IN POOR RURAL AREAS, farmers often struggle with fragile, sloped and degraded soils, erratic or low rainfall, poor market access, and high transport costs. To overcome these obstacles, they usually have to shift to more intensive agricultural production systems that raise productivity and reduce or reverse the need to expand their crop area. The challenge is to do this profitably while ensuring the sustainable use of land, soil, water, and other resources.

As emphasized in the World Development Report 2008, strategies for turnaround in these areas involve two key interventions. The first is to improve technologies for sustainable management of land, water, and biodiversity, and the second is to put local communities in the driver’s seat to manage natural resources. Conservation farming—and particularly the...
use of reduced or zero tillage—is a key sustainable land management technology that incorporates both of these. It promises more productive farms and lower greenhouse gas emissions, although the extent of these varies with climatic conditions and remains the subject of scientific debate.

Reduced or conservation tillage, in contrast to zero tillage, reduces but does not necessarily eliminate plowing. Unlike conventional tillage, zero-tillage involves no plowing of soils and incorporates mulching, that is, application of crop residues over the soil. The result is an increase in the storage, or sequestration of carbon in soils. Carbon is sequestered in zero-till systems as organic matter decomposes more slowly in undisturbed soil, and emits less carbon as a result. Mulching, meanwhile, is a form of recycling organic matter.

Also, with reduced plowing, farmers consume less fuel, thereby reducing another source of greenhouse gas emissions.

The local and global benefits of conservation tillage

Conservation tillage can reduce soil degradation and erosion, increase overall farm profitability, improve water conservation, while also cutting labor and fuel requirements associated with plowing. But zero-till farming systems need to control weeds, pests and crop diseases, while also reducing soil acidity and replenishing soil nitrogen, all of which are problems that become more acute when soils are not plowed. Application of herbicides and pesticides—a common measure to control weeds and pest infestations in zero-till systems—can also have adverse consequences for the environment and health of farm workers.

Complementary farming practices such as crop rotations with leguminous crops to replenish soil nutrients, using crop cover, mulching, and integrated weed and pest management are alternatives to using herbicides and pesticides in zero-till systems.

The potential of zero-tillage to mitigate GHG (Greenhouse gas) emissions depends on the characteristics of the soil, the availability of water, and the climate in a given location; the impact is greater in warm, humid climates than it is in cool or dry ones (Figure 1). Compared to other cropland management practices such as set-asides of areas under forest and water management, per-hectare benefits in terms of carbon sequestration may be modest, particularly in cool–dry climate zones. But if modest per-hectare reductions in emissions were applied to large cropping areas currently under conventional tillage, the large scale adoption of zero-tillage would make its contribution to mitigating climate change significant.

A promising start but challenges remain from weeds, pests and diseases

Despite challenges to its application in areas with shallow, acidic or compact soils, zero-tillage has become widespread in the United States, Brazil, Argentina, Canada, and Australia. Worldwide, the area under zero-till systems has expanded to over 72 million hectares. In Brazil—the leading success story in the adoption of this technology—zero tillage has expanded from fewer than 1,000 hectares in 1973-74 to nearly 22 million, or 45 percent of total cultivated land, in 2003-04 (Laxmi and others 2007).

The rapid spread of the zero-till technology in Brazil was prompted by severe soil degradation in the late 1960 and 70s in the country’s subtropical south, caused by the expansion of soybean and wheat cultivation, combined with intensive plowing and burning of residues. By some estimates, for every kilogram of soybeans harvested, 10 kilograms of soil were lost to erosion using conventional tillage. The technology has spread to Paraguay and the cerrado—Brazil’s tropical savannah region. Brazil boasts a high adoption rate by smallholder farmers, with 90 percent of smallholders in the country’s south having switched to zero tillage, although not all of them have done this permanently, or adopted the full range of technology.

Zero-till is becoming an increasingly important conservation technology in the rice–wheat cropping systems of India and Pakistan. National and international research institutes have also been supporting development of improved technologies and adoption of zero till systems in highly eroded parts of

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**Figure 1: Potential to Sequester Carbon Through Zero Tillage Varies by Climate Zone**

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Uptake of Carbon Dioxide (tCO₂/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-moist climate zone</td>
<td></td>
</tr>
<tr>
<td>Cool-dry climate zone</td>
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</tbody>
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*Note: The estimates represent the average change in soil carbon stocks (CO₂) on a per hectare basis per year for a 20-year time horizon in the top 30 centimeters of soil. These average estimates are derived by IPCC based on the statistical analysis of results from about 200 studies. Source: Intergovernmental Panel on Climate Change (IPCC). 2007. Working Group III Report “Mitigation of Climate Change.” Geneva, Switzerland. Intergovernmental Panel on Climate Change.*
the East African highlands, and it has proven effective in controlling soil erosion in Nigeria (Jourdain and others 2001).

Conservation tillage can result in large farm-level benefits and a significant potential contribution to mitigation of climate change. Experimental data from India’s Indo-Gangetic Plains corroborate these global and local benefits. In 2004-05, nearly 1.6 million hectares—about one sixth of the total area under rice-wheat systems—were cultivated in this region using zero or conservation tillage. A survey of 400 farm households in Haryana region’s rice-wheat systems, and 759 households in Punjab has revealed significant farm-level benefits from this agricultural practice: yield gains averaging 6-10 percent and cost savings on the order of 5-10 percent (Bollinger and others 2006).

Zero tillage also reduced water use by 20-35 percent for wheat, eased soil erosion, and increased soil carbon content. It is estimated that lower diesel use compared to conventional tillage reduces CO2 emissions by around 90 kilograms per hectare. Extrapolating these reductions over the 3.43 million-hectare potential area for zero tillage adoption in the region would result in a reduction of CO2 emissions by 0.31 million tons per year and savings of 120 million liters of diesel.

Targeted research to adapt conservation tillage to local conditions

ADAPTIVE AGRICULTURAL RESEARCH is needed to develop suitable cropping systems and crop varieties adapted to zero-till systems in different climates and socio-economic situations. In Brazil, the successful application of zero-till has been driven by concerted efforts by leading farmers and their organizations and the private sector, supported by state and national research organizations, and international research agencies. After years of experimentation since the mid-1980s, zero-till has been adapted to the needs of farmers in Brazil’s cerrado through research on suitable farming practices and farm equipment, as well as demonstrations, seminars, field courses and training. The cerrado region is now the major expansion area for the technology, with over six million hectares under zero till.

Despite the apparent success in promoting the use of zero-tillage in Brazil, many smallholder farmers do not fully adopt optimal practices and tend to resort to intermediate systems that combine elements of conventional and zero-tillage.

The survey data in India have revealed that owners of better-endowed and larger farms tend to be early adopters of zero or conservation tillage. Smallholders also reap the benefits of this resource-saving technology if they are able to hire zerotillage drills or drilling services at the right time; over 60 percent of adopters of zero-tillage in the survey contracted drilling services. Of those who did not adopt in Haryana, most cited lack of access to drills or drilling services as the main reason for their decision to revert back to conventional tillage. Achieving wider and fuller adoption of zero-tillage—rather than partial adoption, which was the case for about three-quarters of adopters surveyed—requires further research and adaptation of the technology to the smallest plots in the Indo-Gangetic Plains. Even with conservative assumptions about the yield gains and cost savings, zero-tillage and conservation tillage research programs promise an estimated internal rate of return of over 50 percent to the research investment.

Field data on 15 representative farms in Mexico have revealed similar problems. Although conservation tillage always resulted in higher economic returns than traditional extensive agricultural systems, it also required high initial out-of-pocket cash outlays for weed and pest-control chemicals. Research efforts consequently need to focus on developing pest- and disease-resistant crop varieties, as well as equipment and weed and pest control technologies suitable to the needs of small-scale farmers with few resources.

Integrated management approaches offer an alternative to the application of chemical herbicides and pesticides—reducing the need for cash outlays and avoiding the environmental and health problems posed by agrochemicals. Experimental data in Paraná, in southern Brazil, demonstrate that integrated weed management (IWM) can reduce costs of weed control by over a third relative to systems that use herbicides. Brazilian zero-till systems using IWM rely on cover crops and mulching. Cover crops such as pigeonpea and other legumes, used in rotation with grain crops, compete against weeds and can reduce the severity of pest infestations, while also fixing soil nutrients such as nitrogen. Mulch, which consists of crop residues used as protective cover to help control weeds, repel insects and retain water, is another important element of IWM systems. Like IWM, integrated pest management (IPM) replaces agrochemicals with alternative techniques, from crop rotation with cover crops, and the planting of disease- and pest-resistant crop varieties, to encouraging pest-predator populations.

To date, IWM and IPM have been successfully applied only in experimental settings and under optimal conditions in zero-till farming systems. The challenge for researchers is to work with farmers to develop technologies and equipment that are both affordable and adapted to local climatic conditions. This research would assess the potential contribution of zero-tillage systems to mitigating climate change, as well as the feasibility of including carbon sequestration in soils as part of the package of post-Kyoto funding mechanisms for reduction of greenhouse gas emissions.

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References


(References continues, next page)
environment, including effective competition policy, contract enforcement, setting grades and standards, and enacting and applying food safety legislation. In addition, many countries need to develop credible public institutions to enforce regulations to guard against uncompetitive behavior in the marketing system.

Public-private partnerships can also play an important role in fostering research and capacity-building to develop and sustain sound agricultural practices that meet new domestic and international food safety standards, and help farmers adopt them.

A collaboration between strong producer organizations and the private sector, built on their shared interest in achieving scale and market power, will be critical. The private sector can help smallholders to participate as partners in modern supply chains through innovative vertical coordination arrangements with producer groups. It can also facilitate farmer organizations to access credit, inputs, extension, and certification and training in good agricultural practices to meet quality, food-safety, and international sanitary standards. The producer organizations offer the vital link to farmers.

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