FACTS Reports

Field Actions Science Reports
The journal of field actions

Special Issue 6 | 2012
Reconciling Poverty Eradication and Protection of the Environment

Overview of the Global Spread of Conservation Agriculture

Aperçu de la progression de l'agriculture de conservation (AC) dans le monde

Perspectiva general de la propagación mundial de la agricultura de conservación

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OpenEdition Journals

Electronic version
URL: http://journals.openedition.org/factsreports/1941
ISSN: 1867-8521

Publisher
Institut Veolia

Electronic reference
Theodor Friedrich, Rolf Derpsch and Amir Kassam, « Overview of the Global Spread of Conservation Agriculture », *Field Actions Science Reports* [Online], Special Issue 6 | 2012, Online since 06 November 2012, connection on 01 May 2019. URL : http://journals.openedition.org/factsreports/1941

http://factsreports.revues.org/1941
Published 12 septembre 2012

FACTS Reports

Overview of the Global Spread of Conservation Agriculture

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Abstract. The global empirical evidence shows that farmer-led transformation of agricultural production systems based on Conservation Agriculture (CA) principles is already occurring and gathering momentum worldwide as a new paradigm for the 21st century. The data presented in this paper, mainly based on estimates made by farmer organizations, agro-industry, and well-informed individuals provide an overview of CA adoption and spread by country, as well as the extent of CA adoption by continent. CA systems, comprising minimum mechanical soil disturbance, organic mulch cover, and crop species diversification, in conjunction with other good practices of crop and production management, are now practiced globally on about 125 M ha in all continents and all agricultural ecologies, including in the various temperate environments. While in 1973/74 CA systems covered only 2.8 M ha worldwide, the area had grown in 1999 to 45 M ha, and by 2003 to 72 M ha. In the last 11 years CA systems have expanded at an average rate of more than 7 M ha per year showing the increased interest of farmers and national governments in this alternate production method. Adoption has been intense in North and South America as well as in Australia and New Zealand, and more recently in Asia and Africa where the awareness and adoption of CA is on the increase. The paper presents the history of adoption and analyses reasons and actual regional trends for adoption to draw conclusions about future promotion of CA.

Keywords. No-tillage, crop residue, sustainability, constraints, adoption.

1 Introduction

1.1 The need for considering the environmental footprint of agriculture

There appears to be no alternative but to increase agricultural productivity (i.e. crop yield per unit area) and the associated total and individual factor productivities (i.e. biological output per unit of total production input, and output per unit of individual factors of production such as energy, nutrients, water, labor, land and capital) to meet the global food, feed, fiber and bio-energy demand and to alleviate hunger and poverty. However, until now, agricultural intensification from intensive tillage-based production systems generally has had a negative effect on the quality of many of the essential natural resources such as soil, water, terrain, biodiversity and the associated ecosystem services provided by nature. This degradation of the land resource base has caused crop yields and factor productivities to decline and has forced farmers, scientists and development stakeholders to search for an alternative paradigm that is ecologically sustainable as well as profitable. Another challenge for agriculture is its environmental foot print and climate change. Agriculture is responsible for about 30% of the total greenhouse gas emissions of CO_2, N_2O and CH_4 while being directly affected by the consequences of a changing climate (IPCC, 2007).

The new paradigm of "sustainable production intensification" as elaborated in FAO (2011a) recognizes the need for a productive and remunerative agriculture which at the same time conserves and enhances the natural resource base and environment, and positively contributes to harnessing the environmental services. Sustainable crop production intensification must not only reduce the impact of climate change on crop production but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in crop production systems above and below the ground to improve ecosystem services for better productivity and healthier environment. A set of soil-crop-nutrient-water-landscape system management practices known as Conservation Agriculture (CA) has the potential to deliver on all of these goals. CA saves on production energy

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input and mineral nitrogen use in farming and thus reduces emissions; it enhances biological activity in soils, resulting in long term yield and factor productivity increases. While not tilling the soil is a necessary, but not sufficient condition for truly sustainable and productive agriculture, CA has to be complemented with other techniques, such as integrated pest management, plant nutrient management, and weed and water management (FAO, 2011a).

1.2 Definition and description of Conservation Agriculture

According to FAO, Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely:

1. Continuous no- or minimal mechanical soil disturbance (i.e., no-tillage and direct sowing or broadcasting of crop seeds, and direct placing of planting material in the soil; minimum soil disturbance from cultivation, harvest operation or farm traffic, in special cases limited strip tillage);
2. Permanent organic soil cover, especially by crop residues, crops and cover crops; and
3. Diversification of crop species grown in sequence or associations through rotations or, in case of perennial crops, associations of plants, including a balanced mix of legume and non legume crops

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical tillage are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes (FAO, 2011b).

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. The yield levels of CA systems are comparable with and even higher than those under conventional intensive tillage systems, which means that CA does not lead to yield penalties. At the same time, CA complies with the generally accepted ideas of sustainability. As a result of the increased system diversity and the stimulation of biological processes in the soil and above the surface as well as due to reduced erosion and leaching, the use of chemical fertilizer and pesticides, including herbicides, is reduced in the long term. Ground water resources are replenished through better water infiltration and reduced surface runoff. Water quality is improved due to reduced contamination levels from agrochemicals and soil erosion (Laurent et al., 2011). It further helps to sequester carbon in soil at a rate ranging from about 0.2 to 1.0 t/ha/year depending on the agro-ecological location and management practices (Corsi et al., 2012). Labor requirements are generally reduced by about 50%, which allows farmers to save on time, fuel and machinery costs (Saturnino and Landers, 2002; Baker et al, 2007; Lindwall and Sonntag, 2011; Crabtree, 2010). Fuel savings in the order of around 65% are in general reported (Sorrenson and Montoya, 1984; 1991).

1.3 History, development and relevance of CA

Tillage, particularly in fragile ecosystems, was questioned for the first time in the 1930s, when the dustbowls devastated wide areas of the mid-west United States. Concepts for reducing tillage and keeping soil covered came up and the term conservation tillage was introduced to reflect such practices aimed at soil protection. Seeding machinery developments allowed then, in the 1940s, to seed directly without any soil tillage. At the same time theoretical concepts resembling today's CA principles were elaborated by Edward Faulkner in his book "Ploughman's Folly" (Faulkner, 1945) and Masanobu Fukuoka with the "One Straw Revolution" (Fukuoka, 1975). But it was not until the 1960s for no-tillage to enter into farming practice in the USA. In the early 1970s no-tillage farming reached Brazil, where farmers together with scientists transformed the technology into the system which today is called CA. No-tillage and mulching were also tested in the 1970s in West Africa (Greenland, 1975; Lal, 1977, 1976). Yet it took some 20 years before CA reached significant adoption levels in South America and elsewhere. During this time farm equipment and agronomic practices in no-tillage systems were improved and developed to optimize the performance of crops, machinery and field operations. This process is still far from being over as the creativity of farmers and researchers is still producing improvements to the benefits of the system, the soil and the farmer. From the early 1990s CA began to spread exponentially, leading to a revolution initially in the agriculture of southern Brazil, Argentina and Paraguay. During the 1990s this development increasingly attracted attention from other parts of the world, including development and international research organizations such as FAO, CIRAD and some CGIAR centres. Study tours to Brazil for farmers and policy makers, regional workshops, development and research projects were organized in different parts of the world leading to increased levels of awareness and adoption in a number of African countries such as Zambia, Tanzania and Kenya as well as in Asia, particularly in Kazakhstan and China. The improvement of conservation tillage and no-tillage practices within an integrated farming concept such as CA also led to increased adoption, including in industrialized countries, after the end of the millennium, particularly in Canada, Australia, Spain and Finland.

CA crop production systems are experiencing increased interest in most countries around the world. There are only few countries where CA is not practiced by at least some farmers and where there are no local research results available about

CA. The total area under CA in 2011 is estimated to be some 125 million hectares (FAO, 2011c). CA is practiced by farmers from the arctic circle (e.g. Finland) over the tropics (e.g. Kenya, Uganda), to about 50º latitude South (e.g. Malvinas/Falkland Islands); from sea level in several countries of the world to 3,000 m altitude (e.g. Bolivia, Colombia), from extremely dry conditions with 250 mm a year (e.g. Morocco, Western Australia), to heavy rainfall areas with 2,000 mm a year (e.g. Brazil) or 3,000 mm a year (e.g. Chile). No-tillage is practiced on all farm sizes from less than half a hectare (e.g. China, Zambia) to thousands of hectares (e.g. Argentina, Brazil, Kazakhstan). It is practiced on soils that vary from 90% sand (e.g. Australia) to 80% clay (e.g. Brazil's Oxisols and Alfisols). Soils with high clay content in Brazil are extremely sticky but this has not been a hindrance to no-till adoption when appropriate equipment is available. Soils which are readily prone to crusting and surface sealing under tillage farming do not present this problem under CA because the mulch cover avoids the formation of crusts. CA has even allowed expansion of agriculture to land areas considered marginal in terms of rainfall or fertility (e.g. Australia, Argentina). All crops can be grown adequately in CA and to the authors' knowledge there has not yet been a crop that would not grow and produce under this system, including root and tuber crops (Derpsch and Friedrich, 2009).

The main barriers to the adoption of CA practices continue to be: knowledge on how to do it (know how), mindset (tradition, prejudice), inadequate policies, for example, commodity based subsidies (EU, US) and direct farm payments (EU), unavailability of appropriate equipment and machines (many countries of the world), and of suitable herbicides to facilitate weed and vegetation management (especially for large scale farms in developing countries) (FAO, 2008; Friedrich and Kassam, 2009).

2 Global area and regional distribution

Global data of CA adoption are not officially reported, but collected from local farmers' and interest groups. The data are assembled and published by FAO (FAO, 2011c). For the data collection the CA definition is quantified as follows:

1. Minimum Soil Disturbance: Minimum soil disturbance refers to low disturbance no-tillage and direct seeding. The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. Strip tillage is allowed if the disturbed area is less than the set limits.
2. Organic soil cover: Three categories are distinguished: 30-60%, >60-90% and >90% ground cover, measured immediately after the direct seeding operation. Area with less than 30% cover is not considered as CA.
3. Crop rotations / associations: Rotation/association should involve at least 3 different crops. However, repetitive wheat or maize cropping is not an exclusion factor for the purpose of this data collection, but rotation/association is recorded where practiced.

The worldwide spread of CA in 2011 (about 125 M ha) is shown in Table 1, ranking the countries according to area adopted. CA in recent years has become a fast growing production system. While in 1973/74 the system was used only on 2.8 M ha worldwide, the area had grown to 6.2 M ha in 1983/84 and to 38 M ha in 1996/97 [18]. In 1999, worldwide adoption was 45 M ha, and by 2003 the area had grown to 72 M ha. In the last 11 years CA system has expanded at an average rate of around 7 M ha per year from 45 to 125 M ha showing the increased interest of farmers in this production system.

Table 1. Extent of Adoption of Conservation Agriculture Worldwide (countries with > 100,000 ha) (FAO, 2011c)

Country	CA area (ha)
USA	26,500,000
Argentina	25,553,000
Brazil	25,502,000
Australia	17,000,000
Canada	13,481,000
Russia	4,500,000
China	3,100,000
Paraguay	2,400,000
Kazakhstan	1,600,000
Bolivia	706,000
Uruguay	655,100
Spain	650,000
Ukraine	600,000
South Africa	368,000
Venezuela	300,000
France	200,000
Zambia	200,000
Chile	180,000
New Zealand	162,000
Finland	160,000
Mozambique	152,000
United Kingdom	150,000
Zimbabwe	139,300
Colombia	127,000
Others	409,440
Total	**124,794,840**

The growth of the area under CA has been especially significant in South America where the MERCOSUR countries (Argentina, Brazil, Paraguay and Uruguay) are using the system on about 70% of the total cultivated area. More than two thirds of no-tillage practiced in MERCOSUR is permanently under this system, in other words once started the soil is never tilled again.

As Table 2 shows 45% of the total global area under CA is in South America, 32% in the United States of America and Canada, 14% in Australia and New Zealand and 9% in the rest of the world including Europe, Asia and Africa. The latter are the developing continents in terms of CA adoption. Despite good and long lasting research in these continents showing positive results for no-tillage systems, CA has experienced only small rates of adoption.

Because of the benefits that CA systems generate in terms of yield, sustainability of land use, incomes, timeliness of cropping practices, ease of farming and ecosystem services, the area under CA systems has been growing exponentially, largely as a result of the initiative of farmers and their organizations.

Table 2. Area under CA by continent

Continent	Area (ha)	Percent of total
South America	55,464,100	45
North America	39,981,000	32
Australia & New Zealand	17,162,000	14
Asia	4,723,000	4
Russia & Ukraine	5,100,000	3
Europe	1,351,900	1
Africa	1,012,840	1
World total	**124,794,840**	**100**

Except in a few countries (USA, Canada, Australia, Brazil, Argentina, Paraguay, and Uruguay), however, CA has not been “mainstreamed” in agricultural development programs or backed by suitable policies and institutional support. Consequently, the total arable area under CA worldwide is still relatively small (about 9%) compared to areas farmed using tillage. Nonetheless, the rate of adoption globally since 1990 has been growing exponentially, mainly in North and South America and in Australia and New Zealand. The area under CA is on the increase in all parts of Asia, and large areas of agricultural land are expected to switch to CA in the coming decade as is already occurring in China, Kazakhstan, and most likely in India.

Although much of the CA development to date has been associated with rainfed arable crops, farmers can apply the same principles to increase the sustainability of irrigated systems, including those in semi-arid areas. CA systems have also been tailored for orchard and vine crops with the direct sowing of field crops, cover crops and pastures beneath or between rows, giving permanent cover and improved water infiltration, soil aeration and biodiversity. The common constraint mentioned by farmers to practicing this latter type of inter-cropping is competition for soil water between trees and crops. However, careful selection of deep rooting tree species and shallow rooting annuals resolves this. Also, as there is less runoff, more water enters the soil thereby improving water use efficiency. Functional CA systems do not replace current good land husbandry practices but integrate with them instead.

CA can be seen as an alternate approach to ecologically underpin production systems to enhance productivity, sustainability and resilience. However, introduction and adoption of CA must overcome a range of constraints that have been highlighted by a number of stakeholders (e.g., FAO, 2008).

2.1 Adoption in the Americas

CA adoption is highest in the southern parts of South America and in the North-Western Parts of North America with adoption levels above 50%. In Canada, with 13.5 M ha under CA, long term and wide adoption of Conservation Agriculture has resulted in visible environmental benefits, including the disappearance of dust storms as well as a higher biodiversity (Lindwall and Sonntag, 2010). Environmental services provided through CA are increasingly recognized, for example through carbon payment schemes as in Alberta, Canada. In the USA CA adoption of 26.5 M ha is still at a significantly lower level in percent of the cropland (16%), despite experience with no-till for a long period of time. However, for a number of reasons, including commodity focused subsidies, permanent no-till is applied only on about 10 to 12% of the area under no-tillage. Yet, in the USA the awareness about crop rotations and cover crops as well as the additional benefits of permanent no-till systems is also growing as a result of organized farmers’ associations such as the Conservation Agriculture Systems Alliance (CASA).

Table 3. CA adoption in some selected countries of Latin America (FAO, 2011c)

Country	CA area (ha)
Argentina	25,553,000
Bolivia	706,000
Brazil	25,502,000
Chile	180,000
Colombia	127,000
Mexico	41,000
Paraguay	2,400,000
Uruguay	655,100
Venezuela	300,000
Total	**55,464,100**

In Latin America the adoption levels of no-till farming in Argentina, Paraguay, Uruguay and Southern Brazil are approaching the 100% mark (Table 3). However, there are serious concerns about the quality of the CA adoption. Following market pressures, which are partly increased by government policies, a considerable proportion of farmers is opting for soya monocropping, even without any cover crops between two soya crops, which, despite applying no-till, results in erosion and soil degradation and cannot be considered as “real” CA. Taking this situation into account, the area under good quality CA is less than half of the total area under no-till cropping, particularly in Argentina and Uruguay. The problem is being addressed in Brazil and Uruguay with strengthened extension, legal regulations for cover crops in the specific case of soya and subsidy programs for good quality CA.

2.2 Adoption in Europe

CA is not widely spread in Europe, excluding Russia (Table 4): no-till systems do not exceed 1% of the arable cropland. Only Africa has a smaller absolute area under CA than Europe. Since 1999 ECAF (European Conservation Agriculture Federation) has been promoting CA in Europe, and adoption is visible in Spain, Finland, France and UK, with some farmers at 'proof of concept' stage in Ireland, Portugal, Germany, Switzerland, and Italy. Especially in Spain, Portugal and Italy the growth of CA in perennial crops, such as fruit orchards, vineyards and olive plantations, has exceeded the adoption rate in annual crops.

Table 4. CA adoption in some selected countries of Europe (FAO 2011c)

Country	CA area (ha)
Finland	160,000
France	200,000
Germany	5,000
Hungary	8,000
Ireland	100
Italy	80,000
Netherlands	500
Portugal	32,000
Slovakia	10,000
Spain	650,000
Switzerland	16,300
United Kingdom	150,000
Total	**1,311,900**

Bridging between Europe and Asia are two countries, Russia and Ukraine, with significant adoption of CA and with active farmers' groups promoting CA. In Russia the area under conservation tillage is reported with 15 M ha, while CA according to the FAO definition is applied on 4.5 M ha. In the Ukraine CA has reached 600,000 ha.

2.3 Adoption in Asia

Asian countries have seen increasing uptake of CA in the past 10-15 years. In Central Asia, a fast development of CA has been observed in the last 5 years in Kazakhstan which now has 10.5 M ha under reduced tillage, mostly in the northern drier provinces, and of this 1.6 M ha (10% of crop area) are "real" CA with permanent no-till and rotation that puts Kazakhstan amongst the top ten countries in the world with the largest crop area under CA systems. China too has had an equally dynamic development of CA which began 20 years ago with research and then increased adoption during the last few years, including extending the CA system to rice production. Now more than 3.1 M ha are under CA in China and 23,000 ha in DPR Korea where the introduction of CA has made it possible to grow two successive crops (rice or maize or soya as summer crop, winter wheat or spring barley as winter crop) within the same year, through direct drilling of the second crop into the stubble of the first (Table 5).

In the Indo-Gangetic Plains across India, Pakistan, Nepal and Bangladesh, in the wheat-rice cropping system, there is large adoption of no-till wheat with some 5 M ha, but only marginal adoption of permanent no-till systems and full CA. In India, the adoption of no-till practices by farmers has occurred mainly in the wheat portion of the wheat-rice double cropping system.

Table 5. CA adoption in some selected countries of Asia (FAO, 2011c)

Country	CA area (ha)
China	3,100,000
Kazakhstan	1,600,000
Korea, DPR	23,000
Total	**4,723,000**

2.4 Adoption in West Asia and North Africa

In the WANA (West Asia and North Africa) region, much of the CA work done in various countries has shown that yields and factor productivities can be improved with no-till systems. Extensive research and development work has been conducted in several countries in the region since the early 1980s such as in Morocco, Tunisia, Syria, Lebanon and Jordan, and in Turkey (Table 6). While Morocco and particularly Tunisia showed a modest growth in CA adoption, the uptake has literally exploded in Syria, spreading over nearly 20,000 ha in only few years. The main reason for the rapid uptake has been the shortage of fuel and increased availability of locally produced affordable no-till seeders, which are now being exported to other countries in the region, and the efforts of development and promotion activities by organization such as GIZ, ICARDA, ACSAD and Aga Khan Foundation.

Table 6. CA adoption in selected countries of North Africa and Near East (FAO, 2011c)

Country	CA area (ha)
Lebanon	1,200
Morocco	4,000
Syria	18,000
Tunisia	8,000
Total	**31,200**

Key lessons from international experiences about CA and considerations for its implementation in the Mediterranean region show the potential benefits that can be harnessed by farmers in the semi-arid Mediterranean environments while highlighting the need for longer-term research including on weed management, crop nutrition and economics of CA systems. In addition, it is clear that without farmer engagement and appropriate enabling policy and institutional support to achieve effective farmer engagement and a process for testing CA practices and learning how to integrate them into production system, rapid uptake of CA is not likely to occur.

Work by ICARDA and CIMMYT has shown benefits of CA especially in terms of increase in crop yields, soil organic matter, water use efficiency and net revenue. CA also shows the importance of utilizing cropping and crop diversification with legumes and cover crops instead of a fallow period, providing improved productivity, soil quality, N-fertilizer use efficiency and water use efficiency. CA is perceived as a powerful tool of land management in dry areas. It allows farmers to improve their productivity and profitability especially in dry areas while conserving and even improving the natural resource base and the environment. However, CA adaptation in drylands faces critical challenges linked to water scarcity and drought hazard, low biomass production and acute competition between conflicting uses including for soil cover, animal fodder, cooking/heating fuel, raw material for habitat etc. Poverty and vulnerability of many smallholders that rely more on livestock than on grain production are other key factors.

2.5 Adoption in Sub-Saharan Africa

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

CA is now beginning to spread to Sub-Saharan Africa region, particularly in eastern and southern Africa as can be seen in Table 7. Building on indigenous and scientific knowledge and equipment design from Latin America, and, more recently, with collaboration from China, Bangladesh and Australia, farmers in at least 14 African countries are now using CA (in Kenya, Uganda, Tanzania, Sudan, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Zambia, Zimbabwe, Ghana and Burkina Faso). CA has also been incorporated into the regional agricultural policies by NEPAD (New Partnership for Africa's Development).

In the specific context of Africa with resource-poor farmers, CA systems are relevant for addressing the challenges of climate change, high energy costs, environmental degradation, and labor shortages. So far the area under CA is small, but there is a steadily growing movement that already involves more than 400,000 small-scale farmers in the region for a total area of nearly 1 M ha.

Table 7. CA adoption in Sub-Saharan Africa (FAO, 2011c)

Country	CA area (ha)
Ghana	30,000
Kenya	33,000
Lesotho	2,000
Malawi	16,000
Madagascar	6,000
Mozambique	152,000
Namibia	340
South Africa	368,000
Sudan	10,000
Tanzania	25,000
Zambia	200,000
Zimbabwe	139,300
Total	**981,640**

In Sub-Saharan Africa CA is expected to increase food production while reducing negative effects on the environment and energy costs, and to result in the development of locally-adapted technologies consistent with CA principles.

3 Conclusions

CA represents the core components of a new alternative paradigm for the 21st century and calls for a fundamental change in production system thinking. It is counterintuitive, novel and knowledge and management intensive. The roots of the origins of CA lie more in the farming communities than in the scientific community, and its spread has been largely farmer-driven. Experience and empirical evidence across many countries has shown that the rapid adoption and spread of CA requires a change in commitment and behavior of all concerned stakeholders. For the farmers, a mechanism to experiment, learn and adapt is a prerequisite. For policy-makers and institutional leaders, transformation of tillage systems to CA systems requires that they fully understand the large and longer-term economic, social and environmental benefits CA paradigm offers to the producers and the society at large. Further, the transformation calls for a sustained policy and institutional support role that can provide incentives and required services to farmers to adopt CA practices and improve them over time (FAO, 2008; Friedrich and Kassam, 2009; Friedrich et al., 2009; Kassam et al., 2009, 2010). Originally the adoption of CA was mainly driven by acute problems faced by farmers, especially wind and water erosion, as for example southern Brazil or the Prairies in North America, or drought as in Australia. In all these cases farmers' organization was the main instrument to generate and spread knowledge that eventually led to mobilizing public, private and civil sector support. More recently, again pressed by erosion and drought problems, exacerbated by increase in cost of energy and production inputs, government support has played an important role in accelerating the adoption rate of CA, leading to the relatively fast adoption rates for example in Kazakhstan and China, but also in African countries such as Zambia and Zimbabwe, among others, and this is attracting support from other stakeholders.

Today the main reasons for adoption of CA can be summarized as follows: (1) better farm economy (reduction of costs in machinery and fuel and time-saving in the operations that permit the development of other agricultural and non-agricultural complementary activities); (2) flexible technical possibilities for sowing, fertilizer application and weed control (allows for more timely operations); (3) yield increases and greater yield stability (as long term effect); (4) soil protection against water and wind erosion; (5) greater nutrient-efficiency; and (6) better water economy in dryland areas. Also, no-till and cover crops are used between rows of perennial crops such as olives, nuts and grapes. CA can be used for winter crops, and for traditional rotations with legumes, sunflower and canola, and in field crops under irrigation where CA can help optimize irrigation system management to conserve water, energy and soil quality, reduce salinity problems and to increase fertilizer use efficiency.

At the landscape level, CA enables several environmental services to be harnessed at a larger scale, particularly C sequestration, cleaner water resources, drastically reduced erosion and runoff, and enhanced biodiversity. Overall, CA as an alternative paradigm for sustainable production intensification offers a number of benefits to the producers, the society and the environment that are not possible to obtain with tillage agriculture (Kassam et al., 2010). So, CA is not only climate-smart, it's smart in many other ways.

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