Making Conservation Tillage Conventional, Building a Future on 25 Years of Research: Research and Extension Perspective

Rolf Derpsch

Consultant, CC 13223, Shopping del Sol, Asuncion, Paraguay

Corresponding author's e-mail: rderpsch@quanta.com.py

ABSTRACT

Although no-till (NT) has shown numerous advantages over conventional tillage methods, the technology has shown relatively slow adoption rates in many regions of the world. In this paper, some of the reasons for slow adoption are analyzed. Mindset is probably among the biggest obstacles to expanded no-till use. Knowledge is also among the main constraints to expanded NT adoption. Although research has generated copious knowledge, this knowledge is often not reaching the farmer. Sometimes conditions for the utilization of technology are not met. Technology diffusion investigations show that farmer-to-farmer extension is one of the most effective ways of achieving rapid adoption of innovations. A greater effort has to be made in creating societal awareness of the many positive effects of NT, not only for farmers themselves but for society as a whole. Research priorities should be directed towards intensifying work with green manure cover crops, crop rotations, biological control of diseases, pests and weeds, soil biology, adaptation of NT to site-specific conditions using a systems approach and on-farm research. The technology should also be developed further for small farmers and research should be done with a greater variety of crops in order to widen the possibilities of crop rotations. Finally a greater effort has to be made in analyzing the economics of NT in a systems approach, taking all on-farm and off-farm benefits of the system into consideration.

KEYWORDS

Technology transfer, crop rotation, economics, cover crops, systems research

CONSTRAINTS TO THE ADOPTION OF NO-TILL

From past research and farmers experience with the no-till system we have learned that crop residues left on the surface protect the soil surface from wind and water erosion, increase the organic matter content of the soil and protect the soil from solar radiation, promoting soil biological activity and bio-diversity, while improving nutrient efficiency, soil structure and water economy. No-till improves water quality and is capable to a large extent of reverting the chemical, physical and biological soil degradation that in extreme cases leads to desertification.

A great wealth of knowledge has been generated on several aspects of the no-till system in the past. It is not the intention of the author of this paper to mention the many research achievements of the past 25 years in this field; this can be done reviewing the literature.

Compared to 25 years ago we have made enormous progress in machinery and herbicide development and much knowledge has been generated (Derpsch 2001a). Why is it that some countries have had relatively slow adoption rates of this technology? While in Brazil, Argentina and Paraguay no-till has been adopted on 45% to 60% of all agricultural land, in the USA the adoption has been only 17.5%. Extremely little adoption has occurred in Europe, Africa and Asia. About 98% of no-till adoption has taken place in the Americas and Australia and only 2% in the rest of the world (Derpsch 2001b).

What are the reasons for the slow adoption in some regions of a technology that has so many advantages and only few disadvantages if any at all? These questions and also future research priorities will be analyzed in this paper.

Mindset is probably among the biggest obstacles to expanded no-till use. Attitudes of farmers that have been plowing the soil for generations are difficult to change. While in general research has been generating adequate technological answers to problems farmers face, we probably have neglected to work on changing the attitudes of rural populations. How could we otherwise explain that a good number of landlords in the USA do not allow their tenants (or fathers do not allow their sons) to use no-till

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because the "dirty trash" on the surface has to be plowed under in order to make the field look clean? Contrary to this an increasing number of landlords in South America do not lease their land unless the tenants use NT.

The idea that the soil has to be plowed to produce a crop is so deeply rooted in many societies in Europe and Asia that it is difficult for these cultures to accept a technology that does away with the plow. The older the tradition of plowing in a society, the more difficult a change seems to be. Also, too many farmers in the USA and around the world still burn their residues, not recognizing the value of crop residues on top of the soil. The best technical research results are of little value if efforts are not made to change attitudes and behavior of farmers, researchers, extension personnel and government officials.

In South America "*we have learned, that if the farmer does not make a radical change in his head and mind, he will never bring the technology to work adequately. We found that this is not only true for farmers but also for technicians,* extension personnel *and scientists as well.* No-till *is so different from conventional tillage and puts everything upside down, that anybody that wants to have success with the technology has to forget most everything he has learned about conventional tillage systems and be prepared to learn all the new aspects of this new production system*" (Derpsch, 2001b)

No-till is probably the "Best Soil Management Practice" for extensive agriculture we know of today. Why is it then that incentives in general still go to curing the symptoms of erosion and bad land management (contour banks, etc.) and incentives seldom are invested in promoting the NT system? Government officials should channel incentives and subsidies adequately, but they only will be able to do this if their attitudes change. "no-till is not a farming practice – it is a concept of the mind" (Rick Bieber, NT farmer, South Dakota). If farmers, technicians, extension personnel, scientists and government officials are not able or willing to change, than it will be difficult to meet the goal of this conference which is *"Making Conservation Tillage Conventional"*.

Knowledge is also among the main constraints to expanded No-till adoption. Despite the fact that knowledge has been generated (Derpsch 2001), this knowledge is not reaching the farmer. Sometimes the problem is that the general knowledge is there, but site specific knowledge is lacking. On station research has generated valuable general knowledge, but at a certain stage, researchers and extension personnel have to go out to the farms and conduct site specific on-farm research and technology development with a systems approach. Also, in many countries extension agents do not know enough about the NT system and consequently are not able to transmit adequate knowledge to the farmer.

Another problem is that all too often knowledge is published in scientific papers and publications and not transformed into a language that is more practical and more accessible to extension personnel and farmers. One part of the problem is the reward system of the scientific community. Scientists in general are rewarded for the number and quality of their publications, but the reward system seldom takes into consideration the adoption of an innovation by farmers. Although a thorough knowledge about the erosion process has been generated in the USA already back in the 1940's when the first photographs of the raindrop impact on a bare soil surface were made by the Naval Research Laboratory together with USDA Soil Conservation Service, it is surprising that even today many researchers, extension personnel and farmers in the USA and elsewhere do not understand this process adequately. Many people still think that one has to loosen the soil by intensive tillage to create big pores and increase water infiltration. **Knowledge is useless if it only is on paper and not in the heads of people**. One problem of course is that the literature generated, even in the last decades, is using outdated information about the alleged benefits of traditional tillage, which in general have been shown to be wrong. The most consistent proof of this is the fact that today more than 67 million ha are being successfully planted into no-till worldwide. An important step is to ensure incorporation of the knowledge accumulated in the NT system in university and college curricula. For this, lecturers need to be trained and new teaching material has to be developed, a task that could well be accomplished by researchers. Today in Brazil for instance there are a number of universities offering degree programs in NT at the graduate level, and many have incorporated NT specialization programs at the undergraduate level (Landers *et al.*, 2001).

CONDITIONS FOR THE UTILIZATION OF TECHNOLOGY

If innovations are to be adopted by farmers, *they* must want to, *they* must know how to, and *they* must be able to follow recommendations. Strategies for the implementation of no-till should carefully consider that *"the results of various diffusion investigations show that **most individuals do not evaluate an innovation on the basis of scientific studies of its consequences**, although such objective evaluations are not entirely irrelevant, especially to the very first individuals who adopt. Instead most people depend mainly upon a subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have previously adopted the innovation. This depen-*

dence on the communicated experience of near-peers suggest that the heart of the diffusion process is the modeling and imitation by potential adopters of their network partners who have adopted previously" (Rogers, 1983).

Information to the general public

Although we have made remarkable technological progress developing no-till, we have failed to inform society as a whole about farmers' contribution to the almost total mitigation of arable land degradation in this system (Landers *et al.*, 2001). Through NT technology we have found a system that is highly economic to farmers and combines agricultural sustainability with natural resource preservation. Despite the fact that a lot has been done in publicizing the enormous impact of tillage on CO_2 emissions to the atmosphere and how NT transforms the soil from a source of carbon dioxide to a carbon sink, the public in general is not aware of these research findings. A much bigger effort has to be made in creating societal awareness about the many positive effects of NT, not only for farmers themselves but also for society as a whole. The downstream benefits of NT adoption are many: NT reduces the impact of soil erosion on roads, waterway, dams, etc., reduces the costs of cleaning drinking water; reduces the cost of electricity generation; increases water infiltration; reduces the risk of flooding; provides greater and more stable yields; allows the production of cheaper food contributing to food security; provides for sustainable rural development that benefits all sectors of society, etc., etc. But, "even if the truth is known, it isn't important unless efforts are made to assure public perceptions are the same" (Beck, 2002).

FUTURE RESEARCH PRIORITIES

There are a number of issues that researchers in general have neglected in the past which need to be addressed more intensively in the future. Research especially needs to be intensified on cover crops, crop rotations, biological controls of diseases, pests and weeds, soil biology and adaptation of the NT system to site-specific conditions using a systems approach and on-farm research. Research should also concentrate on developing the technology further for small farmers and for a greater diversity of crops. Last but not least, researchers should increase their efforts to evaluate the economics of NT.

Green Manure Cover Crops (GMCC)

The missing element in the no-till system in many regions in the world is the systematic application of Green Manure Cover Crops that enrich crop rotations. Research conducted in Brazil and Paraguay has shown that GMCC's are not only an economic viable option, but that they are indispensable to reduce weed infestation and herbicide costs, reduce diseases and pests, produce the permanent cover needed in the NT system and increase organic matter content of the soil. Therefore, in the NT system it is mandatory that GMCC's are included in crop rotations. In regions were GMCC's are not used research has to select and screen adequate species that can be fitted into specific windows of the farming system. Once it is known which GMCC's can be used in a certain window, research has to study the residual fertilizer effect of these cover crops on the main crops in terms of weed, diseases and pest suppression (or not), increases in yields of cash crops, reduction in nitrogen application rates, etc. Only when this data is available can economists evaluate the economic benefits of cover crops. Without conducting system-approach economic studies over several years, it will not be possible to determine the economic benefits of GMCC's. We have to be aware that farmers in general will only use cover crops when they show economic advantages over the conventional situation. Derpsch *et al.* (1991) showed that soybean [*Glycine max* (L.) Merr.] yielded up to 60% more following black oat (*Avena strigosa* Schreb*.),* a common cover crop in South America, than following wheat (*Triticum aestivum* L.), and that the black oat system demonstrated a quantifiable economic benefit.

Crop rotation

A great proportion of no-till still continues to be practiced in monoculture. Monoculture is defined as repeating the same crop each year in the same place. Under this definition, double cropping wheat and soybean is understood as monoculture in South America. Research has to make a larger effort in showing the advantages of crop rotations over monoculture. This needs a systems approach and long term trials (Reeves, 1997), because differences between rotation and monoculture will be greater the longer an experiment is run. A good example is the rotation trial at Rothamsted Experiment Station in the UK, where after a 100 years of experimentation it is shown that wheat in monoculture with 140 kg ha^{-1} N produced about the same (3 tons ha^{-1}) as wheat without N were adequate rotation has been practiced (Boguslawski 1981). Today we know that diseases are one of the biggest problems of NT. This problem can in general be solved using sound crop rotation.

Biological controls of diseases, pests and weeds

No-till increases the potential benefit from using biological controls, allowing a reduction in use of agricultural chemicals. Research has to demonstrate how chemicals can be replaced by biological controls. There are already good examples of efficient biological controls being practiced by farmers. Research in Paraguay has shown that control of the soybean caterpillar *Anticarsia gematalis* with *Baculivirus anticarsia*, is much more effective in the NT system than in conventional tillage (Kliewer *et al.*, 1998). The NT pioneer farmer Herbert Bartz in Rolandia, Brazil, reports not having used post-plant insecticides on soybean for the last 18 years (Landers *et al.*, 2001). Research in Paraguay has also shown it is possible to suppress weeds effectively and economically seeding cover crops or cash crops immediately or as soon as possible after harvesting one crop. In this system it was possible not to apply herbicides at all for 3 years in a row (Vallejos *et al.*, 2001). The potential of reducing weeds with cover crops and adequate management practices has not been sufficiently studied and recognized. More research with a systems approach is needed in this field.

Soil biology

Research has done a fairly good job in understanding and quantifying the effects of tillage systems on chemical and physical soil properties. This has not been the case with respect to biological soil properties. Biological soil processes are probably the most important part of soil fertility and yet we have not been able to come up with a practical and easy method of quantifying biological soil fertility. *"By modifying the structure of the soil ecosystem and the soil-litter interface, NT systems provide the ideal environment for the re-establishment of ecosystem engineers such as earthworms and scarab beetle larvae, of saprophagous and litter transforming organisms such as termites and millipedes and of predator population (pseudoscorpions, centipedes, diplura and spider), thus enhancing the system's natural biological control and regulation mechanisms"* (Brown *et al.*, 2001). Research has to address the issue of soil biology and biological fertility more intensively than in the past.

ADAPTATION OF NT TO SITE-SPECIFIC CONDITIONS USING A SYSTEMS APPROACH AND ON-FARM RESEARCH

This has also been a missing element in many regions. In order to make technology work, adaptive on-farm research is needed. This research has to have a holistic management or systems approach. This means that management decisions and policy techniques need to be based on a broader perspective than has been common in the past (Beck, 2002). Farmers deal with systems, why should researchers continue to ignore this?

Small farmer

While not too long ago it was believed that no-till could only be practiced on big farms with tractors, Brazil and Paraguay have made great progress in developing the NT system for small farmers. Other countries in Latin America, Asia and Africa have to increase their effort in research and development of NT technology for draft animals and also for manual production systems.

Research with a greater variety of crops

There are a large number of crops that have proven to grow well in the no-till system, but still there are doubts that some crops like potato (*Solanum tuberosum* L.) and cassava (*Manihot esculenta* Crantz) can grow in this system. In the meantime there are experiences with potato grown in NT in Colombia (Birbaumer, 2000) and cassava grown in NT in Paraguay (Florentìn *et al.*, 2001). Both crops have grown well in this system and farmers obtained higher yields when NT was used as compared to conventional cultivation. Although farmers are already using potato and cassava in the NT system, little research has been done with those crops. Researchers should be encouraged to work with non traditional no-till crops in order to widen the possibilities of crop rotations.

THE ECONOMICS OF THE NO-TILL SYSTEM

Many economic studies have produced misleading results because they have oversimplified evaluations, not taking important aspects of the system into account. Research should increase the effort in evaluating the economics of no-till, avoiding simplistic comparisons of one or two crops. Instead economic studies should have a systems approach and be carried out over several years, considering all aspects of the farming system, not forgetting the value of soil degradation in conventional tillage (erosion, loss of organic matter), the improvement in soil fertility in the NT system (reduction in fertilizer application rates), considering the cost of traditional soil conservation, taking offsite costs of erosion into account, consider the fact that a tractor will last 16 to 20 years in a No-till system as against only 8 to 10 years in the conventional tillage system, that less and smaller tractors are needed, etc., etc.

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