Current status, prospect and policy and institutional support for Conservation Agriculture in the Asia-Pacific region

A. Kassam[1], Li Hongwen[2], Y. Niino[3], Theodor Friedrich[4], He Jin[2], Wang Xianliang[2]

(1. *School of Agriculture, Policy and Development, University of Reading, Reading, RG6 6AR, United Kingdom*;
2. *Conservation Tillage Research Centre of Chinese Ministry of Agriculture, College of Engineering, China Agricultural University, Beijing 100083, China*;
3. *FAO Regional Office for Asia and the Pacific, Bangkok 10200, Thailand*; 4. *FAO-Cuba, Havana, Cuba*)

Abstract: The current growing demand for Conservation Agriculture (CA) at the national level in the countries of the Asia-Pacific region presents an opportunity to promote its widespread adoption and up-scaling through national policy and institutional support that appears necessary. Despite the obvious benefits of CA, it does not spread automatically unless the constraints that hinder adoption are understood and addressed in specific situations. These can include a combination of intellectual, social, financial, biophysical, technical, infrastructure constraints, or policy related support. Knowing what the bottlenecks are is important in developing strategies to overcome them. This paper presents: (a) some of the generic policy opportunities that exist for the adoption and uptake of CA; (b) a summary proceedings and outcome of the Regional Expert Consultation Workshop held in Beijing and sponsored by FAO Regional Office for Asia-Pacific which describes the status of CA in the Asia-Pacific region; (c) the challenges to CA adoption and uptake in the Asia-Pacific region; and (d) the conditions that need to be taken into account in designing and promoting policy and institutional support strategies for up-scaling CA.

Keywords: Conservation Agriculture, policy and institutional support, adoption, Asia-Pacific region, tillage, agricultural mechanization, CA alliance, institutional cooperation
DOI: 10.3965/j.ijabe.20140705.001

Citation: Kassam A, Li H W, Niino Y, Friedrich T, He J, Wang X L. Current status, prospect and policy and institutional support for conservation agriculture in the Asia-Pacific region. Int J Agric & Biol Eng, 2014; 7(5): 1－13.

1 Introduction

In the Asia-Pacific region, the rate of increase in crop yields has slowed and yield gains are becoming difficult to maintain because of the degradation of land and water resources upon which agriculture depends. In the region, agriculture in general has been changing from traditional subsistence farming to 'modern' commercial farming at different rates in different nations. This has led to specialization in commercialized farming with mechanization, intensive tillage and increased agrochemical use, leading to degradation of soil health and soil ecosystem functions. The use of high levels of external inputs and labour-saving technologies has resulted, in some cases, to abandoning some of the important ecologically-based practices such as crop rotation and diversified cropping or soil mulch cover.

Soil erosion, loss of soil organic matter and soil structure, and poor soil health resulting from soil tillage and exposed soils compels us to look for alternatives to

Received date: 2014-09-11 **Accepted date:** 2014-10-13
Biographies: A. Kassam, PhD, Professor, research interests: Conservation Agriculture and sustainable agriculture intensification. Mailing address: 88 Gunnersbury Avenue, Ealing, London W5 4HA, United Kingdom. Email: amirkassam786@googlemail.com. **Y. Niino,** Land Management officer, research interests: land management. Email: Yuji.Niino@fao.org. **Theodor Friedrich,** FAO representative in Cuba, research interests: Conservation Agriculture. Email: Theodor.Friedrich@fao.org. **He Jin**, PhD, Associate Professor, research interests: Conservation Agriculture and farm machine. Email: hejin@cau.edu.cn. **Wang Xianliang**, Master student, research interests: conservation agriculture machinery. Email: 13126728942@126.com.
*__Corresponding author: Li Hongwen__, PhD, Professor, research interests: Conservation Agriculture, agricultural machine and equipment engineering. Mailing address: College of Engineering, China Agricultural University, No.17, Qinghuadonglu, Haidian District, Beijing 100083, China. Email: lhwen@cau.edu.cn.

reverse the process of soil degradation and decreasing productivity. The natural approach to this is no or minimum mechanical soil disturbance and maintaining soil cover in a diversified cropping system. This produces many ecological and socio-economic benefits, and has led to movements promoting an alternate kind of farming which has become generally known as Conservation Agriculture (CA). CA involves: (i) no tillage and direct seeding into untilled soil which maintains soil organic matter and reduces soil compaction; (ii) protection of the soil surface with an organic mulch cover which also serves as a substrate for soil micro-organisms and meso-fauna to build and maintain soil pore space and structure; and (iii) crop diversification through crop rotations or associations or sequences, involving annuals and perennials including legumes.

Practices such as the precise placement of agrochemicals, and application of animal manure, crop residues and green manure crops, can enhance the positive effects of CA even further. The controlled movement of farm vehicles on permanent tracks in CA systems also facilitates the reduction or elimination of soil compaction from excessive use of heavy machinery for field operations. So, CA can contribute to environmental conservation and enhances and sustains agricultural production while promoting ecosystem services such as water cycling, nitrogen fixation and carbon sequestration. CA aims to conserve, improve, and make more effective use of natural resources through the integrated management of available soil, water, and biological resources, combined with purchased external inputs. It contributes to environmental conservation and enhances and sustains agricultural production. Thus, CA can also be referred to as resource-efficient type of agriculture.

Natural ecosystems have always been relied upon to support the continuity of agriculture production and ecosystem services such as flood and erosion control, mediation of water quality, stream flow regulation, microclimate regulation, and biodiversity in its various forms. Improper agricultural practices can reduce the ability of ecosystems to provide food and other services. Some of these services can be developed based on appropriate technologies such as CA and complementary practices that restore natural ecosystem functions and improve the resilience of farming systems against biotic and abiotic stresses, thus enhancing food security. This is why CA is considered to be an ecologically suitable basis for sustainable production intensification.

In 2013, there were some 155 Mha of arable crop land under CA, corresponding to about 11% of the global crop land, spread across all continents and agro-ecologies, with some 50% of the CA area being located in the developing countries. During the past decade or so, CA has been spreading at the annual rate of some 8.3 Mha, as more development attention and resources are being allocated towards its dissemination by governments, public and private sector institutions, international research and development agencies, non-governmental organizations (NGOs) and donors. In the last ten years Conservation Agriculture has been spreading in Asia and Africa, as well as in Europe.

This paper reviews the current status of CA in the Asia-Pacific region and discusses the policy and institutional support required for the promotion of CA in the region. Further, it provides an appropriate rationale for the establishment of a CA Alliance for Asia-Pacific (CAAAP)[1].

2 Current status of CA in the Asia-Pacific region

Conservation Agriculture had been adopted over 155 Mha of arable cropland in 2013, corresponding to about 11% of the global cropland, spread across all continents and agro-ecologies[2]. In the Asia-Pacific region, many countries have been exposed to no-tillage systems and CA for the past 10-15 years and some of them, such as Kazakhstan and China, have included this into their government policies[3-5]. However, compared with some developed countries (such as USA, Australia), the adoption of CA in the Asia-pacific region is low because CA began to be promoted in the different nations of the region at different times. What is now common across the region is that nearly all countries have begun to accept the need to promote CA as part of the national production intensification strategy. Further, as part of the CA research and knowledge promotion, national governments and their agricultural sectors are beginning to realize its many advantages to the producers as well as to the consumers and to the society in general and are making effort to organize policy and institutional support to facilitate the adoption and up-scaling CA. While there are constraints to adoption of CA and they must be addressed nationally at the producer and sector level, the development of CA in the Asia-Pacific region is moving forward as elaborated in the following sections.

2.1 China

In China, the total population is 1,300 million but only 130 Mha of land can be used for agriculture, corresponding to, on average, 0.1 ha of agricultural land per person. Drought, soil and wind erosion, stubble burning, all provide a justification for the application of CA. China started no-tillage studies in the 1950s, and maize no-tillage seeding experiments in two crops (winter wheat-summer maize) a year region of North China in the 1980s; In 1992, aiming at the problem of lacking CA equipment, China began the study on CA technology, with the emphasis on the development of no-tillage seeders; In 1999, Conservation Tillage Research Centre (CTRC) was set up at China Agricultural University by Chinese Ministry of Agriculture (MOA), specifically for CA; In 2002, MOA began to demonstrate and extend CA in China, and organized the first national CA field meeting in Linfen, Shanxi Province; In 2009, China State Council ratified the National Construction Program of Conservation Agriculture. This program was formulated by MOA and the National Development & Reform Commission (NDRC), and promoted rapid development of CA in China[6]. By the end of 2013, CA was being practiced on more than 6.6 Mha, and total four times of the second prize of National Scientific and Technological Progress Award have been granted in the field of CA. The powered anti-blocking technology for no-tillage seeder, which was completed in 1997, makes it possible to no/minimum tillage seed wheat after maize harvesting and received the second prize of State Scientific and Technological Progress Award in 2009.

The machines and tools of CA have developed considerably in China, and more than 100 factories at different levels exist in China. Typical CA machines and tools contain manual direct seeders, no/minimum tillage seeders for 2-wheel tractor, middle and small no/minimum tillage seeders (strip rotary hoe seeder, strip chop seeder, powered disc seeder, rice strip rotary hoe transplanter, etc) for four-wheel tractor[7].

So far, many policies for CA have been formulated, such as the Central Document No. 1 which stressed CA for eight years, and MOA and the Ministry of Finance (MOF) supported to expand the spread of CA from 2002 and beyond. However, there are still some barriers that exist to hinder the adoption and promotion of CA in China, such as lack of affordable and easily-used CA machines, farmers' traditional mindset, and some inactive scientists and governmental officials who are not fully convinced about the benefits of CA.

2.2 India

India has the 2nd largest agricultural land area in the Asia-Pacific region, and has more than 140 Mha under cultivation, 63.3 Mha net irrigated area and engages 58% of total workforce. Indian population has tripled in the last 40 years but food-grain production quadrupled in spite of the fact that 78% of the farmers cultivate less than 2 ha. The Green Revolution was a great achievement in the mid-sixties, which was attributed to policy support, institutional infrastructure and trained human resources. But there are still future food security challenges that must be addressed, and the largest paradox is the fact that same land area, with less water, nutrients, fuel, labour and in changing climatic conditions must now produce more. CA began with on-farm testing of zero tillage drill in 1990, and did a rapid development with many initiatives still in place after more than 20 years. There are many benefits of CA in India, however, there are still some challenges, such as: overall potential wheat yields are decreasing; decrease is more than 1.5 t/ha if the date of sowing is December 1st from 1981 to 2009, and November end to December 1st sowing was fine up to end of 2000, but with terminal effect November 3rd to November 17th sowing performed better, so the future trends suggest that the date of sowing may shift a bit forward to the end of October and therefore short duration rice varieties are needed.

In a recent review of the Consultative Group on International Agriculture Research (CGIAR) impact, it has been reported that India's CA programme has saved USD 164 million with an investment of USD 3.5 million with internal rate of return of 66%, the highest amongst all the CGIAR programmes. Suitable machinery, mind-set and variable results are major issues in the adoption of CA in India. Future uptake pathways in India include: design and develop CA machinery suited to diverse farmer typologies and ecologies; studies on crop-livestock interactions and crop residue management for multiple use; environmental foot prints of CA systems; define institutional arrangements and developmental needs for scaling-up and scaling-out of CA systems; capacity building at different scales and levels; and new course in CA system at the University level.

2.3 Southeast Asia

In the Southeast Asia region, such as Laos, Vietnam, Cambodia, Philippines and East Timor, CA is: an alternative to intensive commercial agricultural systems based on high chemical input; a solution to restore soil fertility and degraded environment (acidic or salty or polluted soils; erosion both at plot and landscape levels); and a solution to intensify and diversify agriculture in mountainous areas. CA is based on three principles: no or minimum mechanical soil disturbance; permanent organic soil cover; diversified crop rotations. There are still some regional challenges identified as priorities for agricultural development as follows:

(1) restoration of soil fertility in degraded areas;

(2) intensification and diversification of agriculture in mountainous areas, and alternatives to 'slash & burn' practices;

(3) development of capacity for 'Human Resources Development' to address the needs of all CA development and dissemination actors. In addition, the CA Network for South East Asia (CANSEA) was introduced. The network started in 2009, and the objective is to work together what cannot be done alone. There are six core members in the network: China, Vietnam, Thailand, Cambodia, Laos, and Indonesia. The generic activities of the network include supporting exchanges of experience, results and training, and communication and dissemination of results.

2.4 Central Asia

Central Asia consists of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Current and emerging challenges for CA include: growth of population followed by increasing demand for food and feed; expanding area under irrigation; declining arable land per capita and increasing competition for land and water; rising prices of inputs and land degradation, and CA can address these challenges. Effectiveness of CA has been shown in several ways: better development of crops and higher rates of return from agricultural investments and less erosion in the irrigated areas. In addition, crop residues can slow evaporation of soil moisture because residues are slower to degrade, and no-tilling also conserves soil moisture, so more organic matter is produced, outweighing the initial loss of feed. Moreover, CA can reduce farm power and energy for field production, number and size of tractors, mineral fertilizer use, and mitigate climate change. Research has shown that except in Kazakhstan, the adoption of CA is very little in other countries of Central Asia. Barriers include:

(1) mind-set - overcoming the culture of the plough, and there are more difficulties for researchers who have expounded the need for intensive tillage;

(2) more effort is needed in dissemination and local manufacture of the adapted equipment;

(3) lack of extension services throughout the region and lack of farmer expertise;

(4) competition for crop residues because smallholder farmers generally manage mixed crop-livestock systems where crop residues are used as animal feed.

3 Policy and institutional support opportunities for CA in the Asia-Pacific region

Major changes in ecological awareness and knowledge have been occurring globally during the past three decades in the understanding of the root causes of agricultural land degradation and sub-optimal agricultural performance. This understanding has increasingly become a basis for the promotion of sustainable production intensification, sustainable agricultural land management, and rehabilitation of degraded agricultural land. Experiential knowledge from the farming communities and formal scientific knowledge from research community have been accumulating from all continents regarding the role of CA in sustainable agriculture intensification, improving food security and enhancing livelihoods and the environment.

This is why Food and Agriculture Organization (FAO) of the United Nations is promoting CA as a ‘Save and Grow’ production system. These developments serve to strengthen policy-related opportunities for promoting the testing, adaptation, adoption and dissemination of CA to address the following major challenges faced by the Asia-Pacific region, as well as internationally, namely: (a) the concerns regarding pervasive food insecurity and poverty, high prices for food, production inputs and energy, wide-spread degradation of agricultural land resource base, resource scarcity, and climate change; (b) the continuing high environmental impact of tillage-based agriculture; (c) the short-comings of the relatively high-cost tillage-seed-fertilizer-pesticide-credit approach to agricultural development and sustainable livelihoods for the resource-poor small farmers trapped in a downward spiral of land degradation, fragile economies and ineffective policy and institutional support; (d) the natural and man-made disasters and crises which often lead to emergencies involving large rural populations whose agriculture systems and livelihoods have to be rehabilitated through relief and development measures. These concerns and situations are creating opportunities for transforming tillage-based agriculture, that is increasingly being recognized to be ecologically and economically unsustainable, into CA system[5,8-10].

CA enables producers to intensify production sustainably, improve soil health and minimize or avoid negative externalities. CA is able to support and maintain ecosystem functions, and services derived from them, while limiting agro-chemical and mechanical soil interventions - required for intensifying the production - to levels which do not disrupt these functions. Thus, intensification with CA can allow harnessing efficiency (productivity) gains as well as producing ecosystem benefits. CA offers the following four sets of potential benefits to all producers, whether they operate on small or large scale of farm size, and to all types of soil-based systems of agricultural production, and to society at large[5,9,11,12]: (i) higher stable production, productivity and profitability with lower input and capital costs; (ii) capacity for climate change adaptation and reduced vulnerability to extreme weather conditions; (iii) enhanced production of ecosystem functions and services; and (iv) reduced greenhouse gas emissions.

CA principles translate into a number of locally-devised and applied practices that work simultaneously through contextualized crop-soil-water-nutrient-ecosystem management at a variety of scales. According to FAO[13,14], the adoption of CA has resulted in savings in machinery, energy use and carbon emissions, a rise in soil organic matter content and biotic activity, less erosion, increased crop-water availability and thus resilience to drought, improved recharge of aquifers and reduced impact of the variability in weather associated with climate change. It can also result in lowered production costs, leading to more reliable harvests and reduced risks[13,14].

4 Policy and institutional support implication for CA in the Asia-Pacific region

One of the key elements of successful adoption and up-scaling of CA is policy and institutional support in national programmes as elaborated in this section 4 which is based on Kassam et al.(2014)[15]. This means there must be proactive buy-in at the policy level backed-up by significant institutional support in a range of services from both public and private sector before CA can be embedded in national programmes. Such policy support would be reflected through mainstreaming appropriate CA interventions in policies of relevant developmental sectors which include agriculture, environment, education, commerce, trade and industry.

4.1 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[16,17] 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: use of well adapted good quality seeds; enhanced and balanced crop nutrition, based on and in support of healthy soils; integrated management of pests, diseases and weeds; 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 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[16,18,19]. Similarly, knowledge and service institutions in the public and private sectors tend to be aligned to supporting conventional tillage-based systems.

There are many problems including: water erosion, wind erosion etc in the long terms of farming system that makes the Conservation Agriculture adopted and up-scaled. 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)[9,20].

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[21,22]. However, 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[18,23] or Argentina. To date, some 10% 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.

4.2 Necessary conditions for CA adoption

CA is management intensive, requiring more planning than tillage-based systems. It cannot be reduced to a standard technology package, adoption requiring both change and adaptation based on experiential learning[9,24]. The following sections elaborate the necessary conditions for the introduction of CA and transformation of tillage-based systems.

4.2.1 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.

4.2.2 Dynamic institutional capacity to support CA

CA is a dynamic system in constant development and adaptation. 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 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[25] 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. One way to support integration would be to develop common indicator sets to assess progress towards the environmental, economic and social benefits of CA.

4.2.3 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. 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[26,27].

4.2.4 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[28]. 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'[29]. 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. The development of such groups can then become a powerful means of encouraging others to join the movement.

4.2.5 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[5]. 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. 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.

4.2.6 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: 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; explore new potentials and possibilities based on what is already known and observed; 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; advance knowledge about pest, disease and weed interactions under CA conditions; design new mechanization concepts for CA systems including aspects such as compaction management and promotion of no-till seeders for small farmers; undertake 'blue-sky' exploratory research with possible relevance to CA.

Also, too few 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. 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.

4.2.7 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[10,16,18,27]. 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[30]. 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.

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.

4.2.8 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 dis-adoption, 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.

4.2.9 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[18,23,31,32,33] .

4.2.10 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[23,31,34,35,36,37].

4.3 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[16,38]. 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.

4.3.1 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[39].

4.3.2 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[33], and in farmland stewardship programmes such as Australia's Landcare[40,41].

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.

5 Prospects for CA in the Asia-Pacific Region

Prospects for CA in the Asia-Pacific region are now better than ever before because most countries in the region not only are keen to transform their agriculture onto a sustainable base, but also some countries such as China, India, Pakistan, Bangladesh, Laos, Vietnam, Cambodia, Philippines and North Korea now have research and extension activities on CA and some countries such as China and India have a significant area already under no-till crops. In addition to FAO, there are several international organizations such as International Wheat and Maize Improvement Centre (CIMMYT), International Rice Research Institute (IRRI), International Centre for Agricultural Research in Dry Areas (ICARDA), International Centre for Research in Agroforestry (ICRAF), and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) as well as some aid agencies such as International Fund for Agriculture Development (IFAD), Asian Development Bank (ADB), Australian Centre for International Agricultural Research (ACIAR) and United States Agency for International Development (USAID) who are seriously promoting CA research and development activities in the region. There are some regional networks such as Asia Pacific Association of Agricultural Research Institutions (APAARI), South Asia Conservation Agriculture Network (SACAN) and Conservation Agriculture Network for South East Asia (CANSEA) and institutes such as Borlaug Institute for South Asia (BISA), Asian Institute for Technology (AIT) and Sustainable Agriculture & Natural Resource Management (SANREM) who have a strong research and development interest in CA. Thus overall there is an emerging strong interest in promoting CA in the Asia-Pacific region. This will require all stakeholders in the public, private and civil sectors to increasingly work together in support of promoting CA.

CA is more a system's approach to agriculture production management than a single technology because it offers a way to produce more with less while at the same time preserves and enhances many of the ecological functions a natural soil has to offer in a natural ecosystem. CA also offers economic benefits to farmers who apply it. But, there are a number of challenges that CA faces throughout the largely agricultural region of Asia-Pacific including lack of crop diversification on small and large-size farming areas, knowledge about CA systems among extension and technical staff, knowledge about CA at decision-making levels, farmers' ability to decide on diversified crop rotations, and the implements needed for use in the CA. Nevertheless, farmers in the Asia-Pacific region are now becoming increasingly aware of CA as a new, promising technology. Awareness comes in the form of accepting no-till as a viable system in growing crops as opposed to the earlier total rejection of agriculture without tillage. Usually manufacturers, importers and dealers are proactive with the objective of increasing the demand for CA implements. Yet, the present political systems in Asia-Pacific region indicate that the public rather than the private sector is now being called upon to initiate and lead such efforts. Agriculture in the Asia-Pacific region is diverse, and has a great potential to revitalize the agricultural economies of the countries in the region via improved productivity (efficiency) and higher total output through CA-based agriculture development. CA will have to shoulder the largest burden of making sustainable intensification of production systems a reality for food, fodder and fibre crops and livestock in Asian-Pacific countries.

The demand for food and fodder production will continue to grow in the region, and several countries have the potential of becoming significant grain exporters at the regional and international level. Wheat, rice, maize, cotton, several pulses and livestock are the most important agricultural commodities in the region, and with a trend to diversification, oil crops such as rapeseed, sunflower, safflower and soya could likewise become even more important commodities than they are now. In addition, most if not all of the perennial tree systems, including those in plantations, lend themselves to becoming CA systems such as is the case with oil palm, cocoa and rubber in Malaysia. Similarly, irrigated cropping systems also can benefit from adopting CA principles as seen in South Asia region.

Considerable knowledge has been generated about CA practices in the Asia-Pacific region, in both rainfed as well as irrigated areas, and more recently for plantation crops. In fact, the potential of CA for sustainable agricultural development has been demonstrated in the region, and outside the region with similar environments[42]. Building the technical and scientific capacity of national partners will be essential for moving to large-scale CA adoption and uptake. Researchers, extension workers and farmers will continue exchanging experience and knowledge about the new CA methods. Consequently, for the foreseeable future, facilitating national development strategies for up-scaling of CA, conducting training courses with national partners remain a high priority in the efforts undertaken by FAO, CIMMYT, IRRI, ICRAF, ICRISAT, ICARDA, CIRAD and other international organizations and programmes such as IFAD, ADB, ACIAR, SANREM, USAID and national donors, to promote CA in the region.

6 Concluding remarks

From global evidence, as well from evidence within Asia-Pacific region as well from the deliberations of the Regional Consultation Workshop, CA potentially represents a more-secure paradigm of agriculture than that which is based on tillage of the soil. Consequently, CA does deserve close attention because of its wider socio-economic and environmental implications and possibilities for faster spread.

The lack of general knowledge and understanding 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 the Asia-Pacific region. However, the evidence of increased adoption and uptake in other regions and continents during the recent years for example in China and in South Asia indicates that this situation can change, and the uptake of CA can be expected to accelerate over the coming years.

As seen already, there are a number of good reasons for farmers not immediately adopting CA, despite the acknowledged advantages. Farmers have to first overcome a number of hurdles. Foreseeing these hurdles and problems allows developing strategies to overcome them. Crises 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. Thus, actual regional challenges are providing at the same time opportunities to accelerate the adoption process of CA and to shorten the initial slow uptake phase.

In this regard, it is vital that all national knowledge systems in the Asia-Pacific region 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 (rather than comparing CA with conventional systems which is often of academic value and not advancing the further development of knowledge to facilitate the introduction and spread of CA).

There is growing evidence from farmer fields, landscape-based development programmes and scientific research in most agro-ecologies across all continents that CA is very largely positive for productivity, profit and environment. As all the benefits of CA take several years to fully manifest themselves, fostering a dynamic CA sector requires an array of enabling policy and institutional support over a longer term time horizon, including the availability of necessary inputs and equipment, and the fostering of farmer-driven innovations. Undertaking these improvements will enable governments, civil institutions and farmers to progress together.

Acknowledgements

We acknowledge with thanks the financial support provided for this work by the Program for Changjiang Scholars and Innovative Research Team in University of China (Grant No. IRT13039), and FAO Regional Office for Asia-Pacific.

[References]

[1] FAO. Policy and Institutional Support for Conservation Agriculture in the Asia-Pacific Region. FAO Regional Office for Asia-Pacific. Bangkok, Thailand. December 2013.

[2] Kassam A H, Friedrich T, Derpsch R, Kienzle J. Worldwide adoption of Conservation Agriculture. The 6th World Congress of Conservation Agriculture. 22-27 June, 2014, Winnipeg, Canada.

[3] Friedrich T, Derpsch R, Kassam A H. Overview of the global spread of Conservation Agriculture. Facts Reports, 2012; 6: 1–7.

[4] Derpsch R, Friedrich T, Kassam A H, Li H W. Current status of adoption of no-till farming in the world and some of its main benefits. International Journal of Agricultural and Biological Engineering, 2010; 3(1): 1–25.

[5] Kassam A H, Friedrich T, Shaxson F, Pretty J. The spread of Conservation Agriculture: Justification, sustainability and uptake. International Journal of Agriculture Sustainability, 2009; 7(4): 292–320.

[6] He J, Li H W, Wang Q J, Gao H W, Li W Y, Zhang X M, et al. The adoption of conservation tillage in China. Annals of the New York Academy of Sciences, 2010; E96–E106.

[7] He J, Zhang Z Q, Li H W, Wang Q J. Development of small/medium size no-till and minimum-till seeders in Asia: A review. International Journal of Agricultural and Biological Engineering, 2014; 7(4): 1–12.

[8] Shaxson T F, Kassam A H, Friedrich T, Boddey R, Adekunle A. Underpinning conservation agriculture's benefits: The roots of soil health and function. In: 'An International Technical Workshop: Investing in Sustainable Crop Intensification: The case for Improving Soil Health' FAO. 22–24 July, 2008, Rome.

[9] Friedrich T, Kassam A H. Adoption of conservation agriculture technologies: Constraints and opportunities. Invited paper, IV World Congress on Conservation Agriculture. 4-7 February 2009, New Delhi, India

[10] FAO, 2001a. The Economics of Conservation Agriculture, 2001.

[11] Pretty J. Agricultural sustainability: Concepts, principles and evidence. Phil Trans Royal Society of London B, 363 (1491), 2008: 447–466.

[12] Pretty J, Toulmin C, Williams S. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability, 2011; 9(1): 5–24.

[13] FAO. Investing in sustainable crop intensification: The case for improving soil health. Report of the International Technical Workshop, FAO, Rome, July 2008. Integrated Crop Management, Vol. 6, FAO, Rome (www.fao.org/ag/ca/).

[14] FAO. FAO CA website at: www.fao.org/ag/ca. Accessed on [2012-11-15].

[15] Kassam A H, Friedrich T, Shaxson F, Bartz H, Mello I, Kienzle J, Pretty J. The spread of conservation agriculture: Policy and institutional support for adoption and uptake. Facts Reports Vol. 7, 2014.

[16] Derpsch R. History of crop production with & without tillage. Leading Edge, The Journal of No-Till Agriculture, published by No-till On The Plains, 2004; 3(1): 150–154.

[17] Montgomery D R. Dirt, the erosion of civilizations. University of California Press, Berkeley, Los Angeles and London, 2007; pp. 285.

[18] Bolliger A, Magid J, Amado T J C, Skora Neto F, Ribeiro M F S, Calegari A, et al. Taking stock of the Brazilian "Zero-Till Revolution": A review of landmark research and

farmers' practice. Advances in Agronomy, 2006; 91: 47–110.

[19] Goddard T. No-till farming systems. WASWC Special Publication No. 3, Bangkok, Thailand, 2008.

[20] FAO. Save and grow: A policymaker's guide to the sustainable intensification of smallholder crop production, 2011; pp. 98.

[21] Alston J M, Norton G W, Pardey P G. Science under scarcity: Principles and practice of agricultural research evaluation and priority setting. Cornell University, 1995.

[22] Rogers E M. The Diffusion of Innovations. New York: Free Press, 1995.

[23] Junior R C, Araújo A G, Llanillo R F. No-Till Agriculture in Southern Brazil. Factors that facilitated the evolution of the system and the development of the mechanization of conservation farming, FAO and IAPAR, 2012; pp. 77.

[24] Derpsch R. No-tillage and Conservation Agriculture: A progress report. In No-Till Farming Systems. Goddard T, Zoebisch, M A, Gan Y T, Ellis W, Watson A, Sombatpanit S.(eds) World Association of Soil and Water Conservation (WASWC). Bangkok, 2008; 3:7–39.

[25] Shaxson T F. Re-thinking the Conservation of Carbon, Water and Soil: A Different Perspective, Agronomie, 2006; 26: 1–9.

[26] WOCAT. Where the land is greener: case studies and analysis of soil and water conservation initiatives worldwide. Liniger H, Critchley W (eds). Netherlands: CTA-FAO-UNEP-CDE, 2007.

[27] Borsy P, Gadea R, Vera Sosa E. Forest Management and Conservation Agriculture: Experiences of smallholder farmers in the eastern region of Paraguay. Integrated Crop Management, 2013; 18: 192

[28] Pretty J. Social capital and the collective management of resources, 2003; 302: 1912–1915.

[29] Marongwe S L, Kwazira K, Jenrich M, Thierfelder C, Kassam A H, Friedrich T. An African success: The case of conservation agriculture in Zimbabwe. International Journal of Agricultural Sustainability, 2010; 9(1): 153–161.

[30] FAO, 2001b. Conservation agriculture: Case studies in Latin America and Africa. Soils Bulletin, 2011; 78: 66.

[31] Baig M N, Gamache P M. The economic, agronomic and environmental impact of no-till on the Canadian prairies. Alberta Reduced Tillage Linkages. Canada, 2009.

[32] Crabtree, B. Search for sustainability with No-Till Bill in dryland agriculture. In: Beckenham W A. Crabtree Agricultural Consulting, 2010.

[33] ECAF. Making sustainable agriculture real in CAP 2020: The role of conservation agriculture. European Conservation Agriculture Federation (ECAF), 2012; pp. 43.

[34] Sorrenson W J. Financial and economic implications of no-tillage and crop rotations compared to conventional cropping systems. TCI Occasional Paper, 1997.

[35] Fileccia T, Kassam A H. Conservation agriculture and food security in Kazakhstan. Working Paper, FAO Investment Centre Division, June 2009.

[36] Lindwall C W, Sonntag B. (eds). Landscape transformed: The history of conservation tillage and direct seeding. Knowledge Impact in Society, 2010.

[37] González Sánchez E, Pérez García J J, Gómez Ariza M, Márquez García F, Veroz González O. Sistemas agrarios sostenibles económicamente: el caso de la siembra directa, Vida Rural, 2010; 312: 24–27.

[38] Kassam A H, Friedrich T, Derpsch R. Conservation agriculture in the 21st century: A paradigm of sustainable agriculture. European Congress on Conservation Agriculture, 2010; 10: 4–6.

[39] Pieri C, Evers G, Landers J, O'Connell P, Terry, E. No-Till farming for sustainable rural development. Agriculture and Rural Development Working Paper, 2002.

[40] Flower K, Crabtree B, Butler G. No-till cropping systems in Australia. In No-Till Farming Systems. Goddard, T., Zoebisch, M.A., Gan, Y.T., Ellis, W., Watson A., Sombatpanit, S.(eds). World Association of Soil and Water Conservation, 2008; 3: 457–467.

[41] Llewellyn R S, D'Emden F, Gobbett D. Adoption of no-till and conservation farming practices in Australian grain growing regions: current status and trends. Preliminary report for SA No-till Farmers Association and CAAANZ, 26 January 2009.

[42] Jat R A, Sahrawat K L, Kassam A H. Conservation agriculture: Global prospects and challanges. CABI International. 2014; pp. 393.