CropLife
INTERNATIONAL

Representing the Plant Science Industry

Conservation Technologies and the Plant Science Industry

Managing Natural Resources Sustainably

Conservation Technologies and the Plant Science Industry

Managing Natural Resources Sustainably

September 2005

Contents

Contents

FIGURES AND TABLES

Foreword

Foreword

The contribution of plant science technologies to conservation and enhancement of natural resources globally is an under-appreciated success story.

Billions of tonnes of topsoil are being retained on agricultural fields, and prevented from entering waterways and water bodies as the number one global water pollutant: sediment. Billions of tonnes of soil particles are prevented from entering the air column as airborne particulates, and millions of tonnes of greenhouse gasses are effectively trapped in agricultural soils that are not continuously tilled. Air pollution is further reduced due to lower amounts of particulates and gasses entering the air as a consequence of fires employed for vegetation or crop residue management, as well as reduced need to burn off diesel and other fuels to power intensive mechanical tillage. Hundreds of millions of hectares of fragile land with all its associated biodiversity are retained for wildlife habitat and preservation of threatened and endangered species.

All these environmental benefits are enabled by agricultural practices and technologies that have driven a fundamental change in what has been a basic human activity for thousands of years. Crop protection technologies, used as part of an Integrated Pest Management strategy, have enabled humans to switch methods of crop production and protection and pest and vegetation management from highly destructive practices such as energy-intensive mechanical tillage and burning, to more environmentally responsible methods involving conservation tillage and selective application of pesticides. More recently, plant biotechnology, through the use if herbicide-tolerant crops, has renewed interest and expanded conservation technologies to areas where it has previously been difficult.

The enhanced productivity associated with sustainably-intensified agriculture has enabled production to remain concentrated on well-adapted lands and halted or slowed expansion into marginal land with thin and sloping soils and high measures of biodiversity. In some cases, conservation tillage practices have enabled the recovery and restoration of farmland degraded by more destructive tillage practices. Ultimately, rather than losing topsoil through agricultural activities, the use of conservation tillage practices actually builds topsoil on productive soils.

The work is not finished: No farmer is ever satisfied that a crop was as good as it could have been or that the practices were as good as they should have been. No environmentalist is ever satisfied that the basic needs of man are appropriately balanced against our desires for healthy and abundant biodiversity and clean air and water. Nonetheless, modern technology has helped us realize great strides toward truly sustainable agriculture, and offers great promise for addressing the continuing challenges.

Croplife International has produced this publication to highlight stories of success around the world, and of continuing needs for sustainable agriculture based on conservation technologies. These practices integrate management of available soil, water and biological inputs, such as improved seeds, crop protection products and fertilisers, to improve productivity of farmlands in a way that conserves or improves the natural resource base and the environment for future generations. It is our hope that these success stories will serve as models and an inspiration for those facing related challenges in other situations, and will help focus and stimulate attention and effort on these important agricultural practices.

CropLife International would like to express its sincere thanks Ashok Seth, former World Bank staff and consultant to this project, for his work in compiling this report. We would also like to acknowledge the invaluable input all the authors, researchers, and practitioners whose efforts have made this report possible.

Raymond Forney

Raymond Forney, Ph.D.
Global Stewardship Manager, DuPont Crop Protection
Chair, Stewardship and Sustainable Agriculture Committee, CropLife International

Christian Verschueren
Director General, CropLife International

The Plant Science Industry

The Plant Science Industry

Committed to sustainable agriculture through innovative technologies

The plant science industry, represented by CropLife International, invents, develops, manufactures and delivers innovative products, technologies and services designed to improve the global production of food, feed and fibre and other useful products in a sustainable way.

Improvements in agricultural technologies and practice mean that today's population has access to more food per head available than 40 years ago. In addition to increasing crop yields in many parts of the world, advances in agricultural technologies have also contributed to a safer food supply, and in some cases, improved environmental quality.

Over the next 30 years, agriculture will have to sustain an additional 2 billion people from an increasingly fragile resource base. Ever-growing demands and increasing pressures on land and water resources mean that agriculture has to become even more productive, efficient and environmentally sound. This will require the continued application of new scientific knowledge, improved resource management and continued public and private research investment in emerging technologies.

The plant science industry shares the international community's recognition that major improvements in agricultural performance are fundamental to achieving the overall goals of sustainable development, as put forth in Agenda 21, signed by 100 heads of state and governments in Rio de Janeiro in 1992, and reaffirmed during the 2002 World Summit on Sustainable Development held in Johannesburg[1].

We are committed to being "part of the solution," and will continue to provide innovative solutions that protect the environment, enhance economic viability of farms and rural livelihoods, and improve the quality of life for farmers and their communities. To accomplish this, we work hand-in-hand with a range of stakeholders, including farmers, international organisations, NGOs and the public sector.

In support of this commitment, industry undertakes locally adaptive fieldwork and provides technical services and training to ensure the safe and effective use of its products around the world, and particularly in developing countries. We work with a network of qualified personnel and partner organisations to test, analyse and disseminate products and techniques that address different needs and priorities. We work closely with farmers in product testing and development in order to enhance the relevance and acceptance of our products and technologies. In addition, we share knowledge and experience to contribute to decisions on issues related to international and national policies and regulations for sustainable agriculture and economic development.

---

[1] UN. 2002. Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August - 5 September, 2002.United Nations, New York, USA

Agricultural Growth

Agricultural Growth and the Environment

The Evolving paradigm

Many industrialized and developing countries have achieved impressive rates of agricultural growth in the recent past. For example, Asia transformed its agriculture by doubling rice and wheat production during the period from 1970 to 1995 by expanding planting areas and using Green Revolution (GR) technologies[2]. Over the same period, real per capita rural incomes almost doubled and poverty declined[3]. However, these gains did not come without some negative consequences. Economic disparities increased within countries, and so did environmental damage resulting from inappropriate use of applied inputs (fertilizers, crop protection products, irrigation)[4].

As the new century begins, the world faces enormous challenges to meet the food, feed and fibre needs of a growing population with rising incomes. It is estimated that by 2025 the global population will be approximately 7.9 billion, up from 6 billion currently. Global cereal and meat demands will increase by 46% and 56% respectively[5].

Since prospects for further expansion of agricultural land and irrigated areas are limited, increased food demand must be met primarily through higher productivity on existing cultivable land. Moreover, increased production needs to be achieved in ways that are safe for the environment, farmers and consumers. Access to science-based agricultural innovations and technologies are critical to achieving this.

Innovative solutions incorporate natural regenerative processes, such as nitrogen fixation, nutrient recycling, maintenance of soil structure and fertility, and protection of natural enemies of insect pests, weeds and diseases, into agricultural practices. These approaches make better use of the indigenous knowledge of farmers and, where appropriate, combine it with new science-based technologies for optimum results.

Figure 1: More people means less land per person

	Population growth		
	World population (billion)	Arable land & permanent crops (billion ha)	Farmland per person (ha)
1950	2.5	1.3	0.5
1975	4.0	1.4	0.4
2000	6.0	1.5	0.3
2020	7.5	1.5	0.2

Source: International Food Policy Research Institute, 2002

---

[2] In 1968, William Gaud, the administrator for the US Agency for International Development (USAID), coined the term “Green Revolution” to describe the agricultural growth in Asia resulting from wide-scale adoption by farmers of new varieties, irrigation, fertilizers, and crop protection inputs.

[3] Rosegrant and Hazell. Transforming the rural Asian economy: The unfinished revolution. Published for the Asian Development Bank by the Oxford University Press. 2000

[4] IFPRI (2002). Green Revolution: Curse or Blessing? International Food Policy Research Institute Brief – A slightly altered version of an article by P. Hazell in J Mokyr, ed. The Oxford Encyclopedia of Economic History, Oxford University Press, 2003.

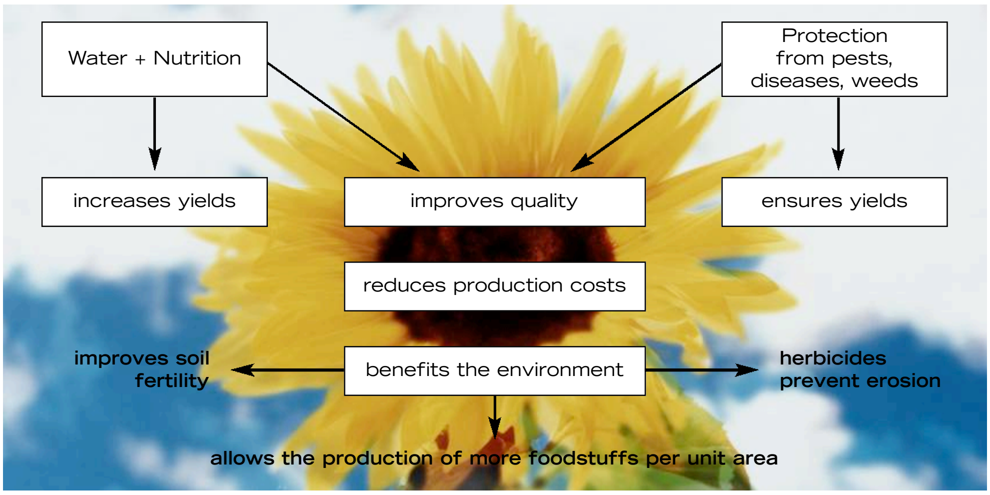
[5] Rosegrant MW, Ximing Cai and SA Cline (2002). World Water and Food to 2025: Dealing with Scarcity International Food Policy Research Institute, Washington DC, USA

Conservation Technologies and Sustainable Agriculture

What are the characteristics of conservation technologies[6]?

Traditional farming practices normally involve intensive soil tillage. This practice was normally associated with increased soil fertility due to mineralisation of nutrients. However, farmers realised that in the longer run, excessive tillage actually reduces soil organic matter content and exposes soil to wind and water erosion, which in time leads to lower productivity. To compensate for the loss of natural regenerative processes, intensive agriculture has increasingly relied on fertilizer applications and other chemical inputs to increase productivity.

Figure 2: Plants need adequate water, nutrition and protection



Source: Food for All. 1996 publication of IFA/GCPF

---

[6] Common definitions of conservation technologies:
TILLAGE: to work the land with a plough and other tillage implements prior to planting and raising the crop.
CONSERVATION TILLAGE: see the definition below in footnote 9
NO-TILL: any practice which leaves the soil undisturbed from harvest to planting. Planting or drilling is done in a narrow seedbed or slot created by a coulters, row cleaners, disc openers, etc. Weed control is generally done using herbicides.
CHISEL PLOUGHING: Ploughing using a metal tool with a cutting edge at the end of the blade
ZERO-TILL: Same as No-till
MINIMUM-TILL: Tillage and planting of crop with minimum disturbance of soil which maintains at least 30% of the soil surface with crop residue after planting to reduce soil erosion.
RIDGE-TILL: Involves planting of crop in seedbed prepared on ridges with sweeps, ridge openers or coulters. Residue is left on surface between ridges. Except for injection of nutrients, soil is left undisturbed.
MULCH-TILL: Planting of crops through crop residue with tillage tools such as chisels, field cultivators, discs, sweeps and blade. Some disturbance of crops is involved prior to planting.
FAST START (Chemical Aid to Tillage): Seed bed is created in the fall after harvest using conventional tillage implements after which soil is left undisturbed until planting. Herbicides are used for weed control prior to planting if needed after which crop is planted using no-till equipment
STRIP-TILL: Strip-till is performed in the fall directly after harvest, and involves building small mini-ridges or berms in which fertilizer can be placed. In the spring , seeds are planted directly into the berms, while the row middles remain untilled and covered with undisturbed crop residue. Herbicides are used for weed control.

In his work "Plowman's Folly," the famous American author William Faulkner described the plough as "the villain of the world's agricultural drama."[7] Although the negative effects of tillage operations have been recognised for sometime, it was only after the discovery of suitable selective, non-selective, contact and residual herbicides that effective solutions to combat these problems became possible. This stimulated world-wide investigations by the private sector (the plant science industry and manufacturers of farm implements), public research institutions and enterprising farmers to develop innovative crop establishment techniques that either fully eliminated or minimised the need for tillage operations[8].

Under techniques developed to suit various crops and environments -- no-till, zero-till, minimum-till, ridge-till, mulch-till -- seed is sown directly into the previous crop's stubble, with little or no intermediate tillage. Later, crop rotation and maintenance of permanent or semi-permanent groundcover (live cover crop or crop residue mulch) are included as an integral part of this approach, now commonly known as conservation tillage[9]. These techniques have proven to be equally suitable for small, medium, and large farms.

Conservation tillage protects the upper soil layer from wind and water erosion and loss of ground moisture. It also improves soil biodiversity by providing a congenial environment for bacteria, insects and fungi. The abundance of soil organisms helps decomposition of mulch and its incorporation into soil as humus, contributing to stabilisation of soil structure and enhancement of soil fertility. Maintenance of mulch is estimated to increase soil organic matter content by about 1 percent every 10 years[10].

---

[7] Faulkner, (1943). Plowman's Folly. University of Okalahoma, Norman, OK.

[8] Calderrbank, A 1968. The bipyridylium herbicides. Advances in Pest Control Research Vol. 8:127-235. Shear, G.M. (1985). Introduction and History of Limited Tillage. Chapter 1 in A.F. Wiese (ed.) Weed control in limited-tillage systems. WSSA, Champaign, IL

[9] Conservation tillage is any tillage and planting system that covers more than 30% of the soil surface with crop residue after planting to reduce soil erosion by water. Where wind erosion is a primary concern, conservation tillage includes any system that maintains at least 450 kg/ha of flat small-grain residue equivalent on the surface throughout the critical wind erosion period. No-till, minimum-till, ridge-till, and mulch-till are types of conservation tillage (Conservation Tillage Information Centre, 2002).

[10] Thomas, G T (1990). Labranza cero resultados en EEUU y observaciones en campos Argentinos. Rosario Argentina, AAPRESID

In the past, soil tillage was used along with plant residue burning as a control mechanism for weeds, insects and diseases. Under conservation tillage, weeds present prior to sowing can be controlled using herbicides. This is complemented with a need-based use of integrated crop and pest management technologies and systems (ICM/IPM)[11] that enhance production system resilience and do not hinder the re-establishment of balance between pests and beneficial organisms and between crops and weeds. Conservation tillage thus provides an effective entry point for other resource conservation technologies that enhance production system resilience and sustainability.

Although the specific components of the conservation package will differ in relation to location-specific needs of temperate, subtropical, and tropical agriculture, the key elements that apply in all situations include:

- Minimum disturbance of soil, where needed with the help of herbicides used as an aid to cultivation
- Maintenance of mulch consisting of either a live cover crop or dead crop residue
- Sound crop rotations
- Need-based matching of conservation tillage with ICM/IPM practices

How do conservation technologies fit into sustainable agriculture?

Conservation technologies are at the heart of sustainable agriculture, providing dynamic solutions to problems encountered in increasing food production without damaging the eco-system or depleting natural resources for future generations. The farming system based on conservation technologies is not low-output agriculture. It provides comparable yields to intensive conventional farming and relies on the sustainable use of high-input technologies.

Although benefits of conservation tillage are now well recognised, there are some areas of concern that generate resistance to changing over from conventional farming. One such area relates to weed management during the transition period, which may require a different management strategy. Similarly, farmers are concerned about potential for changes in weeds, diseases and insect pest problems. Experience shows that the combining of ICM and IPM approaches with conservation tillage is an effective way of addressing these problems and enhancing sustainability.

---

[11] INTEGRATED CROP MANAGEMENT (ICM): There are many definitions of ICM. For the purposes of this document it has been defined as ‘management of crop production on the whole farm in a way that maintains and enhances the environment for wildlife and people while at the same time producing economic yields of high quality’.
INTEGRATED PEST MANAGEMENT (IPM): An FAO and the plant science industry accepted definition of IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other investigations to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

Table 1: How conservation technologies address sustainable farming issues compared to conventional techniques

Problem Area	Conventional Farming	Conservation Technologies
Nutrient deficiency	Corrected with inorganic fertilizers	Relies on integrated nutrient management through biological regeneration, plus targeted use of organic or inorganic fertilizers. Where appropriate, includes integration of livestock production for nutrient recycling.
Water deficiency	Corrected with irrigation	Emphasises management of soil organic matter (use of cover crops and mulch) for efficient capture of rainfall, soil moisture conservation and targeted irrigation.
Erosion control	Corrected with physical barriers	Minimises erosion through reduced or no-till practices along with retention of cover crops/residue in arable agriculture and vegetation management in non-crop situations.
Soil structure deficiencies and compaction	Corrected with intensive tillage, which further decreases biological oxidation and soil carbon	Restores soil using cover crops, residue management, crop rotation, and minimum/zero tillage.
Pest management	Use of calendar or need-based spraying of crop protection chemicals	Manages insect, weed, diseases and other pests using IPM approaches, which are economic, environmentally safe, and socially acceptable.
Environmental degradation	Corrective measures involve variations in intensive tillage and associated management practices, which provide limited protection against soil erosion and secondary damage through silting and contamination of surface and groundwater from leaching and run-off of applied chemicals.	Reduces soil erosion, water run-off from farms and emission of green house gases.
Loss of biodiversity and wildlife habitat	Caused by intensive soil cultivation, planting of similar biotypes over large areas, applied inputs during crop growth. Higher productivity through intensification can slow spread of agriculture to fragile and marginal areas.	Additional cover provided by crop mulch encourages micro-fauna and flora diversity and other wildlife species. Sustainable increases in productivity from existing areas avoid spread of agriculture to marginal areas.

Conservation Technologies for the 21st Century and Beyond

Approximately 80% of conservation tillage is practiced in the Americas (North and South America), about 14% in Australia and, despite positive long-term research on its benefits, only 6% in the rest of the world, including Europe, Africa, and Asia. Table 2 shows the estimated area under no-tillage in different parts of the world.

Table 2: Total area under no-tillage in different countries in 2004/2005

Country	Zero Tillage, 1999/2000 (ha)
USA [1]	25.304.000
Brazil [2]	23.600.000
Argentina (*) [3]	18.269.000
Canada [4]	12.522.000
Australia [5]	9.000.000
Paraguay [6]	1.700.000
Indo-Gangetic-Plains (**) [7]	1.900.000
Bolivia [8]	550.000
South Africa [9]	300.000
Spain [10]	300.000
Venezuela [11]	300.000
Uruguay [12]	263.000
France [13]	150.000
Chile [14]	120.000
Colombia [15]	102.000
China [16]	100.000
Others (Estimate)	1.000.000
Total	**95.480.000**

Source: FAO (Land and Water Division and www.rolf-derpsch.com (1) John Hassel CTIC, 2005; 2) FEBRAPDP, 2005; 3) AAPRESID, 2004; 4) Dr. Doug McKell, Soil Conserv. Council of Canada, 2004; 5) Bill Crabtree, WANTFA, 2005, 6) MAG – DEAG, Soil Conservation Program, 2005; 7) Dr. Peter Hobbs & Raj Gupta 2005; 8) Carlito Los, 2005, 9) Richard Fowler, 2003; 10) ECAF Homepage, 2005; 11) Rafael E. Perez, 2004; 12) Miguel Carballal AUSID, 2005; 13) ECAF Homepage, 2005; 14) Carlos Crovetto, 2005; 15) Fabio Leiva, 2005; 16) Li Hongwen, 2005) (*) Preliminary information based on 40% of data collection at 03/04 (**) Includes four countries in South Asia, India, Pakistan, Bangladesh and Nepal

The estimated land area dedicated to conservation tillage worldwide is over 90 million hectares, with approximately 45% of the total in Latin America, 41% in the United States and Canada, 10% in Australia and about 3.6% in the rest of the world, including Europe, Africa and Asia.

The United States is among the few countries in the world that conduct surveys on the different forms of conservation tillage. Information in other parts of the world is very scarce or non-existent and in most cases is based on estimates. In 1995, the Weed Science Society of America published a monograph that reviewed the progress of conservation tillage systems with emphasis on weed control practices under different crops around the world[12]. Since that time a lot more information, especially on the long-term benefits of these systems, has become available. At the same time, new knowledge and technologies have enabled the introduction of conservation agriculture to new areas and production systems. This is highlighted by the case studies and examples contained in this report.

The studies presented here, which have been summarised from published literature or have been collected especially for this report, provide examples where members of the plant science industry have worked with researchers and farming communities to develop and implement conservation tillage in different parts of the world.

---

[12] Wiese, AF (ed.). (1995). Weed control in limited tillage systems. Published under the monograph series of Weed Science Society of America. Champaign, Il., USA

Conservation practices reduce pollution caused from burning of foliage

The Brazil experience[13]

Starting in the 1960s, Brazil saw a rapid expansion of agricultural frontiers and intensification of production systems, including greater emphasis on soybean production either as a single crop or in rotation with wheat. In many areas, these crops replaced livestock and coffee production. Over the last three decades, these changes, combined with heavy rains, hilly terrain, and intensive tillage, led to serious erosion problems over vast areas. Searching for more environmentally-friendly and economically-viable production systems, farmers, development agencies and researchers started to work with conservation tillage practices, mainly in the southern region of Parana, Santa Catarina and Rio Grande do Sul.

The plant science industry started supporting this work in the early 1970s, using herbicides for weed control prior to direct drilling of soybeans. Working with scientists, farmers and manufacturers of farm implements helped develop the first no-till package for Brazil. Based on lessons learned from initial experiences, and with the continued support of pioneering farmers, more research groups, farmer cooperatives and clubs were organised to expand research and development activities. These groups, assisted by national and international public and private organisations, ensured that conservation tillage has become an important part of Brazilian agriculture, covering an estimated 23.6 million hectares.

Effective control of weeds with herbicides and maintenance of crop residues in the soil surface, along with increased availability of appropriate farm machinery and effective extension and training, has made it possible for many crops in Brazil to be planted using conservation tillage systems. These crops include soybeans, maize, wheat, barley, sorghum, sunflower, beans, green manure cover crops, and, increasingly, irrigated rice. In addition, innovative approaches have been developed for regeneration of pastures for better integration of crop-livestock production systems and vegetable production. Farmers adopting these practices are reporting higher yields, improved incomes, better soil health and quality and savings in time and labour.

In sugarcane fields, mechanical harvesting of ‘green’ sugarcane along with retention of foliage as soil cover improves land and water management practices. Mechanical harvesting of green cane, combined with conservation practices also enhances labour productivity and reduces pollution caused from burning of foliage prior to harvesting in the traditional system.

Studies on the impact of tillage systems and plant residue cover on the biology and population dynamics of weeds and efficacy of herbicides show that adoption of conservation tillage for crop establishment affects the overall need and tactics for weed management, which should be studied and planned to suit the changed conditions[14].

---

[13] based on Derpsch R (2002). Sustainable agriculture. In Saturmino H M and J N Lander (eds.) The environment and zero tillage. Associacao de Planto directo no Cerrado, Brasflia.
Ekboir J M, K Boa and A A Dankyi (2002). Impact of no-till technologies in Ghana. CIMMYT Economic program Working Paper. CIMMYT, Mexico
Pieri C, G Evers, J Landers, P O'Connell and E Terry (2002). No-till farming for sustainable rural development. Agriculture and Rural Development Department Working Paper. The World Bank, Washington DC, USA;
Saturmino H M and J N Lander (2002). The environment and zero tillage. Associacao de Planto directo no Cerrado, Brasflia.. World Bank (1998a). Implementation Completion Report, Brazil, Land Management I Project, Parana. ESSD Sector Management Unit, LAC, World Bank, Washington DC, USA;
World Bank (1998b). Implementation Completion Report, Brazil, Land Management II, Santa Catrina Project. ESSD Sector Management Unit LAC, World Bank, Washington DC, USA.

[14] Christofeletti, PJ (2004). Conservation of natural resources in Brazilian agriculture. Paper presented during the 4th International Weed Science Congress. 20-24 June, 2004, Durban, South Africa.

The Paraguay experience[15]

The introduction of soybean and wheat to southern and eastern Paraguay in the 1970s using conventional mechanised soil-preparation practices contributed to soil degradation and erosion, with long-term consequences for the sustainability of commercial agriculture.

Conservation techniques were developed to overcome negative impacts of tillage

Learning from the experiences of neighbouring southern Brazil, conservation tillage techniques were developed to overcome the negative impact of mechanised tillage and intensive high-input crop management practices. As a result of continued research and development work involving both the public and the private organisations, large, medium, and small-scale farmers now practice conservation tillage techniques over nearly 1.7 million hectares involving reduced or zero tillage, mulch management and crop rotations.

The most commonly followed rotations in southern and eastern Paraguay vary in length from three to five years and involve crops such as oats, wheat, soybean, maize and sunflower. The shorter turn-around time between crops under conservation tillage has also broadened options of crops that can be grown within a cropping year.

The Chile experience[16]

The main impetus for the introduction of conservation technologies to Chilean agriculture came from the pioneering work of Carlos Crovetto Lamarca, who, after experiencing serious soil erosion problems under conventional cultivation systems, planted Chile's first maize under no-tillage at his Chequen farm near Concepción in 1978. He combined the establishment of crops without tillage with mulch management by leaving about 14,300 kg/ha of corn residues and 6,200 kg/ha of wheat residues on the surface.

Today, through 19 years of continuous no-tillage practice and lessons learnt from this initial experience, conservation practices are being applied to the whole farm and involve planting of row crops, forages, and trees. As a result, soil quality, farm productivity and habitats for wildlife have improved. One inch of topsoil has been added with better physical and chemical characteristics and water holding capacity. Over the years, crop yields have improved, reaching 19,600 kg/ha for irrigated corn and 10,800 kg/ha for dryland wheat.

However, despite 20 years of successful no-tillage farming and visits by numerous interested parties (farmers, researchers, public officials) to the Chequen farm, the system has not expanded to more than about 100,000 ha in Chile. Wheat, oats and rapeseed are the main crops under no-tillage in Chile (representing around 95% of the total hectares), in addition to barley, triticale, lupins, lentils, and maize.

---

[15] based on Sorrenson, W J (1997). Paraguay: Financial and economic implications of no-tillage and crop rotations compared to conventional cropping systems. FAO Investment Center Occasional Paper Series No. 9. Food and Agriculture Organization of the United Nations, Invest Centre, Rome, Italy; and Ekboir J (ed.) (2002). CIMMYT 2000-2001 World Wheat Overview and Outlook: Developing no-tillage packages for small-scale farmers. Mexico,

[16] based on the book by Carlos Crovetto Lamarca 'Stubble Over the Soil' . Revised and translated into English by: Jerry Lemunyon, Fort Worth, Texas; David Schertz, Washington DC; Lewis Daniel, Lakewood, Colorado,; Stefanie Aschmann, Lincoln, Nebraska; Donald Baldwin, Enterprise, Oregon; Linda Oyer, Albuquerque, New Mexico; and Maria Montes, San Juan, Puerto Rico. Published by the American Society of Agronomy, Madison, WI, USA 1996 and reprinted in 1998

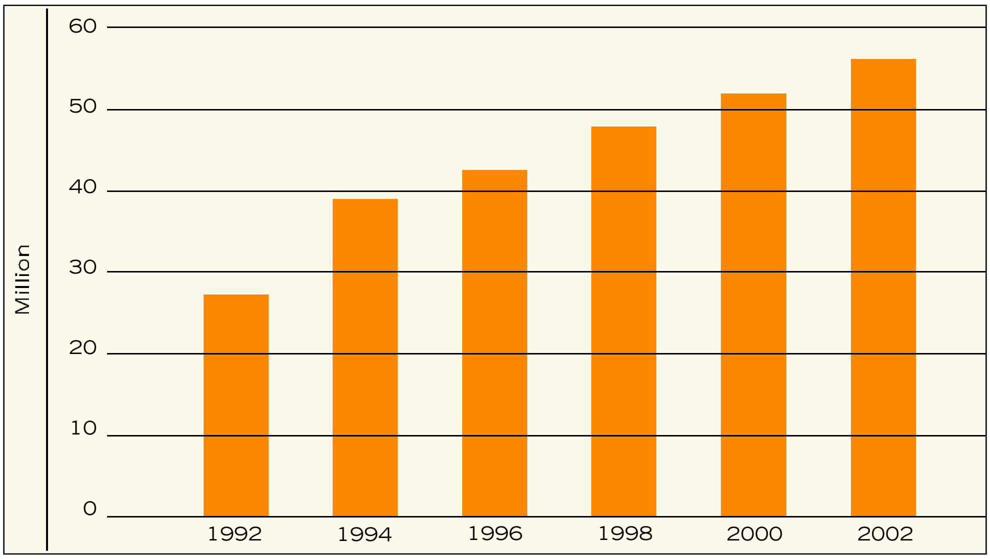
The USA experience[17]

In response to the damage caused by intensive tillage for crop establishment, which exposed soils to wind erosion and loss of organic matter, the introduction of stubble-mulch farming in the Great Plains was one of the earliest examples of the keep conservation technologies in the United States and was the forerunner of no-tillage. It was developed primarily for controlling wind erosion, but its value for reducing run-off and controlling water erosion was also apparent[18].

Stubble mulch-based conservation farming involves maintenance of surface residue cover and seeding into residue cover with as little movement of these covers as possible[19]. Demonstrations and adoption of new techniques started on a few farms in Kentucky in 1961-62 and continued to grow steadily throughout the country in the 1970s and 1980s. Rapid expansion occurred in the 1990s with the introduction of efficient high-residue seeding equipment, improved weed, insect, and disease control technologies, and federal legislations requiring soil conservation on highly erodible soils.

Today, conservation tillage, involving minimum and/or no-tillage systems and mulch management, is practiced over 50 million hectares, out of which about 25 million hectares are under no-till systems in different cropping systems in all parts of the country (see figure below).

Figure 3: Area under conservation tillage in the US (2002)



Source: CTIC National Crop Residue Management Survey

---

[17] based on ER Phillips and SH Phillips (1984) Ed. No-tillage agriculture, Principle and Practice. Van Nostrand Reinhold Co., New York, 306 pp; USDA (1985).
Conservation tillage. Things to consider. Agricultural Information Bulletin No. 46, Washington DC;
Wiese, AF (ed.). 1995. Weed control in limited tillage systems. Published under the monograph series of Weed Science Society of America. Champaign, Il., USA;
USDA Soil Conservation Service (1991 and 1992). Lines on the land and Crop residue systems for conservation and profit. Des Moines, Iowa, USA;
Fawcett, R and D Towery (2004). Conservation Tillage and Plant Biotechnology- How new technologies can improve the environment. The Conservation Technology Information Center (CTIC), West Lafayette, IN, USA

[18] McCalla, TM and TJ Army. (1961). "Stubble-mulch farming." Advances in Agronomy, 13: 125-196,

[19] UDSA (1992). Crop residue systems for conservation and profit. USDA Soil Conservation Service, Des Moines, Iowa, USA

Farmers adopting conservation tillage practices have been able to reduce their cost of production, eliminate erosion with improved soil health and obtain more stable and higher yields, especially under adverse growing conditions. Agricultural research, backed up by farmer experiences, shows that the land under long-term no-till systems can eventually regain characteristics of native soils before the advent of high-input intensive agriculture. They have also highlighted many broader environmental benefits, including reduction in soil erosion, which saves millions of tonnes of topsoil each year, as well as decreased sediment and chemical run-off entering streams, reduction in releases of greenhouse gases into the atmosphere and improvements in biodiversity both in the soil and on the farmland. Research from North Carolina shows that in conventional soybean fields, quail chicks needed 22 hours to obtain their minimum requirement of insects. In no-till fields, only 4.2 hours were required – nearly the same as the 4.3 hours required in their natural habitat[20].

The benefits of conservation technologies are discussed in more detail in a later section of this report. Given the rich diversity of conservation systems adopted in the USA, only a few examples of the most widely-used technologies are discussed here.

The Midwest

The widely-practiced planting systems for the most important crops of the Midwest - maize (corn) and soybean - involve no-till/reduced-till techniques for crop establishment along with residue management. Under the no-till system, the soil is left undisturbed from harvest to planting, except for weed control treatment and nutrient injection (with less than 10% of ground surface disturbed). The crop is established using suitable direct-seeding equipment. With minimum tillage, the seedbed is prepared using appropriate farm implements, but residue from the harvest of the previous crop is left on the soil surface. Crop rotations are followed from a high residue-producing crop such as maize, sorghum, or forages (grass or legume), to a low residue-producing crop such as soybean, sunflower or root crop.

---

[20] The Conservation Technology Information Center (CTIC) “Conservation Tillage and Plant Biotechnology: How New Technologies Can Improve the Environment By Reducing the Need to Plow” http://www.ctic.purdue.edu/CTIC/BiotechPaper.pdf

Inland Pacific Midwest, Pacific Northwest (PNW); Palouse River Basin and Nez Perce Prairies[21]

The inland wheat production areas of PNW are subject to severe soil erosion. Two rotations dominate the production systems: monoculture wheat and wheat-barley-pea rotation. Conservation tillage systems (chisel ploughing or no-till planting) effectively reduce soil erosion and improve water infiltration left from winter precipitation.

Conservation tillage combined with a winter wheat- spring barley- spring dry pea rotation, along with effective weed management (non-selective and selective herbicides) provides high average profitability with low economic risk. Decreases in crop yields and net returns are observed when weed management is poor or when a monoculture wheat system is used. The excellent performance of this conservation system highlights the importance of effective weed control and adoption of diverse crop rotations.

Colorado, Nebraska, South Dakota[22]

In the wheat belt comprising of highly erodible drylands, the winter wheat-fallow is the most common crop rotation in areas with less than 430 mm of rainfall. In areas receiving 430 to 560 mm rainfall, the winter wheat- maize or sorghum - fallow rotation are also common cropping systems.

An innovative conservation approach, termed ecofallow, has been developed to meet land management requirements under US federal government legislation applicable to HELs[23]. Ecofallow includes management of weeds during the fallow period by using herbicides or herbicides plus tillage, with minimum disturbance of crop residues and soil. Typically, wheat is sown in October and harvested in July. Thereafter, the land is left fallow for 15 months to trap and conserve water. Weeds are kept under control during the fallow period.

In slightly higher rainfall areas, the ecofallow system provides growers with greater flexibility to add a spring crop (sorghum or maize) into the rotation and in timing of field operations. Benefits of the ecofallow approach include: cost-effective weed control, reduced soil erosion and the potential to store more water in the soil. As a result, this system provides higher yields than the conventional tillage practices involving mechanical weed control and seedbed preparation.

---

[21] based on Washington State University (1993). IPM Research Project for Inland Pacific Northwest Wheat Production. Research Bulletion XB 1029. College of Agriculture and Home Economics Research Center, WSU, Pullman, WA, USA; Young FL, AG Ogg Jr, RI Papendick, DC Thill and JR Alldredge (1994). Tillage and Weed Management Affects Winter Wheat Yield in an Integrated Pest Management System. Agronomy Journal. 86:147-154; Young DL, K Tae-Jin and FL Young (1994). Profit and risk for integrated conservation farming systems in the Palouse. Journal of Soil and Water Conservation 49(6):601-606; and Young FL, AG Ogg Jr., DC Thill, DL Young and RI Papendick (1996). Weed management for crop production in the Northwest wheat (Triticum aestivum) region. Weed Science 44:429-436.

[22] Based on University of Nebraska (1996) Getting Started in Ecofarming: for Growing the Winter Wheat Crop. Publication No. G91-1009-A Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources, Lincoln, Nebraska.

[23] HELs: Highly Erodable Lands

Southern USA (Mississippi Delta)[24]

The highly-erosive climate and erodible soils of this region require special measures for erosion control and for maintaining crop productivity. For many years, the only research in the southern United States to determine the soil erosion effectiveness of no-till conservation tillage practices was conducted at Holly Springs, Mississippi.

Conservation tillage studies with soybeans, corn, grain sorghum, and cotton showed that no-till and reduced-till cropping systems can dramatically reduce erosion. Whole farm economic analysis of cotton-corn or cotton-soybean production in Mississippi farms has shown that no-till systems provide savings in the cost of production by reducing 'number of trips over the field' and reduce overall investment in farm machinery, fuel, maintenance and labour. However, on some heavy cotton soils, sub-soiling is necessary to overcome problems related to compaction. This practice has become more feasible with the development of improved farming tools, which can till deeper into the soil, with minimal disturbance of surface residues.

Integrated Vegetation Management in 'Rights-of-Way'[25]

Conservation technologies in agriculture are not limited to tilling practices, but also help to conserve natural resources and deliver benefits for the environment. Rapidly improving technologies for sustainable intensification of agriculture enable higher production from existing agricultural areas, which provides opportunities for broadening of biodiversity conserving areas.

In non-agricultural situations, thousands of kilometres of rights-of-way (land set aside for use as highway or power-line corridors) must be maintained to allow access for maintenance workers and to prevent vegetation from growing into the power-lines. Integrated vegetation management (IVM) based on a combination of control options avoids the negative impacts of mechanised clearance and maintenance of these areas. Under IVM, the problem species are identified and reduced or eliminated using a combination of options including biological, chemical, cultural, and mechanical methods. The choice is based on effectiveness, safety, environmental impact and cost. Mechanical cutting may be appropriate in some situations, especially to reduce vegetation height and density.

With the removal of problem trees and other invasive weeds, space is created for the growth of desirable low-growing species comprising grasses, wildflowers, shrubs, and small trees. This mix of desirable species not only maintains itself, but also provides food and shelter for a wide variety of wildlife, adding to biodiversity.

For example, the integrated use of herbicides and other measures allowed Delmarva Power to manage its electric service reliability and right-of-way access needs in a more efficient, economical, and environmentally sensitive manner in many counties in Delaware, Maryland and New Jersey. Field observations confirmed an increase in fauna and flora, including bobwhite quail, wild turkey, bees, and butterflies, which thrived on the increased availability of food, pollen, and shelter. It was concluded that a well-managed right-of-way corridor involving judicious use of herbicides can help to recreate a balanced ecosystem necessary for the survival of many less-competitive and/or endangered species under a range of climatic conditions.

---

[24] based on Conservation Tillage Cotton Rice Conference 2002 January 24-25, 2002 - Tunica, Mississippi Sponsored by: National Conservation Tillage Digest

[25] based on Johnstone R A (1990). Vegetation management: Mowing to spraying. Journal of Arboriculture 16 (7) and Conectiv (2003). Integrated vegetation management program. http://www.conectiv.com/civ/our_environment/veg_mgmt

The Canada experience[26]

With the availability of improved herbicides and suitable farm implements such as direct drills in Canada, it became possible to control weeds and successfully plant a crop without tillage. By 1975, many farmers had become serious about converting to zero tillage, and they experimented with different approaches. They provided valuable feedback to university researchers, the plant science industry, and machinery manufacturers for continued improvement of technological options.

Conservation tillage is now practised on more than 12 million hectares covering a range of crops including wheat, maize and canola. The advantages of conservation tillage have been demonstrated by continuous no-till cropping on numerous farms. These advantages include moisture management, higher productivity, and lower costs of production, including reduced fuel costs. On the environmental side, there is reduced risk of soil erosion, improved soil quality and reduced greenhouse gas emissions.

Recent results from the New Brunswick projects show that soil and environmental conditions can significantly influence results under all crop establishment systems compared (conventional, minimum and zero-tillage). The zero-till projects also showed a difference in crop performance over different soil types and field exposure. Silage corn yields were lower on heavier textured silt loam. However, on more rolling, gravely and medium-texture loam and sandy soils, yields were better. This is because on the heavy loam, crop residues prevented the soils from warming up, and with the cold, wet conditions of the region, crop growth was retarded. Silage barley performed very well under zero-till.

Fuel consumption under reduced tillage was dramatically reduced. Fuel requirements were cut by about 40% under low tillage, and by about 70% under zero-till.

Europe: The UK experience with the Soil Management Initiative (SMI)[27]

Modern agricultural practices, mainly characterised by intensive tillage and external inputs, have had a damaging effect on the soil environment in the UK. Soil degradation due to erosion and compaction processes is probably the most serious environmental problem caused by conventional agriculture. Losses of 2.3 million tonnes of soil per year across the UK have been reported, with 44% of arable land being vulnerable to such problems[28].

At the same time, there have been instances of deterioration in water quality due to leaching of nutrients and pesticides into surface and ground water, loss of carbon (as CO_2) from cultivated land contributing to changes in global climate and loss of biodiversity at all levels.

Recent work by SMI with improved farm machinery, herbicide technologies and rotations (of crops, of herbicides and of drilling dates) shows that adoption of no-tillage or minimum tillage practices combined with crop residue management can help to minimise or even avoid the negative effects of aggressive conventional cultivation systems.

---

[26] based on Coutts G R and R K Smith (1991). Zero-tillage production manual. Manitoba and North Dakota Farmers Association, Brandon, Manitoba, Canada; and Soil Conservation Council of Canada (SCCC) Web site at www.soilcc.ca

[27] based on Soil Management Initiative (SMI) publication 'A guide to managing crop establishment', (2003). and 'Improved soil management for agronomic and environmental gain'. SMI is an independent organization that promotes the adoption of cultivation systems designed to protect and enhance soil quality, and to minimise soil erosion and water pollution, whilst maintaining or enhancing farm economic returns.

[28] Code of good agricultural practice for the protection of soil, MAAF, 1998

Based on experiences of farmers operating under different soil, crop and climate situations across the UK, SMI work has confirmed several major benefits of conservation tillage systems (mostly involving reduced cultivation and crop residue management) reported from other member countries of the European Conservation Agriculture Federation (ECAF)[29].

These benefits include savings in crop establishment costs, energy use and in some cases higher yields; improved soil quality, resulting from improved soil fertility, increased carbon capture to build organic matter, decreased soil erosion, improved water permeability improved bulk density and aggregate stability; improved water quality due to reduced water run-off and sediments leaving fields with pesticides and nutrient residues; reduced $C0_2$ emission due to improved retention in crop residue and soil as well as reduced use of fuel; and increased biodiversity due to improved conditions for soil organisms, as well as for bird species.

It is estimated that in the UK some 1.5m ha, representing nearly 30% of agricultural land is now under conservation agriculture. Well thought-out strategies for crop residue management, weed control and crop protection are necessary for this success. Although confined to combinable crops (e.g. cereals, oil-seed rape), the current status is a significant advance over the situation in the 1970s.

Europe: Perennial Crops (Vines and Olives) in Mediterranean Countries (Spain, Italy and France)[30]

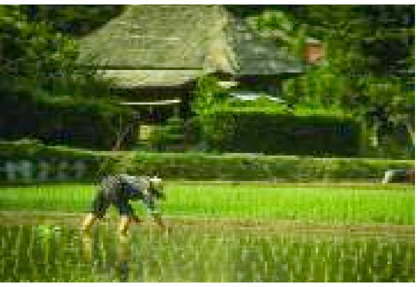
In the Mediterranean climate, soil erosion affects 50 - 70% of agricultural land, adding an estimated 25% to production costs each year. Increasing intensification of conventional agricultural over the last four decades has significantly contributed to this trend. In common with more temperate parts of Europe, other concerns related to conventional agricultural practices include: reduction in soil organic matter; decrease of biodiversity; soil compaction; increased CO_2 emissions into the atmosphere; and reduced storage of water in the soil. Conservation agriculture helps to address these concerns.

Spain and Portugal, with about 20% and 10% agriculture under conservation agriculture respectively, have taken the lead in developing and introducing these techniques, including weed management approaches in perennial crops (vines and olives). Soil erosion, including that resulting from natural run-off events caused by high rainfall (which can sometimes be over 100mm in one day), threatens the long-term viability of olive and vine cultivation in Mediterranean basin. These crops form the staple of agriculture in this region. Evaluation of different agronomic practices for their effectiveness in reducing soil erosion and improving soil structure has shown that inter-row weed control with herbicides without disturbing the soil not only provides some surface mulch, but also leaves soil stabilising root systems intact. It has been observed that, depending on the weather conditions, the root mass left in soil can reduce loss of soil by up to 66% (138 t/ha) in French vines and by 98% (48 t/ha) in Spanish olives.

---

[29] ECAF is a network of leading European academics, scientists and farmers to promote farming practices collectively known as conservation agriculture to improve and maintain agrarian soil and its biodiversity.. It brings together fourteen national associations in Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Portugal, Slovakia, Spain, Switzerland and the UK.

[30] ECAF (2004). Conservation agriculture in Europe. www.ecaf.org; Llewelyn C. (2004). Soil conservation in Mediterranean viticulture. Progress Report Autumn 2001 to Winter 2003. Cranfield University, Silsoe, UK; and Gomez J (2004). Soil conservation in olive orchards. Progress Report June-December 2003. Cordoba University, Spain.



The South Asia experience: Indo-Gangetic plains

Nearly half of the 401.72 million hectares that make up the total land area of South Asia's Indo-Gangetic plains (IGP) -- Bangladesh, India, Nepal, and Pakistan is devoted to feeding and providing livelihoods for 1.8 billion people[31]. Rice and wheat are the staple food crops and contribute more than 80% of the total cereal production in these countries. This system is fundamental to employment, income, and livelihoods for hundreds of millions of rural and urban poor of South Asia[32].

Suitable thermal regimes for rice and wheat cultivation, development of short-duration, nitrogen-responsive cultivars, expansion of irrigation, and the ever-increasing demand for food, were some of the driving forces for increased production through area expansion and intensification of the rice-wheat system during the Green Revolution period starting in the early 1960s. In the last four decades, high growth rates for food grain production -- wheat 3.0%, rice 2.3% -- have kept pace with population growth.

Evidence is now appearing that further intensification of input use since the adoption of Green Revolution technologies has provided lower marginal returns[33], and the continued intensification of cropping in some situations is leading to degradation of the resource base through salinisation, over-exploitation of groundwater, physical and chemical deterioration of the soil, and pest problems[34]. Increasing adoption of resource-conserving technologies involving tillage and crop establishment options, such as minimum and zero-tillage systems for wheat planting in rice-wheat rotation, are enabling farmers to sustain productivity. Field results show that these technologies improve yields, reduce water consumption, and decrease negative impacts on the environment. When combined with integrated approaches to pest and disease control, these techniques provide options for sustainable intensification and diversification of rice-wheat systems.

Strong research and development support by national and international agricultural research groups, including the private sector, along with socio-economic changes in the IGP countries are leading to rapid adoption of conservation technologies by farmers. It is estimated that over the last five years the area under minimum/zero-tillage for the establishment of winter season crops (wheat, maize, lentil, chickpea, peas etc.) has increased to nearly 2 million hectares (m.ha), mainly in India and Pakistan[35].

---

[31] Food and Agriculture Organization (FAO), (1999). FAO production book, Vol.53, FAO, Rome, Italy.

[32] Gupta, RK, PK Naresh, PR Hobbs, Z Jiaguo, and LK Ladha (2002). Sustainability of post-green revolution agriculture: The rice-wheat cropping systems of the Indo-Gangetic plains and China. P 1-27. In JK Ladha et al (ed.) Improving the productivity and sustainability of rice-wheat systems: Issues and Impact. ASA Special Publ. 65. ASA, Madison, WI, USA.

[33] Ladha, JK, KS Fischer, M Hossain, PR Hobbs and B Hardy (2000). Improving the productivity and sustainability of rice-wheat systems of Indo-Gangetic plains: A synthesis of NARS-IRRI partnership research. P. 1-31. Discussion paper No. 40. International Rice Research Institute, Los Banios, Philippines.

[34] Byerlee, D., (1992). Technical change, productivity and sustainability in irrigated cropping systems of South Asia: Emerging issues in the post-green revolution era. J of Int. Dev. 4, 477-96; and Byerlee, D and R Murgei (2001). Sense and sustainability revisited: The limits of total factor productivity measures of sustainable agricultural systems. Agricultural Economics, 26: 227-36.

[35] Gupta, RK and AK Seth (2004). A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic Plains (IGP). A paper presented during the 4th International Weed Science Congress. 20-24 June, 2004, Durban South Africa.

South-East Asia: The Malaysia experience

Rubber and oil palm are two very important crops in the Malaysian economy, occupying 1.6 million and 3.4 million hectares, respectively[36]. These crops are cultivated both by smallholder farmers and large plantations. Under the traditional clean-clearing method of planting and replanting, logged-over forests or old stands of rubber and oil palm are mechanically felled and burned. This approach exposes the soil to erosion and contributes to environmental pollution.

The plantation industry has now developed a 'zero-burning' replanting technique under which the old stands of palms are mechanically felled and shredded and left as mulch to decompose *in situ*. Prior to felling, baselines for new planting rows, roads, mechanisation paths, and drains are pegged.

Planting rows for new crops are cleared and prepared immediately after felling. The shredding operation is completed within two months after felling of the old stand. It is a common practice to terrace steep slopes and make silt pits to reduce soil erosion due to heavy rains during crop growth. At the same time, establishment of creeping leguminous crops to provide rapid ground cover in the inter-row areas provides added protection from soil erosion until the palm oil or rubber canopy develops to provide full cover over the inter-row areas. In addition, the leguminous species fix nitrogen adding to soil fertility.

Besides contributing to a cleaner environment, the 'zero-burning' technique replenishes soil organic matter and improves the physical and chemical properties of the soil. Weed growth in planting rows is kept in check, mostly with post-emergent herbicides[37].

The Australia experience[38]

In Australia, many soils in areas dominated by wheat-pasture rotations have low moisture-holding capacity, are nutrient-poor, and are prone to wind erosion. Accordingly, the main focus of conservation tillage technologies, which have now been adopted over 9 million hectares, has been to improve land and water management practices, especially to conserve moisture and reduce soil erosion.

The pasture phase of wheat-pasture rotation includes a mixture of grasses and clover. At the time of changeover from the pasture phase, wheat is direct drilled under zero tillage, three to five days after herbicide application. Planting of wheat without cultivation allows large areas to be covered quickly and crops to be established early, making full use of moisture from early season rains and shortening the period when soils are exposed to wind erosion. More efficient use of moisture improves productivity, reducing overall costs of production. Direct drilling, especially where hardpan occurs below sowing depth or where there is compaction due to repeated tractor passes, helps with moisture retention and root growth. Given the risk-prone nature of Australian agriculture, a reduction in the cost of production and improved moisture management and protection against soil erosion are important considerations in the adoption of technological innovations.

---

[36] Malaysia Ministry of Agriculture, 2002

[37] Tajudin M H, Teoh Cheng Hai and K A M Ali (1993). 'Zero-burning' – An environmentally friendly replanting technique. Proceedings International Palm Oil Conference. In: The zero burning techniques for oil palm cultivation. A Golden Hope Plantations Berhad publication

[38] based on http://www.syngenta.com.au and Schmidt, CP, PK Bedford and D Tennant (1994). Effect of different direct drilling and conventional sowing techniques on soil strength, root growth and grain yield of wheat on sandplain soils in Western Australia Australian Journal of Agriculture Research, 45(3):547-564.

West Africa: The Ghana experience[39]

Even though public institutions in West Africa started research on zero-tillage systems in the 1960s, little progress was made in transferring this knowledge to farmers. It was not until the 1990s, when the national and international research and development institutions, non-government organisations and the private sector formed a partnership to support further participatory research and extension work, that information about benefits of conservation tillage began to be appreciated and adopted by farmers. Since the traditional method for maize planting followed by small-scale farmers in Ghana and some other West African countries involves very little cultivation, focus of the renewed effort was to develop effective weed control and stubble management practices.

The partnership programme emphasised on-farm demonstrations to show the advantages of conservation tillage to farmers. Using participatory approaches, an entire farm-management system was promoted. This included the use of certified seed, organic and inorganic fertilizers, pre- and post- planting weed control, and harvesting techniques that left crop residues in the field. This work was supported by pre-season farmer training, field days, field tours, workshops, and distribution of printed extension material. Some rural banks and district councils also got involved in the promotion work by providing credit to selected farmers. No-till farming has given higher yields both in normal and drier years due to improved land management and moisture retention. From the early 1990s to 2000 it is estimated that more than 100,000 farmers have adopted conservation tillage methods on about 45,000 hectares to cultivate maize and grain legumes.

East Africa: Experience from the dry foot slopes of Mount Kenya[40]

The semi-arid foot slopes and highland plateau West and North-West of Mount Kenya is characterised by high pressures on natural resources resulting from land use intensification on the mountain slopes and high soil and water resource demand in the lowlands. The soils are mainly likeclay with highly variable rainfall distribution (100 - 700mm per growing season). The area is now settled largely by small-scale farmers who intercrop maize and beans, and also grow potato and wheat on small parcels of land averaging 0.5 – 2.0 hectares. A small part of the area is under wheat production by large-scale farmers. More recently, some of the unsettled areas and part of the area under large-scale wheat has been converted into irrigated horticulture production.

Due to variable rainfall and high water losses through evaporation and run off, water stress and crop failures are common. To avoid frequent crop failure, different conservation technologies have been tested along with introduction of animal-drawn farm implements. The main techniques tested involve ripping open soil to a depth of 25 cm and, where necessary, sub-soiling to break hardpan, as well as using herbicides to control weeds.

In an average rainfall season, wheat (variety Mbuni) yields on a small-farm were doubled from 1.6 - 3.4 t/ha. In a large-scale farm with mechanised drilling and combine operations, yields reached 5.6 t/ha. Small-farm maize yields were raised by 116% (from 1.8 to 3.9 t/ha), beans by 76% (from 0.3 t/ha to 0.8 t/ha), and potatoes (variety Tigoni) by 60% (from 8 to 13 t/ha). Moreover, the amount of run-off during heavy storms was reduced by half. Farmers with ripping equipment were able to rent them to others, thereby raising their income.

---

[39] based on Mensah-Bonsu and H G Obeng (1997). Effects of cultural practices on soil erosion and maize production in the semi-deciduous rainforest savannah. Transitional zone of Ghana. In D J Greenland and R Lal (eds.) Soil and Crop Production in the Humid Tropics. John Wiley, Chichester, UK. Pp. 509-519. and Ekboir J (ed.) (2002). CIMMYT 2000-2001 World Wheat Overview and Outlook: Developing no-tillage packages for small-scale farmers. Mexico, DF. CIMMYT

[40] based on Gitonga J. N., FI Kihara ,K Mutunga, HP Liniger (2004). Conservation Agriculture on the Dry Foot Slopes North-West of Mount Kenya. Paper presented during the 4th International Weed Science Congress, 20-24 June, 2004, Durban, South Africa.

Despite these promising results, adoption by farmers has been fairly limited. Challenges to increased adoption include the need to improve availability and reduce cost of conservation tillage implements; integrate water conservation and soil fertility improvement measures; increase knowledge and skills of farmers and extension workers; increase documentation and dissemination of information on broader benefits of consevation technologies both to farmers and policy makers.

Southern Africa: South Africa Experience[41]

Over the last 25 years in SouthAfrica, considerable research and development work has been undertaken on conservation systems to conserve and protect soil, water, energy and other resources required for sustainable crop production under various soil and climatic combinations. The main focus of the work has been on maize and wheat production for large farms. However, much of this knowledge has to be effectively transferred to potential practitioners. In addition, there is a large unfinished research agenda, especially to meet the needs of small-holder farmers. Techniques being explored include animal traction, crop rotation and acidification.

Conservation techniques used in maize production involve stubble mulching and reduced or no-tillage using a chisel plough. In the North West Province, no-till maize production with stubble mulching over long periods had no adverse effect on yields. Use of heavier equipment, on the other hand, caused compaction requiring sub-soiling treatment for improved yields. Crop production in the Western and Southern Cape wheat producing areas of South Africa is hampered by generally shallow and stony soils, characterised by a weakly-structured horizon and low organic carbon content. Both areas can be described as winter rainfall areas with long-term annual means of 275 to 500mm of rain. The climate in the Western Cape is typically Mediterranean with hot, dry summers and mild, rainy winters. In the Southern Cape, the percentage of rainfall during the winter gradually decreases from about 80% in the west to 55% in the extreme east. Traditional production systems in these areas include fallowing and mouldboard/disc ploughing. Research on minimum and no-tillage in these areas showed little advantage with regard to soil moisture, but improved soil fertility and workability due to increased soil organic matter content. This resulted in enhanced yields and helped to reduce input costs. The adoption of minimum and no-till agriculture has increased in recent years in these areas.

---

[41] based on Fowler R (1999). Conservation tillage research and development in South Africa. In. Kaumbutho P.G and T. E. Simalenga (Ed.). Conservation Tillage with Animal Traction A Resource Book of Animal Traction Network for Eastern and Southern Africa (ATNESA), Harare, Zimbabwe; and Agenbach GA (2004). minimum and no-till agriculture in the western and southern cape wheat producing areas in South Africa. Paper presented during 4th International Weed Science Congress, 20-24 June 2004, Durban South Africa.

Linkage between conservation tillage and herbicide-tolerant biotech crop varieties[42]

Experiences of farmers and researchers, especially in the US and Latin America, have shown that availability of effective herbicides and accumulation of crop residues on the soil surface reduces the severity of weed problems, which in many situations also reduces the overall use of herbicides. Nevertheless, weed flora can change and the ability to achieve effective control of difficult perennial weeds or the development of resistance to commonly-used herbicides remain important issues for farmers adopting conservation tillage practices. In addition, use of biotech crops in conservation technology systems helps in reducing the volume of herbicide applied and the risks associated with chemical run-off.

To address these concerns, farmers have adopted integrated approaches involving the use of mulch, crop rotation, and new herbicides where available. In addition, biotechnology has given farmers newer options, including the use of genetically modified crop varieties that are tolerant to herbicides. These varieties have rapidly become popular with farmers worldwide, especially in North and South America and China. It is estimated that in 2004 the global area planted to biotechnology-derived crops was about 81million hectares[43].

Although no-till farming does not require biotechnology, use of GM seeds has renewed interest and expanded these methods to areas where it has previously been difficult. Recent surveys of farmers growing genetically modified soybean, corn, and cotton in the US and canola in Canada have shown that, in all cases, availability of herbicide-tolerant crops has increased adoption of conservation tillage practices[44].

---

[42] Based on Bull L, H Delvo, C Dandretto and B Lindammod (1993). Analysis of pesticide use by tillage systems. In: Corn and Soybean Agricultural Resources: Inputs. USDA, ERS, AR-32.; Papendick R I (1996). No-tillage impacts on soil. Twenty years of experience. In: Congresso Nacionalde Siembra Directa 4. Villa Giardino, Spain. P. 59-86.; Da Silva J B (2002). Zero-tillage: Reduction of environmental risks with herbicides. In: H M Saturnino and J Landers (eds.): The environment and zero-tillage Associacao de Plantio Directo no Cerrado, Brasilia. Pp89-96.; James C. (2002) Global status of commercialised transgenic crops: 2002. International Service for Acquisition of Agri-biotech Applications (ISAAA) Briefs No. 27. ISAAA, Ithaca, New York; Fawcett R S and D Towery (2002). Conservation tillage and plant biotechnology: How new technologies can improve the environment by reducing the need to plough. Conservation Technology Information Centre, West Lafayette, IN, USA; and Van Acker R C, A L Brule-Babel and L F Friesen (2003). An environmental safety assessment of Roundup Ready wheat: Risks for direct seeding systems in Western Canada. A report prepared for The Canadian Wheat Board. For submission to: Plant Biosafety Office of the Canadian Food Inspection Agency, Ottawa, Ontario, Canada.

[43] James, C. 2004. International Service for the Acquisition of Agribiotech Applications (ISAAA) Briefs 32-2004: Preview: Global Status of Commercialised Biotech/GM Crops: 2004. ISAAA, Cornell University, Ithaca, NY, USA. www.isaaa.org <http://www.isaaa.org/>

[44] Fawcett R S and D Towery (2004). Conservation tillage and plant biotechnology: How new technologies can improve the environment by reducing the need to plough. Conservation Technology Information Centre, West Lafayette, IN, USA.

Benefits of Conservation Technologies

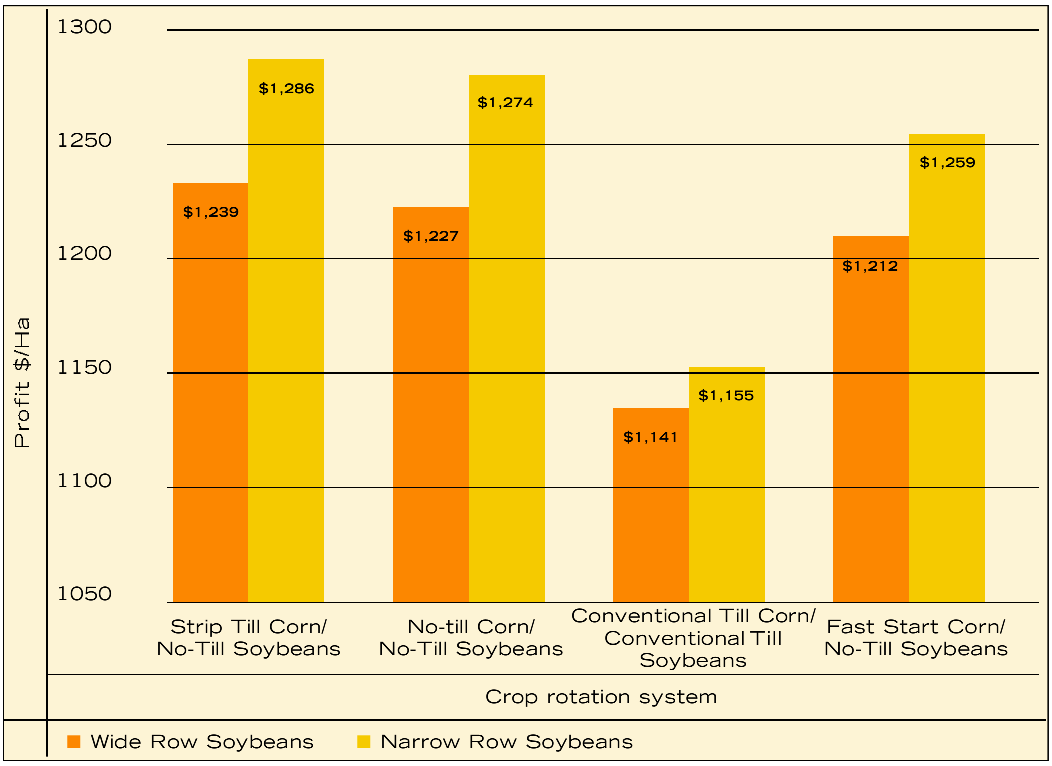
In countries where conservation technologies have now been in use for sometime, there is evidence that agricultural lands maintain productivity and provide economic, environmental, and social benefits at farm, community, national and global levels. The benefits are accrued both by large- and small-scale farmers.

Economic benefits

Of all the reasons to consider conservation technologies, none is more important to an individual farmer than the economic benefits. The profitability of farm operations is an annual concern that is strongly influenced by the cost of production.

Increases in land and labour productivity and lower operational costs, leading to increased farm incomes, have been commonly reported by farmers as one of the main reasons for adopting conservation technologies. Long-term trends in crop yields indicate that the benefits to production are substantial. For example, in the US, the yields of maize cultivated with no-till techniques were about 90% greater than tilled maize during the first years after conversion. This gradually increased to 100% after 20 years[45]. Evidence shows that it takes about nine years for no-till soil to develop higher residual organic matter, improved physical conditions, and improved moisture retention[46].

Figure 4: Five Year total profit* for corn/soybeans rotation



Source: Alesii, B (2004) Impact Different Tillage Practices have on Crop Yield, Production Cost, Profit and Soil Quality in a Corn/Soybean Rotation. Paper presented during the 4th International Weed Science Congress 2004, Durban, South Africa

* Excludes cost of land and government payments

---

[45] Ismail I, RL Blevins and WW Frye (1994). Lon-term no-tillage effects on soil properties and continuous corn yields. Soil Science Society of America \journal 58:194-198

Table 3: Brazil: Comparison of direct immediate benefits in maize and soybean production under no-till (conservation tillage) and conventional tillage

		Yield (kg/ha)			Decrease in Hours/ha/year under No-till (%)		
Farm type	Crop	Conventional	No-till	Increase (%)	Labour	Equipment Use	Fuel Consumption
Mechanised	Soybean	2440	3100	27	-10	-27	-27
	Maize	4500	5840	29.8	-51	-19	-19
Animal Traction	Soybean	1460	2000	37	-59	-46	—
	Maize	4000	4800	20	-55	-66	—

Source: World Bank, 1998 a, 1998 b.

Table 4: Paraguay: Annual income and variable and fixed costs in the first and tenth year under conservation-tillage and conventional-cropping systems of a typical large farm (135 ha) in San Pedro and Itapua regions

		First Year (US$)		Tenth Year (US$)	
Region	Parameter	Conventional Cropping	Conservation Tillage	Conventional Cropping	Conservation Tillage
San Pedro	Total farm income	77,031	75,010	68,632	93,762
	Total variable costs	53,484	51,467	53,026	48,166
	Total fixed costs	18,618	14,974	18,618	14,454
	Net farm income	4,929	8,569	-3,013	31,142
Itapua	Total farm income	64,688	63,675	61,454	102,856
	Total variable costs	38,818	36,674	41,792	56,077
	Total fixed costs	18,567	17,229	18,567	13,075
	Net farm income	7,304	9,771	1,095	33,703

Source: Sorreson (1997)

---

[46] Ismail I, RL Blevins and WW Frye (1994). Long-term no-tillage effects on soil properties and continuous corn yields. Soil Science Society of America journal 58:194-198

Sorrenson, W J (1997). Paraguay: Financial and economic implications of no-tillage and crop rotations compared to conventional cropping systems. FAO Investment Centre Occasional Paper Series No. 9. Food and Agriculture Organization of the United Nations, Invest Centre, Rome, Italy.

World Bank (1998a). Implementation Completion Report, Brazil, Land Management I Project, Parana. ESSD Sector Management Unit, LAC, World Bank, Washington DC, USA.

World Bank (1998b). Implementation Completion Report, Brazil, Land Management II, Santa Catrina Project. ESSD Sector Management Unit LAC, World Bank, Washington DC, USA.

Table 5: Paraguay: Annual income and variable and fixed costs in the first and tenth year under conservation-tillage and conventional-cropping systems of a typical large farm (135 ha) in San Pedro and Itapua regions

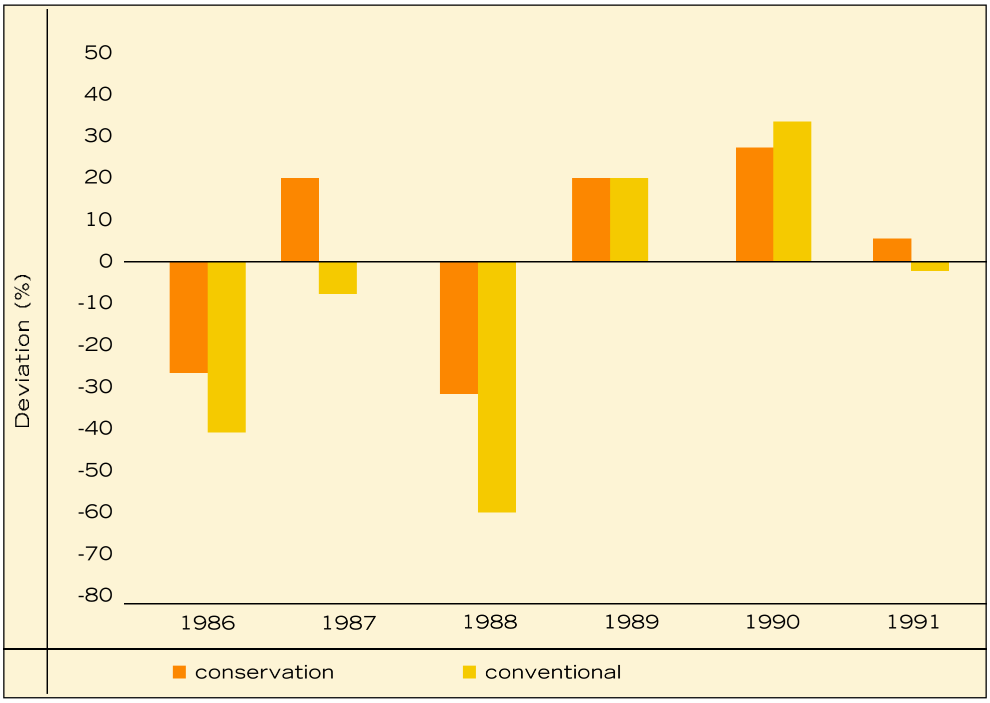
	San Pedro				Itapua			
	First Year		Tenth Year		First Year		Tenth Year	
Parameter	Conventional Cropping	Conservation Tillage	Conventional Cropping	Conservation Tillage	Conventional Cropping	Conservation Tillage	Conventional Cropping	Conservation Tillage
Net Farm Income US$	4,930	8,570	-3,010	31,140	7,300	9,770	1,100	33,700
Return on Capital (%)	1.8	3.2	-1.1	13.3	1.8	2.4	0.3	8.3
Annual Tractor Hours	1,228	1,177	1,210	776	1,179	981	1,179	786

Source: Sorreson (1997)

Risk management

Long-term gains in productivity and more stable production can only be achieved by improving soil quality, which also reduces risks for farmers by stabilising yields, especially in dryland agriculture. For example, Figure 5 shows results from a six-year field study in the US Pacific Northwest, which shows that the deviation from six-year wheat yield averages (5007 kg per ha) was higher under conventional tillage (ranging from -60% to +27%) as compared to conservation tillage (-30% to + 22%). Factors that contributed to these differences included weather related factors (temperature, moisture) and variations in response to weed management levels (minimum, moderate and maximum).

Figure 5: Percentage deviation from wheat and yield averages (1986-1991)



Source: Young, FL, AG Ogg Jr., RI Papendick, DC Thill and JR Alldredge (1994). Tillage and weed management affects winter wheat yield in an Integrated Pest Management system. Agronomy Journal. 86:147-154

Environmental impact

In countries where conservation tillage practices have been widely practiced for many years, e.g., United States, Brazil, Australia and Canada, considerable information is now available to show environmental benefits of conservation tillage practices, some with global implications. Conservation tillage is improving soil quality, reducing erosion and water run-off from agricultural land, protecting water quality and reducing CO_2 emissions in to the atmosphere. These benefits help countries to meet demanding environmental protection regulations.

Soil quality[47]

Soil quality is largely determined by organic matter content and responds to soil management practices. Over time, conventional cultivation generally results in a reduction in the organic matter content of soils. For example, the Soil Survey and Land Research Centre of the UK has shown that under conventional tillage from 1980 to 1995, there has been a decrease in the number of sites with a high organic content (>4%). In contrast, as shown in Table 6, from a long-term study of soil in Ontario, Canada, a change from conventional (disc or mouldboard ploughing) to conservation tillage (minimum/ no-till) over time results in an increase in the soil organic matter content.

Table 6: Organic matter at two depths after 18 years of various tillage treatments of Ontario soil under corn

Tillage system	Soil organic matter (tonnes per hectare)		
	0-15 cm	15-30 cm	0-30cm
No-till	86	65	151
Chisel plough	73	52	125
Disc	74	58	133
Mouldboard plough	66	64	130

Source: E.G. Gregorich et al (1995),

---

[47] Gregorich E.G., D.A. Angers, C.A. Campbell, M.R. Carter, C.F. Drury, B.H. Ellert, P.H. Groenevelt, D.A. Holmstrom, C.M. Monreal, H.W. Rees, R.P. Voroney, and T.J. Vyn (1995) Changes in Soil Organic Matter in D.F Acton and L.J. Gregorich (eds.) The health of our soils - toward sustainable agriculture in Canada. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa.

Soil erosion and water quality[48]

Erosion

Soil erosion is a major environmental threat worldwide. It is estimated that over the last 40 years, nearly one third of world's arable land has been lost to erosion. Quality soil continues to be lost at the rate of over 10 million hectares per annum. Intensification of conventional agriculture (increased mechanisation and ploughing) and adoption of cropping systems that leave the soil surface bare during the rainy season have largely contributed to this trend. Crop yields in eroded soils tend to be 9-34% lower than in protected soils. It is estimated that erosion increases the cost of agricultural production by 25% each year.

Reduction or elimination of tillage along with retention of crop residue helps to reduce soil erosion. For example, in the US it is estimated that adoption of conservation tillage practices decreased erosion on croplands by 30% and wind erosion by 31% in 1997, which equates to almost 1 billion tonnes per year of soil savings.

Water quality

The US Environment Protection Agency's 1998 National Water Quality Inventory reports sedimentation as the most important pollutant affecting water quality in the United States. High levels of sedimentation of waterways leads to destruction of aquatic habitats (and decreased storage capacity of reservoirs) and increases the need for water treatment and dredging.

---

[48] Troeh FR and LH Thompson (1993). Soils and soil fertility. Oxford University Press, New York.

Pimentel D, C Harvey, P Resosudemo, K Sinclair, D KUrz, M McNair, S Crist, L Shpirtz, L Fitton, R Saffouri and R Blair (1995). Environmental and economic cost of soil erosion and conservation benefits. Science, 267: 1117-1123.

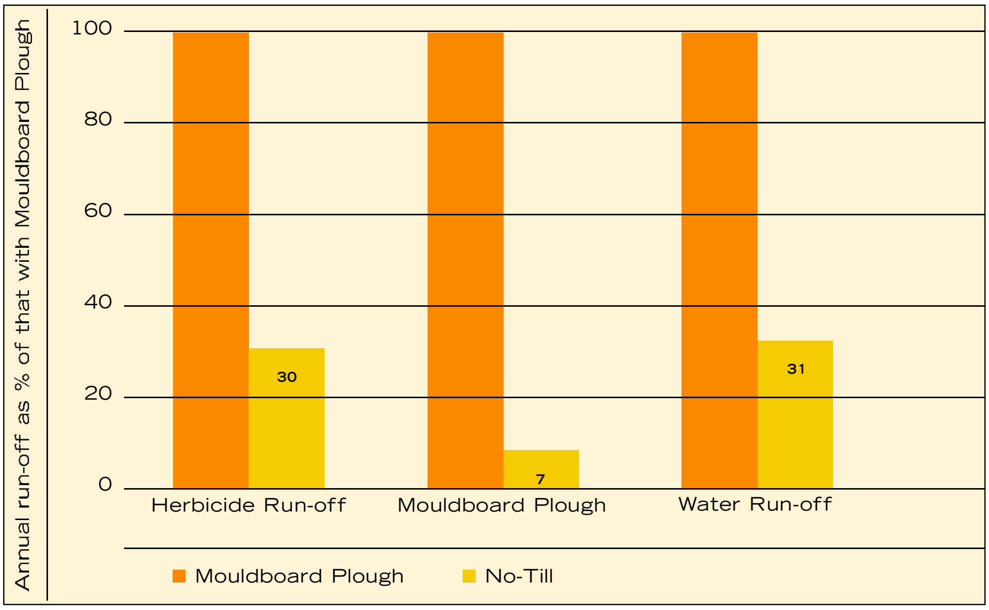
NRCS (2000). Summer Report 1997. National Resource Inventory. US Department of Agriculture, Natural Resource Conservation Service, Washington DC, 99 pp.

Christensen B, JM Montgomery, RS Fawcett and D Tierney (1995). Best management practices for water quality. Conservation Technology Information Centre, West Lafayette, Indiana, USA.

US Environmental Protection Agency (2000). Quality of Our Nation's Water: A summary of national water quality inventory, 1998 report to congress . EPA 841-S-00-001. http://www.epa.gov/305b/98report/98brochure.pdf

Fawcett R S and D Towery (2004). Conservation tillage and plant biotechnology: How new technologies can improve the environment by reducing the need to plough. Conservation Technology Information Centre, West Lafayette, IN, USA.

Figure 6: Run-off and erosion in no-till watersheds compared to conventional tillage watersheds



Source: Fawcett R and D Twery (2004). Consevation tillage and plant biotechnology. CTIC, West Lafayette, IN, USA

Reduced carbon dioxide (greenhouse gas) emission and improved air quality[49]

Maintenance of mulch under conservation tillage systems increases the ability of soil to sequestrate CO_2 and reduces emissions, protecting the atmosphere. In some soils, following several years under a conservation tillage system, organic matter content has been shown to increase by as much as 2000 kg/ha/year. Increased organic matter also improves the soil's nutrient and water holding capacity. As shown below, tillage increases oxidation of soil organic matter content releasing large quantities of CO_2, whereas conservation tillage can reduce CO_2 emission by up to 80%.

Table 7: USA: Carbon dioxide emissions over a 19-day period after tilling wheat stubble with different methods

Tillage method	Cumulative CO_2 Loss (t/ha)
Mouldboard plough	9.13
Disk harrow	3.88
Chisel plough	3.65
No-tillage	1.84

Source: Reicosky, 1998; and Reicosky and Lindstrom, 1995[49]

In an analysis of cropland as a source and sink for atmospheric carbon at the global level, it has been estimated that about 7% of the current atmospheric inventory is lost from cultivated soils globally[50]. This carbon can be sequestered by adoption of improved management practices such as conservation tillage.

It is well documented that fossil fuel burning releases CO_2, which contributes to global warming. There is scientific evidence that soil tillage has been a significant component of increases in atmospheric CO_2[51].

Another benefit of conservation technologies is that it requires considerably less tractor horsepower and fewer trips across fields with tillage equipment. This results in 40 - 50% reduction in fuel usage depending on the number/type of tillage trips, soil structure, and moisture content. For every litre of fuel saved, 0.3 to 0.4 kg of CO_2 is not released into the atmosphere[52]. In the US, it is estimated that in 2002 total savings from all conservation tillage practices may have reached about 1200 million litre of fuel. In addition, by reducing wind erosion, conservation tillage also reduces the amount of dust (suspended solid participles) that reaches the atmosphere, which in many parts of the world (Australia, India, Pakistan, Middle East, US, Canada, Latin America, and Africa, and parts of China) can be an important source of air pollution. Table 8 below summarises the range of economic and environmental benefits observed in the UK from adoption of conservation technologies.

---

[49] Reicosky D J, M J Lindstrom and S Masielewicz (1994). Conservation Tillage. Swan Lake Research Farm, US Department of Agriculture, Agriculture Research Service, Soil Conservation Laboratory, Morris, Minnesota, USA. August 24, 1994.; Reicosky D C and M J Lindstrom (1995). Impact of fall tillage on short-trm carbon dioxide-flux. InSoils and Global Change. R Lal, J Kimble, E Levine and B A Stewart (eds.), Lewis Publishers, Chelsea, USA. pp. 177-187; Reeves D W (1997). The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil & Tillage Research 43:131-167.; Reicosky D C (1998). Strip tillage methods: Impact on soil and air quality. In Mulvey (ed.). Environmental Benefits of soil management. Proceedings of the ASSSI National Soils Conf., Brisbane, Australia. Pp. 56-60.

[50] Lal R, J M Kimble, R F Follet and C V Cole (1998). The potential of US cropland to sequester carbon and mitigate the green house effect. Ann Arbor Press, Chelsea, MI., USA

[51] Lal R (1997). Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2-enrichment. Soil &Tillage Research. 43(1-2):81-107.

[52] Jasa P A, D Skelton, A Jones and E Dickey (1991). Conservation tillage and Planting Systems. Cooperative Extension Service, University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

Table 8: UK: Benefits from soil conservation tillage over conventional tillage

Component	Average Benefit
Establishment costs	Saving £10-40/ha
Energy use for crop establishment	Saving 76 kw/hr/ha
Work rate (250 ha farm)	Saving 52 min/ha
Infiltration rate	43% increase
Soil moisture retention (0.8 cm)	18% increase
Soil bulk density	4% improvement
Number of organisms	44% increase
Earthwork biomass	63% increase
Run-off	48% reduction
Sediment loss	68% reduction
Loss of total phosphate	81% reduction
Loss of available phosphate	73% reduction
Soil Mineral Nitrogen depletion	69% reduction
Total Oxidised Nitrogen emissions	94% reduction
Soluble Phosphate emissions	78% reduction

Source: Soil Management Initative booklet 'Improved soil management for agronomic and environmental gain'

Wildlife habitat and biodiversity[53]

Conservation practices that incorporate about 70% of crop residue in the top soil and leave the remaining 30% on the soil surface, provide a congenial environment for soil organisms and many bird species, small mammals and reptiles. Similarly, maintenance of tree and other vegetation on farm boundaries creates improved quality habitat for birds. The organisms living in the soil, e.g. earthworms, fungi and bacteria, benefit the most from conservation techniques and, in turn, help to improve the soil structure and natural fertility.

Increased production from existing agricultural areas using conservation technologies provides opportunities for improved management of natural resources and broadening of biodiversity conservating areas. Although there is currently not enough research to show how population densities of wildlife species change, evidence from a range of taxa from a number of countries suggests that high-yield farming may allow more species to persist[54]. This is because increasing yields are likely to reduce pressure to clear intact habitats. Active involvement of local communities in this process not only allows two-way knowledge sharing on location specific issues, but also provides an effective stewardship mechanism for long-term sustainability.

---

[53] CTIC (2002). Economic Benefits with Environmental Protection. Conservation Technology Information Centre, West Lafayette, IN, USA.; and Zaborski ER and BR Stinner (1995). Impact of soil tillage on soil fauna and biological processes. P. 13-15. In: Farming for a Better Environment. A White Paper of the Soil and Water Conservation Society, Ankeny, Iowa, USA. pp.67.

[54] Green, RE, SJ Cornell, JPW Scharlemann abd A Balaford. 2005. Farming and the fate of wild nature. Science: 307 (550-555)

Social impact

The need for sustainable management of natural resources presents different challenges in industrialised and the developing countries. With its high productivity and excess production, agriculture in industrialised countries must find ways of responding to important environmental and food quality issues of concern to the society.

Government policies and regulations in these countries are now increasingly requiring adoption of technologies that minimise impact of modern agriculture on the natural resource base, restore soil eco-systems and protect the environment, and preserve biodiversity on-farm, as well as in non-farm situations.

Conservation technologies help to address these concerns and optimise land potential to support sustainable agricultural production.
However, for these practices to be adopted in many countries, farmers need to be convinced that the new way of farming is better for them both in short- and long-term.

In developing countries, the need is to reduce poverty and reverse other social consequences of low productivity and a deteriorating natural resource base.
In many countries, farmers have met increasing food demand by expanding agriculture to marginal lands and encroaching forest reserves. The search for higher productivity has in some situations resulted in excessive use of chemical inputs and over-exploitation of natural resources, especially land and water resources with negative social consequences.Adoption of conservation technologies has the potential to make agriculture more efficient by reducing labour requirements for land preparation, crop planting and weeding while conserving land and water. Since a number of farm operations are still undertaken manually, conservation tillage reduces drudgery and permits releases of labour for other economic and social needs.

Given the diversity and changing nature of environmental and socio-economic issues in agriculture, it is essential that farming communities, public institutions, the plant science industry, NGOs and other interested stakeholders continue to work together to arrive at mutually acceptable goals for production technologies that help to supply safe and affordable food and improved environmental quality for all.

Table 9: Summary: Benefits and impacts of conservation tillage technologies

Farm Level	Community/Watershed Level	Global Level
Savings in labour, power and time through reduced cultivation and weeding requirements	Reduced soil loss and improved water flow and recharge of water table	Reduced soil erosion and improved land quality
Reduced investment in farm implements due to prolonged life and reduced inventory	Improved water quality due to reduced sedimentation and movement of pollutants	Improved carbon balance through reduced carbon emission , lower fuel and energy consumption, and increased carbon sequestration
Reduced erosion and improved soil health	Increased awareness and protection of natural resources	Improved protection of biodiversity at microflora and fauna levels
More stable and higher yields	Reduced costs of maintenance of communal infrastructure, e.g. rural roads, watershed protection measures	Improved hydrological cycles at river basin/ continental level
Reduced cost of production and improved farm income	Improved sustainability of production systems, food security and quality of life for rural communities	Recognition of role of farming communities in providing environmental services for the society
Reduced drudgery and more available time for social needs		

Notes

Notes

Notes

Notes

Notes

Notes

CropLife International is the global federation representing the plant science industry. It supports a network of regional and national associations and their member companies in over 90 countries, and is led by companies such as BASF, Bayer CropScience, Dow AgroSciences, DuPont, FMC, Monsanto, Sumitomo and Syngenta.

The plant science industry invents, develops, manufactures and sells products and services designed to improve the global production of food, feed and fibre and other useful products in a sustainable way. The industry performs this mission through the use of biology, chemistry, biotechnology, plant breeding and other techniques while providing safeguards for human health and the environment. Through collaboration with a range of stakeholders, CropLife International initiates stewardship programmes that foster a life-cycle approach to the sustainable use of agriculture products.

CropLife International regional association members:

CropLife America
1156 15th Street N.W., Suite 400, Washington DC 20005, USA
Tel: +1 202 296 15 85, Fax: +1 202 463 0474, www.croplifeamerica.org

CropLife Africa Middle East
P.O. Box 961810 Sport City, 11196 Amman, Jordan
Tel: +962 6 552 30 39, Fax: +962 6 553 30 544, ali-croplife@nets.com.jo

CropLife Asia
25f, Rasa Tower, 555 Phaholyothin Road, Chatuchak Bangkok 10900, Thailand
Tel: +66 2937-0487, Fax: +66 2937-0491, www.croplifeasia.org

European Crop Protection Association (ECPA)
Avenue E. van Nieuwenhuyse 6, B-1160 Brussels, Belgium
Tel: +32 2 663 1550, Fax: +32 3 663 1560, www.ecpa.be

Japan Crop Protection Association (JCPA)
Nihonbashi Club Building, 5-8. I-Chome, Nihonbashi Muromachi, Chuo-ku, Tokyo 103, Japan
Tel: +81 3 3241 0230, Fax: +81 3 3241 3149, www.jcpa.or.jp

CropLife Latin America
444 Brickell Avenue, Suite 705, Miami, FL 33131, USA
Tel: +1 305 373 3713, Fax: +1 305 373 4642, www.croplifela.org

CropLife Canada
21 Four Seasons Place, Suite 627, Etobicoke, Ontario, Canada, M9B 6J8
Tel: +1 416 622 9771, Fax: +1 416 622 6764, www.croplife.ca

CropLife International aisbl
Avenue Louise 143
1050 Brussels, Belgium
tel +32 2 542 04 10
fax +32 2 542 04 19
croplife@croplife.org
http://www.croplife.org

For more information on Conservation technologies visit CropLife International's website

www.croplife.org

Graphic Design: NAos design © CropLife International aisbl September 2005