biophysical and socio-economic conditions, farm management objectives, attitudes to risk and complementary relationship 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 adoption and spread 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 would ensure that policies are designed which both accommodate and promote the location-specific nature of CA. It can be argued that the location-specific nature of CA-related polices is not unique as this would also apply to policies related tillage-based production systems. This is not so because the main difference between the two production paradigms is that many of the ecosystem services for environmental sustainability cannot be harnessed effectively with the currently dominant tillage-based agriculture (Pretty, 2008; Kassam *et al.*, 2009; FAO, 2011; Pretty *et al*., 2011). Thus, CA-related policies would not only enable the transformation of production systems into ecologically more sustainable and less degrading systems, but also sustain the on-farm and landscape level harnessing of environmental services from agriculture land use (ECAF, 2012; Kassam *et al.*, 2013).

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 by farmers (Cernea & Kassam, 2006). This would include the development of group extension approaches (FAO 2001b) when dealing with smallholders who are operating in poverty stricken situation with degraded resource base and poor access to markets.

We suggest five key issues policymakers need to consider:

4.2.1 Policy coherence

CA is compatible with existing approaches to promoting agricultural and environmental sustainability, such as watershed management. Any policies regarding (for example) existing laws on water use, health, the use of pesticides and other inputs, and the burning or incorporation of crop residues, can influence the adoption of CA. A first step in creating legal rules for the protection of natural resources may be to establish a national framework whose responsibilities are shared between the land users and the executing organizations. However, the interdisciplinary nature of CA means that policies will cut across traditional government 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. A particular aspect where government policy coherence is needed is in the area of sustainable mechanization to avoid the simultaneous promotion of tillage equipment as well as no-till equipment.

4.2.2 Policies to actively encourage knowledge sharing

For farmers to take the leading role in implementing CA, there is a need for policies that encourage knowledge-sharing amongst stakeholders at all levels. 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 policy environments.

4.2.3 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 as well as ecosystem services as groundwater recharge, flood prevention, and improved water quality. 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 must be supportive of these sorts of local initiatives within the national legal framework.

4.2.4 Policies relating to farm-level risk management

Adopting CA may, in the short term, involve costs and risks. Switching to CA quickly may appear too risky. Farmers may start with 10% of their land under CA, and move forward with the rest of the land as they gain experience with the new management system. If CA is to be a national priority, governments need to recognise the public good 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. From the review of CA-related experiences and 'live' cases examined and cited for this paper earlier, it would appear that the potential productivity, socio-economic and environmental benefits of such policies and incentives are likely to exceed the cost in most if not all cases. This is an area where more environmental economic research needs to be supported and strengthened to establish the nature of the cost:benefit relationships involved in CA-based policies and programmes.

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

- 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;
- Cleaner air during times of land preparation (dust from tillage) or harvest (burning of residues);
- Increased stability of food supplies due to greater resilience of crops in the face of climatic drought;
- Better livelihoods on farms with the potential to reverse rural-urban migration trends.

4.2.5 'Sustainability' as justification for policy support for rapid up-scaling

The capacity of CA specifically to address the improvement of sustainability – through improved functioning of 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. After CA has been promoted in Kazakhstan by CIMMYT and FAO in the early 2000s it has had a rapid development as a result of farmers' interest, enabling and facilitating policies, and an active input supply sector. While the total CA area in the country in 2004 was less than 1,000 ha, it grew until 2007 to 600,000 ha and in 2008 to 1.3 million ha, placing Kazakhstan in only four years among the top ten CA adopting countries worldwide. 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 (Suleimenov, 2009).

5. Conclusions

If Conservation Agriculture is effective, then a key question would be to ask why is it not spreading more rapidly? We have suggested a number of reasons for farmers not spontaneously adopting CA, despite the acknowledged advantages. Knowing these hurdles 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 higher food and energy prices and input costs, and increasing environmental concerns to issues of climate change, facilitate the justification for policy makers to introduce supportive policies and institutional services. Thus, 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. However, with the exception of few catastrophic events, changes occur gradually and hence the need for a fundamental change is not recognized. As a result wrong answers, providing window dressing rather than addressing the root causes might actually divert the attention and further delay adoption of CA.

First national and international knowledge systems must increasingly align their work in research, education and extension to helping to understand the root problems and the role CA systems and practices can play to then facilitate policies for accelerated adoption. Research in particular must help to solve farmer and policy constraints to CA adoption and spread, requiring research comparing CA with conventional systems to generate scientific evidence along with empirical evidence for policy makers to invest into CA. Additionally new research knowledge on CA systems generated on-farm and on-station is also required to advance their further development and adoption.

People and institutions, both public and private sector, everywhere have everything to gain from adopting CA as a basis for sustainably increasing agricultural production and ecosystem services. The greater impact that can result from the adoption of CA as a matter of policy and good stewardship is that agriculture development in the future everywhere can become part of the solution of addressing national, regional and global challenges including resource degradation, land and water scarcity, climate change.

There is growing evidence from farmer fields, landscape-based development programmes and scientific research in tropical, sub-tropical and temperate agro-ecologies across all continents that CA can be positive for productivity, farm profit and environment. As full benefits of CA take several years fully to manifest themselves, fostering a dynamic CA sector requires an array of enabling policy and institutional support over the longer term, including the availability of necessary inputs and equipment, and the fostering of farmer-driven innovations. The lack of knowledge about CA as well as a supportive enabling environment for its promotion, and the fact that the national institutions, public and private, are mainly serving tillage-based agriculture, are the main reasons for CA not spreading faster in Africa, Asia and Europe. However, the evidence of increased adoption and uptake in these continents during the recent years indicates that the situation is changing, and the uptake of CA is expected to continue over coming years.

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