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Overview of the Worldwide 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 globally as a new paradigm for the 21st century. The data presented in this paper has been collected by the Food and Agriculture Organization of the United Nations from several sources including estimates made by ministries of agriculture, by farmer organizations, and well-informed individuals in research or development organizations; they provide an overview of CA adoption and spread by country, as well as the extent of CA adoption by continent.

CA systems, comprising no or minimum mechanical soil disturbance, organic mulch soil cover, and crop species diversification, in conjunction with other good practices of crop and production management, are now (in 2013) practiced globally on about 157 M ha, corresponding to about 11% of field cropland, in all continents and most land-based agricultural ecologies, including in the various temperate environments. This change constitutes a difference of some 47% globally since 2008/09 when the spread was recorded as 106 M ha. The current total of 157 M ha represents an increase in adoption of CA by more countries but the estimate is on the conservative side as the updated database does not capture all the CA cropland.

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 the area had grown to 72 M ha. In the last 10 years CA cropland has expanded at an average rate of more than 8.3 M ha per year and since 2008/2009 at the rate of some 10 M ha per year, showing the increased interest of farmers and national governments in this alternate production concept and method. Adoption has been intense mainly in North and South America as well as in Australia and Asia, and more recently in Europe and Africa where the awareness of and support for CA is on the increase.

The paper presents an update of the adoption of CA since 2008/09.

Keywords. No-Till, Mulch, Crop Diversification, Sustainability, Adoption, Policy

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, labour, land and capital) to meet the global food, feed, fiber and bioenergy demand and to alleviate hunger and poverty. There is also a need to enhance the resilience of productions systems to biotic and abiotic stresses, particularly those arising from climate change. Further, it is necessary to avoid degradation of agricultural land and ecosystem services, and to rehabilitate degraded agricultural land due to past abuse.

However, until now, agricultural intensification based on 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 (Montgomery, 2007; Kassam *et al*., 2013; Dumansky *et al*., 2014). This degradation of the land resource base has caused crop yields and factor productivities to decline and promoted the search for an alternative paradigm that is ecologically sustainable as well as profitable (Goddard *et al.*, 2006; Jat *et al*., 2014; Farooq & Siddique, 2014). 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 (IPPC, 2014).

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) delivers on all of these goals (Kassam *et al*., 2013; Jat *et al*., 2014; Siddique and Farooq, 2014). CA saves on energy and mineral nitrogen use in farming and thus reduces greenhouse gas 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, which also involves soil cover and cropping system diversification, has to be complemented with other techniques, such as integrated pest management, plant nutrient management, weed and water management (FAO, 2011).

1.2 Definition and Description of Conservation Agriculture

According to FAO (FAO, 2014a), 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:

Continuous no- or minimal mechanical soil disturbance (i.e., no-tillage and 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 or band seeding disturbing less than 25% of the soil surface (FAO, 2014b));

Maintenance of a permanent organic soil mulch cover, especially by crop residues, crops and cover crops; and

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 formulated and 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, 2014a).

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 (Kassam *et al*., 2009; Friedrich, 2013; Jat *et al*., 2014; Siddique & Farooq, 2014). 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 ecological sustainability (Shaxson *et al*., 2008; Kassam *et al*., 2009, 2013, 2014a; Basch *et al*. 2012; Dumansky *et al*., 2014). 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 (Bassi, 2000). It further helps to sequester carbon in soil at a rate ranging from about 0.2 to 1.0 t/ha/year or more depending on the location and management practices (González-Sánchez et al., 2012; Sá et al., 2013; Corsi *et al*., 2014). Labour requirements are generally reduced by about 50%, which allows farmers to save on time, fuel and machinery costs (Saturnino & Landers, 2002; Baker *et al*., 2007; Lindwall & Sonntag, 2010; Baig & Gamache, 2009; Crabtree, 2010). Fuel savings in the order of around 60% or more are in general reported (Sorrenson & Montoya, 1984, 1991; Friedrich *et al*., 2009).

1.3 History, development and importance 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 (Derpsch, 2004; Kassam *et al*., 2010, 2014a).

In the early 1970s no-tillage reached Brazil, where farmers together with scientists transformed the technology into the system which today is called CA. Yet it took another 20 years before CA reached significant adoption levels. 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 started growing exponentially, leading to a revolution 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, World Bank, GIZ, CIRAD and CGIAR. 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, Zimbabwe, Mozambique, Tanzania and Kenya as well as in Asia, particularly in Kazakhstan and China. The improvement of conservation and no-tillage practices within an integrated farming concept such as CA led also to increased adoption including in industrialised countries after the end of the millennium, particularly in Canada, USA, Australia, Spain, Italy, Finland, Ukraine and Russia.

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 about CA available (Jat *et al*., 2014). The total cropland area under CA in 2008/09 was estimated to be 106 M ha (Kassam *et al*, 2009; Derpsch & Friedrich, 2009a). For 2010/11 it was initially estimated to be 125 M ha (FAO 2011b; Friedrich *et al*., 2012) but during the updating of the database in 2013, it was found that the total global CA cropland area in 2010/11 was some 145 M ha. For 2013, the global total CA cropland area was initially estimated to be 155 M ha (Kassam *et al.*, 2014b) but since then it has been reported to be 157 million hectares due to the increase in CA area in Argentina which had not been reported at the time of the 2013 update (see database at http://www.fao.org/ag/ca/6c.html) (FAO, 2014b).

CA is practiced by farmers from the arctic circle (e.g., Finland) over the equatorial tropics (e.g., Kenya, Tanzania, 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 in the Mediterranean environments with 250 mm or less 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).

CA is practiced on soils that vary from 90% sand (e.g., Australia) to 80% clay (e.g., Brazil's Oxisols and Alfisols). Soils with high clay content in Brazil are extremely sticky but this has not been a hindrance to 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 marginal soils in terms of rainfall or fertility (e.g., Australia, Argentina).

No-tillage CA is practiced on all farm sizes from less than half a hectare to few hectares (e.g., China, Zambia, and Paraguay) to thousands of hectares (e.g., Argentina, Brazil, and Kazakhstan). All crops can be grown adequately in CA systems 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 & 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 and alternative management strategies to facilitate weed and vegetation management (especially for larger farms in developing countries) (Friedrich & Kassam, 2009; Jat *et al.*, 2014; Farooq and Siddique, 2014). Other area-specific constraints in semi-arid areas during the transformation to CA system relate to initial low supply of crop residues and vegetation biomass for soil mulch cover development; to initial short-term competition for crop residue as livestock feed; and to manual weed control during initial years while soil mulch cover and integrated weed management practice is being established. However, increasingly, farmers who do become seriously interested in adopting CA seem to be finding local solutions to above mentioned barriers. Many such cases have been reported for small and large farms in all continents (see list of publications at: www.fao.org/ag/ca). This has been helped in recent years by more international and national organizations including FAO, IFAD, World Bank, EU, AU-NEPAD, CIRAD, ACT, some CGIAR Centres, NGOs, some governments in the North and the South, national and multinational corporations, the growth of no-till/CA organizations worldwide, and bilateral and multi-lateral donors increasing their support for CA as they have increased their awareness of the relevance and effectiveness of CA to sustainable production intensification. Thus, the continuing spread of CA globally is creating a need for effective national and regional policy and institutional support (Kassam *et al*., 2014c).

2. Global area and regional distribution

The global empirical evidence shows that farmer-led transformation of agricultural production systems from tillage-based to CA is now a world-wide phenomenon. In recent years the spread has gathered even more momentum as a new paradigm for 'sustainable production intensification', and as an example of 'climate smart agriculture'.

The updated information on the adoption of CA in 2013 presented in this paper applies only to arable cropland and is based on several sources: official statistics (e.g. Canada and USA); survey estimates by no-till farmer organizations and agroindustry (e.g. Australia, Brazil, Argentina, Paraguay and

Uruguay), by Ministry of Agriculture (e.g. China, Malawi, Zimbabwe), NGOs (e.g. Europe, Russia, Madagascar, Zambia), well-informed individuals from research and development organizations (e.g. India, Kazakhstan, Ukraine). It has been possible to update the database for most countries except for Africa where much of the information is still from the 2010 database. A useful overview of adoption of CA in individual countries in 2008/2009 is given in Kassam *et al.* (2009) and in Derpsch and Friedrich (2009a); in 2010/11 in Kassam *et al*. (2010) & Friedrich *et al*. (2012). A global state of the arts review of CA is given in Jat *et al*. (2014) and Farooq and Siddique (2014).

Global data of CA adoption are not officially reported, but collected from the above mentioned sources. The data are assembled and published by FAO (FAO 2014b). For the data collection the CA definition is quantified as follows:

- *No or minimum mechanical 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.
- *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.
- *Crop rotation/association*: Rotation/association should involve at least 3 different crops. However, repetitive wheat, maize or rice cropping is not an exclusion factor for the purpose of this data collection, but rotation/association is recorded where practiced.

It was estimated that the global extent of CA cropland in 2008/09 covered about 106 M ha (7.5% of global cropland) (Kassam *et al*., 2009). In 2013 it was about 157 M ha (11% of global cropland), representing a difference of some 51 M ha (some 47%) over the five year period (Table 1). CA in recent years has become a fast growing production system. While in 1973/74 CA was applied on only 2.8 M ha worldwide (Figure 1), the area had grown to 6.2 M ha in 1983/84 and to 38 M ha in 1996/97 (Derpsch, 1998). In 1999, worldwide adoption was 45 M ha, and by 2003 the area had grown to 72 M ha. In the last 10 years CA cropland area has expanded at an average rate of around 8.3 M ha per year, from 72 to 157 M ha. Since 2008/09, the rate of change has been about 10 M ha, showing the increased interest of farmers in the CA farming system approach, mainly in North and South America and in Australia, and more recently in Kazakhstan with large farms, and in India and China with small farms, where large increases in the adoption of CA are expected and indeed are occurring.

Since 2008/09, the number of countries where CA has been adopted and being promoted has increased from 36 to at least 55 in 2013 as shown in Table 1. However, several countries where CA is known to be practiced are not included in Table 1. These include Vietnam, Cambodia and Laos in Asia, Ethiopia, Burkina Faso and Cameroon in Africa, and Denmark and Sweden in Europe. Further, the area of CA systems based on perennial crops or mixture of annual and perennial crops that is not included in the total CA area reported in this paper is on the increase in many countries in all continents. These CA systems involve plantation crops such as oil palm, cocoa, rubber, tea, coffee, coconut; orchards and vines such as olive, fruit and nut trees, grape, kiwi; pastures; and agroforestry. Thus the CA areas reported in this paper are conservative estimates.

Table 1. Extent of Adoption of CA Worldwide by country in the 2008/09 and 2013 updates

Country	CA area ‘000ha 2008/09 update	CA area ‘000 ha 2013 update
USA	26,500.00	35,613.00
Brazil	25,502.00	31,811.00
Argentina	19,719.00	29,181.00
Canada	13,481.00	18,313.00
Australia	12,000.00	17,695.00
China	1,330.00	6.670.00
Russia	-	4,500.00
Paraguay	2,400.00	3,000.00
Kazakhstan	1,300.00	2,000.00
India	-	1,500.00
Uruguay	655.10	1,072.00
Spain	650.00	792.00
Bolivia	706.00	706.00
Ukraine	100.00	700.00
Italy	80.00	380.00
South Africa	368.00	368.00
Zimbabwe	15.00	332.00
Venezuela	300.00	300.00
Finland	200.00	200.00
France	200.00	200.00
Zambia	40.00	200.00
Germany	354.00	200.00
Chile	180.00	180.00
New Zealand	162,00	162.00
Mozambique	9.00	152.00
United Kingdom	24.00	150.00
Colombia	102.00	127.00
Malawi	-	65.00
Turkey	-	45.00
Mexico	22.80	41.00
Moldova	-	40.00
Slovakia	10.00	35.00
Kenya	33.10	33.10
Portugal	25.00	32.00
Ghana	-	30.00
Syria	-	30.00

Tanzania	-	25.00
Greece	-	24.00
DPR Korea	-	23.00
Switzerland	9.00	17.00
Iraq	-	15.00
Sudan	10.00	10.00
Tunisia	6.00	8.00
Madagascar	-	6.00
Hungary	8.00	5.00
Morocco	4.00	4.00
Uzbekistan	-	2.45
Lesotho	0.13	2.00
Azerbaijan	-	1.30
Lebanon	-	1.20
Kyrgyzstan	-	0.70
Netherlands	-	0.50
Namibia	-	0.34
Belgium	-	0.27
Ireland	0.10	0.20
Total	106,505.23	156,980.96
% difference		47.39

source: FAO (2014b) - AQUATSTAT: www.fao/org.ag/ca/6c.html

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 more than 70% of the total cultivated crop 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.

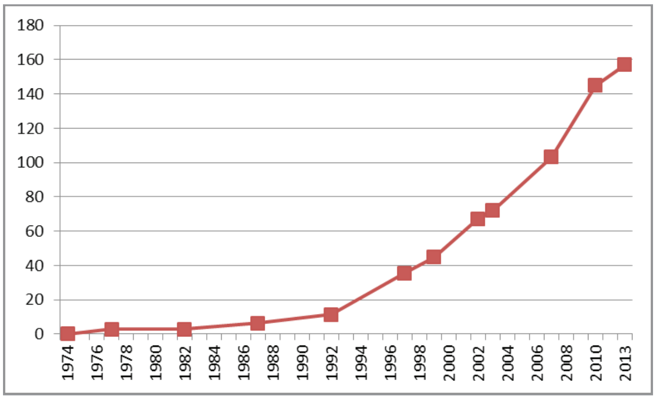

Figure 1. Global uptake of CA in M ha of arable cropland

As Table 2 shows some 66.4 M ha (42%) of the total global area under CA is in South America, corresponding to some 60 % of the cropland in the region, and some 54 M ha (34%) is in the USA and Canada, corresponding to 24% of the cropland of the region. Some 17.9 M ha (11%) is in Australia and New Zealand, corresponding to 36% of the cropland and some 10.6 M ha (7%) is in Asia, corresponding to 3% of the cropland in the region. Some 8.4 M ha (5%) of the total global CA area is in the rest of the world, comprising 5.2 M ha in Russia and Ukraine, 2.0 M ha in Europe and 1.2 M ha in Africa, corresponding to about 3%, 3% and 1% of their total cropland respectively.

Table 2. Cropland area under CA (M ha), CA area as % of total cropland, and CA area as % of cropland by continent, in 2013

Continent	Cropland under CA (MA ha)	Per cent of global CA area	Per cent of cropland
South America	66.4	42.3	60.0
North America	54.0	34.4	24.0
Australia & NZ	17.9	11.4	35.9
Asia	10.3	6.6	3.0
Russia & Ukraine	5.2	3.3	3.3
Europe	2.0	1.3	2.8
Africa	1.2	0.8	0.9
Global total	157.0	100	10.9

Europe and Africa are the developing continents in terms of CA adoption and uptake. However, because of the good and long lasting research in these continents, showing positive results for CA systems, plus increasing attention being paid to CA systems by NEPAD (New Partnership for Africa's Development), governments, EC (European Commission), NGOs such as ECAF (European Conservation Agriculture Federation) and ACT (African Conservation Tillage), the private sector, international organizations and donors, CA has experienced significant rates of adoption in recent years. For example, CA area in Europe of 2.04 M ha estimated in 2013 is greater by some 30% than the 1.56 M ha that was estimated in 2008/09. For Sub-Saharan Africa, most of the data of CA adoption in the 2013 update is actually from the year 2010/11 except for Zimbabwe and Malawi, and corresponds to some 157% greater area under CA at the continental level, from 0.48 M ha in 2008/09 to 1.22 M ha in 2013. Updated CA area information for Africa is still being collected, and it is expected that the net CA area continentally may have changed considerably since 2008/09, particularly in countries such as Tanzania, Kenya, Zambia, Zimbabwe and Mozambique, and more countries such as Ethiopia, Burkina Faso and Cameroon are expected to show the existence of CA area.

From a global perspective, it seems that there is a diverse pattern of productivity, economic, social and environmental benefits that CA systems generate. This includes: increase in input factor productivity and yield, improved sustainability of production and farm land, better incomes, timeliness of cropping practices, ease of farming and reduction in drudgery, and improved ecosystem services. Consequently, the total area under CA systems in the world has been growing as shown in Figure 1, largely as a result of the initiative of farmers and their organizations. However, technical and financial support from governments, donor agencies and international organizations for CA research and development in Africa and Asia has increased in recent years (FAO, 2013; ACT, 2014), and uptake of CA in countries and Africa and Asia is expected to accelerate in the coming years.

In countries such as USA, Canada, Australia, Brazil, Argentina, Paraguay, Uruguay, Zambia, Zimbabwe, China and Kazakhstan, CA is being "mainstreamed" in agricultural development programmes or backed by suitable policies and institutional support. Consequently, the total area under CA worldwide is greater by 47% since 2008/09, from 106 M ha (7 % of global cropland) to 157 M ha (11% of cropland). The adoption of CA globally since 1990 has been growing mainly in North and South America and in Australia, and more recently in Asia in particularly Kazakhstan, China and India, and in Europe specially in Spain and Italy, and apparently also in Africa including in Zambia, Zimbabwe, Malawi and Mozambique. Thus, the area under CA is expanding in all regions of the world, and large areas of global agricultural land are expected to switch to CA in the coming years and decades.

Although much of the CA development to date has been associated with rainfed annual cropping systems, farmers can apply the same principles to strengthen the sustainability of irrigated systems, including those in arid and 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, stated by farmers, to practising this latter type of inter-cropping is competition for soil water between trees and crops. However, careful selection of deep rooting tree species and shallow rooting annuals can resolve this constraint. Also, as there is less runoff more water goes into the soil, thus improving both water capture and water use efficiencies. Functional CA systems do not replace but should be integrated with current good land husbandry practices. In the dry areas of Africa, it has been reported that CA with nitrogen fixing trees such as *Faidherbia albida* is widespread (Garrity *et al*., 2010). Orchard crops and vines are being converted into CA systems in Europe (Gomez *et al*., 2009). Plantation tree crops such as oil palm, rubber, cocoa, citrus and coconut are also being successfully managed under CA systems in a number of countries such as Malaysia (Othman *et al*., 2012). In India, the area under CA rice-wheat and rice-maize cropping systems has been expanding in recent years (Jat *et al*., 2009, 2010).

2.1 Adoption in the Americas

CA adoption is highest in the North-Western Parts of North America and in the southern parts of South America with adoption levels above 50%. Since 2008/09, the area under CA in the North America region has changed by 40% from 40.0 M ha to 54.0 M ha in 2013 (Table 3). In Canada, currently with 18.3 M ha of CA, long-term and wide adoption of CA has resulted in visible environmental benefits, including the disappearance of dust storms as well as a greater biodiversity (Baig and Gamache, 2009; Lindwall and Sonntag, 2010). Environmental services provided through CA are increasingly recognized, for example through carbon payment schemes as in Alberta.

Table 3. CA adoption in the countries of North America in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
USA	26,500.00	35,613.00
Canada	13,481.00	18,313.00
Mexico	22.80	41.00
Total	40,003.00	53,967.00
% difference		40.0

Table 4a. CA adoption in the countries of South America in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
Brazil	25,502.00	31,811.00
Argentina	19,719.00	29,181.00
Paraguay	2,400.00	3,000. 00
Uruguay	655.10	1,072.00
Bolivia	706.00	706.00
Venezuela	300.00	300.00
Chile	180.00	180.00
Colombia	102.00	127.00
Total	49,564.10	66,377.00
% difference		33.9

In the USA, CA adoption on 35.6 M ha is still at a significantly lower level in terms of the percent of the cropland (21.5%), despite long time experience with no-till farming. However, for a number of reasons, including commodity focussed subsidies, no-till is applied permanently only on about 10 to 12% of the area under no-tillage. Yet, also in the USA the awareness about crop rotations and cover crops as well as the additional benefits of permanent no-till systems is growing as a result of organized farmers' associations such as the Conservation Agriculture Systems Alliance (CASA).

In South America the adoption levels of no-till farming in Argentina, Paraguay, Uruguay and Southern Brazil are approaching the 100 % (Table 4a). Since 2008/09, the area under CA in the South America region has changed by some 33.9% from 49.6 M ha to 66.4 M ha in 2013. However, there are serious concerns about the quality of the CA adoption. Following market pressures, which are partly increased by government policies, a considerable number of farmers are opting for soya mono-cropping, 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 CA. With this the area under good quality CA is, particularly in Argentina and Brazil, significantly lower than the total area under no-till cropping. The problem is being addressed in Brazil with strengthened extension and in Uruguay with legal regulations for cover crops in the specific case of soya and subsidy programmes for good quality CA.

2.2 Adoption in Europe

Since 2008/09, CA area for annual crops has changed by some 30% from 1.6 M ha to 2.0 M ha in 2013, corresponding to 2.8% of the arable cropland (Tables 2 and 4b). In 2008/09, CA was reported in 11 countries but in 2013, this increased to 14 countries. Since 1999, ECAF (European Conservation Agriculture Federation) has been promoting CA in Europe, and adoption is visible in Spain, Italy, Finland, France, UK, Switzerland and Germany. Especially in Spain and Italy the growth of CA in perennial crops, such as fruit orchards, vineyards and olive plantations, has exceeded the adoption rate in annual crop systems.

Table 4b. CA adoption in the countries of Europe in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
Spain	650.00	792.00
Italy	80.00	380.00
Finland	200.00	200.00
France	200.00	200.00
Germany	354.00	200.00
United Kingdom	25.00	150.00
Slovakia	10.00	35.00
Portugal	28.00	32.00
Greece	-	24.00
Switzerland	9.00	17.00
Hungary	8.00	5.00
Netherlands	-	0.50
Belgium	-	0.27
Ireland	0.10	0.20
Total	1,564.10	2,035.97
% difference		30.1

Bridging between Europe and Asia, Russia and Ukraine are two countries with significant adoption of CA and with also active farmer groups promoting CA. In Russia the area under conservation tillage is believed to be some 15 M ha, but CA according to FAO definition is estimated to be applied on about 4.5 M ha. In Ukraine, CA has reached some 700,000 ha in 2013.

2.3 Adoption in Asia

Asian countries have seen considerable uptake of CA in the past 10-15 years, and since 2008/09, CA area is nearly threefold (291%) greater, from some 2.7 M ha in 2008/09 to some 10.3 M ha in 2013 (Table 5). In 2008/09, CA area was reported in only two countries in the Asia region, but in 2013 CA area was reported in 11 countries. In Central Asia, a fast development of CA can be 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 some 2.0 M ha (12.5 % 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. In addition, Uzbekistan, Azerbaijan and Kyrgyzstan have made a committed start of promoting rainfed and irrigation CA cropping systems (Nurbekov *et al*., 2014) and so has Turkey. Area under CA in Syria and Iraq has continued to increase due to shortages of fuel (Piggin *et al*., 2015).

Table 5. CA adoption in the countries of Asia in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
China	1,330.00	6,670.00
Kazakhstan	1,300.00	2,000.00
India	-	1,500.00
Turkey	-	45.00
Syria	-	30.00
Korea, DPR	-	23.00
Iraq	-	15.00
Uzbekistan	-	2.45
Azerbaijan	-	1.30
Lebanon	-	1.20
Kyrgyzstan	-	0.70
Total	2,630.00	10,288.65
% difference		291.2

China too has been experiencing an equally dynamic development of CA. It began over 20 years ago with research, and then the adoption of CA increased during the last few years and the technology has been extended to rice production system. Now some 6.7 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 modest adoption of permanent no-till systems and full CA. The exception appears to be India, where the adoption of no-till practices by farmers has occurred in the rice-wheat double cropping system, and also in the rainfed upland areas involving crops such as maize, cotton, pigeon pea and chickpea.

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 (Kassam *et al.*, 2012; Gonzalez-Sanchez *et al*., 2015; Piggin *et al*., 2015). Extensive research and development work has been conducted in several countries in the region since the early 1980s such as in Morocco, Tunisia, Syria, Iraq, Lebanon and Jordan, and in Turkey (Table 6). Since 2008/09, area under CA has changed manifold from 10,000 ha to 103,200 ha. In 2008/09, only two countries indicated the existence of CA area, but in 2013 the number increased to six.

Table 6. CA adoption in the countries of the WANA region in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
Turkey	-	45.00
Syria	-	30.00
Iraq	-	15.00
Tunisia	6.00	8.00
Morocco	4.00	4.00
Lebanon	-	1.20
Total	10.00	103.20
% difference		932.0

While Morocco and particularly Tunisia has shown a modest growth in CA adoption, the adoption has literally exploded in Syria increasing in only few years to 30,000 ha to be the second largest CA adopter in the region after Turkey with 45,000 ha. Iraq too now has some 15,000 ha of CA, benefitting from the work done by ICARDA in Syria, Iraq and elsewhere (Piggin *et al.*, 2015). The main reason for the rapid uptake has been the increased availability of locally produced affordable no-till seeders in Syria which are now being exported to other countries in the region and the efforts of development and promotion activities by organization as GIZ, ICARDA and ACSAD.

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, crop-livestock integration, residue management and economics of CA systems. Some of the crop-livestock integration issues such as residue management need to be resolved at the community level because after harvest residues are in demand by livestock herders. In addition, it is clear that without farmer engagement and appropriate enabling policy and institutional support to achieve effective farmer and community engagement and a process for testing CA practices and learning how to integrate them into crop-livestock 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 utilising 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, while exhibiting superior performance compared to tillage-based farming, CA adaptation in drylands faces critical challenges linked to water scarcity and drought hazard, low biomass production and acute competition between conflicting uses including 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.

Table 7. CA adoption in the countries of Sub-Saharan Africa in the 2008/09 and 2013 updates

Country	CA area '000 ha 2008/09 update	CA area '000 ha 2013 update
South Africa	368.00	368.00
Zimbabwe	15.00	332.00
Zambia	40.00	200.00
Mozambique	9.00	152.00
Malawi	-	65.00
Kenya	33.10	33.10
Ghana	-	30.00
Tanzania	-	25.00
Sudan	10.00	10.00
Madagascar	-	6.00
Lesotho	0.13	2.00
Namibia	-	0.34
Total	475.23	1,223.34
% difference		157.4

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 (Table 7). Building on indigenous and scientific knowledge and equipment design from Latin America, and, more recently, with collaboration from China, Bangladesh and Australia, as well as with CIMMYT, ICRISAT, ICRAF, CIRAD, ACT, FAO and NGOs as well as donor agencies, farmers in at least 15 Sub-Saharan African countries are now using CA (in Kenya, Uganda, Tanzania, Sudan, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Namibia, Zambia, Zimbabwe, Ghana and Burkina Faso). CA has also been incorporated into the regional agricultural policies by NEPAD.

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 labour shortages. So far the CA area is still small, but there is a steadily growing movement involving already far more than 400,000 small-scale farmers in the region for a total area of some 1 M ha in 2010/11, and since then there has been further spread in several countries, although not fully documented, such as Kenya, Madagascar, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe. In 2008/09, CA was reported in seven countries, but in 2013 there were 12 countries with area under CA. The increase in the spread of CA since 2010/11 recorded in the 2013 update is based on the CA area expansion reported only from Malawi and Zimbabwe as it was not possible to obtain updates from Ghana, Kenya, Madagascar, Mozambique, South Africa, Sudan and Zambia. This limited 2013 update shows that the total area of CA in Sub-Saharan Africa is more than 1.22 M ha, an expansion of some 157% from 0.48 M ha in 2008/09. However, from expert knowledge that was expressed at the 1st Africa Congress on Conservation Agriculture in March 2014, it is likely that the CA area in Sub-Saharan Africa may now be much greater than 1.22 M ha, spread over more than 12 countries.

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. Concluding comments

CA represents the core components of a new alternative paradigm 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 supported by development-oriented agriculturalists. Experience and empirical evidence across many countries has shown that the rapid adoption and spread of CA requires a change in commitment and behaviour 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 (Kassam *et al.*, 2009; Friedrich & Kassam, 2009; Friedrich *et al.*, 2009; Kassam *et al.*, 2014c).

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 mobilising 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. In Europe too there has been greater concern shown by EU towards soil degradation and the need for greater environmental management in agriculture. This has led the Common Agricultural Policy to enable EU governments the possibilities to provide incentives to farmers to adopt soil conservation practices.

Today the main reasons for adoption of CA can be summarised 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, fertiliser 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 use efficiency and water economy in dryland areas. Also, no-till and cover crops are used between rows of perennial crops such as olives, nuts and grapes or fruit orchards. 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 fertiliser 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. So, CA is not only climate-smart, it is smart in many other ways.

Globally the total CA area is still relatively small compared to arable areas farmed using tillage. However, as this paper shows, this is changing, and the spread of CA worldwide appears to have been expanding at the rate of 10 M ha per annum since 2008/09, and it is expected that large areas of agricultural land in Asia, Africa, Europe and Central America will increasingly switch to CA in the coming decades as is already occurring in Kazakhstan, India and China. The reason for this is that in the last two decades, promotion and adoption of CA has been receiving increasing attention from governments, donor agencies, international technical assistance-agencies, NGOs and Foundations, and service sectors.

In some countries such as USA, Canada, Australia, Brazil, Argentina, Paraguay and Uruguay, it appears that CA is being "mainstreamed" in agricultural development programmes. But only in a few countries such as Canada, Switzerland, Kazakhstan, China, Zambia, Zimbabwe and Malawi, it is being backed by government policies and some public and private sector institutional support.

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