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Global achievements in soil and water conservation: The case of Conservation Agriculture

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Abstract

In response to the dust bowls of the mid-thirties in the USA, soil and water conservation programmes involving reduced tillage were promoted to control land degradation, particularly soil erosion. The farming and land management practices that were considered to adequately address soil and water conservation objectives were based on no-till seeding and maintenance of soil mulch cover. This collection of practices led to what became known as conservation tillage, although no-till systems by definition avoid soil disturbance by no-till direct seeding, and maintain an organic mulch cover on the soil surface.

This article is an overview of achievements in soil and water conservation on agricultural lands through the experience derived from the adoption and spread of Conservation Agriculture (CA) world-wide. CA is an agro-ecological approach to sustainable production intensification. It involves the application of three inter-linked principles that underpin agricultural production systems based on locally formulated practices: (i) permanent no or minimum mechanical soil disturbance, which in practice entails direct seeding through mulch into no-till soils; (ii) maintenance of soil cover with crop residues and green manure crops, particularly legumes; and (iii) diversified cropping system involving annuals and perennial in rotations, sequences and associations.

In 2011, CA had spread over 125 million hectares (9% of the global cropped land) across all continents and most agro-ecologies, including small and large farms. In addition, there is a significant area of CA orchards in the Mediterranean countries. CA is now considered to be a practical agro-ecological approach to achieving sustainable agriculture intensification. It offers environmental, economic and social advantages that are not fully possible with tillage-based production systems, as well as improved productivity and resilience, and improved ecosystem services while minimizing the excessive use of agrochemicals, energy and heavy machinery. While there are challenges to the adoption of CA, there is also increasing interest from producers, the civil society, donors and private sector institutions to further promote and service the uptake and spread of CA globally.

Key Words：No-till, Soil erosion, Agro-ecological, Ecosystem services, Save and grow

1 Introduction

Reducing soil disturbance by tillage in agricultural land began in the Great Plains in the USA in the 1930s in response to the devastation caused by prolonged drought (Derpsch, 2004). This period became known as the “dust bowls”. Initial research on ‘conservation’ or reduced tillage involved early versions of a chisel plough, by which plant residues could be retained on the soil surface to alleviate wind and water erosion (Duley and Fenster, 1954; Mannering, 1979). Stubble mulch farming was also developed (Fenster, 1960), and this became a forerunner of no-tillage farming. This collection of practices led to what became known as conservation tillage, although no-till systems by definition avoid soil disturbance by no-till seed drilling, and maintain an organic mulch cover on the soil surface (King and Holcomb, 1985; Kassam et al., 2009).

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The book, *Ploughman's Folly* by Edward Faulkner (1943), an extension agronomist in Ohio, was an important milestone in the development of conservation agricultural practices. Faulkner questioned the wisdom of inversion ploughing and explained the destructive nature of soil tillage. He stated: "None has ever advanced a scientific reason for plowing". Further research in the UK, USA and elsewhere during the late-1940s and 1950s made no-tillage farming possible. The practice began to spread in the USA in the 1960s, and in Brazil, Argentina and Paraguay in the 1970s, with farmers such as Herbert Bartz, Manoel Henrique (Nono) Pereira, Frank Dijkstra and John Landers in Brazil, Heri Rosso, Rogelio Fogante Victor Trucco and Mario Gilardoni in Argentina, Carlos Crovetto in Chile and Akinobu Fukami in Paraguay championing the transformation of tillage farming into no-till farming systems. In Brazil, no-till research was pioneered in Londrina in 1971 with initiatives from Rolf Derpsch on plots often visited by Herbert Bartz; in 1972 Rolf Derpsch sent his no-till wheat seeder to Herbert Bartz's farm "Rhenania" at Rolandia, Paraná (30 km from Londrina), to seed a demonstration plot of half hectare of wheat after soybean.

In the USA in 1973, Shirley Phillips and Harry Young published the book *No-tillage Farming* (Phillips and Young, 1973), the first of its kind in the world. This was followed in 1984 by the book *No-Tillage Agriculture*: *Principles and Practices* by E. R. Phillips and S. H. Phillips (Phillips and Phillips, 1984). In Southern Rhodesia (now Zimbabwe), Tom Borland, a weed control specialist, published an article in 1974 in the Rhodesian Agriculture Today: *Which way weed control and tillage* ? (Borland, 1974), after a study tour to the USA where he met with most of the no-till pioneers including Harry Young. He also published a series of articles on no-till in *The Rhodesian Farmer* magazine over the period from 1976 to 1979, and were later reprinted in *South African Farmer's Weekly* (Borland, 1980). This was followed in 1984 by Brian Oldreive in Zimbabwe designing an approach called Farming God's Way (subsequently called Foundation for Farming) comprising no-till, mulch cover and rotation (Oldreive, 2006). In West Africa, research on no-till farming was started in 1970 at the International Institute for Tropical Agriculture (IITA), Nigeria, and a series of articles and bulletins on mulch farming techniques and no-till farming were published in the 1970s and 1980s (e. g., Lal, 1973, 1974a, 1974b, 1975, 1976a, 1976b, 1983).

In addition to these pioneers, there have been many other innovators in no-till farming since the early seventies who have made tremendous contributions to its growth and popularity. To mark the 40th Anniversary of the publishing of *No-Till Farmer*, its editor Frank Lessiter published a list of "40 Legends of The Past from North America" (Lessiter, 2011). Elsewhere, other no-till farming champions[4] have included: John Baker in New Zealand, Terry Wiles, David Sharp, Ivo Mello and Ademir Calegari in Brazil, Gino Minucci, Mario Nardone, Jose Araya, Roberto Peiretti, Hugo Ghio, Jorge Romagnoli, Horacio Aguero and Luis Giraudo in Argentina, Bill Crabtree, Steven Powles and Allen Postlethwaite in Australia, and Wolfgang Sturny in Switzerland.

The modern concept of no-till farming—now generally known as Conservation Agriculture (CA) — involves the simultaneous application of three inter-linked principles based on locally formulated practices (Friedrich et al., 2009; Kassam et al., 2009, 2011a): (i) permanently minimising or avoiding mechanical soil disturbance (no-till seeding); (ii) maintaining a continuous soil cover of organic mulch with plants (crop residue, stubble and green manure/cover crops including legumes); and (iii) growing diverse plant species in the cropping systems that, in different rainfed and irrigated farming systems (e. g. arable, horticulture, agro-forestry, crop-livestock, plantation, mixed systems with root and tuber crops and groundnuts, rice-based systems), can include annual and perennial crops, trees, shrubs and pastures in associations, sequences or rotations, all contributing to enhancing soil quality and system resilience.

CA, in conjunction with good crop, nutrient, weed and water management, is at the heart of FAO's new sustainable agricultural intensification strategy (FAO, 2011) which takes an ecosystems approach to enhance productivity and resilience as well as the flow of ecosystem services while reducing emissions that come from the agriculture sector (Kassam et al., 2011a). These characteristics are also an integral part of climate-smart agriculture that seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce GHG emissions and sequester carbon (World Bank, 2012). At the heart of sustainable agricultural intensification, or sustainable land management, is the integration of soil and water conservation practices in agricultural production, with concurrent objectives of enhanced economic returns and environmental management.

This paper is an elaboration of the achievements in soil and water conservation as reflected by the uptake and spread of the practice of CA.

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[4] There have been many champions of no-till farming in different parts of the world. Our aim is not to offer a comprehensive list but to mention some names of "early" pioneers.

2 Spread of Conservation Agriculture

CA involves a systems approach to soil and water conservation upon which a sustainable intensification strategy can be developed. This is now happening in all continents and most agro-ecologies. In addition, important 'structural' soil and water conservation approaches were developed including terracing, contour bunding and hedges to break slope lengths, wind breaks and hedge rows, water capturing pits, basins and half-moons, etc. These measures are totally compatible with CA and can be used in combination with CA production systems as complementary protection measures. However, this paper focuses largely on CA systems as a way to raise farm output, production factor efficiency (productivity), resilience and the flow of ecosystem services including soil and water conservation.

Worldwide, CA in arable cropland is now (2011 figures from www. fao. org/ag/ca) practiced on an estimated 125 million ha (nearly 9%) of arable cropland, mainly in North and South America, particularly the USA, Canada, Brazil, Argentina and Paraguay, and in Australia and New Zealand (Table 1) (Friedrich et al., 2013). Also, it is becoming increasingly popular in China, Kazakhstan, Ukraine and Russia. During the past decade, it has begun to spread in Asia more generally (including on the Indo-Gangetic Plains), in Europe (including the UK) and in Africa (Friedrich et al., 2013). CA has spread over 1 million ha in Africa, including in South Africa, Mozambique, Zambia, Zimbabwe, Malawi, Madagascar, Kenya, Sudan, Ghana, Tunisia and Morocco. Approximately, two-thirds of the area is under small-holder production. Much of the latter adoption has occurred in recent years as a result of more policy and extension attention and development resources being directed towards the promotion of CA through participatory dissemination and scaling approaches. Over the past decade the area of CA has increased at an average rate of 7 million ha per year, but in recent years it appears to have increased to some 10 million ha per year.

Table 1 **Global area distribution of CA by continent**

Continent	Area (ha)	Percentage of total	CA as percentage of arable cropland
South America	55,464,100	45	57.3
North America	39,981,000	32	15.4
Australia & NZ	17,162,000	14	69.0
Russia & Ukraine	5,100,000	4	3.3
Asia	4,723,000	4	0.9
Europe	1,351,900	1	0.5
Africa	1,012,840	1	0.3
World	124,794,840	100	8.8

The above pattern of adoption and spread of CA tells a country-specific or region-specific story of why, how and when it all began, what is the current status of adoption and how it is spreading, and what are the future prospects. In the case of the USA, the initial impetus to reduce soil disturbance and adopt no-till farming arose in response to the "dust bowls" of the 1930s. In the case of countries such as Brazil, Argentina and Paraguay, where no-till farming started in the 1970s and 1980s, the main initial driver was soil degradation due to devastating soil erosion, from intense tropical and sub-tropical storms, of exposed and loose top soil due to intensive tillage. In Canada and Australia, the initial drivers were wind and water erosion, but subsequently factors such as greater productivity and profit, expansion of cropping diversity in sub-tropical and cool temperate environments, and reduced costs of fertilizer, pesticide, energy and time became important.

In recent years, interest in CA has spread to Africa, Asia and Europe (FAO, 2007, 2009, 2013; Karabayev, 2008; Basch et al., 2008; Fileccia, 2008), the main drivers being stagnating productivity due to soil erosion, loss of soil organic matter and soil structure, soil compaction, and rising costs of production and potential impacts of climate change. CA is increasingly being recognised as important for longer-term sustainability and resilience of food production and agriculture systems, in the face of increased climatic variability and climate change. In some countries CA is still limited to the research sector, it is increasingly seen as an appropriate practical concept to promote in the future to achieve sustainable production intensification and to rehabilitate degraded agricultural lands and ecosystem services. While CA has its share of critics, differences in perspectives and appropriateness of CA are not over the efficacy of locally formulated CA practices but rather more with process of deciding where and how to promote the adoption and spread of CA.

3 Benefits from Conservation Agriculture

What has become clear is that tillage agriculture at any level of technological development is not ecologically or economically capable of sustaining current production levels or/and production intensification. This is because it degrades the soil, disrupts soil-mediated ecosystem functions and reduces soil productive capacity (Montgomery, 2007; Huggins and Reganold, 2008; Shaxson et al., 2008; Basch et al., 2012; Lal and Stewart, 2013). Tillage agriculture is not capable of fully harnessing necessary ecosystem services such as clean water, carbon sequestration, water and nutrient cycling, climate regulation and erosion control. With tillage agriculture there is destruction of soil structure, porosity, soil life and biodiversity, and there is excessive respiration, and soil organic matter decomposition, leading to accelerated soil erosion. Being a net emitter of greenhouse gases, tillage agriculture constantly reduces organic matter content of the soil which has a direct correlation with soil quality and soil productive capacity (Shaxson et al., 2008; Corsi et al., 2012). Soil carbon is a major determinant of the soil's ability to hold and release water and other nutrients that are essential for plant growth and rooting systems. Soil carbon also plays an important role in maintaining the biotic habitats that make land management systems sustainable, resilient, and resistant to degradation. Carbon sequestration, the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils, can help reverse soil health degradation and soil fertility loss, and reduce the impact of climate change on agricultural ecosystems (World Bank, 2012; Lal and Stewart, 2013).

In contrast to tillage agriculture, CA not only offers a way to sequester carbon and intensify production in an ecologically sustainable way, it is considerably less costly, and economically, environmentally and socially beneficial. CA utilises the whole ecosystem and all the natural biodiversity including soil microorganisms and soil meso fauna to build soil health and productive capacity and protect crops from weeds, insects and pathogens (FAO, 2011; Kassam et al., 2013). Given CA's ability to improve rainfall infiltration and soil moisture storage as well as increase in soil and root volume, there is improved interactions between plant roots and soil nutrients, and between plant roots and soil microorganisms such that there is greater resilience to biotic and abiotic stresses in CA systems compared with tillage systems. In conjunction with effective erosion control and enhancement of soil carbon, CA is a sustainable land use approach with soil and water conservation as its core objective (Lal and Stewart, 2013).

CA also allows greater precision and timeliness with farm operations and higher efficiencies of input use in smallholder farms. This is particularly important in pro-poor development projects where purchased production inputs are not only scarce but must be affordable. Higher input factor productivities with low levels of inputs in CA systems can provide a greater return to investment and a more robust basis for sustainable production intensification. On larger farms with CA, it becomes possible to overlay controlled traffic farming and GPS-based precision farming to affect higher efficiencies of energy and input use. These efficiencies have opened the door for policy and program initiatives such as the carbon offset credit scheme that has been operating in Alberta, Canada for several years based on CA, and to which controlled traffic farming and GPS-based precision farming are being added (Haugen-Kozyra and Goddard, 2009; Baig and Gamache, 2009; Lindwall and Sonntag, 2010).

Similarly, in Brazil, a programme called "cultivating good water" has been operating in the Paraná 3 basin based on CA on large and small farms in order to improve the quality and quantity of clean water feeding into the Itaipu Dam, thereby considerably extending its operating life span (ITAIPU, 2011; Mello and van Raij, 2006; Laurent et al., 2011). In China, the spread of CA on small farms has helped in reducing the dust in the atmosphere in Beijing (Li et al., 2007). In Spain, CA-based olive orchards have reduced soil erosion and flood risks in some 30% of the olive groves (Franco and Calatrava, 2006; Leyva et al., 2007; Martinez, 2009). In Western Australia, due to the adoption of CA in the semi-arid winter rainfall areas, there has been a significant reduction in land degradation from previous misuse with tillage agriculture (Crabtree, 2010). These changes, although seemingly small, in fact often impact large scale areas in the agricultural landscape, and are instrumental in delivering fundamental ecosystem services such as carbon sequestration, watershed services, cleaner air, reduced flood risks and rehabilitation of degraded lands. Harnessing such services can be promoted through schemes in which farmers can receive payments for improved environmental and biodiversity management in agricultural landscapes (Kassam et al., 2013).

When farmers decide to switch to CA from tillage farming, the expected mix of economic and environmental benefits manifest itself over time. The benefit mix varies in make-up and time scale depending on several factors including: agro-climatic conditions and variability within and between seasons; initial status of soil health and drainage under tillage systems; farm size and source of farm power; cropping system sophistication; yield levels under tillage systems; farmer expertise and experience of CA systems; access to production inputs, equipment and machinery; and competition for crop residues as livestock feed. They vary also to the extent that farm and community level supports are available, and market opportunities are present to expand production into more value added cropping systems with expanded crop rotations. Although the permutations in farm ecological and socio-economic conditions throughout the globe are very large, a growing pattern of economic and environmental benefits on the agricultural landscape is evolving, and is being increasingly recognised.

In general, CA benefits can include: increased factor productivities and yields (depending on prevailing yield levels and extent of soil degradation); up to 70% decrease in fuel energy or manual labour; up to 50% less fertiliser use; 20% or more reduction in pesticide and herbicide use; some 30% less water requirement; and reduced cost outlay on farm machinery. Further, with CA it is possible to enhance climate change adaptability of cropping systems, farms and landscapes because of improved soil-plant moisture relations while at the same time achieving greater carbon sequestration and lower emissions of greenhouse gases particularly CO_2, N_2O and CH_4. Due to higher rainfall infiltration and reduced runoff and soil erosion, CA also decreases flood risks, raises water resource quality and quantities, and can reduce infrastructure maintenance costs and water treatment costs (Friedrich et al., 2009; Kassam et al., 2009).

Experiences worldwide have shown that similar or higher yields can be obtained with no-tillage compared with conventional tillage systems (Crabtree, 2010; Derpsch et al., 2012; Thierfelder et al., 2013; Kassam et al., 2013). When yield with no-tillage is lower than with conventional tillage, some of the following reasons may be responsible:

- Lack of knowledge or experience on how to manage crops with no-tillage techniques.
- No-tillage may have been performed with bare soil conditions or with insufficient soil cover with crop residues.
- Lack of experience of the machine operator at seeding.
- Inadequate no-tillage machinery may have been used.
- Poor weed control.
- Poor disease and pest control.
- N fertilization may not have been adjusted during the first few years of applying no-tillage technology or a leguminous crop may not have been seeded previously to provide the additional N needed initially to account for immobilization in surface residues and soil organic matter.
- No-tillage may have been implemented on an extremely degraded and/or eroded soil with very low organic matter content, in which micro-and macro biological activity and fertility limits initial success.
- Comparative research studying conventional and no-tillage systems may have optimized rotations for conventional tillage, whereas sequences may be sub-optimal for no-tillage.

In general there is no inherent reason at the production system level why yields under CA, even during the conversion phase, should be lower than in tillage based farming, if all the necessary modifications in soil and crop management are applied (except for the normal learning curve). This is reflected in the observation that whenever the conversion process is accompanied by experienced farmers (often supported by experienced researchers), yields usually do not drop but increase; yield drops are normally seen only in cases of inexperienced new adopters as a result of the above problems. This can also be true for some inexperienced scientists and academics who attempt to undertake comparative research on the performance of conventional tillage systems and CA systems over a number of years without fully understanding what is involved in being able to establish proper CA conditions. They thus end up with unreliable results, upon which they draw inaccurate conclusions on the advantages with CA, or that CA has lower yields than conventional or that CA claims are exaggerated and not supported by research evidence. This can lead to misinforming decision makers and even causing confusion in the minds of the uninformed. In order to avoid these problems it has been suggested to standardize no-tillage research (Derpsch et al., 2013) to ensure that everybody applies the same principles and has the same understanding on how to manage a CA system.

4 Some challenges

CA is not a universal solution, but it offers an important alternative approach incorporating ecologically principles within crop production systems. This results in more sustainable, resource enhancing and conserving farming systems, offering on-farm productivity benefits and landscape level ecosystem services. FAO refers to this as a "Save and Grow" approach to sustainable production intensification with an ecosystem approach (FAO, 2011). However, like with any farming system, adoption of CA has constraints. CA is more knowledge and management intensive, and technologies normally have to be tailored to specific production environments. Establishing CA can be difficult in the initial years, particularly in some semi-arid areas more clayey soils, compact soils, and on poorly drained soils. Special innovations are often required in these conditions. Also, pest and disease control can be problematic in instances where specific residues attract specific pests; often pesticides/herbicides may be required, at least in the initial years. Leaving crop residues on the field as mulch eliminates an important source of animal fodder in areas where livestock are important in farm economies. Other location-specific socio-economic issues may include the perception of productivity loss in initial years or possible displacement of paid farm labour. On larger farms in certain countries where CA introduction is new, the lack of appropriate equipment for seeding and fertiliser placement through surface mulches can be problematic.

Adoption and spread of CA internationally offers lessons which show that the above-mentioned challenges can be and are being overcome by farmers, rich and poor, small and large, through locally-formulated solutions involving a range of public and private sector stakeholders working together with farmers along different pathways of adoption and transformation. The negative effects of difficult biophysical conditions can be reduced and overcome as new, improved, physical and biological soil conditions are established through CA practices, and diversified crop rotations and associations can keep crop pest and disease risks low. Integrated weed management is easier where hand cultivation is practised; and the use of an initial herbicide application followed by crop rotations and maintenance of a continuous soil cover by plants and mulch can eventually reduce weed competition.

Below ground crops such as white potato, sweet potato, cassava, groundnut and sugar beet have also been planted successfully into untilled soil, and harvested with minimal soil disturbance using appropriate harvesting equipment or cultivation practices (e. g. for cassava see Howeler et al., 2013). Rice also is produced with no-till systems, without puddling the soil and without permanent flooding. This approach has been shown to work in levelled paddies in South America and Asia but also more recently with permanent raised beds, particularly in the Indo-Gangetic Plains (Jat at al., 2009; Saharawat et al., 2010; Kassam et al., 2011b). With System of Rice Intensification (SRI), which requires moist aerobic soils instead of flooded soils, no-till rice-based systems on permanent raised beds has been shown to offer considerable productivity and economic benefits (Sharif, 2011). In CA systems with livestock husbandry, total biomass production is increased over time so that it is possible to manage on-farm residue allocation between livestock feed and soil protection dynamically in order to satisfy both goals (Landers, 2007). Where communal grazing of crop residues is a constraint in maintaining soil cover, a community-based solution can be developed to control grazing so that some crop residue is retained. Suitable mechanical equipment is increasingly becoming a minor constraint, as markets develop for local manufacture and provision of such equipment.

5 Future prospects

In the coming decades, every effort by all stakeholders must be made to transform tillage agriculture to CA. There are several ways to support immediate and wide spread scaling up CA (World Bank, 2012; Kassam et al., 2014):

- Develop and implement enabling government policy and programme initiatives by encouraging and strengthening government capacity to update agricultural policies, reform perverse commodity support programmes, and institute policy reform that supports the up-scaling of CA, especially in Asia, parts of Latin America and the Caribbean, Africa and Europe—where it is perhaps most urgently needed.
- Develop and implement an enabling policy environment for private sector participation in development and support for promotion of CA.
- In all new agriculture development projects, include CA as the basis for sustainable production intensification and engage all relevant stakeholders to ensure success, including creating an enabling environment for private sector participation.
- Advocate for initial government support in terms of incentivesto make appropriate farm equipment more readily accessible and to reduce any risks of possible productivity loss during the initial years of switching to CA.

- Develop large scale programmes that would offer payments to CA farmers for harnessing ecosystem services such as carbon sequestration, watershed services for increasing the quality and quantity of water resources, control of soil erosion and reduction in flood risks, and sustaining pollination services.
- Revise universities' agriculture curricula to include teaching the next generation of farmers and agricultural development practitioners about CA as an alternative and sustainable way of farming.
- Provide agricultural universities and schools with relevant literature and publications about CA in the local language.
- Fund more innovative practical research totackle soil, agronomic and livestock husbandry challenges through universities and research centres.

More advantage of the benefits offered by CA can be realized if all stakeholders become involved in facilitating the transformation process as is happening in countries such as Brazil, Argentina, Paraguay, USA, Canada and Australia. This is also beginning to occur in Europe (e. g. Finland, Spain), Africa (e. g. Zambia, Zimbabwe) and Asia (e. g. Kazakhstan, China) (Friedrich et al., 2013; Kassam et al., 2010, 2013). However a more structural response to the opportunities presented by CA calls for a realignment of agricultural institutions, including research, extension and education, as well as agriculture development policies to enable CA to become the preferred agriculture paradigm of choice around which to strengthen national and international food and agriculture systems (Kassam et al., 2014). The World Conservation Agriculture Congress process has evolved as a global multi-stakeholder CA Community of Practice (CA-CoP) that is facilitating the uptake and spread of CA internationally as a basis for commercialization as well as rural economic and civil society development. During the past decade, efforts to promote CA have become increasingly better organized, and donor agencies, governments, national research and extension systems, private sector firms, NGOs and farmers themselves are engaged in finding ways and means to introduce and spread CA as a basis for sustainable land management as well as for the adaptation to climate change.

The future requires that farming and agricultural landscapes be multi-functional, ecologically sustainable and integrated into the greater ecosystems alongside non-agricultural land uses. This means that agricultural production enhancement must go hand in hand with the enhancement and delivery of desired ecosystem services, and that production systems must be efficient with high production factor productivities, and resilient in on-farm performance and socio-economic development. Soil erosion by wind and water needs to be stringently controlled in agricultural production systems, and not viewed as being unavoidable. There are many local, national and international food production and agricultural challenges which must be addressed, including: food, water and energy insecurity, climate change, pervasive rural poverty, and degradation of natural resources.

This journal issue of national and regional assessments clearly shows that the principles of CA and the locally formulated adaptation practices have the capacity to slow and reverse productivity losses and environmental damage, thus offering an innovative and sustainable approach to farming in all agroecologies. While this may sound optimistic, to all the authors who have contributed their practical expertise to this special issue, CA based farming systems appear to be the best available option for meeting future food and agricultural security.

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