Leaving the Plow Behind

Zero-tillage rice-wheat cultivation in the Indo-Gangetic Plains

Olaf Erenstein

The Indo-Gangetic Plains—named for the Indus and Ganges Rivers—is the breadbasket of the Indian subcontinent. This large swath of land, running from Pakistan across northern India and southern Nepal and into Bangladesh, is South Asia's center of wheat and rice production. Since the mid-1990s, hundreds of thousands of farmers, nudged by stagnating crop yields, have adopted a new way of farming known as zero tillage.

Zero tillage (see Chapter 8) is a cultivation practice that not only helps preserve soil fertility and conserves scarce water, but also boosts yields and increases farmers' profits by reducing their production costs. Instead of plowing their fields and then planting seeds, farmers who use zero tillage deposit seeds into holes drilled into the unplowed fields. An estimated 620,000 wheat farmers in northern India have adopted various forms of zero tillage on an estimated 1.76 million hectares of land under rice and wheat cultivation, with average income gains amounting to US$180–340 per household per year.

"Drilling" for Crops

The Green Revolution (see Chapter 3) transformed the Indo-Gangetic Plains. The technological package of improved wheat and rice seed, chemical fertilizer, and irrigation, accompanied by supportive policies, led to rapid productivity growth and the advent of rice–wheat systems. In rice–wheat systems, farmers cultivate two crops a year. During the cool, dry winter they grow wheat—the traditional mainstay of food security in the northwest Indo-Gangetic Plains—and during the warm monsoon season, they switch to growing rice. This pattern of cultivation now covers an estimated 14 million hectares of land in the region.[1]

Since the 1990s, however, productivity growth in rice–wheat systems has stagnated for both crops.[2] The main culprits appear to be land degradation—or, the decline in soil quality associated with inappropriate soil and water management—and the tendency for farmers to plant wheat too late to achieve the highest possible yields. By the time farmers have finished harvesting their rice, they are often hard-pressed to prepare their fields and plant wheat in a timely fashion. Rising productivity in rice and wheat has long been the linchpin of food security and rural economic growth in the region, so the slowdown in productivity growth generated serious concern.

A promising option to help address this problem has arisen in the form of zero-tillage cultivation. What if farmers do not have to plow their fields before planting wheat? Eliminating this step not only saves precious time, but also avoids disturbing the soil in ways that contribute to soil degradation and the growth of weeds. By sowing seeds in unplowed fields in small slots or trenches that are carved out by tractor-drawn seed drills, farmers can also avoid drying out the soil and, thus, can use water more sparingly.

The success of zero-tillage cultivation in Argentina, Brazil, Canada, and the United States provided the initial impetus for zero tillage in the

This chapter is based on Erenstein, O. 2009. *Zero tillage in the rice-wheat systems of the Indo-Gangetic Plains: A review of impacts and sustainability implications*. IFPRI Discussion Paper. Washington, D.C.: International Food Policy Research Institute.

Indo-Gangetic Plains. But the zero-tillage practices used on large mechanized farms in the aforementioned countries did not immediately translate into viable practices for small-scale, resource-poor farmers in South Asia.

At first, the specialized agricultural machinery required to plant seeds in a zero-tillage system was not available in the region. In the mid-1980s, though, the International Maize and Wheat Improvement Centre (CIMMYT) introduced a prototype drill in Pakistan. Using this prototype, scientists from Pakistan's National Agricultural Research Centre developed zero-tillage methods suitable for local conditions. In India, CIMMYT introduced a prototype in 1989, and, in 1991, the first prototype of an Indian zero-tillage seed drill was developed at the G. B. Pant University of Agriculture and Technology in Pantnagar.

The goal, however, was to develop a model that local manufacturers could produce and sell at an affordable price. Working with CIMMYT and the Rice-Wheat Consortium for the Indo-Gangetic Plains (a consortium of national and international agricultural research institutions and other partners), both countries undertook programs to further develop and commercialize zero-tillage drills. Private sector companies improved and adapted the prototype drills, based on feedback from farmers. Most farmers using zero-tillage technology in the region now rely on locally manufactured zero-till seed drills, drawn by tractors, with 6 to 11 tines that sow wheat directly into unplowed fields with a single pass of the tractor.

India in particular was highly successful at developing local manufacturing capacity to adapt and produce zero-tillage drills at a competitive cost. In 2003, the average price of a zero-till drill was $325 in India, compared with $559 in Pakistan.[3] Close links between scientists and farmers in India also helped. Private manufacturers placed machines in villages, where farmers could try them out, allowing for rapid feedback and the refinement of implements. State and local government officials helped disseminate the new technology and even subsidized the equipment to lower its cost to farmers. The Rice-Wheat Consortium helped build the public–private partnership, nurtured it through its formative stages, and facilitated technology transfers from international and national sources.

Rice-wheat inter-cropping

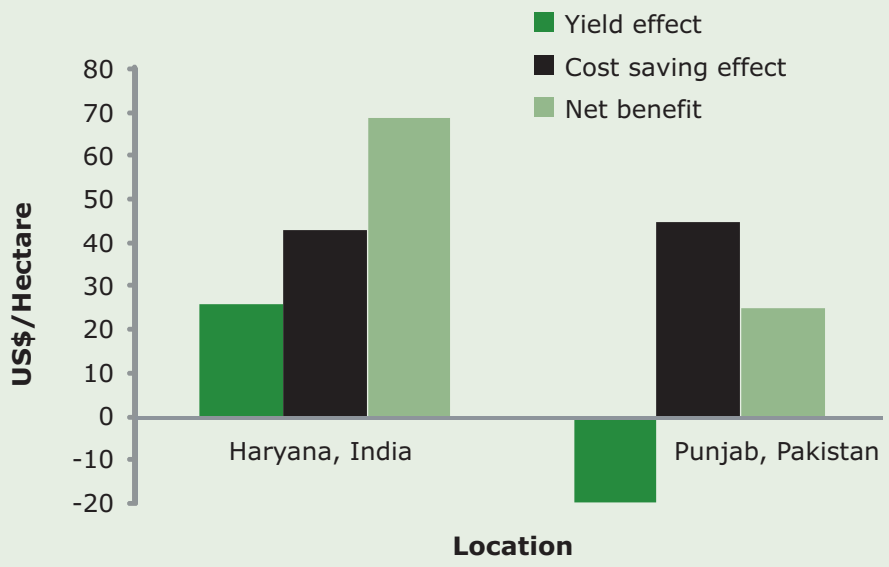
Falling Costs, Rising Incomes

The spread of zero-tillage technology began in the late-1990s and accelerated in the early-2000s, particularly in the northwest Indo-Gangetic Plains of India, where zero- or reduced-tillage wheat accounts for between one-fifth and one-fourth of the wheat area.[4] Surveys of farm households from 2003–04 found that 34.5 percent of sampled farmers in India's Haryana and 19 percent in Pakistan's Punjab used zero tillage (although many of them did not use zero tillage on their entire wheat crop).[5] The spread of zero tillage has been slower in Pakistan than in India, hampered by, among other things, bureaucratic struggles within the national system about whether or not zero tillage was viable as well as a smaller presence of the Rice-Wheat Consortium. In the Indo-Gangetic Plains of India, about 620,000 farmers use zero- and reduced-tillage wheat, which is now estimated to cover 1.76 million hectares of land. Studies show that the payoffs to the investments in the research and development of zero- and reduced-tillage techniques by the Rice-Wheat Consortium of the Indo-Gangetic Plains and CIMMYT were substantial, aided by accelerating farmers' adoption of these practices by at least five years.[6]

In India, a review of zero-tillage wheat studies showed that adopting farmers could increase their incomes by about $97 per hectare of land, for two reasons—zero tillage raised their wheat yields and reduced their production costs.[7] Adopter farm households could increase their annual overall incomes by $180 to $340. Large-scale farm surveys confirmed both a significant yield effect and cost-saving effect in Haryana (see Figure 9.1). But similar farm surveys in Punjab in Pakistan found zero tillage to be primarily a cost-saving technology for wheat cultivation, with no significant yield effect.

The biggest contributor to farmers' increased income is the cost-saving effect. Using zero tillage, farmers spend much less time and fuel using tractors to prepare the land and plant wheat. The tractor-drawn zero-tillage drills allow farmers to make just one pass through their fields rather than the eight passes typically needed during traditional cultivation. As a result, farmers achieve an immediate—and recurrent—cost savings amounting to

Figure 9.1—Financial advantage of zero tillage over conventional tillage for wheat, 2003–04



Source: Erenstein, O. 2009. Adoption and impact of conservation agriculture–based, resource-conserving technologies in South Asia. In *Proceedings 4th World Congress on Conservation Agriculture, February 4–7, 2009, New Delhi, India.* New Delhi: World Congress on Conservation Agriculture.

about 15 to 16 percent of their operational costs, or about $52 per hectare of land in India.[8]

In addition, zero tillage has been shown to increase wheat yields in India by 5 to 7 percent, further boosting farmers' returns.[9] The rise in yields is closely associated with the timelier planting of wheat. If farmers cannot manage to plant wheat before mid-November, heat stress at the end of the wheat season can reduce their yields by 1 to 1.5 percent a day.[10] By allowing farmers to plant wheat more quickly after the rice harvest, zero tillage can reduce these yield losses.

Zero tillage has reportedly increased families' food consumption in some areas, probably through higher disposable income. And the adoption of zero-tillage cultivation has helped households free up time and money for various other productive, social, and leisure endeavors as well.

Doing More to Reach the Poor

Zero tillage has so far primarily benefited farmers in the northwest Indo-Gangetic Plains of India, who typically operate more intensive and productive rice–wheat systems, have greater institutional support, and suffer from less poverty than do farmers in the eastern Indo-Gangetic Plains. The eastern plains, an area with 500 million people, are characterized by smallholders (70 to 90 percent of farm households farm fewer than 2 hectares of land) and widespread poverty (more than two-thirds survive on less than $2 per day).[11] Yet zero tillage has the potential to generate even greater yield gains and cost savings in these areas, where agriculture is less intensive.

Another issue is whether zero-tillage cultivation practices are displacing agricultural laborers. With the Green Revolution–induced intensification of agricultural production in the Indo-Gangetic Plains, farm labor opportunities have been an important source of income for landless and migrant workers. Yet given that wheat cultivation in the Indo-Gangetic Plains is already highly mechanized with the use of tractors, diesel pumps, and other equipment, this risk appears small—at least with respect to wheat cultivation. But if farmers adopt zero tillage for rice cultivation, laborers could indeed lose their earnings from the labor-intensive process of transplanting rice seedlings into wet fields. It is thus important to carefully examine the implications of disseminating this technology more widely.

A Step toward Agricultural Sustainability

Zero-tillage cultivation is having positive environmental impacts in the Indo-Gangetic Plains. It saves fossil fuel, reduces greenhouse gas emissions, and cuts water use. Research has shown that farmers can save 36 liters of diesel fuel per hectare of land, an 80 percent savings over conventional wheat tillage.[12] More research is needed to quantify the full range of environmental impacts.

Still, zero tillage should be used as a stepping stone to a broader agricultural concept known as conservation agriculture, which involves minimal disturbance of the soil, retention of residue mulch on the soil surface, and a rational use of crop rotations—an approach increasingly recognized as essential for sustainable agriculture. Zero tillage currently foregoes many of the benefits associated with conservation agriculture because it is applied to only one of the two cropping seasons, without adequate residue management or crop rotation. Reducing the tillage of rice still presents a challenge, particularly in terms of water and weed management and available rice varieties. Researchers in the Indo-Gangetic Plains are working to address these challenges and develop viable "double no-till" rice–wheat systems in which zero-tillage practices are applied to both rice and wheat cultivation.

Lessons Learned

Despite the wealth of information on zero tillage in the Indo-Gangetic Plains, much still remains to be learned about the spread of the technology and its impacts. Nonetheless, several key lessons from the success of zero tillage present themselves.

Create a technology attractive to private users and producers

The key to successfully introducing a new technology is a financially attractive intervention. In many cases, interventions that are attractive from an environmental or social point of view do not get off the ground because of a lack of interest by commercially minded actors—farmers who produce

for the market or equipment distributors who sell to farmers. Zero tillage proved attractive from a private viewpoint—for both technology suppliers and technology users—in the Indo-Gangetic Plains.

It is important to show that the technology delivers on its promises in the farmers' villages and fields. Research and development should actively involve farmers through, for instance, participatory projects, farmer-to-farmer exchanges, and traveling seminars. Moving agricultural experts away from the yield paradigm can be a challenge. Producing the same with less can be an attractive proposition to farmers because it enhances their bottom line, but it implies a shift in mindset that has traditionally focused on producing more per unit of area.

Another critical aspect is to link farmers with knowledgeable and accessible technology suppliers, including local manufacturers who can make equipment that will do the job well at a competitive price and adapt and repair it as needed. The successful business model that emerged for zero-tillage drills also benefited from the fact that the zero-tillage drills are applicable across the Indo-Gangetic Plains—a large area with many farmers.

Pay attention to context

Context was imperative in the success of zero tillage in India. The slowdown in productivity growth in rice–wheat systems and concerns about production costs and sustainability opened the door to resource-conserving technologies like zero tillage. Concerned by stagnating productivity, many farmers became interested in prospects for improving their bottom line. The increasing problem of herbicide tolerance of the weed Phalaris minor in the Indian state of Haryana also helped break through farmers' reluctance to even try zero-tillage technology. Researchers were interested and excited by the prospects of enabling change in farmers' fields. Policymakers were interested in technological solutions to enhance the sustainability of South Asia's breadbasket while avoiding more demanding institutional changes.

Harvesting wheat with a sickle, India

Use institutions and people to promote the technology

The Rice-Wheat Consortium played a pivotal and innovative role as facilitator, information provider, technology clearinghouse, and capacity builder. By providing resources to help get the technology out into farmers' fields and manufacturers' workshops, and by offering a forum in which interested parties could interact, the consortium played a critical role in spreading zero-tillage technology in the Indo-Gangetic Plains. Key champions in the agricultural research and development system also picked up the technology and promoted it despite initial resistance.

Conclusion

Hundreds of thousands of farm households in the Indo-Gangetic Plains have increased their farm income by adopting zero-tillage cultivation, while also generating significant benefits for the environment—reductions in water and fuel use and improvements in soil conservation. Concerted efforts by an array of stakeholders that spanned public and private sectors, national and international research systems, and included several persevering champions provided the institutional support for this technological opportunity to materialize. The success of zero-tillage wheat so far could serve as a stepping stone to conservation agriculture and equitable rural development. And by raising farmers' incomes and preserving the natural resource base on which agriculture depends, zero tillage is laying the groundwork for improved food security in South Asia's Indo-Gangetic Plains in the years to come. ■

NOTES

1. Timsina, J., and D. J. Connor. 2001. Productivity and management of rice-wheat cropping systems: Issues and challenges. *Field Crops Research* 69 (2): 93–132.
2. Ladha, J. K., D. Dawe, H. Pathak, A. T. Padre, R. L. Yadav, B. Singh, Ya. Singh, Y. Singh, P. Singh, A. L. Kundu, R. Sakal, N. Ram, A. P. Regmi, S. K. Gami, A. L. Bhandari, R. Amin, C. R. Yadav, E. M. Bhattarai, S. Das, H. P. Aggarwal, R. K. Gupta, and P. R. Hobbs. 2003. How extensive are yield declines in long-term rice–wheat experiments in Asia? *Field Crops Research* 81: 159–180.
3. Erenstein, O., U. Farooq, R. K. Malik, and M. Sharif. 2007. *Adoption and impacts of zero tillage as a resource-conserving technology in the irrigated plains of South Asia*. Comprehensive Assessment of Water Management in Agriculture Research Report 19. Colombo, Sri Lanka: International Water Management Institute.
4. Several factors make it difficult to reliably measure zero-tillage adoption in the Indo-Gangetic Plains, one of which is the very use and interpretation of the term "zero tillage." Survey respondents may understand this term to mean (1) the use of the zero-till drill (with or without tillage), (2) the practice of not tilling (with or without the zero-tillage drill), or (3) the practice of "reduced tillage"—that is, cultivation using a minimal degree of tilling. See Erenstein, O. 2009. Adoption and impact of conservation agriculture–based, resource-conserving technologies in South Asia. In *Proceedings 4th World Congress on Conservation Agriculture, February 4–7, 2009, New Delhi, India*. New Delhi: World Congress on Conservation Agriculture.
5. Erenstein et al. 2007.
6. Laxmi, V., O. Erenstein, and R. K. Gupta. 2007. *Impact of zero tillage in India's rice–wheat systems*. New Delhi: International Maize and Wheat Improvement Center and Rice-Wheat Consortium; Laxmi, V., O. Erenstein, and R. K. Gupta. 2007. Assessing the impact of NRMR: The case of zero tillage in India's rice-wheat systems. In *International research on natural resource management: Advances in impact assessment*, ed. H. Waibel and D. Zilberman. Wallingford, U.K.: Food and Agriculture Organization of the United Nations and CAB International.
7. Erenstein, O., and V. Laxmi. 2008. Zero tillage impacts in India's rice-wheat systems: A review. *Soil & Tillage Research* 100 (1–2): 1–14.
8. Erenstein et al. 2007; Erenstein and Laxmi 2008.
9. Erenstein and Laxmi 2008.
10. Ortiz-Monasterio, J. I., S. S. Dhillon, and R. A. Fischer. 1994. Date of sowing effects on grain yield and yield components of irrigated spring wheat cultivars and relationships with radiation and temperature in Ludhiana, India. *Field Crops Research* 37 (3): 169–84.
11. Erenstein 2009.
12. Erenstein, O., U. Farooq, R. K. Malik, and M. Sharif. 2008. On-farm impacts of zero-tillage wheat in South Asia's rice-wheat systems. *Field Crops Research* 105 (3): 240–252; Erenstein and Laxmi 2008.