World Association of Soil and Water Conservation

Special Publication No. 3

No-Till Farming Systems

Editors:

T. Goddard, M. Zoebisch

Y. Gan, W. Ellis

A. Watson, S. Sombatpanit

"Calendario Agrícola Incaico – Agricultural Calendar of the Incas"

Drawing by Phelipe Guaman Poma de Ayala, Peru; early 17th century

By courtesy of Rolf Derpsch, Conservation Consultant,
Asunción, Paraguay

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Cover photo credits: ***Front cover:*** *Background:* Close view of new pea field (Reduced Tillage Linkages). *Insets:* Indian farmers standing in wheat field (Suraj Bhan); Swiss tractor seeding into yellow rape (Wolfgang Sturny); Very close view of emerging sesame (Rolf Derpsch); White bullocks pulling seeder (Rolf Derpsch). ***Back cover:*** *Background:* Field view of flattened stubble with seed slot (Rolf Derpsch*). Insets:* Man holding manioc-cassava (Rolf Derpsch); Close-up of trowel and soil (Carlos Crovetto).

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“No one has ever advanced a scientific reason for plowing.’’

“There is simply no need for plowing in the first instance. And most of the operations that customarily follow the plowing are entirely unnecessary, if the land has not been plowed.’’

“There is nothing wrong with our soil, except our interference.”

“It can be said with considerable truth that the use of the plow has actually destroyed the productiveness of our soils.”

Edward Faulkner
From *Plowman’s Folly* (1943)

Foreword

Welcome to a very unique book: A truly global collection of information presented by farmers, extension specialists, discipline professionals and research scientists. The World Association of Soil and Water Conservation (WASWC) had become aware of the range of no-till farming systems around the world, and realized the need to share this information as widely as possible.

The practice of no-tillage crop production has flourished during the last few decades. It has now been adopted in some form in most countries. Such a ubiquitous phenomenon has few precedents in modern times. The evolution of no-tillage and its adoption rate have not been linear. Progress accelerated as the breakthroughs in science and new technologies gradually accumulated.

The pioneers of no-till had a difficult time. Most were inquisitive farmers skilled in practical problem solving and mechanics, and motivated to continually initiate new avenues of exploration. They could see the rationale behind the practice and the potential benefits from its application. But equipment was limited and of inadequate design for the wide range of applications required. And their knowledge of the complex production ecology of no-till systems was very limited. However, their enthusiasm was infectious, and others increasingly joined in the quest to make no-till farming practical and profitable.

The early practitioners and researchers were challenged by weed problems and fertility management. They soon came to realize that no-till practices create a moving target. The soil's biological, physical, and chemical properties all change over time, as does the composition of weed populations. It takes time for the soil and plant system to reach a new equilibrium. Long-term research was therefore required to unravel the puzzle. However, research grants were most often short term; hence the initial results and recommendations did not always coincide with longer-term field experience. Research scientists had problems trying to represent field conditions on small plots. And no single no-till suite of recommendations fitted all areas, so farmers had to conduct localized field trials to see what worked best in their region and for their particular cropping systems.

The continued evolution of no-till farming requires the sustained enthusiasm of all involved, including farmers, extensionists and scientists. New participants need to receive proper training and education in no-till farming techniques. Support at the national level is needed for no-till to continue to develop. Crop improvement trials need to be done under no-till conditions so that crop traits important to no-till are selected for. Likewise, fertility and agronomic practices need to be conducted on no-till managed land at the plot, field, and landscape scale to encounter the full range of production ecologies.

Research is venturing into new areas such as how innovative cropping systems and residue management can influence soil biological activity and nutrient cycling. Biological tillage is replacing mechanical tillage, and more attention is being given to cropping systems and agronomic practice to control weeds and replace the myopic view of 'herbicides only'. It is the responsibility of all involved in no-till to ensure that such efforts continue into the future so that no-till can be adopted on a far greater scale across the agricultural systems of the globe.

This book aims to celebrate from where no-till has come, and to advance the concept by sharing the latest information and knowledge from around the world. New frontiers and the most recent developments are discussed. One of the most significant of these is the expanding interest in how carbon accumulation in agricultural systems can both enable greater adaptation to climate change and contribute to the mitigation of greenhouse gas emissions. The carbon markets are rapidly taking note of the vast potential for no-till systems to contribute to carbon offsets, thus opening up the opportunity for progressive farmers to gain additional income for their efforts to create more sustainable and productive no-till farming.

Dennis Garrity

Director General
World Agroforestry Centre
Nairobi, Kenya

Preface

No-till farming systems have been developed and applied around the world over several decades. The technology is dynamic: it develops and changes as we overcome obstacles in soil opening, seed placement, fertilizer banding and more. Researchers and farmers continue to modify the systems and apply no-till to a wider range of agricultural production systems. Benefits of no-till have been found in production, economic and environmental aspects of farming. As farmers apply no-till, their agronomic system moves to a new equilibrium. New investments in research of soils and plants are helping no-till to develop further.

We are not aware of any text that reviews global trends in no-till. Some texts review aspects of no-till from a particular standpoint. Those texts are often written by scientists engaged in lab or plot research or from the experience of a particular country. In this text we have not constrained the reporting to a scientific plot based experience, nor have we constrained it geographically. We have encouraged those with experience and expertise in no-till to tell us their stories, which span a broad range of perspectives, including farmer experience and beliefs as well as plot research. This book is the result of the contributions of 78 authors from 20 countries or regions, describing at least 25 study areas of all habitable continents – several of them in more than one instance. These authors possess roughly one thousand person-years of no-till experience!

Bringing so many contributors together from so many countries and constraining them to a common language of English presents its challenges. Some of these papers have been translated from their original language. Some expressions do not translate well.

There may also be regional terms for the same implement or practice. One example of this is a ‘harvester’ or a ‘combine’– two names for the same implement that harvests crops. Another is whether we call placing the seed in the soil ‘planting’ or ‘seeding’. We are of course accustomed to many of these synonyms; others are new. For the simpler terms (planting or seeding) we have not enforced a consistent style. For less common terms, we have attempted to provide a description of the term where the meaning is not evident from the context.

We have encouraged all experts in no-till to contribute, whether they are scientists or field-orientated professionals. We have therefore not required the standards of refereed journal publications such as referencing every claim beyond the immediate work, inclusion of statistical tests, and the substantiation of claims with references or data. You may also see preliminary data from early field trials, and the use of some less 'scientific' terms (e.g. soil health, soil nutrition) in some areas. Through these allowances we hope we have allowed the chapters to retain some of the passion of the writers.

We are therefore very optimistic and feel this book is a useful compendium of the state of no-till from all corners of the world that contains not only an objective review of experimental research, but passion and field observations that may serve academics, professionals and farmers as their companion in motivating and guiding them to continue their work of discovery.

The Editors

October 2007

Acknowledgements

How did it all begin?

In August 2004, as the WASWC President, I was invited by the Asociación Argentina de Productores en Siembra Directa (AAPRESID – Argentine No-Till Farmers Association) to participate in its 12th Congress in Rosario, Argentina, from which I had gained first hand knowledge about no-tillage in agriculture. Mr. Jorge Romagnoli, the AAPRESID President and Mr. Roberto Peiretti, an active Board member as well as President of CAAPAS (Confederación de Asociaciones Americanas por una Agricultura Sustentable – American Confederation of Farmers Organizations for a Sustainable Agriculture), had helped in every way to facilitate my learning of no-till farming practices.

After the meeting I traveled to Brazil where John Landers, Director of the Associaçao de Plantio Direto no Cerrado (APDC – the No-Till Association of Brazil), took me to Brasilia and the vast agricultural region of Mato Grosso do Sul State where many farmers successfully practiced no-till agriculture. Mr. Landers introduced me to many EMBRAPA Cerrados staff in Brasilia, while Dr. Antonio Ramalho helped to liaise with his EMBRAPA Solos in Rio de Janeiro. Discussions with EMBRAPA personnel in both offices provided me with invaluable information on the reasons why or why not Brazilians adopted no-till practices. EMBRAPA is a large Brazilian government agency dealing with agricultural research and development, employing thousands of staff all over the country.

When the idea of no-tillage crystallized in 2005, the WASWC Council agreed to adopt the topic as the subject of its next Special Publication (SP number 3). The authors invited at that time were Rolf Derpsch, Don Reicosky, José Benites, John Landers and Carlos Crovetto, all ‘no-till gurus’ of the Western Hemisphere, where the success of no-till was already recognized. Tom Goddard, WASWC National Representative for Canada, agreed to help edit the 150-page volume, which was given the working title *No-Till Farming Systems*.

At the same time, private sector companies were contacted to ensure that WASWC would be able to publish and distribute the book globally to those who really need it. The following firms kindly agreed to support the project: Syngenta AG, Basel, Switzerland; SEMEATO Farm Machinery Co., Passo Fundo, Brazil; Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands; Donald Fryrear Custom Products and Consultants, Big Spring TX, U.S.A. and The No Tillage Development Center, Chequen Farm, Concepción, Chile. SonTek of San Diego also became involved at a later stage, the same as Mr John Burton of NJ, U.S.A.

Before the publication date, it was proposed that WASWC organization members should be invited to co-publish the book in order to enhance its dissemination through bulk purchases by these organizations, thereby lowering the book's price. It became an unprecedented phenomenon: more than five dozen organizations embraced our offer and became co-publishers. At the same time a large proportion of them had offered to submit their papers, which made the book even more informative than before – something way beyond our anticipations. From a 5-paper book, our SP III had expanded to become a 544-page no-tillage compendium with 34 papers showcasing no-till experience from various territories of the world. Four additional editors (Michael Zoebisch, Yantai Gan, Wyn Ellis and Alex Watson) were invited to help to cope with the increased editing burden and very short deadlines.

For me personally, and for WASWC it is of course most gratifying to see such sustained commitment and willing cooperation to ensure the success of this publication. With initial sales through the co-publishing program already approaching 7,000 copies, we are certain our message will be well read worldwide by those interested in no-till farming systems, and we hope will also stimulate new ideas and initiatives to further refine and adapt the system to local conditions.

Our thanks and most sincere appreciation is extended to all who have offered helping hands to support this publication in various ways. Special thanks are due to the companies and individuals that have given their financial support, enabling us to produce this volume at an attractive price, accessible to a larger portion of the globe – thus fulfilling the global mandate of WASWC in managing and conserving the world's important natural resources – soil and water.

Samran Sombatpanit

Immediate Past President and Editor

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Introduction*

Lester R. Brown

In 1938, Walter Lowdermilk, a senior official in the Soil Conservation Service of the U.S. Department of Agriculture, traveled abroad to look at lands that had been cultivated for thousands of years, seeking to learn how these older civilizations had coped with soil erosion.

He found that some had managed their land well, maintaining its fertility over long stretches of history, and were thriving. Others had failed to do so and left only remnants of their illustrious pasts.

In a section of his report entitled *"The Hundred Dead Cities,"* he described a site in northern Syria, near Aleppo, where ancient buildings were still standing in stark isolated relief, but they were on bare rock. During the seventh century, the thriving region had been invaded, initially by a Persian army and later by nomads out of the Arabian Desert. In the process, soil and water conservation practices used for centuries were abandoned. Lowdermilk noted, "Here erosion had done its worst. ... If the soils had remained, even though the cities were destroyed and the populations dispersed, the area might be re-peopled again and the cities rebuilt, but now that the soils are gone, all is gone."

Now fast forward to a trip in 2002 by a United Nations team to assess the food situation in Lesotho, a small country of 2 million people imbedded within South Africa. Their finding was straightforward: "Agriculture in Lesotho faces a catastrophic future; crop production is declining and could cease altogether over large tracts of the country if steps are not taken to reverse soil erosion, degradation, and the decline in soil fertility."

Michael Grunwald reports in the Washington Post that nearly half of the children under five in Lesotho are stunted physically. "Many," he says, "are too weak to walk to school."

Whether the land is in northern Syria, Lesotho, or elsewhere, the health of the people living on it cannot be separated from the health of the land itself. A large share of the world's 852 million hungry people live on land with soils worn thin by erosion.

The thin layer of topsoil that covers the planet's land surface is the foundation of civilization. This soil, measured in inches over much of the earth, was formed over long stretches of geological time as new soil formation exceeded the natural rate of erosion. As soil accumulated over the eons, it provided a medium in which plants could grow. In turn, plants protect the soil from erosion. Human activity is disrupting this relationship.

Sometime within the last century, soil erosion began to exceed new soil formation in large areas. Perhaps a third or more of all cropland is losing topsoil faster than new soil is forming, thereby reducing the land's inherent productivity. Today the foundation of civilization is crumbling. The seeds of collapse of some early civilizations, such as the Mayans, may have originated in soil erosion that undermined the food supply.

The accelerating soil erosion over the last century can be seen in the dust bowls that form as vegetation is destroyed and wind erosion soars out of control. Among those that stand out are the Dust Bowl in the U.S. Great Plains during the 1930s, the dust bowls in the Soviet Virgin Lands in the 1960s, the huge one that is forming today in northwest China, and the one taking shape in the Sahelian region of Africa.

Each of these is associated with a familiar pattern of overgrazing, deforestation, and agricultural expansion onto marginal land, followed by retrenchment as the soil begins to disappear.

Twentieth-century population growth pushed agriculture onto highly vulnerable land in many countries. The overplowing of the U.S. Great Plains during the late nineteenth and early twentieth centuries, for example, led to the 1930s Dust Bowl. This was a tragic era in U.S. history, one that forced hundreds of thousands of farm families to leave the Great Plains. Many migrated to California in search of a new life, a move immortalized in John Steinbeck's *"The Grapes of Wrath"*.

Three decades later, history repeated itself in the Soviet Union. The Virgin Lands Project between 1954 and 1960 centered on plowing an area of grassland for wheat that was larger than the wheatland in Canada and Australia combined. Initially this resulted in an impressive expansion in Soviet grain production, but the success was short-lived as a dust bowl developed there as well.

Dust storms originating in the new dust bowls are now faithfully recorded in satellite images. In early January 2005, the National Aeronautics and Space Administration (NASA) released images of a vast dust storm moving westward out of central Africa. This vast cloud of tan-colored dust stretched over some 5,300 kilometers (roughly 3,300 miles). NASA noted that if the storm were relocated to the United States, it would cover the country and extend into the oceans on both coasts.

Andrew Goudie, Professor of Geography at Oxford University, reports that Saharan dust storms—once rare—are now commonplace. He estimates they have increased 10-fold during the last half-century. Among the countries in the region most affected by topsoil loss from wind erosion are Niger, Chad, Mauritania, northern Nigeria, and Burkino Faso. In Mauritania, in Africa's far west, the number of dust storms jumped from 2 a year in the early 1960s to 80 a year today. The Bodélé Depression in Chad is the source of an estimated 1.3 billion tons of wind-borne soil a year, up 10-fold from 1947 when measurements began. The 2 to 3 billion tons of fine soil particles that leave Africa each year in dust storms are slowly draining the continent of its fertility and, hence, its biological productivity. In addition, dust storms leaving Africa travel westward across the Atlantic, depositing so much dust in the Caribbean that they cloud the water and damage coral reefs there.

In China, plowing excesses became common in several provinces as agriculture pushed northward and westward into the pastoral zone between 1987 and 1996. In Inner Mongolia (Nei Mongol), for example, the cultivated area increased by 1.1 million hectares, or 22 percent, during this period. Other provinces that expanded their cultivated area by 3 percent or more during this nine-year span include Heilongjiang, Hunan, Tibet (Xizang), Qinghai, and Xinjiang.

Severe wind erosion of soil on this newly plowed land made it clear that its only sustainable use was controlled grazing. As a result, Chinese agriculture is now engaged in a strategic withdrawal in these provinces, pulling back to land that can sustain crop production.

Water erosion also takes a toll on soils. This can be seen in the silting of reservoirs and in muddy, silt-laden rivers flowing into the sea. Pakistan's two large reservoirs, Mangla and Tarbela, which store Indus River water for the country's vast irrigation network, are losing roughly 1 percent of their storage capacity each year as they fill with silt from deforested watersheds.

Ethiopia, a mountainous country with highly erodible soils on steeply sloping land, is losing an estimated 1 billion tons of topsoil a year, washed away by rain. This is one reason Ethiopia always seems to be on the verge of famine, never able to accumulate enough grain reserves to provide a meaningful measure of food security.

Fortunately there are ways to conserve and rebuild soils. In reviewing the literature on soil erosion, references to the "loss of protective vegetation" occur again and again. Over the last half-century, we have removed so much of that protective cover by clearcutting, overgrazing, and overplowing that we are fast losing soil accumulated over long stretches of geological time. Eliminating these excesses and the resultant decline in the earth's biological productivity depends on a worldwide effort to restore the earth's vegetative cover.

The secret of avoiding soil erosion is to never allow the soil to be bare and unprotected, but to ensure that the soil surface is always covered with growing plants or the dead mulch from these same plants. To achieve this in modern agriculture, all types of tillage and soil loosening should be avoided. The no-tillage technology described in detail later in this book has shown to be one of the most efficient methods of protecting the soil from being eroded by wind and water. This system is very similar to a permanent pasture. In addition to reducing erosion, this practice helps retain water, raises soil carbon content, and reduces the energy needed for crop cultivation. Instead of plowing land, disking or harrowing it to prepare the seedbed, and then using a mechanical cultivator to control weeds, farmers simply drill seeds directly through crop residues into undisturbed soil (with special machines), controlling weeds with herbicides. The only soil disturbance is the narrow slit in the soil surface where the seeds are inserted, leaving the remainder of the soil undisturbed, covered by crop residues and thus resistant to both water and wind erosion. Small farmers can no-till seed their crops using a stick or a manual hand planter.

Now widely used in the production of corn and soybeans in the United States, no-till has spread rapidly in the Western Hemisphere, covering 25 million hectares in the U.S.A., 24 million hectares in Brazil, 18 million hectares in Argentina, and 13 million hectares in Canada. Australia, with 9 million hectares, rounds out the five leading no-till countries. Worldwide, the no-tillage technology was applied on 45 million hectares in 1999 and has expanded to about 95 million hectares in 2005. It now exceeds the 100 million hectares mark. Farmers worldwide are increasingly recognizing the environmental benefits of this technology: No-till protects the soil from wind and water erosion, reduces fossil fuel consumption, reduces CO_2 emissions while also providing CO_2 sequestration, and increases soil fertility and productivity. Overall, it helps reduce farm expenses and increase the quality of life for farmers.

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Adapting No-Tillage Agriculture to the Conditions of Smallholder Maize and Wheat Farmers in the Tropics and Sub-Tropics

Olaf Erenstein, Ken Sayre, Patrick Wall, John Dixon and Jon Hellin

Abstract

The paper summarizes CIMMYT's experiences with the adaptation of no-tillage to smallholder conditions in the tropics and sub-tropics, focusing on three contrasting cases: 1) irrigated rice-wheat systems in South Asia; 2) rainfed maize and irrigated wheat systems in Mexico; and 3) rainfed maize in Southern Africa. The term 'Conservation Agriculture' is preferable to 'No-Till agriculture' whenever the three underlying principles - minimal soil disturbance, surface residue retention and crop rotation - are followed. CIMMYT's diverse experiences attest to the wide adaptability of conservation agriculture systems, which can generate clear economic benefits, including substantial reductions in production costs and increased yields. Yields are also stabilized in rainfed areas, thus reducing farmer risk. Moreover, there are potentially enormous environmental benefits. The advantages of conservation agriculture over conventional tillage systems are expected to grow as fresh water becomes scarcer in irrigated systems, as volatility increases in rainfed systems and as climate change begins to bite. Conservation agriculture is not a fixed technological recipe for application across different farming systems; on the contrary, these systems are best developed in situ through a multi-stakeholder adaptive learning process. Experience shows that farmers, researchers, service providers and machinery manufacturers need to be linked within an innovation system that fine-tunes equipment and crop management while strengthening local institutions.

Introduction

No-till (NT) is an agricultural practice or technology whereby a crop is established without any prior tillage. NT is known by various names, including no-tillage, zero-tillage and direct seeding. NT agriculture has received increasing interest worldwide from agricultural research and development workers, policy-makers and mostly from farmers. Two main thrusts explain the increasing interest: *first*, its potential to conserve soil and water, and *second*, its potential to reduce input use, thereby reducing production costs. The latter has become increasingly relevant in view of surging fossil fuel prices and growing concern over global warming. Yet, in a book about NT farming systems, another chapter explaining the rationale for NT seems perhaps superfluous, if not repetitive of previous chapters.

The International Maize and Wheat Improvement Center (CIMMYT, www.cimmyt.org) in Mexico is actively engaged in adapting NT to smallholder maize and wheat systems in the tropics and sub-tropics. CIMMYT's 2004 Strategic Plan reposition the organization to meet the emerging needs of developing countries for agricultural knowledge and technology over the coming 10-15 years, and contribute towards achieving the UN Millennium Development Goals for reducing poverty and hunger (CIMMYT, 2004). In this Strategic Plan, the place of NT and Conservation Agriculture (CA) in CIMMYT's portfolio of primary thrusts was stated specifically. In 2006 CIMMYT released a business plan to show how it intends to create maize and wheat technology that fosters both poverty reduction and food security, whilst contributing to resource conservation and sustainable development (CIMMYT, 2006). Thus the role of resource-conserving technologies such as NT is increasingly evident in CIMMYT's more recent strategic positioning. Still, CIMMYT has a much longer tradition of developing resource conserving technologies including NT, with agronomic work dating back to the 1980s (e.g. Barreto et al., 1989) and earlier.

CIMMYT's long experience with NT is particularly relevant for two reasons. *First*, CIMMYT has long been a strong advocate of on-farm research and has actively worked with farmers, National Agricultural Research & Extension Systems (NARES) and other partners to adapt NT practices to local smallholder conditions. *Second*, maize and wheat are two of the world's three most important cereals. Adapting NT to maize and wheat systems implies a major impact that cuts across continents and the developing world.

The purpose of this paper is to summarize some of CIMMYT's experiences with the adaptation of NT to smallholder conditions in the tropics and sub-tropics. The scope of the present paper is too narrow to review all of CIMMYT's NT experiences over the years. Instead, this chapter will focus on three contrasting cases of ongoing research and development across the developing world. These cases follow a section that discusses NT in relation to CA. Following the case studies, the paper continues with a discussion on NT innovation systems and impact pathways.

No-Till and Conservation Agriculture

NT represents one end of the continuum of farmers' tillage practices – with intensive, full field inversion tillage (e.g. with moldboard plows) at the other extreme and reduced tillage and strip tillage practices in between. NT itself can take various forms, depending on mechanization levels, and includes tractor or animal-drawn direct seeders and manual planters (e.g. jab-planters). NT systems typically save energy (e.g. tractor fuel, animal tillage, human labor), stop or revert soil and land degradation (soil organic matter decline, soil structural breakdown, soil erosion) and lead to more efficient use of water and other inputs. As such, NT is a resource-conserving technology (RCT), i.e. a practice that conserves and/or enhances resource or input-use efficiency.

Conservation agriculture is a wider concept involving minimal soil disturbance, retention of residue mulch on the soil surface and a rational use of crop rotations (FAO, 2007; Harrington and Erenstein, 2005; Hobbs, 2007). Indeed, in many references to NT agriculture, the surface residue retention and crop rotations have been considered important and are increasingly highlighted as important components of successful NT agriculture. The term 'conservation agriculture' is therefore preferably used today to replace the name 'no-tillage agriculture' and to shift the focus away from the tillage component towards the system components of this alternative form of agriculture.

The CA principles of minimal soil disturbance, surface residue retention and crop rotation along with profitability at the farm level, are increasingly recognized as essential for sustainable agriculture. Alternatively, NT alone is an insufficient condition for CA. Indeed, competing crop residue uses and residue management practices impose significant challenges for surface residue retention across the tropics and sub-tropics (Erenstein, 2002, 2003). The distinction between CA and NT is important because NT alone, whilst attractive in the near-term, may prove unsustainable in the longer term (Harrington and Erenstein, 2005). For example, under some circumstances the use of NT without residue retention and without suitable rotations can be more harmful to agro-ecosystem productivity and resource quality than a continuation of conventional practices (Sayre, 2000; Wall, 1999).

The CA principles are defined as common to CA systems. However, as highlighted by Harrington and Erenstein (2005), "the specific components of a conservation agriculture system (establishment methods, farm implement selection, crops in the rotation, soil fertility management, crop residues and mulch management, germplasm selection, etc.) tend to be environment-specific. Local investments in adaptive research are typically needed to tailor conservation agriculture principles to local conditions. This process of 'tailoring' is most efficient when an 'innovation system' emerges and begins to acquire a self-sustaining dynamic". When this happens, "... technology development and adoption [become a] social phenomenon in which agents interact in several ways, creating multiple information flows in many directions. These agents (e.g. public research and extension systems, innovative farmers, commercial firms, foreign research institutions) form networks that co-evolve with the technologies that they create" (Ekboir, 2002).

Across the developing world innovations systems have emerged around NT and CA. Ekboir (2002) has summarized such experiences with NT in Brazil, Bolivia, Paraguay, Mexico, Ghana and the Indo-Gangetic Plains of South Asia. Harrington and Erenstein (2005) have summarized such experiences with CA in South America, Southern Africa, China and Central Asia. These case studies are not restricted to maize and wheat cropping systems and vary considerably in terms of the extent of CIMMYT's involvement. For example, CIMMYT had no involvement in what is widely perceived as the CA's longest success story in

Brazil. Still, a recent review by Bolliger et al. (2006) concludes "… that although there is a wealth of valuable zero-till experience and technologies precipitating from the Brazilian zero-till 'revolution,' numerous challenges in zero-till research, especially in respect to resource-poor smallholder farmers, still remain, and perhaps more holistic, participatory and adaptive on farm-research is necessary in future." Success in the development and dissemination of CA practices for smallholders requires targeting areas with specific economic opportunities for CA and an integrated approach with a practical orientation, farmer participation, community involvement, flexibility and a long-term perspective (Erenstein, 2003; Hellin, 2006).

CIMMYT has worked with national agricultural research and extension systems in many regions to further the adaptation and application of NT and CA principles to both irrigated and rainfed and both wheat and maize systems. For instance, such work in rainfed systems includes maize-based systems in eastern Mexico and Central America, soybean-wheat double cropping systems in Paraguay and Bolivia, wheat-based systems on smallholder farms in the inter-Andean valleys of Bolivia and the highlands of Mexico and Ethiopia, and on large farms of northern Kazakhstan, with its 7-8 million ha of wheat-based agriculture.

In the subsequent sections of this paper we will synthesize some of CIMMYT's experiences in addressing such challenges in NT research with respect to smallholders in three contrasting cases:

- Irrigated rice-wheat systems in South Asia;
- Rainfed maize and irrigated wheat systems in Mexico;
- Rainfed maize in Southern Africa.

These contrasting cases send a common message, underlining the need to strengthen research for development partnerships with NARES, agri-business, farmers and other stakeholders, with an ultimate vision of sustainable smallholder wheat and maize systems based on the principles of CA.

Case 1: No-Till in Irrigated Rice-Wheat Systems in South Asia

The Green Revolution transformed the Indo-Gangetic Plains (IGP), spreading from Pakistan through northern India and the Nepal Terai region to Bangladesh, into the cereal basket of South Asia, with rice-wheat systems now covering an estimated 14 million ha in the region (Timsina and Connor, 2001). The technological packaging of improved wheat and rice seed, chemical inputs and irrigation within a supportive institutional environment for agricultural transformation led to rapid productivity growth. However, productivity growth has stagnated over the past decade (Kumar et al., 2002), leading to concerns over national food security and lagging rural economic growth. Degradation of the natural resource base is widely seen as the root cause for this stagnation. Thus, resource-conserving technologies and CA are increasingly viewed by the R&D community as the means to restore productivity and reverse land degradation.

To date, most significant progress has been made with addressing the challenge of reducing tillage in the rice-wheat systems of the IGP (Figures 1 and 2). With the rapid spread of tractor-drawn NT drills, tillage intensity has drastically fallen for the wheat crop, from eight to just a single tractor pass. Farm household surveys in 2003-04 confirmed significant adoption of NT wheat in the rice-wheat systems of NW IGP: 34.5% in India's Haryana and 19% in Pakistan's Punjab (Erenstein et al., 2007a). Experts estimate the total of no-tillage and reduced tillage (NT+RT) wheat area in the IGP to amount to some 2 million ha in 2004-05 (www.rwc.cgiar.org). The main driver behind the rapid spread of NT wheat is the significant, immediate and ongoing 'cost saving effect' that makes adoption profitable (Fig. 3, corresponding with a 15-16% saving on operational costs - Erenstein et al., 2007a). The cost saving effect primarily reflects the drastic reduction in tractor time and fuel for land preparation and wheat establishment. A significant yield effect can further boost the returns to NT (Haryana, India in Fig. 3, corresponding with a 4% yield increase - Erenstein et al., 2007a). The yield effect, where it exists, is closely associated with enhanced timeliness of wheat establishment after rice. Terminal heat implies that wheat yield potential reduces by 1-1.5% per day of delayed planting after 20th November (Hobbs and Gupta, 2003; Ortiz-Monasterio et al., 1994; Randhaw et al., 1981). Approximately 30% of wheat cultivation is under late sowing in the Indian IGP, and NT allows for timelier establishment. NT adoption is closely associated with the farm resource base and rice-wheat specialization (Erenstein et al., 2007a). The significant wheat area of NT adopters implies larger annual benefits, lower relative learning costs and earlier payback to a NT drill investment.

Figure 1. Tractor with NT drill during a field visit in the E IGP (Bihar), India.

Figure 2. Farmer in NT wheat field in the NW IGP (Haryana), India.

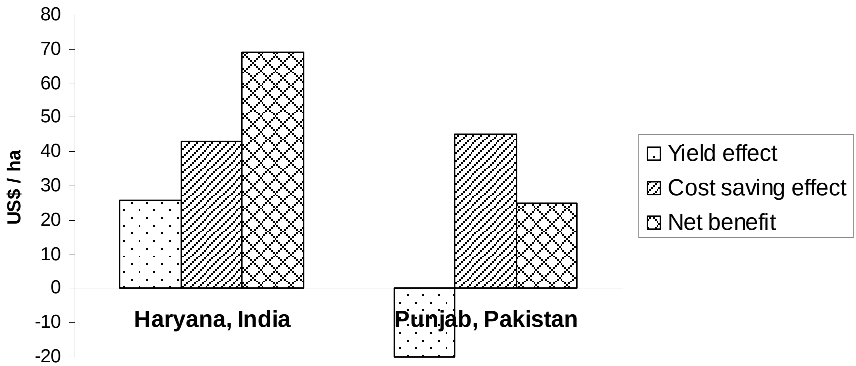

Figure 3. Financial advantage of NT over conventional tillage for wheat in NT adopter farms in 2003-04 in Haryana, India and Punjab, Pakistan (farmer survey findings, adapted from Erenstein et al., 2007a).

The same survey results, however, show that the use of NT in wheat had limited spillovers for the productivity and management of the subsequent rice crop. For the rice crop in the IGP, intensive and wetland preparation followed by transplanting still predominates. Reduction of tillage in rice-wheat systems has thus been only partially successful, reflecting on the one hand the wide acceptance of NT for wheat, and on the other the remaining challenge of reducing tillage for the rice crop (Erenstein, 2006).

The success of reducing tillage for wheat had much to do with the development of an effective delivery pathway for NT drills: a mechanical tractor-mounted seed drill that can seed wheat into an untilled rice field. Several factors proved crucial to the success of such drills in India (Seth et al., 2003). A local manufacturing capacity was developed to produce and adapt NT drills at a competitive cost. The private sector could see substantial market opportunities for their products, whereas the involvement of several manufacturers ensured competitive prices, good quality, easy access to drills by farmers along with guaranteed repairs and servicing. Close linkages between scientists, private manufacturers and farmers enabled placement of machines in villages for on-farm experimentation, allowing rapid feedback and refinement of implements. Private NT service providers have made the 'lumpy' technology divisible and therefore accessible. Recent adoption surveys revealed that 60-74% of NT adopters did not own a NT drill (Erenstein et al., 2007a). Service providers have the added advantage of having hands-on experience and having the self-interest in promoting the technology. Strong support from State and local government officials helped with dissemination, including the provision of a subsidy to lower initial investment cost and laying out extensive on-farm demonstrations and trials. The Rice Wheat Consortium (RWC) for the Indo-Gangetic Plains (www.rwc.cgiar.org, hosted by CIMMYT) played a catalytic role in promoting the public-private partnership, nurtured it through its formative stages and facilitated technology transfer from international and national sources (Seth et al., 2003). It has been estimated that the investments made by RWC and CIMMYT accelerated adoption of NT+RT by 5 years and yielded significant economic benefits (a net present value of US$ 94 million; a benefit-cost ratio of 39 and an internal rate of return of 57% - Laxmi et al., 2007).

The adoption of NT+RT in the IGP is still primarily concentrated in the NW IGP (Laxmi et al., 2007) which corresponds with the more intensive and productive rice-wheat systems and more favorable institutional support. Extending NT+RT to the Eastern IGP presents additional challenges, including the marked rural poverty and a less favorable institutional context. Most of the NT+RT relies on the tractor-drawn NT drill, but in some pockets - particularly low lying areas in the Eastern plains - there is also adoption of surface seeding into the previous crop. The increased use of NT in wheat also serves as a stepping stone to permanent beds in irrigated wheat systems.

In spite of the success of the RWC with NT practices in irrigated agriculture in the IGP, the full environmental benefits offered by CA have yet to be fully realized (Gupta and Sayre, 2007; Laxmi et al., 2007). The vast majority of farmers in the IGP have adopted RCTs like NT because they provide immediate, identifiable and demonstrable economic benefits such as reductions in production costs, savings in water, fuel and labor requirements and timely establishment of crops resulting in improved crop yields. But, in spite of the clear benefits and increasing adoption of RCTs, most farmers, especially the small- and medium-scale farmers, have difficulties in following the basic tenets of CA, particularly residue retention and crop rotation. Most farmers do not retain crop residues on the soil surface as they use crop residues for other purposes, particularly to feed livestock (Erenstein et al., 2007b). Therefore, building on the success of NT+RT wheat, R&D still faces the challenge of adapting and developing sound, economic CA practices that farmers will adopt year round and across crops in the system.

Case 2: No-Till in Rainfed Maize and Irrigated Wheat Systems in Mexico

CIMMYT manages a series of long-term trials located in Mexico. One such rainfed trial was established in 1991 at El Batan (CIMMYT headquarters) to investigate the long-term effects of different tillage, crop residue management practices and crop rotations, based on CA tenets, as compared with the most common farmer, tillage-based practices for wheat and maize production in the surrounding rainfed region. Rainfed cropping predominates in the highlands of central Mexico. Annual rainfall averages between 350-800 mm, occurring during a 4-6 month summer wet season followed by dry and frosty winters. Crops, dominated by maize (*Zea mays* L.), are planted at or just before the onset of the main summer rains. Most rain events are intense afternoon storms, and significant dry spells occur, causing crop water stress at any time during the cropping season. In farmers' fields the soil is bare for much of the year since almost all crop residues are directly removed for fodder or are pastured and/or burned. Fields are subject to frequent tillage and the heavy tillage and lack of ground cover on sloping fields lead to extensive erosion and water runoff, resulting in loss of precious water. Maintenance of ground cover thus plays a key role to make NT successful in these environments (Figs 4 and 5).

Results from the long-term trial confirm the benefits of CA for farmers – including small-scale farmers – in the rainfed highlands of Mexico (Govaerts et al., 2005, 2006a, 2006b, 2007a, 2007b). Grain yields for wheat and maize over a 10-year period (1996 to 2006) are presented in Figure 6, which illustrates that the best CA practice (NT, retention of crop residues and rotation of maize and wheat)

provided continuously higher and more stable yields for both wheat and maize compared to the farmer tillage/residue removal practice, even though optimum inputs and cultivars were used in all cases. Current tillage-based practices combined with crop residue removal on already degraded soils imply that farmers continue to further degrade the productive capacity of their land. This also implies they undermine their ability to capture the potential returns to new improved cultivars. Similarly, with the current traditional wheat and maize cropping practices, other inputs will not be efficiently utilized, including, in particular in this case, rainfall. The long-term trial also highlights that CA practices are economically viable and attractive. On average, the value of the yield gain and cost savings provides substantial returns over variable costs for both wheat and maize, against losses for the farmers' practice. The reduced yield risk in rainfed systems is another significant benefit for smallholders.

Figure 4. Importance of residue retention in zero-till rainfed maize: without residue retention (left) and with residue retention (right) - all other factors constant.

CIMMYT also conducts similar long-term trials in the irrigated areas of northwest Mexico. The main focus has been in the Yaqui Valley located in the state of Sonora. This valley encompasses about 255,000 ha of irrigated land using primarily gravity irrigation systems fed by canals (over 80% of irrigation water) and deep tube wells (around 20% of irrigation water).

Farming is mechanized but operational farm size can range from less than 10 ha to several hundred hectares or more. In the past, farmers planted all their crops on the flat with basin/flood irrigation, but over the past 25 years over 95% of the farmers have changed to planting all crops, including wheat, the most widely grown crop, on raised beds spaced at 70-100 cm from bed center to bed center (Aquino, 1998). Irrigation water is applied via the inter-bed furrows.

Figure 5. Importance of residue retention in zero-till rainfed wheat: without residue retention (left) and with residue retention (right) – all other factors being constant.

Wheat yields for the Yaqui Valley have averaged over 6 t ha^{-1} over the past several years. Farmers growing wheat on beds obtain about 8% higher yields with nearly 25% less operational costs and irrigation water use as compared to those still planting conventionally on the flat, using border/basin flood irrigation (Aquino, 1998). Most farmers, however, currently still practice conventional tillage where the beds are destroyed after each crop harvest by several tillage operations and new beds formed for planting the succeeding crop. This tillage is often accompanied by burning of crop residues although some maize and wheat straw is baled for fodder and, when turn-around-time permits, some crop residues are incorporated during tillage (Meisner et al., 1992).

There has been intense farmer interest in the development of new production technologies based on CA principles. These would allow marked tillage reductions which, when combined with retention of crop residues, have the potential to reduce production costs, improve input-use efficiency, permit more rapid turn-around between crops and more sustainable soil management while still allowing the use of the relatively inexpensive gravity irrigation system. Therefore, a long-term experiment was initiated in 1992 in the Yaqui Valley to compare common farmer practice (based on extensive tillage to destroy the existing beds and the formation of new beds for each succeeding crop), with the permanent raised bed system whereby new beds are formed after a final tillage cycle and are reused as permanent beds with only superficial reshaping needed before planting of each succeeding crop.

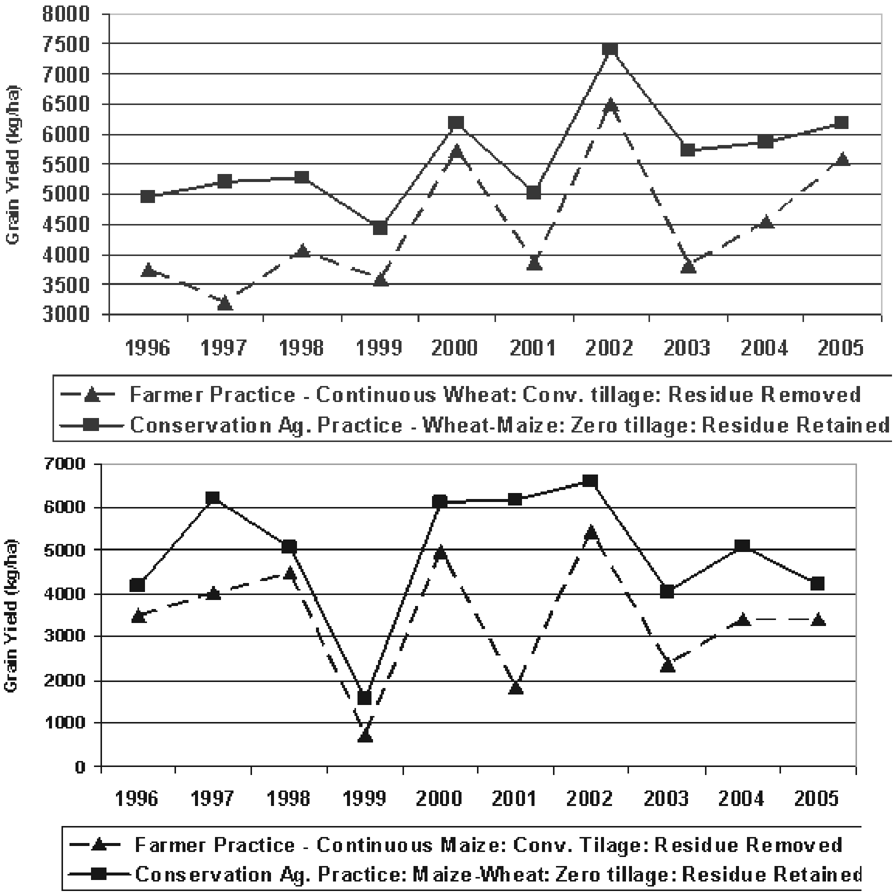

Figure 6. Comparison of rainfed yields for wheat (top) and maize (bottom) for the most common farmer practice versus the best CA practice at El Batan, Mexico from 1996 to 2005 (CIMMYT conservation agriculture trials in Mexico, unpublished data).

Figure 7 presents the wheat yield trends observed from the long-term trial for four contrasting tillage and residue management practices from 1993 to 2007. In the rainfed production systems in central Mexico, CA practices (NT with proper residue management) provided almost immediate benefits in grain yields (Fig. 6) due mainly to more efficient rain water use. In contrast, under the irrigated conditions in the Yaqui Valley no major wheat yield differences were observed between the various contrasting tillage/residue management practices for the first 5 years - 10 crops including the soybean or maize crops planted each summer in rotation with wheat (Fig. 7). However wheat yield declined radically from the 1998 crop onwards on the permanent raised bed treatment where all crop residues from both summer and winter crops were burned. Wheat yields using this practice have dramatically and continually lagged below those for the other management practices studied.

There are many examples where farmers using NT planting without retention of adequate surface residues under rainfed production conditions have failed to achieve satisfactory results. However, there has been little work on adapting CA to gravity irrigated conditions and so there are few clear examples of the need for surface residue retention. The results shown in Figure 7, therefore, clearly reinforce the need for adequate retention of surface residues in attaining sustainable, long-term NT systems, and demonstrate the need to maintain a long-term perspective for CA activities.

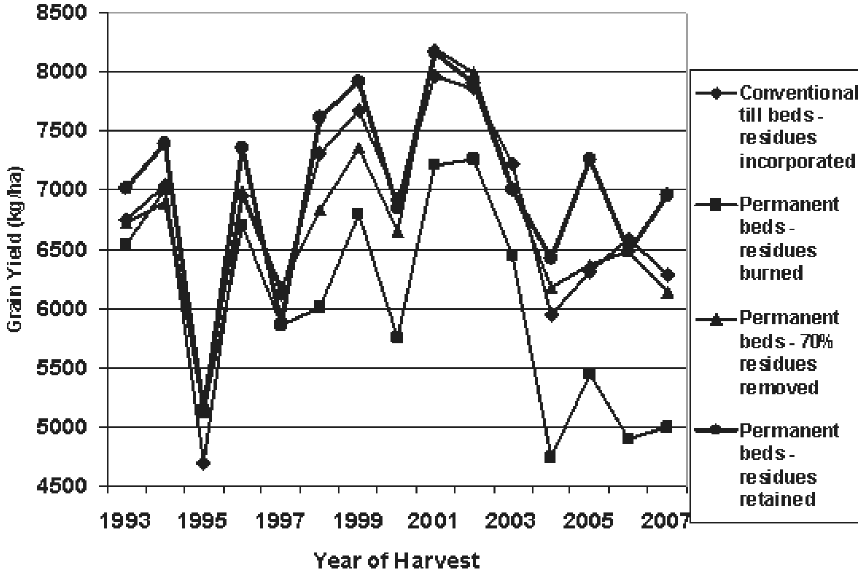

Figure 7. Effect of tillage and residue management with optimum management on wheat grain yields over 15 years in the Yaqui Valley, Sonora, Mexico (CIMMYT conservation agriculture trials in Mexico, unpublished data).

Figure 8 illustrates the clear yield and economic advantage of permanent raised beds over conventionally tilled beds. These results are derived from a large-scale trial/farmer demonstration module where crops are planted when possible for each planting system (usually 7-10 days earlier for wheat in the permanent beds as compared to tilled beds due to faster turn-around between crops). In the trial reported in Figure 7, planting date each year has been the same for all treatments. Because of the marked economic advantages of the permanent raised-bed planting systems, farmers in the Yaqui Valley are now in the early stages of adopting the system.

Yet, despite the potential economic benefits, adoption of CA practices in both rainfed and irrigated systems in Mexico has so far been limited. The Mexican NARES have been variously involved in CA research and promotion in a number of states since the 1990s (Erenstein et al., 1998; Erenstein, 1999a; Erenstein and Cadena, 1997). This has resulted in some examples of CA adoption, but widespread adoption of CA in Mexico has not occurred (Erenstein, 1999b). In some instances small- and medium-scale farmers may not have access to the means to adopt appropriate CA technologies. For instance, one study in western Mexico concluded that although NT was economically viable, cash-constrained small-scale farmers, especially in the dry areas, may not readily adopt it because they lack seeding equipment and need techniques that are less reliant on herbicides (Jourdain et al., 2001). Other studies show that the short-term returns to CA adoption in rainfed systems in Mexico can be constrained by relatively modest immediate benefits and substantial transition costs, including adaptations to crop production, the farm enterprise and the institutional setting (Erenstein, 1999b).

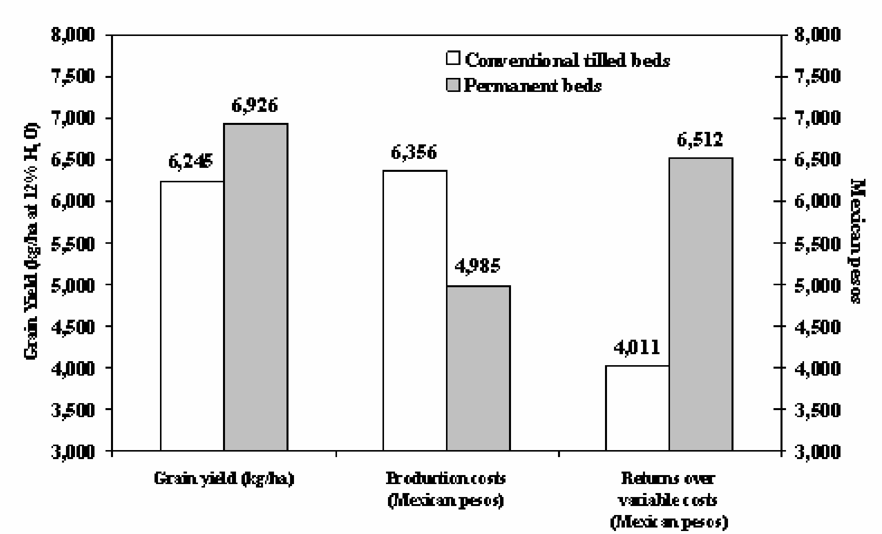

Figure 8. Comparison of average wheat grain yields, variable production costs and returns over variable costs of wheat produced with conventional tilled beds versus permanent raised beds in the Yaqui Valley, Sonora, Mexico from 2001 to 2004 (CIMMYT conservation agriculture trials in Mexico, unpublished data).

This calls for more participatory and adaptive research in farmers' fields to adapt CA to their circumstances. It also flags the need to use long-term trials to highlight the cumulative and substantial benefits over time to farmers and other stakeholders.

Case 3: No-Till in Rainfed Maize Systems in Southern Africa

Drawing on experiences with NT and CA elsewhere, CIMMYT began a concerted effort in 2004 to adapt the principles of CA to the circumstances of smallholder farmers in Southern Africa on projects in Malawi, Tanzania, Zambia, Zimbabwe and, more recently, Mozambique. Maize is the staple for the vast majority of the population of Southern Africa and accounts for 50-90% of caloric intake, with greatest dependence on maize for food among the very poor. It is therefore the main crop grown by the majority of smallholder farmers who generally focus their production strategies on fulfilling family food requirements and then selling any surplus for cash. NT systems have been developed and used on large-scale commercial farms in South Africa and Zimbabwe, but until recently there has been little emphasis on extending these practices to smallholders. However, currently there is much interest in CA in many countries of the region, and major efforts are underway in Zambia (Haggblade and Tembo, 2003) and Zimbabwe to adopt a particular type of CA, locally called Conservation Farming, based on planting in small, manually dug basins.

One of the major lessons learned from other regions of the world is the importance of knowledge in the development and adoption of CA, not only among farmers but also among researchers, extension agents and others involved in agricultural development. The principles of CA have widespread applicability, but the techniques and technologies necessary to put those principles into practice vary widely from place to place and under different socioeconomic conditions. Farmers (and others) need to understand the principles of CA, and why they work, in order to successfully adapt CA options to their own specific conditions. Therefore, our activities to help spread CA in Southern Africa focus on a limited number of communities, with relatively intensive participatory research, demonstration and learning activities in these communities.

There are many impediments to the widespread adoption of CA, and major constraints affecting small farmer adoption of CA have been summarized by Wall (2007). A concerted effort is urgently needed to achieve sustainable systems. Efforts dedicated to non-sustainable systems not only waste resources but undermine long- and medium-term development goals.

As mentioned in the section on the highlands of Mexico, competition for crop residues is a major concern for developing CA systems for smallholder farmers in rainfed areas. Many, therefore, argue that CA is impossible under these conditions because of the value of crop residues for animal feed. However, the alternative prospect of an ever-declining resource base is not an acceptable option, and although experience so far shows that farmers are prepared to leave crop residues on their fields – the benefits are evident and farmer experimentation on their own production fields has already begun – there is an urgent need for investment in finding techniques to make CA a viable alternative to the unsustainable practices of conventional agriculture.

Conditions in the Zimuto Communal Area near Masvingo in central Zimbabwe are particularly harsh, with infertile sandy soils (93% sand) and low and erratic rainfall (200-1,000 mm yr^{-1}, mean 631 mm), and the risk of crop failure is high. Since 2004, a series of seven farmer-managed demonstration plots comparing the farmers' conventional animal traction tillage practices with two CA systems have been conducted on the same sites each season (Fig. 10). The first of the CA practices is a low-outlay intermediate option where the farmer replaces the moldboard plowshare with a ripper tine on the same frame and uses this to open narrow furrows, normally 75 to 90 cm apart, and seed by hand into these furrows. The second is a more expensive option using an imported animal traction direct seeder. Although local production of adapted equipment is being stimulated, as yet the prototypes are still undergoing participatory evaluation. Although yield benefits of the CA systems were not evident in the very dry 2004/2005 season, they were evident in the very wet 2005/2006 season and even in the more normal 2006/2007 season – approximately 600 mm of rain but with extended dry periods (Fig. 9). Although the trend to increasing yield evident in Figure 9 is purely an effect of season type (it could easily have shown the reverse with a different set of seasons), the benefits of the crop seeded with the animal traction direct seeder have been particularly evident.

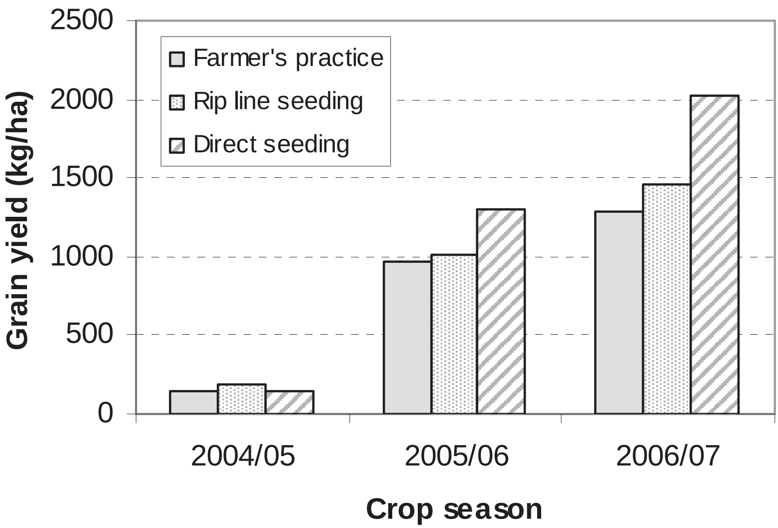

Figure 9. Mean grain yield of maize on seven smallholder farms under conventional agriculture and two CA practices, near Masvingo, central Zimbabwe (CIMMYT conservation agriculture project in Southern Africa, unpublished data).

In the Southern Africa context the economic benefits of CA are still difficult to quantify unambiguously and are confounded by location specificity and seasonal variability, and the corresponding risk implications.

Figure 10. Conservation agriculture demonstration plot on the farm of Mr. Makwara in the Zimuto Communal Area in central Zimbabwe – CA plot on the left has developed much better than the crop with conventional tillage on the right. Both plots use the same crop variety (maize) and have the same fertilizer treatment.

Figure 11. Mr. H. Zvamarima stands between the conventional agriculture plot (left) and the conservation agriculture plot (right), in a demonstration plot he has installed on his land near Chavakadze village, Shamva District of Zimbabwe. Both maize crops are the same variety and have the same fertilizer level.

However, for small-holder farmers, cash benefits per unit of land may not be the most important measure; labor productivity (Ekboir et al., 2001, 2002) and risk reduction are likely more important factors. Labor savings with CA are very evident where chemical weed control has been used (e.g. in Ghana – Ekboir et al., 2001, and our experience in Malawi) but are not as evident (and may even be negative in the first years) with manual weeding, leading to many cases of disadoption (Rockstrom et al., 2001). Manual hoe weeding also results in considerable soil disturbance, thereby reducing the benefits of CA (Thierfelder, unpublished data).

However, social issues also present challenges: communal stubble grazing after harvest is the norm in many rainfed smallholder mixed crop/livestock systems, including those in Eastern, Southern and Northern Africa, West Asia, Mexico, and in Central and South America. After the harvest period is over, grazing animals are free to roam and individual farmers are unable to protect residues from grazing. Community participation is thus a prerequisite: it is important that the whole community realizes the benefits of CA and acts cohesively to reverse the long-term deleterious effects of soil organic matter decline. Two very positive examples demonstrate how this issue may be resolved. A *first case* is near the town of Karatu in northern Tanzania. A farmer with whom CIMMYT collaborates originally started managing CA systems under the auspices of a project funded by the German government. Based on his experiences, he convinced his neighbors of the benefits of CA, and persuaded them to adopt the system. He then convinced them that, as soil cover and residues were so important, they should, as a community, restrict the free grazing of their animals. This has led to a "residue-friendly" community in the heart of feed-strapped Africa, where farmers realize that leaving their residues on the soil surface is more beneficial than passing them through an animal. A *second case* is the Shamva District of Zimbabwe where a local policymaker has observed the benefits of residue retention in the CA demonstration/validation plots and has re-enacted local and forgotten regulations which permit farmers to deny access to their fields to grazing animals. This latter example has been extremely important to us as it shows the benefits not only of the demonstration to farmers of the benefits of CA, but also of the incorporation of policymakers into the innovation system.

We have learned that encouraging adoption of CA is less a technology concern, and more relates to mindset and the way people think. In the Shona language, the most widely spoken language in Zimbabwe and northwestern Mozambique, the word for agriculture and plowing is the same – 'kurima'. People need to learn to dissociate the two concepts: agriculture does not depend on plowing, and continuing to plow tropical soils, with the resultant soil organic matter decline, structural degradation and soil erosion, is unsustainable.

Spreading CA under the conditions of smallholder farmers will not be easy and, as has been the case in all places where there has been considerable adoption of CA, it takes considerable time (at least 10 years) to achieve appreciable levels of adoption: once the pioneers have mastered the system, adaptation and adoption become rapid or even explosive. However, continuity and persistence are necessary – not only on the part of farmers and agricultural workers, but also on the part of governments and aid agencies.

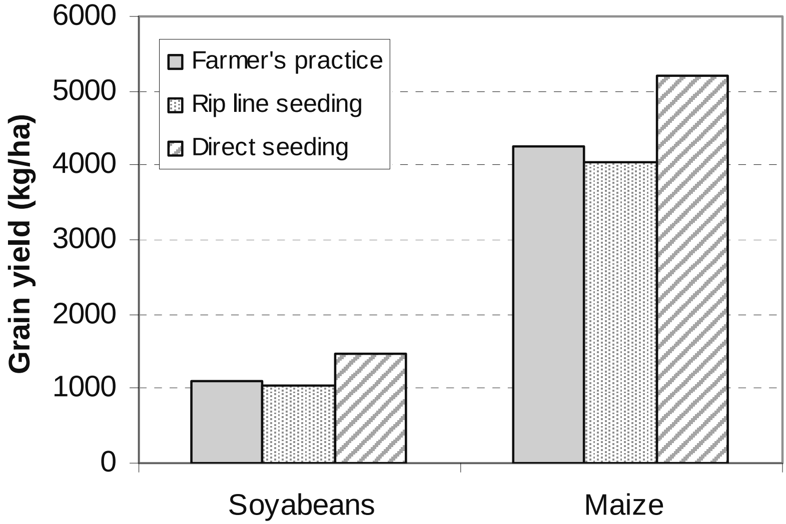

Figure 12. Soybean and maize yields under three management practices in farmer-managed plots on three different smallholder farms near Shamva, NE Zimbabwe, 2006/07 crop season (CIMMYT conservation agriculture project in Southern Africa, unpublished data).

No-Till Innovation Systems and Impact Pathways

Of the wide range of smallholder farming systems around the world (Dixon et al., 2001), the cases reported in this chapter focus on maize and wheat systems in contrasting settings in the tropics and sub-tropics (Table 1). The diverse series of CIMMYT experiences with CA practices like NT attest to the wide adaptability of CA systems. The cases comprise two intensive irrigated wheat-based systems and two rainfed maize systems. The level of production risk in the rainfed systems is naturally higher: but the cases show how CA practices can enhance yields in the short term and reduce yield variability. The accounts illustrate the clear economic benefits that accrue to farmers and society from adopting elements of CA in irrigated systems in South Asia and Mexico, and the potential benefits of CA in rainfed systems in Southern Africa and Mexico. However, as shown in the long-term irrigated trials in Mexico, the benefits might not be apparent during the first 5 years; hence the importance of a long-term vision in agricultural research and the importance of long-term trials. It also illustrates the challenge of making CA more attractive to smallholder farmers whose time horizons, of necessity, are often short term.

Table 1. Selected characteristics of the case studies.

	Case 1	Case 2a	Case 2b	Case 3
Location	South Asia (NW India, Pakistan)	Mexico (central)	Mexico (NE)	Southern Africa (Zimbabwe)
Cropping system	Irrigated rice-wheat	Rainfed maize based	Irrigated wheat based	Rainfed maize based
Yield variability	Low	High	Low	Very high
Yield effect CA practices	Positive due to timely planting	Already positive in short term and more stable	Positive but with 5 year delay	Already positive in short term and more stable
Local innovation systems capacity	Medium, with active collaborative equipment innovation	Low innovation	High level of innovation	Generally low
Residue management	Wheat straw used for livestock feed; rice straw surplus burned	Used for livestock feed	Surplus burned and/or incorporated	Used for livestock feed
Adoption CA practices	Rapid for NT wheat in the NW Indo-Gangetic Plains	Low	Low	Negligible

The foregoing cases also illustrate the merits of approaching CA research and development as a multi-stakeholder innovation system, as indicated in the introductory sections of this chapter. Each case shows the importance of engaging multiple stakeholders (farmers, researchers, business, machinery manufacturers, marketing agents, etc.) in the development and adaptation of the CA systems and the supporting agricultural institutions. Of course, development of CA systems is not a one-off input: the systems must be capable of dynamic responses to changing circumstances. CA requires the coordinated application of a series of new crop management practices which need adaptation to local conditions. The lack of adapted equipment for CA is often a binding constraint which can be overcome through the close involvement of machinery manufacturers. Similarly, the engagement of input suppliers and access to markets has been an essential ingredient of successful adaptation and adoption of CA.

Another critical issue for environmental sustainability is the management of crop residues, which varies depending on biomass production, equipment and alternative demands for crop residues for energy or livestock. It is clear that a considerable period of adaptation is required before a significant number of farmers adopt. For instance, the Southern Africa case is just getting under way and so significant adoption could only be expected after 5-10 years.

One challenge faced by CIMMYT and other organizations lies in improved diagnosis of the constraints to faster development and adoption of CA practices, and in estimating the complex and far-reaching impacts of CA research (Dixon et al., 2007). Such information will allow CIMMYT to assist its partners to ensure that CA practices are more widely adopted/adapted and contribute to livelihood security. CIMMYT has developed the U-impact pathway as a framework to help meet this challenge. Adoption of CA practices is influenced on the supply side by the input delivery pathway from research to farm (input value chains), and on the demand side by the characteristics of the farm household system and the marketing or value-adding chains from farm to consumer (output value chains). These three elements (input value chains, farm household system characteristics, and output value chains) can be viewed as the U-impact pathway. This pathway determines the rate and extent of adoption of the CA practices, the magnitude of direct and indirect impacts, and the potential for feedback loops leading to improved functioning of the input and output value chains.

Adoption of CA practices is influenced by the nature and performance of the input value chains that deliver inputs and services to the farm gate. They comprise CA service providers, the extension agents (both formal and informal, e.g. farmer-to-farmer) and often, providers of complementary inputs such as credit and fertilizer. Availability of these 'inputs' also influences the rate of technology adoption and level of intensification. A case in point was the development of NT drills in the rice-wheat systems in South Asia, as discussed above.

However, it is the decisions of farm women and men that ultimately will determine whether CA practices are adapted and adopted, leading to increased productivity, improved livelihoods, other primary and secondary impacts, and reduced poverty. Farm household decisions on technology adoption depend on their personal assessments of expected changes in marginal costs, benefits and risk (both direct and indirect, as well as in cash and kind) in the specific farm system. Agriculture can therefore be viewed as an integrated technical-social system in which farmers and service providers create solutions to production and livelihood problems, taking advantage of new opportunities through the modification of technologies and existing farming systems (Hall et al., 2005).

The process of identifying and meeting farmers' needs is more efficient when an innovation system emerges. In order to target CA more effectively, research organizations and their partners need a better understanding of the innovation systems and impact pathways and networks that link research outputs to institutional outcomes and farm-level impacts, notably improved household livelihoods.

This approach implies a shift of focus from crops to people-centered livelihoods and from linear technology selection and transfer to a non-linear complex systems approach which explicitly recognizes feedback loops, farmer innovation and systems dynamics and evolution.

The cases highlight that one of the main drivers of the rapid spread and widespread acceptance of CA is the combination of some 'yield effect' and a substantial 'cost saving effect' that ensure the short-term profitability of adoption. However, farmers also need access to markets to dispose of surplus production at a reasonable price. Access to produce markets is often a critical determinant of adoption of agricultural technology and practices such as CA. Increasingly, researchers and development practitioners who have traditionally focused on natural resource management are now taking a greater interest in issues concerning market access (Hellin, 2006).

A common thread in all three case studies is the research for development partnerships with, amongst others, agri-businesses active in the output (and input) chain(s). Furthermore, an analysis of this last leg of the U-impact pathway can help identify significant constraints to the adoption of CA. For example, the output value chains in the rice-wheat systems of the north-west IGP in South Asia are characterized by widespread public intervention, particularly assured produce prices and marketing channels for rice and wheat grain. Although these foster intensification, they also represent a major obstacle to the third component of CA – the practice of crop rotation. The combination of secure produce markets and irrigation means that rice and wheat production are a low risk activity that had proven difficult to displace until recently.

The impact of adaptation and adoption of CA goes far beyond farmers. Beyond the direct food security benefits, welfare improvements derive from the improved distribution of benefits among different actors along both input and output value chains, including manufacturers, farmers, traders and consumers. Further benefits accrue to farmers from on-farm diversification, and to other rural poor through jobs created in the local farm and non-farm economy. This type of impact pathway analysis provides a plausible specification of the dominant links and critical roles of the key actors, leading to greater adoption of CA practices and generation of greater local knowledge. An understanding of these links and roles allows for feedback, and subsequently for the adaptation of behavior by actors in the chains to foster greater impact.

Lastly, researchers need to acknowledge that in the developing world, the capacity of farming to provide the sole means of survival for rural populations is diminishing fast. Whether due to declining crop prices, competition for land, poor access to markets, or declining productivity due to soil and land degradation, successful intensification and diversification may also lead to off-farm employment and even to a voluntary (cf. forced) exit from farming. Farmers are increasingly moving into rural non-agricultural work and the contribution of non-farm work to rural people's livelihoods should not be underestimated (Berdegue et al., 2000;

Ellis, 1999). It may be the case that adopters and adapters of CA eventually exit from farming. If they do so, the exodus may not necessarily indicate that research efforts have been in vain. On the contrary, it may be the case that the adoption of CA has enabled farmers to improve their incomes and to pursue a different (non-farm) livelihood outcome.

Conclusion

The term ‘Conservation Agriculture’ (CA) is preferable to ‘No-Till agriculture’ whenever the CA principles - minimal soil disturbance, surface residue retention and crop rotation – are followed. CIMMYT’s experiences with CA are testament to the wide adaptability of CA systems. CA can generate clear economic benefits, including substantial reductions in production costs and increased yields. Yields are also stabilized in rainfed areas, thus reducing farmer risk. Moreover, there are potentially enormous environmental benefits stemming from savings in irrigation water, diminished weed pressure, improved soil management and reduced emission of greenhouse gases. The rapid adoption of NT in the smallholder irrigated IGP in northern India echoes the spread of CA in rainfed commercial family farming in Brazil, eastern Paraguay and Argentina in the late 20th century.

The environmental dividends from the ongoing uptake of CA in Asia are expected to be immense, notably in the irrigated areas of India and China. The widespread adaptation and adoption of CA in rainfed smallholder agriculture in Africa would tackle head-on the poverty complex of poor farm assets, degraded resources, vulnerability, and lack of diversification. As institutions grow stronger, markets open for more diversified produce, and policies shift towards improved resource management; the institutional environment for CA adaptation and adoption is thereby progressively improving. Moreover, the advantages of CA over conventional tillage systems are expected to grow as fresh water becomes scarcer in irrigated systems, as volatility increases in rainfed systems and as climate change begins to bite. CA is not a fixed technological recipe for application across different farming systems; on the contrary, CA systems are best developed in situ through a multi-stakeholder adaptive learning process. Experience shows that farmers, researchers, service providers and machinery manufacturers need to be linked within an innovation system that fine-tunes equipment and crop management while strengthening local institutions.

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‘Where the land is greener’ Documenting and Evaluating No-Till Knowledge and Experiences

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Abstract

World Overview of Conservation Approaches and Technologies (WOCAT) is a network of soil and water conservation (SWC) specialists from all over the world with a common vision: that land and livelihoods are improved through sharing and enhancing knowledge about sustainable land management.

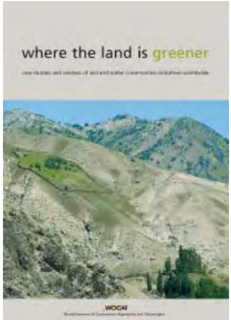
The well illustrated WOCAT book *where the land is greener* is the first hard-copy compilation of case studies by the WOCAT team. Nine different categories of technologies are presented in the book, i.e. manuring/composting, vegetative strips/cover, agroforestry, water harvesting, gully rehabilitation, terraces, grazing land management, ‘other technologies’ and conservation agriculture. The technologies are supported by matching studies of the ‘approaches’ that underpinned their development and spread.

The book describes five case studies about conservation agriculture (CA). The CA case studies are from Morocco, UK, Kenya and two examples from Australia and cover a wide range of different and specific CA technologies. Their impacts on ecosystem services were analyzed and policy points were derived.

Introduction

WOCAT has developed tools to document, monitor and evaluate SWC know-how and to disseminate this around the globe in order to facilitate an exchange of experiences. The book *where the land is greener* presents experiences based on case studies derived from WOCAT’s research and field work. *Where the land is greener* looks at soil and water conservation from a global perspective. This well illustrated book is the first hardcopy compilation of case studies by the WOCAT team. Over 40 technologies from more than 20 countries are described. There are some well established successes, but many little known ‘islands of promise’ also. Various land use categories are covered – rangeland as well as cropland. Nine categories of technologies are differentiated: manuring/composting, vegetative strips/cover, agroforestry, water harvesting, gully rehabilitation, terraces, grazing land management, conservation agriculture and ‘other technologies’. The technologies are supported by matching studies of the ‘approaches’ that underpinned their development and spread. Some of these are descriptions of projects, but several are fascinating explanations of how spontaneous development has occurred.

The book does not stop at case studies: there are two main analytical sections taking the technologies and approaches in turn, resulting from a systematic search for the common elements of success. Finally there are policy points for decision makers and donors – who are challenged now to invest in making the land greener.



Five cases of conservation agriculture (CA) are compiled in the book. These are from Morocco, UK, Kenya, and two examples from Australia. As well as outlining the success and potential of each system, the case studies present various problems solved by CA that include soil compaction, slugs, soil erosion and water inefficiency. They cover a wide range of different and specific conservation agriculture technologies. In the example from the UK the form of conservation technology applied improves soil quality through non-inversion tillage, which also improves cost-effectiveness and assists in timely crop establishment. The Kenyan case study describes the application of CA amongst small-scale farmers. Here the applied technology is further promoted through self-help groups. The case study from Morocco is a no-till system with a focus on careful crop residue management. Of the two examples from Australia, one presents experiences in ‘no-till with controlled traffic’ farming, which involves direct drilled grain production with permanent wheel tracks. The second example from Australia presents a case study entitled the ‘green cane trash blanket’. A short overview of the five technologies and their related approaches is given in Figure 1.

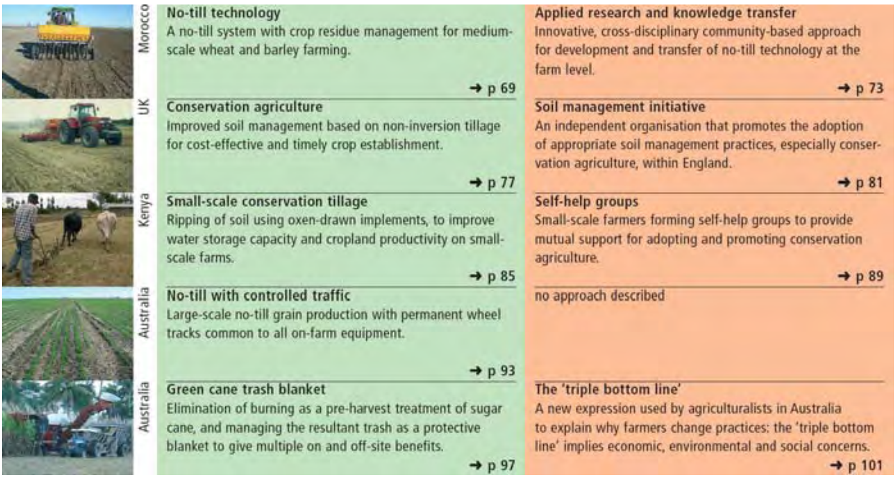


Figure 1. Overview of the five conservation agriculture case studies presented in the WOCAT book: *where the land is greener* (WOCAT, 2007).

The section that follows, extracted from *where the land is greener*, illustrates how cases are presented, using a standard format, and shows which information can be obtained from the WOCAT database on SWC technologies and approaches. The Australian example of the ‘green cane trash blanket’ has been selected, because of its multiple on- and off-site impacts. It is not only farmers that benefit in this case - but the Great Barrier Reef also.

Technology – ‘Green cane trash blanket’

Elimination of burning as a pre-harvest treatment of sugarcane, and managing the resultant trash as a protective blanket to give multiple on and off-site benefits

Under conventional production systems, sugarcane is burnt before being harvested. This reduces the volume of trash – comprising green leaves and dead leaves – making harvesting of the cane simpler, and subsequent cultivation of the soil easier. In the humid tropics of Far North Queensland, harvesting of cane used to be carried out by hand – as it still is in many parts of the developing tropics. Burning was necessary to make harvesting possible in a dense stand (and to reduce the danger of snakes). However, with the advent of mechanical harvesters in the 1960s, burning continued to be practiced through habit.

A new practice then brought fundamental changes in soil management: The ‘green cane trash blanket’ (GCTB) technology refers to the practice of harvesting non-burnt cane, and trash blown out behind in rows by the sugarcane harvester. This trash forms a more or less complete blanket over the field. The harvested lines of cane re-grow (‘ratoon’) through this surface cover, and the next year the cycle is repeated: the cane is once again harvested and more trash accumulates in the inter-rows. Generally the basic cropping cycle is the same, whether cane is burnt or not. This involves planting of new cane stock (cuttings or ‘billets’) in the first year, harvesting this ‘plant crop’ in the second year, and then in years three, four, five and six taking successive ‘ratoon’ harvests. In year six, after harvest, it is still common, even under the GCTB system, to burn the residual trash so that the old cane stools can be more easily ploughed out, and the ground ‘worked up’ (cultivated) ready for replanting.

A minority of planters, however, are doing away with burning altogether, and plowing in the residual trash before replanting. A further variation is not to plow out and replant after the harvest in year six, but to spray the old cane stock with glysophate (a broad spectrum non-selective systemic herbicide) to kill it, then to plant a legume (typically soy bean) as a green manure crop, and only replant the subsequent year after plowing-in the legume. Under the latter system, one year of harvest is lost, but there are added benefits to the structure and nutrient content of the soil.

Whatever variation of GCTB is used, there are advantages in terms of increased organic matter, improved soil structure, more biodiversity (especially belowground) and a marked reduction in surface erosion – from over 50 t ha^{-1} of soil to around 5 t ha^{-1} on average. Less erosion is good for the growers – but is also of crucial importance off-site, as sediment lost from the coastal sugarcane strip is washed out to sea, and damages the growing coral of the Great Barrier Reef (Figs 2 and 3).

Approach – The 'triple bottom line'

A new expression used by agriculturalists in Australia to explain why farmers change practices: the 'triple bottom line' implies economic, environmental and social concerns

A fundamental change has occurred in farming practice amongst sugarcane growers in the tropics of far north Queensland. Where it was once standard practice to burn cane before harvest (defoliating green canes for easier harvest), tradition has

Green cane trash blanket
Australia

Elimination of burning as a pre-harvest treatment of sugar cane, and managing the resultant trash as a protective blanket to give multiple on and off-site benefits.

Under conventional production systems, sugar cane is burnt before being harvested. This reduces the volume of trash – comprising green leaves, dead leaves and top growth – making harvesting of the cane simpler, and subsequent cultivation of the soil easier. In the humid tropics of Far North Queensland, harvesting of cane used to be carried out by hand – as it still is in many parts of the developing tropics. Burning was necessary to make harvesting possible in a dense stand (and to reduce the danger of snakes). However, with the advent of mechanical harvesters in the 1960s, burning continued to be practiced through habit.

A new system then brought fundamental changes in soil management: The 'green cane trash blanket' (GCTB) technology refers to the practice of harvesting

left: Harvesting of green sugar cane and simultaneous spreading of the separated residues, leaving a dense mulch cover, the so called green cane trash blanket. (Hanspeter Liniger)
right: A 'ratoon': a re-growing sugar cane sprouts through the trash blanket after harvest. (Hanspeter Liniger)

Location: Far North Queensland, Australia

Figure 2. The first page of the 4-page summary of the 'Green cane trash blanket' technology in Australia (WOCAT, 2007).

been turned on its head and now almost no one burns. Instead a 'green cane trash blanket' system has developed, with multiple benefits and few or no drawbacks so far.

Impacts of the technology

Production and socio-economic benefits		Production and socio-economic disadvantages
+	overall farm income increase	none

Socio-cultural benefits		Socio-cultural disadvantages
++	improved knowledge SWC/erosion	none
++	enhanced reputation of sugar cane growers as 'environmentally friendly'	

Ecological benefits		Ecological disadvantages
+++	runoff and soil loss reduced (from >50 t/ha to 5 t/ha; although the location is relatively flat, soil erosion can be high due to high rainfall)	none
+++	soil cover improvement	
++	loss of nutrients reduced	
++	increase in soil organic matter	
++	biodiversity enhancement (above and below ground)	
++	improved soil structure	
+	increase in soil moisture	
+	carbon sequestration increased	
+	efficiency of excess water drainage	
+	increase in soil fertility	

Off-site benefits		Off-site disadvantages
++	reduced transported sediments	none
++	reduced downstream siltation	
+	reduced river pollution	
+	reduced downstream flooding	

Figure 3. Benefits and disadvantages of the applied conservation technology - compiled in a standardized form for every case study, both in the book and in the WOCAT database (WOCAT, 2007).

There has been no official campaign or punitive sanctions imposed, no enticing financial incentives offered or charismatic environmental leadership – just a quiet technological revolution, based on the principles of the 'triple bottom line' (TBL). TBL has recently emerged into common usage amongst agriculturalists in Australia. Rather than attributing farmers' actions as simple responses to economic stimuli ('the bottom line') TBL is a framework that helps explain the complexity of factors that influence farmers to modify their practices. TBL suggests that farmers do indeed respond to money, but also to environmental

Participation and decision making

Target groups

Approach costs met by*:

State Government (Bureau of Sugar Experiment Stations)	20%
Growers themselves	80%
	100%

* rough estimate

Decisions on choice of the technology: Made by land users alone (sugar cane growers).
Decisions on method of implementing the technology: Made by land users alone.
Approach designed by: Farmers (with limited support from extension and research).

Community involvement

Phase	Involvement	Activities
Initiation	self-mobilisation	starting up the practice of green cane trash blanket (GCTB)
Planning	not applicable	no specific planning involved
Implementation	interactive	growers spreading the word, support by extension services
Monitoring/evaluation	interactive	growers joining hands with research
Research	interactive	ditto

Figure 4. Box about participation, decision-making and community involvement for the case study - in the standardized form (WOCAT, 2007).

concerns, and furthermore to social considerations as well. This gives credit to farmers for being responsible stewards of the land.

In this particular case, the transition in technology started in 1974, when sugarcane growers in the far north of Queensland were simply unable to burn their cane prior to harvest because of the exceptionally heavy rains. Instead, they had to harvest wet – and green. The technical implications were, *first* a slower harvest speed because machinery had to cope with a greater load of biomass, and *second* a thick residual blanket of trash that covered the soil. The multiple benefits of mulching were recognized by a few growers, who then continued to harvest green cane. Non-burning spread – a technology now described as the 'green cane trash blanket' – until almost every grower adopted it within one generation. While the extension service has supported the transition, growers themselves took the initiative to change. There are indeed small financial benefits, chiefly in terms of reduced overall input costs, but growers have simultaneously been motivated by social and environmental considerations. Burning has come to be considered antisocial: a dirty practice, carrying the danger of fire spreading outside the targeted fields. Neither is it a pleasant task, requiring help of family and friends, often at inconvenient times. From an environmental perspective, the benefits of trash mulch are tangible in terms of improved soil quality, and reduced erosion rates. And, equally important, the end result is the reduced damage to the nearby Great Barrier Reef with its sediment-sensitive living coral (Fig. 4).

Conclusion

The book *where the land is greener* represents successful and/or promising examples of conservation agriculture (CA) and shows how different these particular land management technologies can be. The improvements after implementing CA are remarkable in the five cases reported. An improved cost-effectiveness connected with a decrease in labor input is evident in all five studies. The 'No-till with controlled traffic' example from Australia shows a very significant reduction in labor; from the four men required under a conventional system to the farmer himself as the only person needed. Reductions of fuel cost were significant in the large-scale examples given. An increase in yield didn't appear in all cases, but due to less labor input, overall profitability increased in all cases. Soil organic matter increased remarkably with associated positive effects on soil fertility, soil quality and other related soil properties. All conservation agriculture/no-till examples studied enhanced soil cover on the fields with the positive consequence that surface erosion decreased dramatically and infiltration rates improved accordingly. Improvement in soil structure was noted within all the CA technologies. One of the problems facing conservation agriculture is the increased requirement of herbicides. This is especially evident in the case study from the UK, where there is concern about long-term impacts.

The book describes just five case studies of conservation agriculture under different conditions – a selection from the 20 examples about CA available in the WOCAT database. Of course, there are multiple experiences worldwide, based on local adaptations to no-till systems that have not yet been documented, evaluated or made available widely.

The WOCAT methodology facilitates standardized presentations of these experiences, and allows direct comparison with other SWC technologies or local practices. The methodology allows for the evaluation of the pros and cons of each practice and provides assistance for informed decision-making. In this way various conservation agriculture systems could be assessed and compared with CA alternatives or with other forms of sustainable land management. Thus, a proper documentation and evaluation of existing experiences needs to be strengthened in order to support land users, planners and decision-makers.

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Conclusion

Tom Goddard, Michael A. Zoebisch, Yantai Gan, Wyn Ellis, Alex Watson and Samran Sombatpanit

Perhaps it might not be appropriate to call this chapter 'Conclusion'; it is more likely that the chapter will summarize aspects of no-till which have been presented in the previous chapters. Each of the papers serves to illustrate various aspects or perspectives; together they provide a deeper and more comprehensive insight into the many variables inherent in our farming systems. We hope the authors' efforts to describe diverse applications of no-till systems may be useful to researchers and practitioners studying similar situations elsewhere.

Why are we so 'hard-wired' when it comes to tilling the land? The answer could lie in the intuitive reasoning that soils are generally hard, so how can plant roots penetrate? Or perhaps when we see weeds growing profusely, we fear they will compete with our crops for moisture and nutrients if we do not plow them into the soil first? Or is it for disease or insect control? Despite all these seemingly sensible arguments, readers will recall the quote in Edward Faulkner's *Plowman's Folly* (page ix, this volume) which reminds us that no-till practices have been advocated for several decades already. The materials presented in this volume provide ample evidence demonstrating how no-till systems can produce good crops in many regions around the world, on a range of farm and soil types. Moreover, the authors have given us a fascinating snapshot of the current state in the evolution of no-till towards minimizing soil disturbance, better residue management and an increasing understanding of nutrient cycling mechanisms. We hope that more practitioners will become aware of the versatility of no-till options and develop strategies to adopt no-till on their own land.

How much damage has been caused by tilling the land? Soils in their original state, either prairie or forest soil, generally contain high levels of organic matter (OM) and have many other favorable physic-chemical attributes. With cultivation, the OM content drops, productivity decreases and degradation risk (e.g. erosion) increases. One way to increase the OM content is to incorporate plant residues. In the words of Carlos Crovetto (pers. comm.), *"tillage machines destroy the soil surface by causing erosion and speeding up soil organic matter decomposition through the oxidation process. What a no-tillage system does is to copy as much as possible the action of Mother Nature, by increasing humic substances in the soil and making a very narrow slot where the seed and fertilizer is placed."*

What exactly are the benefits farmers may anticipate from adopting no-till? The technique has shown both theoretically and practically the ability to reduce (1) the use of fossil fuels, (2) farm expenses (increasing profit margins), (3) CO_2 emissions (to mitigate the CO_2 footprint of crop production), (4) soil erosion and, (5) forest encroachment (a concern of many academics, professionals and policymakers). While improving the energy and water cycle on the landscape, no-till can increase biodiversity (considered as one of the many environmental goods that no-till provides to society as a whole). Several authors in this book report the superiority of no-till to other practices, though not always consistently with crop yields. Yield improvements can lag through the initial transition years, showing signs of improvement only after several years. However, it has been claimed by many no-till advocates that in the longer term, no-till crop yields can match or exceed yields from conventional systems. Despite the generally long-term perspective needed to realize the full benefits of no-till systems, many papers in this book (e.g. Birkás et al., Kertesz et al., Diallo et al., Golabi et al.) show positive results from adoption of no-till systems even in the first few years, in the improvement of soil physical conditions and resulting characteristics (i.e. bulk density, infiltration, runoff and soil loss rates).

The relationship between no-till and organic agriculture is also a frequently asked question. Although even 'true no-till' practitioners concentrate on preserving and enriching the soil with plant residues, the practice is not considered 'organic' in the present-day sense, which prohibits use of inorganic fertilizers and farm chemicals. However, the paper of Jeff Moyer from the Rodale Institute shows a unique farming system that makes it possible to incorporate the benefits of no-till technology into a true organic farming strategy. By using the roller/crimper machine, organic no-till field operations for corn production are reduced from nine with a plow-till system to only two with the roller/crimper. This system has shown promising results in both corn and soybean crops. The organic no-till corn yield was greater than that from the standard plow-till organic corn and far greater than from non-organic chisel-plow systems.

Although the history of no-till goes back several centuries, modern no-till management systems began in earnest with the invention of paraquat in the mid-1950s. Field trials began in UK and U.S.A., and extended to Latin America in 1971; subsequently the practice was rapidly adopted by farmers. Recent data on adoption levels of no-till by farmers in Mercosur countries (Brazil, Paraguay, Uruguay and Argentina) have shown adoption rates of 60% or greater, with future projections reaching 85% in less than a decade from now. As practiced in Latin America, no-till systems are mostly categorized as permanent no-till, with no intermittent tillage. In the U.S.A., where the total no-till area accounts for 22% of the arable land – the highest no-till area in the world – only 10-12% of this area (a little more than 2% of the whole arable land of the country) belongs to the permanent no-till category, the remaining land does not realize the full potential benefits of long-term no-till. The first article by Rolf Derpsch in this book offers a nostalgic account of the development of modern no-till systems over the past half century.

Worldwide, approximately 95 million hectares are today under no-till management. Of this area, roughly 47% is in Latin America, 39% in the USA and Canada, 9% in Australia and about 3.9% in Europe, Africa and Asia. Adoption in

Latin America has increased by 59 times in less than 20 years, compared with only 5.9 times for the U.S.A. Why did Latin American farmers embrace no-till so rapidly?

The many contributing factors are summarized well by Rolf Derpsch in his second paper as a 10-step list of guidelines for adoption of no-till. The guidelines underline the need for adequate preparation time early on starting with a change of mindset. He points out that the often considered first step in adopting the practice that many people think of – the purchase of machinery for no-till farming – appears later as the seventh step. Therefore, to shift from conventional farming to conservation farming undoubtedly requires strong will, commitment and planning on the part of farmers as well as learning what and how others have succeeded or failed before them.

Other studies of adoption can be found in other chapters (Mitchell et al., Napier, Basch et al., Gan et al., Bhan and Bharti, and Baker). Even in rice fields, no-till for one of the two crops in a year can also achieve good results, as witnessed in India (Bhan and Bharti) and Thailand (Sombatpanit, personal experience).

Is no-till equally feasible in both developed and developing countries? Indeed, the data show that no-till systems are versatile and can be applied in every country; however, farm size is an important factor. Medium to large size farms have succeeded more often than smaller enterprises. One reason for this is that only a few countries have invested in research and developed appropriate technologies for small farmers. Brazil is among the few countries that manufacture specialized equipment for small farmers (1- and 2-row seeding machines, sprayers, knife rollers, fertilizer and lime spreaders for animal traction, hand jab planters, etc.). Rolf Derpsch in his first chapter reported that in 2002 there were around 200,000 small farmers operating no-till on approximately 450,000 ha and more recently many small farmers in Ghana and India have turned to no-till management. However, more R&D is needed to facilitate the extension of this technology to more small farmers in various countries.

Precision agriculture (PA) is another radical step forward resulting from technology convergence, and has demonstrated its value in optimizing the input-output relationship in crop production. Rohan Rainbow's chapter describes how Australian scientists and engineers succeeded in reaching higher level of crop production through no-tillage. They studied complementary field management systems such as PA and controlled traffic. Controlled traffic systems protect soils that are prone to compaction and allow fertility cycles to occur unimpeded. The technologies used in PA fully complement no-till, and can amplify the benefits of both no-till and controlled traffic systems.

Adoption of no-till does not remove our dependency on machinery and chemicals in agriculture. However, it can and often does reduce the overall amount of machinery and tractor hours; on the other hand no-till machinery is often complex and requires additional skills for operators. The lower intensity of the use of machinery reduces the amount of fuel, resulting in cost savings and lower CO_2 emissions (fewer equipment types needed also reduces the energy required for manufacturing). No-till systems leave weed seeds on the soil surface where they either do not germinate, or else produce weak seedlings with shallow roots that are more susceptible to stress. Weed populations do however shift with no-till, so new weed pressures are inevitable. Continuing research efforts are needed to find new ways to reduce on-farm chemical use, particularly herbicides, in order to minimize environmental impact.

Conservation Agriculture (CA), with no-till as its core technology, has been the focus of interest of many international and development organizations (e.g. CIMMYT, CIRAD, ECAF, FAO, GTZ, World Bank). In the Erenstein et al. paper, CIMMYT's diverse experiences attest to the wide adaptability of no-till which can generate clear economic benefits, including substantial reductions in production costs and increased yields. Presently, CIMMYT has been applying CA in Mexico, Southern Africa and South Asia. Apart from the crop yield, it realizes there are enormous environmental benefits, especially when fresh water becomes scarcer and as climate change begins to bite. Experiences from several years show that farmers, researchers, service providers and machinery manufacturers need to be linked within an innovation system that fine-tunes equipment and crop management while strengthening local institutions.

In terms of national and regional policies towards conservation agriculture involving no-till, Mazvimavi and Twomlow of ICRISAT have provided us with an excellent overview of the policy context in Zimbabwe, where conservation agriculture is well recognized as a drought mitigation strategy. In recent years ICRISAT implemented a strategy to help drought-affected farmers to apply crop inputs more efficiently by introducing the use of planting basins and to apply a small amount of N fertilizer precisely at critical crop development stages. The strategy was an immense success, resulting in yield increases of up to 15-75% in more than 300,000 farm households. It is important to note from this work that practicing conservation agriculture requires a greater time commitment from farmers, a fact which may act as a hidden deterrent to wider adoption.

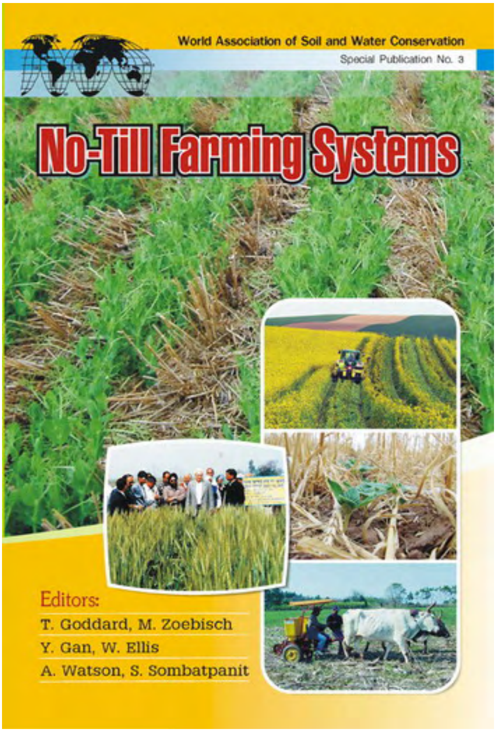
The European Conservation Agriculture Federation (ECAF) shows that for the total arable land of Europe, there are only 15.5% and 1.1% land practice to CA and no-till, which is very small when comparing with other regions (Basch et al.). But the increased awareness of farmers, politicians and society that soils are a non-renewable resource is leading to gradual changes in the overall approach to soil conservation. The implementation of a European Soil Framework Directive is considered to be an important step towards the recognition that conservation tillage and no-tillage are both an economical and ecological sustainable method for crop production.

Séguy et al. describe an example of a CIRAD (French international development organization) developed agro-ecology cropping system in Laos and Madagascar called **D**irect Seeding **M**ulch-based **C**ropping Systems (DMC) and demonstrated its *triple benefits* – environmental, social and economic. Hanspeter Liniger et al. in their paper on WOCAT's assessment of Australian's green cane trash basket similarly call these benefits '*triple bottom line*'. These benefits are also illustrated by the account in the paper by Baker showing that in New Zealand, which does not subsidize its farmers, adoption of no-till is market-driven, and can be used as a barometer for economic success and environmental improvement. These many benefits will surely become more widely documented and quantified by researchers in the future.

What is the future of no-till? According to Baker, growing alarm over the reality of global warming, rising food prices, and increasing competition for land use from biofuels are major factors driving increased adoption of no-till systems. We can therefore expect continued expansion of the no-till acreage for many years to come. Dennis Garrity, writing in his foreword for this book states, "More work related to the use of such practices will need to take place quickly, i.e. it takes time for the soil and plant system to reach a new equilibrium. Long-term research was therefore required to unravel the puzzle. Research is venturing into new areas such as how innovative cropping systems and residue management can influence soil biological activity and nutrient cycling. Biological tillage is replacing mechanical tillage, and more attention is being given to cropping systems and agronomic practices to control weeds and replace the myopic view of 'herbicides only'. It is the responsibility of all of us involved in no-till to ensure that such efforts continue into the future so that no-till can be adopted on a far greater scale across the agricultural systems around the globe."

You have just read Introduction (Les Brown), a CIMMYT paper, a WOCAT paper and Conclusion by the editors.

Other chapters with details about no-till research, development, policy, etc. in 20 countries, are available in the 544-page book.



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Contact Samran Sombatpanit at sombatpanit@yahoo.com for more details or to order copy(ies). You can also buy the book locally and pay in local currency at any address in the next pages.

COUNTRIES WHERE THE *NO-TILL FARMING SYSTEMS* BOOK ARE AVAILABLE TO BUY LOCALLY, USING LOCAL CURRENCY:

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ANNEX I

New Book

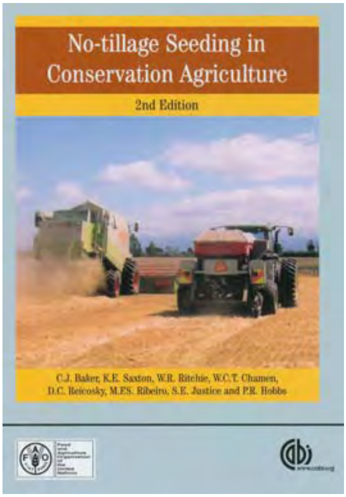
No-Tillage Seeding in Conservation Agriculture

Authors: *Baker, Saxton, Ritchie, Chamen, Reicosky, Ribeiro, Justice and Hobbs*
Editors: *C.J. Baker and K.E. Saxton* (baker@crossslot.com)

A Summary

This 326-page book is an expanded second edition of *No-Tillage Seeding: Science and Practice* (Baker, Saxton and Ritchie), first published in 1996. The second edition was commissioned by FAO (United Nations) and published jointly in 2006 by FAO and CABI, England.

FAO explained why it commissioned the book in a Foreword penned jointly by Shivaji Pandey and Theodor Friedrich. The preface is contributed by the editors and outlines why the book was written and how the reported science has already dictated the design of Cross Slot® no-tillage technologies.



The book's 19 chapters draw on research conducted at New Zealand's Massey University and U.S.A.'s Washington State University that helped identify and eliminate many of the causes of previous biological failures in no-till systems. Other research is reported from the U.S. Department of Agriculture; 4Ceasons Agriculture and Environment, U.K.; Instituto Agronômico do Paraná, Brazil; National Agriculture and Environment Forum, Nepal; and Cornell University, USA.

The book sets the scene by outlining the fundamental principles of no-tillage. The first chapter reports the benefits of no-tillage, many of which are due to maintaining or increasing soil carbon levels. These benefits are given some perspective in a chapter on risks (biological, physical, chemical and economic) associated with no-tillage systems. The authors argue that the risks of crop failure (or even partial failure) are increased when the levels of technology and/or management are decreased, i.e. cheap no-tillage solutions greatly heighten the risk of failure.

The authors illustrate how technical differences between a range of no-tillage machines can be traced back to how their openers operate in the soil. In this respect, the authors dissect opener functions in greater detail than has hitherto been reported elsewhere. For example, the authors examine an extensive range of opener designs that exist, in terms of how they create seed slots and how (or whether) they cover these slots. They even quantify the value of different forms of slot covering material, distinguishing between loose soil and mulch as well as combinations of the two.

Then, in separate chapters, the authors detail the biological responses of various basic opener designs in dry soils, wet soils, and a wide range of surface residues. The authors highlight the unique value of vapor-phase soil water in no-tillage, since the very act of performing conventional tillage virtually eliminates vapor-phase water from performing any significant role in tilled soils. Similarly, the authors explore the role of soil aeration, infiltration and earthworms in wet soils and how all of these factors can be influenced (or more importantly, harnessed) by good no-tillage opener designs.

The importance of, and opener-design-options for, controlling seeding depth in varying soil conditions are examined, together with the desirability of "double shooting" (delivering separately) seed and fertilizer under no-tillage. Its effects on crop yield (compared with broadcast fertilizers) are examined together with the pros and cons of a range of design options for banding fertilizer separately from seed during no-tillage.

Since true no-tillage has much to do with minimizing surface residue disturbance, a separate chapter is devoted to comparing minimum and maximum residue disturbance options in terms of both crop responses and technology design options and a further chapter examines the mechanisms and problems of residue handling by openers.

There is a special chapter on no-tillage for forage cropping that supports the view that all competing vegetation does not necessarily need to be removed prior to seeding when crops are to be fed to animals. The chapter on management of no-tillage systems places emphasis on planning and even gives an example of typical time-line decision-making.

Having outlined the major factors influencing the biological success or failure of no-tillage machines and systems, the book moves logically into an analytical discussion of critical engineering aspects of machine design as they relate to both small-scale and large-scale machines. The book acknowledges that some of the more desirable design features of large-scale machines are impractical and uneconomic to reproduce on small-scale machines that are constrained by limited budgets; the effects of the resulting design compromises on biological risk are also documented.

Because no-tillage is one part of a complex food production system that involves repeated exploitation of the thin and fragile layer of croppable top soil that covers only 4% of the world's surface, other related soil sciences are also integrated into the book. In particular, the importance of soil carbon is dealt with in detail, both in relation to how no-tillage minimizes losses of soil carbon during seeding (compared with conventional tillage) and how it sequesters soil carbon that feeds soil fauna. In turn, soil fauna have much to do with creating soil structure that is essential for maximizing crop yields and minimizing soil erosion. Since compaction from vehicle wheel traffic is almost always detrimental to soil health, the complementary practice of controlled traffic is examined as it has the capability to limit wheel compaction to designated traffic areas and leave productive soils unaffected.

Finally, a book on no-tillage would not be complete without some examples of economic comparisons, which almost invariably come out in favor of no-tillage over tillage. A separate chapter is also devoted to the experimental techniques and procedures used to improve our understanding of the differences between methods of no-tillage. Some of these techniques are unique since some of the authors themselves pioneered aspects of agricultural research that had not previously been examined in detail or under controlled conditions.

The book therefore provides a useful reference for students and scientists alike, but is also designed to appeal to practitioners. Anyone who has attempted or been associated with no-tillage in any context should find this book enlightening. In many cases it will help show why otherwise-unexplained crop failures have occurred when inappropriate equipment, methods, and/or management practices have been applied.

Some 300 quoted references attest to the depth of information sourced for this easy-to-read but information-filled book. A review of this book by T. Francis Shaxson can be read from the BOOK REVIEWS page of WASWC website at http://waswc.soil.gd.cn.

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The Editors: **John Baker,** CEO, Baker No-Tillage Ltd and President NZ No-Tillage Association (Inc.), New Zealand (baker@crossslot.com, www.CrossSlot.com); **K.E. Saxton,** formerly of USDA, ARS, U.S.A.

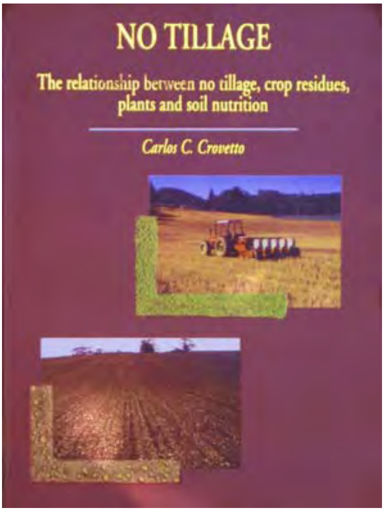
ANNEX II

New Book

NO TILLAGE
The relationship between no tillage, crop residues, plants and soil nutrition

Carlos C. Crovetto

Ten years have elapsed since Carlos Crovetto published his book “Stubble Over the Soil: an introduction to no tillage”. His work has already been edited five times, has been published in four languages and is considered a pioneer work of a farmer for farmers all over the world. The author is now offering his book “No Tillage”, which approaches readers to this new system of soil management.



The author has given lectures in 20 countries, having been 40 times in Argentina, a county where in 15 years traditional agriculture was revolutionized by “direct sowing”. Today, over 17 million ha and 70 manufacturers of machinery for direct sowing have displaced traditional farming practices and tillage implements.

In United States of America he has had a strong influence in forming more conservation-minded farm producers in California, North Carolina, Georgia, Pennsylvania, Delaware, Maryland, Illinois, Ohio, Kansas, North Dakota, and Washington. His agricultural extension work has been recognized by institutions like the Soil and Water Conservation Society, granting him three awards, the last being the “Hugh H. Bennett” Award, the highest distinction, presented to him in August 2001. In the same month and year, the American Society of Agricultural Editors, conferred to him the “Distinguished Services Award” for exceptional and meritorious service to American agriculture.

Intellectually formed under the guidance of important conservationists like W.C. Lowdermilk, E.H. Faulkner, M. Fukuoka, A. Primavesi, J. Molina, and others, Crovetto has been able to stop the erosive processes and recover the productivity of his Chequen farm, with generous devotion and love for his soil.

In this new work, Carlos Crovetto shows us something unique and unpublished. Most of the scientific research and results he shows have been obtained in his farm. He has attracted the interest of Chilean and Foreign Universities, proudly showing Chequen soils after 49 years of profound changes.

During the official release of Carlos' book "Stubble Over the Soil" the former President of the American Society of Agronomy (ASA, 1996) Jerry Nelson stated: "This is the first time that our society (ASA) has published a text about agronomy that has been translated from a foreign language into English, as well as it is the first time we have edited a book written by a farmer. This marks of profound change in our scientific behavior, by accepting farmer experiences materialized with a scientific rigor."

Profound changes proposed by the author and strengthened by his close relationship to the soil will surely help the reader to better understand his most important resource: the soil. At the same time, the agronomic community shall find a remarkable example of a vicious and complex circle of agricultural sustainability.

From the back cover of the book by ***Edmundo Acevedo H.,*** *Eng. Agr. PhD, Faculty of Agronomic Sciences, University of Chile, Santiago, Chile*

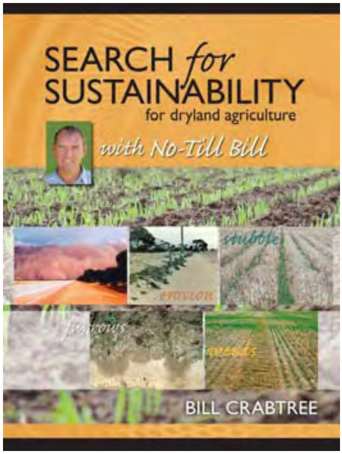
NO TILLAGE: The relationship between no tillage, crop residues, plants and soil nutrition.
ISBN: 956-310-178-6, published in Chile by the author in 2006. 216 pp. Contact Carlos Crovetto at crovetto@entelchile.net for information how to obtain a copy. In U.S.A. you may order from www.conservationinformation.org

ANNEX III

New Book

Search for Sustainability for Dryland Agriculture

by Bill Crabtree



One of Australia's most recognized authorities on no-tillage is "No-Till Bill". Now, after 22 years of research, observations and interaction with no-till innovators he shares his views on the quest to help make the most arid country in the world a sustainable agricultural continent. Bill is an alternative thinker. He is constantly exploring new ways to improve agriculture, and his unconventional determined style has made him a unique character.

Australia is a fascinating country with limited rainfall and some of the most infertile soils. It is a large country, with farms to match. Australian farmers have some of the lowest level of agricultural subsidy of any country. These factors have combined and resulted in a large number of innovations that have led to many new agricultural inventions that have originated in Australia.

This book covers more than just no-tillage, it discusses the land, climate, soils, machinery, agronomy, some animal production and the challenges of fixing problems. It explains situations where tillage may need to be adopted for specific problems, but warns of the risks and exhorts farmers to continue with no-tillage regimes because of the vast range of benefits that result from its sustained use. The book explains at length the weed control and moisture retention benefits that exist in the winter wet and summer dry climates of southern Australia. There is also discussion of sheep, pasture and cover crops and their role in crop rotation, and discussion on the possible future of sustainable agriculture in Australia. The book contains many photos and some graphs and is available for purchase at www.no-till.com.au.

Note: Bill Crabtree (bill.crabtree@wn.com.au) is affectionately known as "No-Till Bill" for the courageous stand he took in promoting no-tillage against popular opinion, in the early 1990s. It was partly this stand for what was right, that won him respect throughout the Australian farming community. He was thanked for this work with two awards. In 1996 he was Landcarer of the Year for Western Australia, and in 2006 he won the prodigious "Seed of Light Award" for excellence in communication.

Bill has an active agronomic consulting business and manages three diverse and important companies in WA. He obtained his B.Ag.Sci and M.Sci from the University of Western Australia and is currently the state Manager for Seed Hawk seeders and AgGuide gps steering systems. He is also the CEO of Green Blueprint International Ltd, who is working on developing a frost resistant wheat. Bill travels widely and speaks on no-tillage, GM technology and sustainable agriculture. He employs three full time staff and is based in Perth, Western Australia. Bill has recently returned to farming on a 9,000 acres property.

Book contents

ANNEX IV

New Book

BLUE AGRICULTURE

Italy's Approach to Conservation Agriculture

Principles, technologies and methods for sustainable production

By

Benites, Benvenuti, Cantile, Campisi, Ceccon, Di Tullio, Caruso, Gonzalez, Holgado, Intrieri, Mazzoncini, Miravalle, Mosca, Pipia, Pisante, Prosdocimi Gianquinto, Ramazzotti, Rotundo, Santilocchi, Sartori, Stagnari, Tabaglio, Tagliavini, Torres, Venturi.

Editor: *M Pisante* (mpisante@unite.it)

Published by: Il Sole 24 Ore Edagricole, Bologna, Italy (In Italian)

(www.edagricole.it, www.edagricole.com)

December 2007

The name BLUE AGRICULTURE was coined by the Italian Association for an Agronomical and Conservative Land Management (AIGACoS). Blue refers to water and the environmental benefits of Conservation Agriculture (CA). The four main principles of CA are: *maintaining soil cover with plant residues, reducing mechanical soil disturbance (tillage), restricting in-field traffic to permanent wheel tracks, and the use of rotation and cover crops.* Adoption of CA in Italy is still low in comparison with other countries; nevertheless, minimum tillage is more common than no-tillage.

This book draws on the expertise and practical experience of experts at Italy's leading research institutes and universities. The book describes their collaborative efforts to investigate, develop and teach practices to (a) increase the productivity of rainfed agriculture in drylands, (b) make a significant contribution to meet basic food needs, and (c) encourage adoption of farm practices that retain water

for increased productivity and improved land quality. Soil moisture utilization for enhanced crop production can be improved through maximizing the capture, infiltration and storage of rainfall water into the soil. An absorptive, organic matter-rich and biologically diverse soil can be achieved through the application of the four principles of Conservation Agriculture as described above.

This 257-page book represents the first Italian publication describing these principles, technologies and methodologies. It uses clear terminology, and provides numerous practical examples of the use of CA to reduce soil erosion and increase productivity in both annual and perennial crops. The book has three sections. The first section deals with the agronomic and environmental concepts and principles of CA as an integrated production system for water and soil management and conservation. There is also a general overview of CA experience in Italy, Europe and worldwide. The Visual Soil Assessment (VSA) method is also described as a practical tool for soil quality monitoring.

The second section describes integrated management systems in CA (annual cropping systems, crop rotation techniques, and guidelines for transition from conventional to conservation agriculture). This is followed by strategies for the adoption of CA in Italy for several annual crops such as durum and winter wheat, corn, soybean, sunflower, canola, vegetables, field horticulture and fruit crops, as well as long-term crops such as olives and viticulture. Suggestions are given to help farmers make the transition from conventional to conservative agriculture.

The third section describes in one chapter developments in the mechanical tools and equipment for CA. In particular it reports on new technologies for machinery such as no-tillage, and shallow and deep methods of minimum tillage. The next chapter provides an economic analysis of costs and profitability of CA. The concluding chapter highlights the energetic-economic comparative advantages of CA, based on a study conducted in Italy for annual crops (corn, wheat and soybean).

The book provides an in-depth discussion of the most important issues in soil erosion phenomena that to a large degree are responsible for the landscape we see today in Italy. Erosion accounts for the formation of plains, valleys and plateaux, the levelling of mountains, and the accumulation of the material that has been eroded from them. Despite the importance of erosion in creating the very areas of our country now used for modern agriculture, accelerated erosion, in which soil erosion outpaces land formation, can have detrimental, even disastrous consequences for agriculture, the environment, and the biodiversity that inhabit fragile ecosystems.

The shift from conventional to CA requires the implementation of several aspects: (a) exposure of farmers to different CA practices, particularly through participatory activity and on-farm demonstrations to show the benefits and practicality of new techniques, tools, equipment, and cropping techniques; (b) training in the practical use of new technologies, combined with flexible funding mechanisms and incentives, particularly during the period of transition; (c) fostering cooperation and dialogue between scientists, suppliers and farmers, and between government and educational institutes; (d) development and use of farmer-friendly tools to measure soil physical health and water-use efficiency; and (e) achieving and publicizing improvements in land productivity, reduction in farming costs, and environmental benefits (e.g. carbon sequestration) resulting from the application of new CA practices, within the BLUE AGRICULTURE integrated management system.

Both our future food security and conservation of the global environment will in large measure depend on advances in the science and technologies of sustainable agriculture, particularly CA. Achieving such advances is indeed possible, but meeting these challenges will require major increases in investment in specific research areas, both in Italy and at a global level. The ever-present challenge in agriculture is to optimize farm productivity in a sustainable fashion, while maintaining the quality of farmers' livelihoods, and minimizing impacts and degradation of the broader landscape. This is particularly true for drylands, where productivity is already low, options are limited and where many rural people live in poverty.

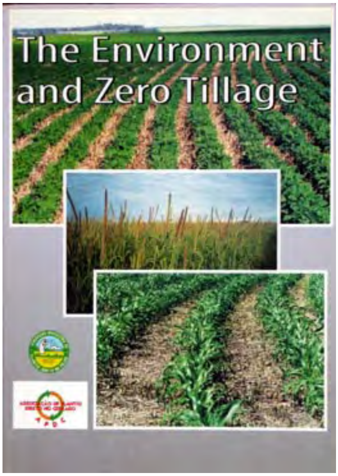
The book has over 250 figures, including several pictures and tables explaining and demonstrating the diverse range of applications of CA and the experimental results from Italy and international studies. Key references and internet resources are reported at the end of each chapter.

ANNEX V

Recently Published Book

The Environment and Zero Tillage

Edited by Helvécio Mattana Saturnino and John N. Landers
Translated by John N. Landers



This impressive book, published recently in 2002, offers a collection of papers by 13 distinguished authors, presented at the 5th Brazilian National Zero Tillage Meeting at Goiânia, Goiás State of Brazil in 1996. The book was first published in Portuguese, then later translated to English. The following extract has been taken from the book's Foreword.

Taking advantage of the highly positive results of the 5th Brazilian National Zero Tillage Meeting in 1996, this book was edited in Portuguese in order to better inform both the farming community and environmentalists, ecologists, politicians, opinion formers, and the general public of the benefits of this new technology, Zero Tillage, which establishes as strong link between the concerns of soil conservation and obligations to the environment. The English edition, translated and published with the support of FAO, brings an international dimension to Brazil's pioneering efforts.

When, in 1995, I had the opportunity to show the Nobel laureate research scientist Norman Borlaug what was being achieved in Brazil in reclaiming the infertile, acid soils of the "Cerrado" (Tropical Savannah) and Amazon regions, we sought to show him that we had at our disposal technologies for sustainable agriculture in the new frontiers of Brazil.

Referring to what he had seen, Dr Borlaug declared in lectures given in Belo Horizonte and São Paulo:

"It is agronomic management – such as planting at the right time, including Zero Tillage, which I admire because it reduces both erosion and costs – which allows expression of the genetic potential of the new varieties" (April 1995).

"In 1995, I had the pleasure to visit various pars of the Cerrado region. I saw many large-scale mechanized operations, in which not only was liming employed but fertilizers were used to very good effect. Also, Conservation Agriculture was practiced, for instance with Zero Tillage and Minimum Tillage, which leave the crop residues on the soil surface in order to increase soil organic matter and reduce erosion. In the central savannahs visited I saw little erosion." (May 1996).

These conclusions complement the declaration of the speakers at the 5th Brazilian National Zero Tillage Meeting, where the papers presented expressed the authors' convictions on the subject of Zero Tillage (ZT). This meeting counted on the illustrious presence of Alberto Duque Portugal, President of the Brazilian National Research Corporation – Embrapa; Paulo Alfonso Romano, the (National) Secretary of Water Resources of Brazil's Environment Ministry as well as the representative of José Roberto Marinho, President of Radio Globo and Chairman of the Board of Directors of WWF-Brazil and Garo Batmanian, CEO of WWF-Brazil.

In the words of the President of Embrapa, we note the auspicious development of Zero Tillage, giving credit to those who merit it:

"We researchers started late in this question (Zero Tillage), in which the farmer took the lead. I would like to underline the initiative of the farmers of Central Brazil who pressured research to get involved with Zero Tillage. As a means of improving the identification of research demands, we have learned that we should pay great attention to what the farmer is saying, because he knows what he's talking about".

With the involvement of the government research institutions alongside the efforts of the farm input suppliers in divulging this technology both pressured by the farmer in his untiring quest for progress, creative and ever-willing to try new practices, we are progressing surely in the direction of greater and greater adoption of Zero Tillage. The annual area covered by protective crop residues is growing every year, already covering 4.5 million hectares in 1995/6 and extending to over 14 million hectares by 1999/2000 (figures for the summer-planted main crop area plus winter small grains).

In describing this picture, it is our duty to recognize the apostolates of three untiring companions in the dissemination and promotion of Zero Tillage, all motivated by their ideals: Manoel Henrique Pereira and Herbert Bartz of Brazilian origin and John N. Landers, an Englishman adopted by Brazil. They merit recognition from both farmers and technicians, all peers in the promulgation and stimulation of sustainable agriculture, practiced throughout the country.

Fernando Penteado Cardoso
Agrolida Ltda., São Paulo-SP, Brazil

The Environment and Zero Tillage, Edited by Helvécio Mattana Saturnino and John N. Landers, Translated by John N. Landers, Brasilia: Associação de Plantion Direto no Cerrado, 2002. 144 pp. ISBN: 85-865006-01-x.

Cover photos show that crop rotation and good biomass generation are fundamental to sustainability.

Copies of the book may be obtained from:

- APDC. SCLRN 712 Bloco C Loja 18 – Brsilai – DF – Brazil – Cep 70760-533; Phone: 55 (61) 272-3191/273-2154; Fax: 55 (61) 274-7245; apdc-DF@terra.com.br or john.landers@uol.com.br
- FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy. Ask Theodor Friedrich at theodor.friedrich@fao.org.

地球之希望

WWW.EARTHSHOPE.ORG

EARTH'S HOPE

Envisioning a Future without Poverty and a World with Intact Ecosystems

Introduction to the Earth's Hope Project

The Environmental Education Media Project for China (EEMPC) has documented the rehabilitation of China's Loess Plateau since 1995 at the request of the World Bank. The findings and images have been presented to over 100 audiences in China, the UK, France, Singapore, Rwanda, Tanzania, Ethiopia, South Africa and the USA.

Loess Plateau: The Geography

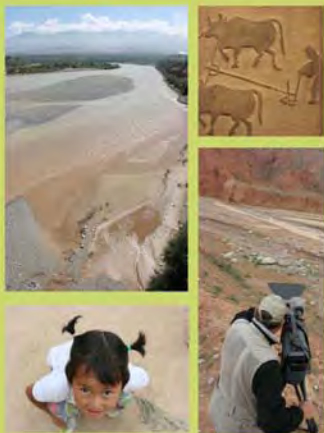
The Loess Plateau is approximately the size of France. It's named for the powdery loess soil that is its primary feature. These mineral-rich wind-borne sedimentary loess deposits accumulated over geologic time and can be hundreds of meters thick.

The Loess Plateau stretches over parts of seven Chinese provinces: Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi and Henan.

Humans and their ancestors have lived in the Loess Plateau for more than 1.5 million years. Settled agriculture first emerged between 9,500 and 10,000 years ago. This is the place where the Han, Qin, Tang and several other Chinese dynasties flourished.

Since the advent of settled agriculture, the fine, powdery loess soil has eroded continuously, and in ever increasing amounts, until the Plateau became the most eroded places on earth.

Chinese history is well documented and we know that the Yellow River has flooded more than 1,500 times in recorded history.



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Cycle of Poverty and Ecological Destruction

Research shows that in the Loess Plateau, a pristine nurturing ecosystem was fundamentally altered by human impact, leading to almost total ecological devastation over a vast area.

Cutting the forests and preparing the earth to plant crops exposed the fragile loess soil to wind and rain, causing the erosion that created massive gullies and a cycle of flooding, drought and famine. Removing the vegetation cover also disrupted the decaying plant litter and devastated the microbiological layer near the soil surface, destroying the cycle of natural fertility and disrupting the ability of water to be absorbed into the soil during rainfall.

Gradually wild plants and animals disappeared. People planted crops on steeper and steeper sides of the gullies and took their sheep and goats further to eat grasses and bushes hoping to eke out a living. However, with their own activities further degrading the natural systems, the people became mired in poverty.

Rehabilitation

It takes an overarching and ambitious vision to believe that what was destroyed over 10,000 years can be restored; yet a little over a decade ago this is what the Chinese began to do.

1. Planning:

Chinese and international planners worked together with experts in hydrology, soil dynamics, forestry, agriculture and economics to design a workable project plan. The team divided their work into two areas: economic and social well-being of the people, and ecologic health of the environment.

2. Policy:

From the planning process, four main policy decisions emerged.

i. Ban on tree cutting – following the devastating floods of 1998.

ii. Ban on planting on steep slopes – reversing centuries of unsustainable agricultural practice.

iii. Ban on free-range grazing of livestock - protecting plants and soils.

iv. Land tenure – clear policies on land tenure were established.

3. Participation:

It was critical to engage the local people to understand and participate in the rehabilitation efforts, and to convince them of the value of rehabilitation work.





4. Engineering:

The Loess Plateau had been so fundamentally altered that restoring economic productivity and ecologic health required basic engineering.

Sustainable water management – it is critical a watershed does not depend on water diverted from other watersheds or from finite underground supplies.

Terracing – flat fields created on the sides of gullies and hills and well-maintained, will reduce erosion while providing economically viable fields.

Sediment Control Dams.

5. Vegetation Cover:

Dune stabilization – to halt the movement of sand dunes afflicting the most fundamentally damaged areas.

Grasses and bushes – indigenous or well-suited varieties are planted.

Trees – through an integrated approach of afforestation and policy change, returning trees to the region is a chance to correct the damage that was done over thousands of years.

Perennial crops (orchards) – an excellent way to stablize the soil cover, while raising incomes and diversifying the economies of small farming communities.

Outcome

Over the past decade as we have documented the Loess Plateau an astounding transformation has taken place, proving it is possible to rehabilitate large-scale damaged ecosystems.

We have filmed as once denuded hillsides came alive with grasses, bushes, trees, birds and insects. Humidity is changing as the hydrological cycle is restored. The entire dynamic of the plateau has changed.

The seemingly hopeless cycle of poverty and ecologic destruction has been broken.

6. Active and Passive Measures:

Active measures generate income from economically viable cropland. An important finding is that when sustainable water and land use are in place, passive rehabilitation methods that let nature restore itself may be more effective than active ones for ecological rehabilitation.

Implications

The lessons of the Loess Plateau have profound implications for the local people, the Yellow River basin and global ecology.

- Ecosystem functions – demonstration of the possibility of restoring fundamental systems that were disrupted by humans, such as the natural fertility of the soil and the hydrological cycle over a huge scale.
- Yellow River Basin – rehabilitation is reducing the levels of eroded loess that led to the dangerous cycle of flooding, drought and famine.
- Sandstorms – restoring vegetation cover reduces the risk of sandstorms originating in the Plateau.
- Climate change – increased vegetation cover and soil organic matter over this huge area is offsetting CO_2 emissions worldwide that are exacerbating climate change.
- Model – the restoration of the Loess Plateau can serve as a model for other regions.

Paradigm Shift in Human Consciousness

The lessons of the Loess Plateau are fundamental to humanity overcoming the massive environmental challenges we face.

Protecting ecologically sensitive land results in massive long-term benefits to soil, biodiversity and climate; whereas trying to exploit these areas for economic benefit only causes more degradation and does not lead to significant financial returns.

In the Loess Plateau we are witnessing a paradigm shift in human consciousness that is addressing mistakes of the past. These lessons could be applied to other damaged ecosystems and could help guide humanity towards a sustainable future.

www.EarthsHope.org

Envisioning a Future without Poverty in a World with Intact Ecosystems

WASWC: Its History, Operations and Publications

By

Bill Moldenhauer and David Sanders (2003)
Updated by Samran Sombatpanit (2007)

WASWC was established in 1983 with the help and support of the Soil and Water Conservation Society (SWCS) of the U.S.A. The original purpose was to support international activities of both SWCS and the International Soil Conservation Organization (ISCO). The world was divided into nine regions with at least one Vice President from each region. Since there was little contact among ISCO participants from one biennial conference to the next, our first priority was to publish a quarterly newsletter with meeting announcements, international conservation news, book reviews, member news, etc. From the beginning, we tried to give recognition to, and a forum for, workers in the international field who had published mainly in the "gray literature" (company, Government (GO) and non-governmental (NGO) agency and organization reports that had had very small circulation).

This continues to be one of our most vital functions. By 1986 there was great interest in the Food and Agriculture Organization (FAO) of the United Nations and many GOs and NGOs in just how effective their international programs were in solving problems in developing countries. WASWC and SWCS organized a workshop in Puerto Rico with the help of several donor organizations and invited speakers to address the success (or failure) of donor sponsored soil and water conservation and land husbandry programs in developing countries worldwide.

This was a very successful conference and resulted in two publications published by SWCS, *Conservation Farming on Steep Lands* and *Land Husbandry: A Framework for Soil and Water Conservation.* Since our Puerto Rico workshop we have held a workshop in Taiwan in 1989, one in Solo, Central Java, Indonesia, in 1991, and one in Tanzania and Kenya in 1993. These have all been published and were circulated by SWCS.

Our Vice President for Europe, Dr. Martin Haigh, has initiated a series of meetings on Environmental Regeneration in Headwaters in various parts of the globe. Our Vice President for the Pacific Region, Dr. Samir El-Swaify, has initiated a series on "Multiple Objective Decision Making for Land, Water and Environmental Management." Four of our members—Samran Sombatpanit, Michael Zoebisch, David W. Sanders, and Maurice Cook have edited a book titled, *Soil Conservation Extension: From Concepts to Adoption.* David Sanders, Paul Huszar, Samran Sombatpanit and Thomas Enters have edited a book titled, *Incen-*

tives in Soil Conservation: From Theory to Practice. Lately, Samran Sombatpanit has edited a voluminous book, *Response to Land Degradation,* with five other editors in 2001 and *Ground and Water Bioengineering for Erosion Control and Slope Stabilization*, with four other editors in 2004. Besides the above publications, past WASWC President Hans Hurni initiated a long-term program, "World Overview of Conservation Approaches and Technologies (WOCAT)," based in Berne, Switzerland in 1992 and had a landmark WOCAT Global Overview book *"where the land is greener"* published in 2006. WASWC has supported Jim Cheatle's "Organic Matter Management Network" based in Nairobi, Kenya. WASWC is also closely allied with Reseau Erosion, a project of Vice President Eric Roose, based in Montpellier, France, and operating mainly in Africa. WASWC is closely allied to ISCO and cooperates fully with planning and conducting its biennial conferences. WASWC is requested and very willing to co-sponsor conferences, symposia and workshops it feels will further its philosophy and objectives.

The WASWC Philosophy: WASWC philosophy is that the conservation and enhancement of the quality of soil and water are a common concern of all humanity. We strive to promote policies, approaches and technologies that will improve the care of soil and water resources and eliminate unsustainable land use practices.

WASWC Vision: A world in which all soil and water resources are used in a productive, sustainable and ecologically sound manner.

WASWC Mission: To promote worldwide the application of wise soil and water management practices that will improve and safeguard the quality of land and water resources so that they continue to meet the needs of agriculture, society and nature.

WASWC Slogan: Conserving soil and water worldwide – join WASWC

The Objectives of WASWC: The basic objective of WASWC is to promote the wise use of our soil and water resources. In doing so WASWC aims to:

• Facilitate interaction, cooperation and links among its members.

• Provide a forum for the discussion and dissemination of good soil and water conservation practices.

• Convene and hold conferences and meetings and conduct field studies connected with the development of better soil and water conservation.

• Assist in developing the objectives and themes for ISCO conferences and collaborate in their running.

• Produce, publish and distribute policies, guidelines, books, papers and other information that promote better soil and water conservation.

• Encourage and develop awareness, discussion and consideration of good conservation practices among associated organizations.

• Liaise, consult and work in conjunction with environmental organizations on the development and promulgation of global environmental and conservation policies, strategies and standards.

Recent Developments: The WASWC has had to face some serious problems in recent years and, as a result, some important changes have taken place. The cost of running WASWC has increased over the years and, at the same time, membership numbers dropped to below 400. The drop in numbers was partly because a membership fee of even US$10 per year is a considerable amount of money for many members from developing countries. Added to this, is the problem of paying in dollars and transferring relatively small sums of money internationally. To overcome these problems, a number of important steps have been taken. *First,* a concerted effort has been made to recruit new members. As part of this campaign, an effort has been made to improve the services provided to members. This has included improving the quality and length of the quarterly newsletter and distributing it by e-mail. *Second,* a flexible system of membership fees has been introduced which means that members can join for as little as US$5 and US$10 per year for respectively developing and developed countries. *Third,* a program of decentralization has also been launched with the appointment of several more Vice Presidents and the establishment of National Representatives, now covering approximately 100 countries. This program is not only bringing our association closer to members but has also provided other advantages including a system whereby it is now possible for local organizations to collect membership fees in local currencies and to pay the secretariat in bulk. *Fourth,* the WASWC council has become more actively involved in encouraging regional and local meetings, conferences and other useful activities. *Fifth,* the WASWC council offers 1-year Guest membership to persons who have participated at any technical meeting worldwide, if they wish so. As a result of these measures, membership has risen to several thousands in 2007.

Another major change has been the move of the WASWC secretariat from the SWCS in the U.S.A. to Beijing in China, on April 1, 2003. It is now hosted by the Ministry of Water Resources. The WASWC appreciates the generous help that it received from the SWCS over the 20 years that the SWCS ran its secretariat and intends to maintain a close association with it in the future. However, the Council believes that this move will have a number of advantages. Our Chinese hosts have offered very generous terms for the running of the secretariat; we will have the opportunity to work in a country where running costs are relatively low and where there is considerable technical expertise available and of interest to many of our members. The most recent development is the establishment of our main website at the Guangdong Institute of Eco-Environmental and Soil Sciences in Guangzhou, in the southern part of China, to offer services to our members along with the other one in Tokyo, Japan, supported by ERECON.

WASWC Council

(For the period up to December 2007)

President: Miodrag Zlatic, Serbia
Deputy President: Machito Mihara, Japan
Treasurer: John Laflen, U.S.A.
Executive Secretary: Jiao Juren, China
Imm. Past President: Samran Sombatpanit, Thailand (& Membership Coordinator)
Councilor for Africa: Mohamed Sabir, Morocco
Councilor for America (Latin): Eduardo Rienzi, Argentina
Councilor for America (North): Ted Napier, U.S.A.
Councilor for Australasia: Ian Hannam, Australia
The next council will operate from January 2008 for a period of 3 years.
Contact Samran Sombatpanit (sombatpanit@yahoo.com) for further information.

Past Presidents

1983-1985: William C. Moldenhauer, U.S.A.
1986-1988: Norman W. Hudson, UK
1989-1991: Rattan Lal, U.S.A.
1992-1997: Hans Hurni, Switzerland
1997-2001: David W. Sanders, UK
2002-2004: Samran Sombatpanit, Thailand
January-March 2005: Martin Haigh, UK
April 2005-June 2006: Samran Sombatpanit, Thailand (Acting)

WASWC Secretariat and Websites: See p. viii, this volume

WASWC Publications

– Published in association with other institutions or publishers –

1988

• *Conservation Farming on Steep Lands.* Edited by W.C. Moldenhauer and N.W. Hudson, ISBN 0935734198

1989

• *Land Husbandry – A Framework for Soil and Water Conservation.* by T.F. Shaxson, N.W. Hudson, D.W. Sanders, E. Roose and W.C. Moldenhauer, ISBN 0935734201

1990

• *Soil Erosion on Agricultural Land.* Edited by J. Boardman, I.D.L. Foster and J.A. Dearing, ISBN 0471906027 (From a meeting co-sponsored by WASWC)

1991

• *Development of Conservation Farming on Hillslopes.* Edited by W.C. Moldenhauer, N.W. Hudson, T.C. Sheng and San-Wei Lee, ISBN 0935734244

• *Soil Management for Sustainability.* Edited by R. Lal and F.J. Pierce, ISBN 0935734236

1992

• *Conservation Policies for Sustainable Hillslope Farming.* Edited by S. Arsyad, I. Amien, Ted Sheng and W.C. Moldenhauer, ISBN 0935734287

• *Soil Conservation for Survival.* Edited by K. Tato and H. Hurni, ISBN 0935734279

• *Erosion, Conservation and Small-Scale Farming.* Edited by H. Hurni and K. Tato, ISBN 3906290700

• Environmental Regeneration in Headwaters. Edited by J. Krecek and M.J. Haigh

1993

• *Working with Farmers for Better Land Husbandry.* Edited by N. Hudson and R.J. Cheatle, ISBN 1853391220

1995

• *Adopting Conservation on the Farm: An International Perspective on the Socio-economics of SWC.* Edited by T.L. Napier, S.M. Camboni and S.A. El-Swaify, ISBN 0935734317

1996

• *Hydrological Problems and Environmental Management in Highlands and Headwaters.* Edited by J. Krecek, G.S. Rajwar and M.J. Haigh, ISBN 8120410483

1997

• *Soil Conservation Extension: From Concepts to Adoption.* Edited by S. Sombatpanit, M. Zoebisch, D. Sanders and M.G. Cook, ISBN 8120411897

1999

• *Multiple Objective Decision Making for Land, Water and Environmental Management.* Edited by S.A. El-Swaify and D.S. Yakowitz, ISBN 1-57444-091-8

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• *Ground and Water Bioengineering for Erosion Control and Slope Stabilization.* Edited by D.H. Barker, A.J. Watson, S. Sombatpanit, B. Northcutt and A.R. Maglinao, ISBN 1-57808-209-9

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• *Monitoring and Evaluation of Soil Conservation and Watershed Development Projects.* Edited by J. de Graaff, J. Cameron, S. Sombatpanit, C. Pieri and J. Woodhill. ISBN 978-1-57808-349-7

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2003: No. 1. *Pioneering Soil Erosion Prediction – The USLE Story.* By John Laflen and Bill Moldenhauer, ISBN 974 91310 3 7, 54 pp. (available on the website)

2004: No. 2. *Carbon Trading, Agriculture and Poverty.* By Mike Robbins, ISBN 974 92226 7 9, 48 pp. (available on the website)

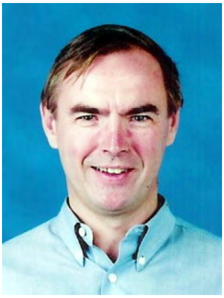
2008: No. 3. *No-Till Farming Systems.* Edited by Tom Goddard, Michael A. Zoebisch, Yantai Gan, Wyn Ellis, Alex Watson and Samran Sombatpanit, ISBN 978-974-8391-60-1, 544 pp.

The Editors

Mr. Tom Goddard has worked with no-till development over the last three decades from research plot scale to farm-field scales while working as a summer student, an agricultural extension agent and a soils specialist. His varied experience ranges across agricultural extension, environmental consulting and applied research. Research activities have covered precision farming applications, site-specific management, landscape science, soil quality monitoring, erosion processes and greenhouse gas emissions. He is currently on a secondment to the policy secretariat from his position as head of soils and climate change section for Alberta Agriculture and Food. He resides in Edmonton, Canada with Elizabeth and their three teenaged children.

Dr. Michael Zoebisch is a soil and water engineer and agronomist with more than 25 years of experience in Asia, Africa and the Middle East. He specializes in land and water management and the conservation of natural resources. Michael is chartered engineer and chartered environmentalist. He has worked for the International Center for Agricultural Research in the Dry Lands (ICARDA) and as Visiting Professor at the universities of Kumasi (Ghana), Nairobi (Kenya) and for the Asian Institute of Technology - AIT in Thailand. Michael has initiated and managed substantial research projects in Kenya, Syria and Thailand. He is currently senior advisor for the university reform program in Ethiopia responsible for curriculum development

Dr. Yantai Gan, a Research Scientist with Agriculture and Agri-Food Canada, the Canadian Federal Department of Agriculture, has been focusing his research on the development of diverse no-till cropping systems in the past 15 years. His research achievement is reflected in some 80 papers published in refereed journals and over 200 technical articles. Currently, Dr. Gan is the Director of North America Pulse Improvement Association and the Director of Canadian Society of Agronomy. He is active in training graduates, being Adjunct Professor at four universities: the University of Saskatchewan in Canada; China Agricultural University in Beijing; Lanzhou University in Lanzhou, China; and Gansu Agricultural University in Gansu, China. He is also serving Associate Editor for Canadian Journal of Plant Science.



Mr. Wyn Ellis is a Senior Adviser with the GTZ Thai-German Programme for Enterprise Competitiveness, based in Bangkok. With 29 years of consultancy experience covering crop protection, biosafety, organic farming, innovation management, and sustainable development, he has advised on major rural development programs in Africa and Asia, and has lived in Asia for the past 22 years. He holds degrees from the Universities of Oxford and Reading in UK.

Mr. Alex Watson has worked as a researcher in New Zealand for the past 25 years. He has over that time been engaged in investigations involving catchment hydrology and associated land use change issues, plantation and forest water use, tree and tree root anchorage and their relationships to slope and wind stability, and erosion process studies. His previous editorial responsibilities have included co-editing *Ground and Water Bioengineering for Erosion Control and Slope Stabilisation* in 2004. He is currently employed by Landcare Research New Zealand Ltd.

Dr. Samran Sombatpanit had worked as a land development officer of the Land Development Department, Thailand, during the period 1964-1999, the last 18 years having spent for soil and water conservation. He established the Soil and Water Conservation Forum of Thailand in 1980 and served as a Vice President of WASWC for Asia in 1995, Deputy President for 1997-2001, President for 2002-2004, Acting President for January 2005 to mid-2006 and Past President for mid-2006 to December 2007. He has edited the book *Soil Conservation Extension* in 1997 and co-edited *Incentives in Soil Conservation* in 1999, *Response to Land Degradation* in 2001, *Ground and Water Bioengineering for Erosion Control and Slope Stabilization* in 2004 and *Monitoring and Evaluation of Soil Conservation and Watershed Development Projects* in 2007.

Words of Appreciation

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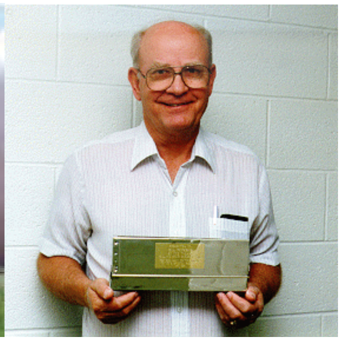
the VSAT (Vertical Settling Aerosol Tube)
for dust particle size determinations.

(Left) *Wind erosion and* (right) *Bill Fryrear with a special chrome-plated BSNE Sampler, which he invented, given to him at his retirement from USDA-ARS*

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All it takes for no-tillage agriculture

Wet sieving apparatus

The aggregate stability of a soil is the resistance of soil structure against mechanical or physico-chemical destructive forces. Soil structure is one of the main factors controlling plant growth by its influence on root penetration, soil temperature and gas diffusion, water transport and seedling emergence and therefore it is an important soil characteristic for farmers. The wet sieving apparatus is used to determine the above mentioned aggregate stability. The wet aggregate stability is determined on the principle that unstable aggregates will break down more easily than stable aggregates when immerged into water. The testing procedure results in an index for aggregate stability.

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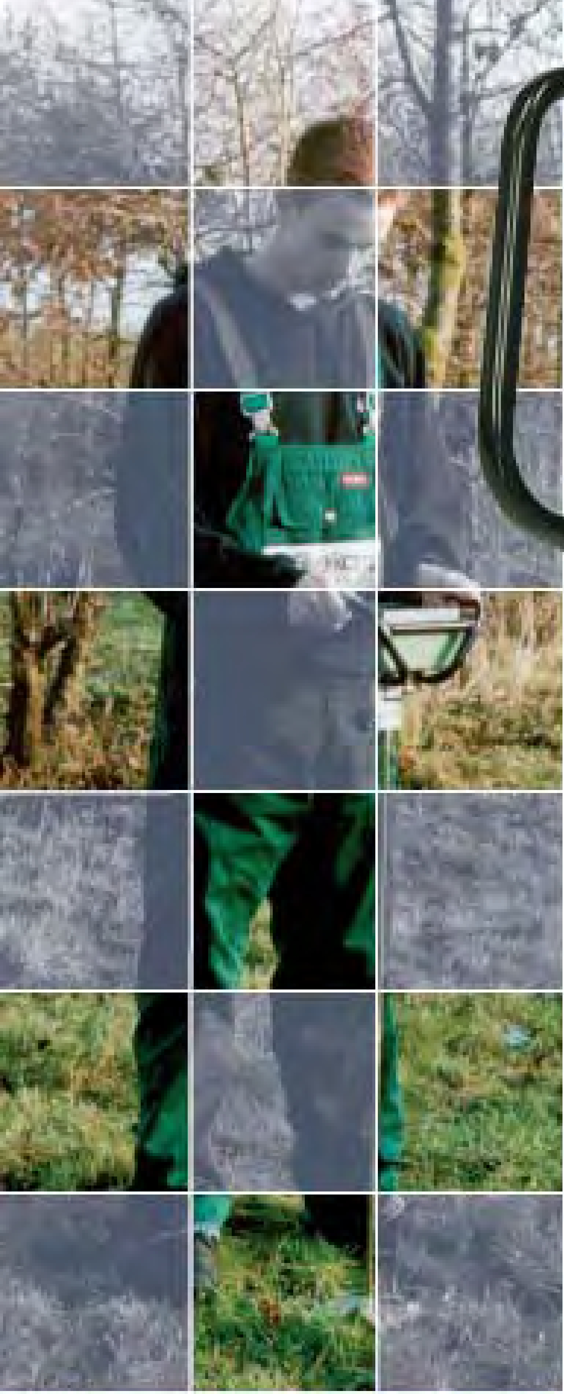

Penetrologger

The resistance to penetration is a means of determining the ground load-bearing capacity, and the ease with which roots will grow through the ground. The resistance to penetration is a mechanical characteristic that, given a certain texture, depends on changing parameters such as degree of humidity, density and the strength of the connection between mineral particles.

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Syngenta is committed to supporting the concepts of conservation agriculture and works with partners and stakeholders worldwide on many projects to enhance soil and water quality.