Agriculture & Rural Development Working Paper

No-Till Farming for Sustainable Rural Development

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Foreword

When organic matter and soil structure are lost through exploitive farming practices such as slash and burn agriculture, monoculture, or excessive tillage, plant yields decline. When land is left barren, sediment and chemicals pollute steams and lakes. When farmers can't afford needed chemicals or improved seeds, plant yields do not increase. When farmers and farm communities do not have access to markets and market information, they receive low prices for their produce. When rural families do not have access to adequate education and health services, they can't be competitive and productive. In other words, to have healthy rural communities and landscapes, land, soil, and water resources must be properly managed; rural policies, infrastructure, and institutions must promote economic growth; and there must be a strategy to improve the lives of all rural residents.

The no-till farming approach discussed in this paper and used in Brazil demonstrates how improved decisionmaking in rural space can occur (on about 14 million hectares, including both large and small farms). Farmers and local community leaders were convinced that changes in land management practices were desirable, based on solid evidence provided by trusted specialists and the experience of farming communities with similar economic, social, and natural resource conditions. These sustainable farming practices incorporate people and technologies into an integrated whole. It is a win-win-win approach that results in greater net returns to the farmer (through reduced labor, fuel, and equipment costs), increased crop yields, and watershed benefits such as cleaner streams and lakes and less road damage.

Brazilian farmers said the primary reasons that they adopted the NT approach were reduced costs and increased yields, both of which led to increased net income. Small-scale, resource-poor farmers said that when they switched from conventional farming methods to the NT approach, they reduced the number of trips across the field from 40 to 60 percent — and with that extra time they were able to earn more off-farm income and diversify their operations into specialty crops, more livestock, or add value to raw products through food processing or other avenues.

Agriculture is reaching the limits of available land and water resources. Thus, future increases in agricultural production and rural income must be derived from smarter use of these resources. Use of purchased inputs such seeds, fertilizers, and pest control chemicals are necessary components of the formula, but not in a prescribed way. No-till farming integrates ecology into the farming system design and considers the complex biological web that is at work in a system of healthy and efficient soils, plants, and animals. It recognizes that management decisions affect the habitats and food sources of organisms important to regulating biological processes, and therefore agricultural productivity.

The initial development and adoption of NT agriculture in southern Brazil (and now in other Latin American countries) occurred because a handful of dedicated farmers, specialists, and community leaders recognized the potential of this integrated approach. They partnered with marketing co-ops, equipment dealers, and chemical providers from the private sector. In the early 1970s they observed the reduced tillage methods being practiced in Europe and the United States, and adapted them (along with other innovations) to semi-tropical conditions. It took about 10 years of adaptive research and experimentation to arrive at four intertwined soil and crop management techniques involved in NT farming practices — no soil turning, maintenance of permanent vegetative cover, direct seeding, and rotation of both cash and cover crops.

Beginning in the mid-1980s, the Ministries of Agriculture at the state and national levels, government-sponsored research and extension agencies, and academic institutions began to see the benefits of this alternative approach, and with the help of early adopters and specialists, have made NT agriculture a core part of their respective programs.

Without the eventual acceptance of the merits of NT agriculture by relevant government agencies and the broader agricultural community, the expansion of NT from the farms of a few true believers to 14 million hectares in Brazil (and nearby countries) would not have occurred. Expansion beyond this level is well underway. A critical component of the broader agricultural community is the leadership provided by farmer-led organizations, particularly Friends of the Land Clubs. They created an environment to exchange experience, test new practices, and hold field days. The partnership arrangement between NT champions, government representatives, farmer organizations, and input and marketing providers kept the right balance between the demand and supply forces of the program. This clearly demonstrates the need for flexibility in expanding successful approaches.

The NT farming approach developed in Brazil and nearby countries is providing a foundation for application in Sub-Saharan Africa and other semi-tropical environments, showing that when land and soil resources are properly managed, good things begin to occur in rural communities and landscapes. No-till farming is certainly not a panacea. However, with globalization and increased competition, cutting production costs will be essential, especially if/where/when subsidies will be removed. In addition, the NT farming approach may well provide a practical and appropriate way to implement the new World Bank Rural Strategy in many tropical countries. This farmer-approved approach is moving to holistic pro-poor rural development and enhancement of returns to labor and land, successfully focusing on the poor as demonstrated by current experience in Paraguay and the southern Brazilian states. It recognizes the importance of fostering broad-based growth, and the participation of the private sector as an engine for change. Although it focuses on micro-watersheds and rural landscapes, NT farming addresses the entire rural space and overcomes the shortcomings of earlier top-down, non-inclusive approaches. And finally, by recognizing the leadership role played by farmer-led organizations, NT farming facilitates the increasingly broad-based stakeholder participation in design and implementation, moving away from working mainly with central governments in project and program design.

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Introduction

In combination with water and solar energy, land and soils form the foundation for agriculture and forests. Their successful management provides food, clothing, and shelter.[1] Land and soils also provide key environmental services such as partitioning of water and gases, a home for a multitude of life forms, pollution control, and mineral recycling. Nearly 1 billion rural households rely directly on the services of natural capital stocks and intricately interdependent ecosystems — water, land and soils, forest and fisheries — for their daily livelihood (World Bank, 2001). As the availability of these resources declines and their quality deteriorates, our livelihood is threatened. The degradation of soils is a major threat to rural households. Soil erosion, salinization, compaction, and other forms of degradation affect 30 percent of the world's irrigated land, 40 percent of rainfed agricultural lands, and 70 percent of rangeland (World Bank, 2001).

Land and soil resources degrade through natural processes, but most degradation is a result of human-induced changes in land use that alter hydrology and long periods during which bare soil is exposed to the sun, wind, and rain. It is estimated that 70 percent of the global (non-glacial) land surface is currently receiving some degree of human intervention, and by 2020 most land areas will be managed. Land degradation, which was observed as early as 7,000 years ago in the irrigated plains of the Middle East, results mostly from inadequate management. Land use and land cover changes occur mainly from agricultural activities. However, what was earlier a local or regional environmental issue has now become global due to a growing world population and rising per capita consumption (Watson et al., 1998). Farmers and herders make management decisions about their investment capital and the available natural resources, decisions that when repeated over and over again on the same landscape potentially have major regional and increasingly global effects. Improved land and water management, as well as legally secure access to these resources, are critical to address poverty and food security, and to improve natural resource sustainability. The challenge is particularly severe for developing countries in the inter-tropical zone, where population growth is the highest, cash income is very low, and availability of suitable land is limited.

In most farming systems around the world, soil tillage has traditionally been considered as a prerequisite to crop planting. Soil inversion using various types of hoes, moldboard or disc plows, and harrows, has been considered normal farming practice. In this document, we refer to these practices as 'conventional' tillage or farming. The negative effects of soil tillage on farm productivity and sustainability, as well as on environmental processes, has been increasingly recognized and documented both in the developed and developing worlds.[2] This recognition has led to the development of alternative farming practices, one of the most promising of which is the no-till (NT) system. No-till farming encompasses four broad, intertwined management practices:

- minimal soil disturbance (no plowing and harrowing),
- maintenance of a permanent vegetative soil cover,

1. Land is best described as a common resource and the principles of good land management apply equally to community- and privately-owned (or managed) land. Densely occupied territories are proliferating all over the world, making the boundary between 'private productive' and 'common natural' land resources elusive, while *de facto* off-site externalities often create undesirable results.

2. For example, loss of organic matter/carbon, soil compaction, rainwater run-off and soil erosion, loss of soil biological activity and biodiversity, increased greenhouse gas emissions, etc.

- direct sowing, and
- sound crop rotation.

No-till farming is a component of the Sustainable Land Management (SLM) and Better Land Husbandry (BLH) approaches, but as we will explore later, NT farming is not merely a technical matter, especially since most of the practices have evolved through farmer innovations. It is equally a matter of people and community empowerment, farmer-led organizations, business development, and partnerships among private and public stakeholders.

No-till systems have been adopted by a wide range of farmers for the last two decades on some 60 million ha worldwide on all farm sizes and under varied cropping systems (Derpsch, 2001), ranging from the Pampas of Argentina and the sub-tropics and tropics of Brazil and Paraguay to the prairies of Canada, the rice-wheat zone of India and Pakistan, and Australia, Central Asia, Central America, USA, and Mexico.[3] There are promising signs of early stages of NT technology development in Africa, such as Côte d'Ivoire, Tanzania, and South Africa, with some success registered in more favorable rainfall areas, but with barriers that must yet be overcome in semi-arid areas (Steiner, 1998).

The USA has the longest experience with NT, but in Brazil it has been to applied to a wide range of farm sizes, and under mechanized, animal traction, and/or manual conditions — encompassing diverse farming systems under temperate, sub-tropical, and tropical conditions. The Brazilian experience has been witnessed, supported, and eventually enhanced through several state and federal programs developed in collaboration with the World Bank and other partners, such as FAO, the German Technical Cooperation Agency (GTZ), and the French International Agricultural Center for Development (CIRAD).

3. No-till agriculture was researched in the USA in the 1940s, and more intensively in the late 1950s. In Europe NT research started in the 1960s, and in 1971 in Brazil and Latin America (Derpsch, 1998). At first it was conceived as an efficient soil conservation technology. With time, in some countries such as Brazil and Paraguay, it has evolved into an holistic agricultural system that incorporates crop rotations, use of cover crops, and maintenance of plant cover throughout the year, with positive economic, environmental, and social impacts.

Photo 1. Maize planted into *Vicia sativa* cover crop in a no-till field in Tupassi (Paraná, Brazil)

This paper discusses the potential role of NT farming as an 'entry point' for sustainable land resource management systems that combine productivity gains, income generation for farmers, and ecosystem management for environmental protection. The development and adoption of NT farming systems should therefore contribute to alleviating rural poverty and improving food security, while at the same time protecting the environment. Although future increases in agricultural production are expected to result primarily from better use of land that is already being exploited (i.e., intensification), area expansion will inevitably continue to occur in parts of the world. Therefore, NT systems development should encompass both better land use and area expansion options.

This document is intended to inform and sensitize rural development stakeholders — agricultural producers; policymakers; institutions for research, training, and development; the private sector; and donors — about the potential contribution of, and need to invest in, NT farming systems development as part of future investments for sustainable rural development.[4]

The main focus of the paper is the practical aspects of implementing NT systems. However, the paper also discusses other dimensions that are essential to successful NT development — education, community empowerment and mobilization, legal and institutional frameworks, research, marketing, and enterprise diversification. These aspects are important to ensure the sustainability of technological improvements and maintain flexibility in the face of climatic variability, changes in market demand, or labor availability.

The first section of this paper outlines the broad principles of Sustainable Land Management (SLM) and Better Land Husbandry (BLH), and provides a description of NT farming practices. The second section highlights the key features and economic and environmental impacts of NT farming. The third section identifies the potential for adoption of NT systems in tropical and sub-tropical conditions with particular reference to Sub-Saharan Africa, drawing on lessons from Brazil and other South American countries. The fourth section deals with what needs to be done in a country to facilitate the change toward SLM and NT systems. The concluding section provides a synopsis on the scope and potential of NT systems to help reduce poverty and contribute to sustainable rural development and environmental strategies in developing countries.

4. This paper is intended to complement guidelines for investment programs or projects for rural development from international financial institutions and other donor agencies.

Sustainable Land Management, Better Land Husbandry, and No-Till Systems

General framework

The goal and challenge of sustainable land management (SLM) is to make optimum use of available biophysical, biological, biochemical, and human resources to produce feed and fiber in a given area. Implicit in SLM is that governments and other major stakeholders give priority to appropriate policies and coordinated interventions that will help to achieve the following five objectives:

- more rational land use,
- fair access to land resources,
- improved land management practices,
- avoidance of land degradation, and
- development of an updated knowledge and information base.

As such, SLM encompasses a broad array of interventions applied to farm fields, roads, infrastructure, marketplaces, parks, water, forest and reserve management, as well as many other elements, to ensure sustainability of the ecological, economic, and social exchanges among residents of a watershed. It also includes the participatory establishment of a conducive legal framework and adoption of socioeconomic practices and technical measures. These SLM systems include specific practices for resource conservation such as reforestation, rural sanitation, buffer strips, and grassed waterways.[5]

Agricultural land management issues cannot be addressed solely through individual solutions. The drive to improved land management must integrate biophysical and socioeconomic forces, which can be termed the Better Land Husbandry (BLH) approach.[6] In this paper, BLH is considered as the 'agricultural component' of SLM (Box 1). It is aligned with and encompasses related approaches such as sustainable agricultural systems (NRC, 1993) and conservation agriculture (Garcia-Torres et al., 2001).[7]

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5. Although indigenous practices such as traditional no-till and minimum tillage and shifting cultivation have been considered as 'sustainable practices' for a long time, their productivity may not be able to cope with the growing population pressure on the land resources. Indigenous NT and minimum tillage practices, however, can be the basis to develop more productive and sustainable NT systems.

6. The concept of husbandry, signifying understanding, management, and improvement, is widely understood when applied to crops and animals. It is equally applicable to land. Land husbandry has been defined as the care and management of agricultural land for productive purposes (Shaxson, 1997).

7. The term conservation agriculture (CA) is largely comparable to NT farming as presented in this document. CA can be defined as "a concept aimed at enhancing agricultural production on a sustainable and environmentally friendly basis. This is achieved by efficient exploitation of natural resources to conserve and enhance soil fertility, soil moisture availability and biological resources. CA practices include no soil inversion and direct planting, maintenance of a soil cover and diversified crop rotation" (FAO, 2001a).

Box 1. Better Land Husbandry (BLH) components

An **integrated and synergistic resource management** approach embraces locally appropriate combinations of the following technical options:

- **Build-up of soil organic matter and related biological activity** to optimum sustainable levels (to improve moisture and nutrient supply and soil structure) through cover crops, and/or better management of crop residue, farmyard manure, green manures, surface mulch, enriched fallows, agroforestry, and the use of compost.
- **Integrated plant nutrition management** with locally appropriate, cost-effective combinations of organic/inorganic and on/off-farm sources of plant nutrients (e.g., organic manures, crop residues, rhizobial N-fixation, transfer of nutrients released by weathering in the deeper soil layers to the surface via tree roots and leaf litter, rock phosphate, lime, and chemical fertilizer).
- **Better crop management**, improved seeds of appropriate varieties, improved crop establishment at the beginning of the rains (to increase protective ground cover, thereby reducing water loss and soil erosion), weed management, and integrated pest management;
- **Better rainwater management** to increase infiltration and reduce runoff to improve soil moisture conditions within the rooting zone, thereby lessening the risk of drought stress during dry spells, while reducing erosion.
- **Improved soil rooting depth and permeability** by breaking the cultivation-induced compacted soil layer through conservation tillage practices by means of tractor-drawn subsoilers, ox-drawn chisel plows, through no-till and hand-hoe planting pits/double-dug beds; and/or interplanting of deep-rooted perennial crops, trees and shrubs, and annual cover crops.
- **Reclamation** where appropriate (if technically feasible and cost effective) of arable land that has been severely degraded by such processes as gullying, loss of topsoil from sheet erosion, soil compaction, acidification, and/or salinization.

Adoption of people-centered learning approaches through which farmers are able to learn about and investigate the costs and benefits of alternative land husbandry practices.

Community-based participatory approaches to planning and technology development that build on the inherent skills and capability of rural people to formulate and implement their own development plans, and to develop and disseminate their own improved land husbandry technology.

Better land husbandry for business through the promotion of field level interventions that offer farmers tangible economic, social, and environmental benefits.

Adapted from FAO and United Republic of Tanzania, 2000.

Organic farming is also seen nowadays as a pathway toward SLM and BLH. However, the 'organic pathway' does not adequately address the most urgent needs of the rural poor in developing countries.[8] At best, it can be seen as a complementary opportunity to generate additional rural income in peri-urban areas and/or on lands with initial or recovered potential for high productivity, and where labor is not a constraint.

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8. Triggered by the perceived excesses of input-intensive agriculture, the organic alternative receives considerable recognition mostly in developed countries from consumer groups concerned with human health and environmental pollution, and from producers receiving a premium for their organic-certified products. Although this approach may find some niche market opportunities, it may not adequately address the main issue of increasing total food production. Either yields are lower due to reduced land-use intensity for fertility restoration or fertility is transferred from other systems as organic wastes or 'natural' fertilizers, both of which increase costs. Lower land-use intensity implies expansion of cropped area, which may be at the expense of natural vegetation. Moreover, 'organic' certification and control of bacterial and heavy metal contamination in organic material used to enhance soil fertility requires a legal framework, generally difficult to establish and enforce.

Better land husbandry is about combining investment in natural capital and investment in human and social capital to ensure the intensification of sustainable farming systems[9] and area expansion where appropriate,[10] as well as the sustainability of improved land management in rural environments (Photo 2). The BLH approach emphasizes the application of skills and knowledge to manage the biological cycles and interactions that determine crop productivity. It differs from the high-input approach that guided agricultural systems in the industrial countries in recent years.

Photo 2. Medium-sized no-till farm in the rolling landscape of Santa Catarina, Brazil

The conventional model of agricultural development stresses intensification through progressively specialized operations and substitution of capital and purchased inputs for labor. This model has fostered lost diversity (in crop germplasm, cropping patterns, and agroecosystem biota), and high cash production costs. Instead, the new approach seeks to meet the concurrent goals of increased productivity and reduced environmental risks in both temporal and spatial dimensions through diverse crops, livestock, inputs, and management practices. Such diversity fosters positive ecological relationships and biological processes within the agroecosystem as a whole. At field and farm level, intensified use of available resources is sought through more diverse rotations and optimal harvesting schedules. Similarly, optimum resource use in rural landscapes of heterogeneous slope, soil type, and water resources is achieved through diverse systems, adopting techniques and growing crops that take full advantage of available sunlight, moisture, nutrient reserves, and biotic interactions, both above ground (for example, through mixed cropping), and below ground (for example, through legume cover crops and deep-rooted tree crops). Finally, the ultimate goal of BLH is to improve productive efficiency and agroecosystem performance through mixed cropping and careful management of all internal resources, as well as necessary external inputs (lime, agrochemicals, seeds, etc.) (NRC, 1993).

No-till farming practices

This sub-section discusses the 'technical' aspects of NT farming, including a general description, followed by a short presentation on specific aspects such as NT equipment, plant cover and cover crops,

9 In general terms, intensification of farming systems refers to the fuller use of land, water, and biotic resources to enhance the agronomic performance of agroecosystems.

10. Although the scope for area expansion is limited and may increasingly occur on marginal land, it will often not be possible to prevent such area expansion, hence the same principles of SLM/BLH must be followed on newly opened land to ensure sustainability of production systems.

crop rotation, and integrated pest management. The successful development of NT systems is discussed later.

What is no-till farming?

No-till farming practices were developed to protect the soil surface from sealing by rainfall, to achieve and maintain an open internal soil structure, to enhance biological processes in the soil, and to develop a means for safe disposal of any surface runoff that nevertheless will occur. No-till farming practices[11] encompass four intertwined soil and crop management techniques:

- **minimal soil disturbance —** restricted to planting/drilling, i.e., no plowing, disking or other forms of soil cultivation;
- **permanent vegetative soil cover** — crop, cover crop, and weed residues are maintained on the surface and none are burned;
- **direct-sowing** — specialized equipment inserts seeds and fertilizer (chemical, organic) through/across/below residues, lime and non-nitrogen fertilizer mostly applied on the surface; and
- **sound crop rotation** — combining different plant families (e.g., cereals and legumes), generating adequate biomass, and continuously using cropland.

All four techniques must be adhered to if economically and environmentally favorable results are to be obtained in a sustainable fashion. The key message is that NT farming practices mimic ecologically sustainable forest ecosystems (Séguy et al., 1996, 2001a).

Specific practices

In an NT system, crops are planted in previously unprepared soil by opening a narrow slot, trench, or band of sufficient width and depth to achieve proper seed coverage and fertilizer placement (Photo 3). [12] No other soil preparation is performed and the soil remains covered by plant residues from previous crops and/or cover crops, and most plant residues remain undisturbed on the soil surface after seeding. A word of caution, however, is required — when the same crop or cover crop is grown on the same piece of land each year, this encourages the build-up of diseases, weeds, and insect pests, which in turn lower yields and decrease profits (Young, 1982; Phillips and Phillips, 1984; Derpsch, 2000). Crop rotation is essential to minimize such problems when employing an NT system.

Farming practices affect soil characteristics, which may also affect soil functions,[13] and consequently have the potential to improve or minimize environmental benefits to the soil. From this perspective,

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11. Erenstein (1997) observed that there is much confusion over terminology and that NT is carried out by many traditional farmers but without a residue or mulch cover. and therefore this term is inexact. A widely used definition of conservation tillage is "any tillage and planting system that covers 30% or more of the soil surface with crop residue after planting, to reduce soil erosion". Conservation tillage is also associated with the substitution of plowing by ripping with tractor or animal traction (e.g., the Magoye ripper for animal traction in eastern and southern Africa).

12. While written technical information was minimal in the 1970s, at the beginning of NT development in Brazil and elsewhere in Latin America, several comprehensive publications as well as practical manuals have been published since early 1980s (Derpsch et al., 1991; Crovetto, 1992; Landers, 1994; Séguy et al., 1996; Hebblethwaite, 1996; Rasolo et al., 1999; FAO, 2000/2001).

13. Soil plays several functions in ecosystems, including: (i) recycling organic material to release nutrients and/or synthesize new organic materials; (ii) partitioning rainfall at the soil surface into runoff, infiltration, and evaporation; (iii) storage and gradual release of water, nutrients, and gases; (iv) maintaining habitat stability, including soil structure and diversity of pore

conventional tillage with plowing/harrowing that incorporates organic residues is less desirable for the environment (Fig. 1). Conventional tillage leaves the soil bare for significant periods of time with high potential to increase water runoff and raise soil surface temperatures. Internally, conventional tillage compacts the soil and collapses the pores and tunnels constructed by soil fauna, thus changing the water,-gas-, and nutrient-holding capacities of the soil. The incorporation of organic residues strongly affects soil biological activity and stimulates the decay rate of these residues as well as residual soil organic matter. Consequently, under tropical conditions, plowing under crop residues usually decreases soil organic matter (Pieri, 1989, 1995).

On the contrary, NT farming practices have overall positive agroecological effects. Undisturbed soil that is permanently protected by vegetative cover mimics or even improves the functions which occur in native ecosystems, including maintenance of

Photo 3. Direct seeding across and under straw with an animal-drawn no-till planter

porous and soft soil layers through litter accumulation, intense biological activity, movement of soil fauna, and root growth. These functions improve efficient water, heat, and gas transfers within the entire soil profile. Such a system of nutrient recycling and improved water-use efficiency is similar to the elegant balance of a forest environment. In addition, crop rotation and cover crops are used to maximize the biological controls of weeds, insect pests, and diseases.

Equipment for no-till systems

Manufacturers now offer a wide range of NT equipment, including planters, adapted sprayers, and harvesters with the ability to spread residues evenly over the entire cutting width. International manufacturers currently offer assorted NT equipment for medium and large mechanized farms. More than 30 companies in Brazil and about the same number in Argentina produce NT equipment, which is now

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sizes, and buffering habitat against rapid changes of temperature, moisture, and toxic materials; and (iv) partitioning energy at the soil surface, which is important in global processes.

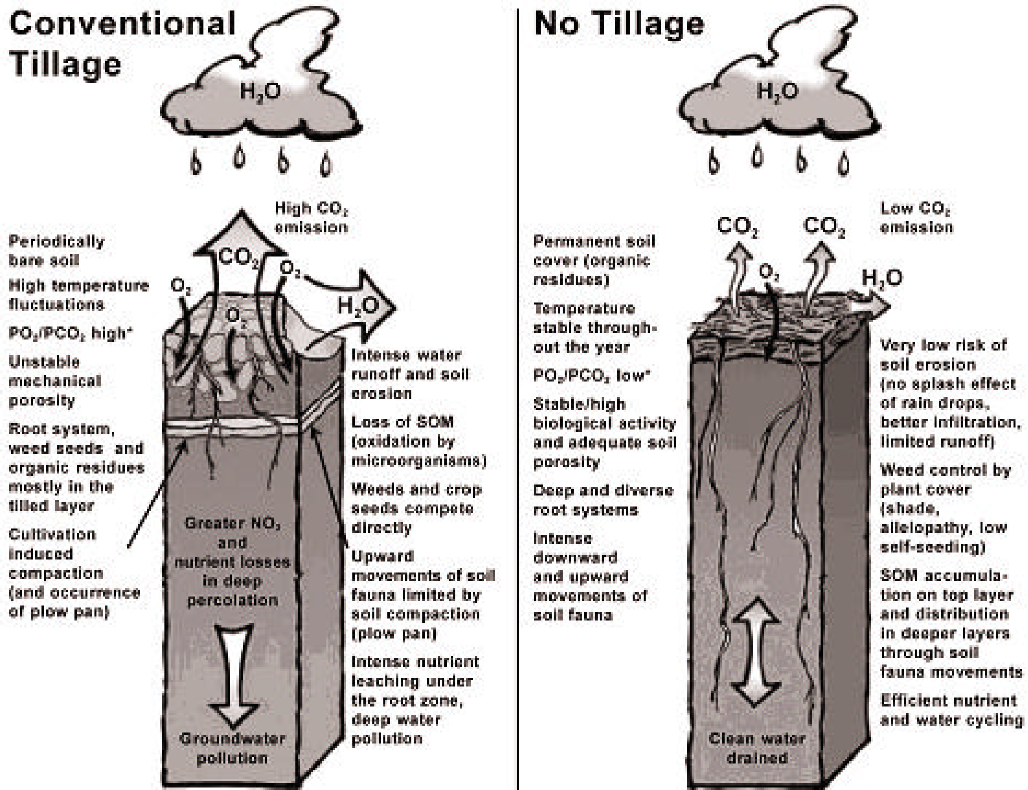
manufactured in other Latin American countries. In addition, the Brazilian industry has pioneered animal-drawn and manual NT equipment, including:[14]

- NT planter (more than 10 models), derived from a prototype 'Gralha Azul', which was conceived by the Agronomic Research Institute of Paraná. The planter has a disc device for cutting plant residues and cover crops, with seed and fertilizer placement boots (Ribeiro et al., 2000) (Photo 4);
- NT planter (four manufacturers), derived from a 'fucador plow' that was developed by a smallholder farmer, it is suited to stony soils (Ribeiro et al., 2000);
- jab planters ('matraca') for direct manual planting, which includes optional fertilizer dispenser;
- a wide range of manual and animal-drawn sprayers (Photo 5), and
- knife-roller ('rolo faca' or small Argentine roll) designed to crush or break and roll cover crops and crop residues and facilitate direct planting (except stony soils and more than 20 percent slope), it is particularly adapted to small farms as a substitute for herbicide applications (Araújo et al., 1993) (Photo 6). Alternatively, steel bars can be welded on top of the discs of disc harrows and the implement used as a knife-roller (Derpsch, 2000).

Photo 4. Animal-drawn no-till planter with seed and fertilizer tanks (Paraná, Brazil)

14. This paragraph draws heavily on Derpsch (2000)

Figure 1 Agroecological effects of conventional tillage and no tillage



Open soil-plant system. This Soil-Plant system is drought prone; accelerates soil surface erosion; requires high input level to maintain fertility; causes sedimentation and water pollution downstream.

Tillage unlocks the potential from microbial activity by creating more reactive surface area for gas exchange on soil aggregates that are exposed to higher ambient oxygen concentration (21%) and higher soil temperature.

Net result is more intense Soil Organic Matter (SOM) oxidation, intense nitrate fluxes, and more CO_2 emission. With less humus accumulation, the soil porosity collapses, water infiltration capacity is reduced, runoff increases and fluxes of nutrients are washed away.

Plowing over time creates a compaction zone which further prevents upward soil fauna movements and downward root development.

Intense nitrate leaching and accompanying cations, e.g., Ca, Mg, out of the shallow root zone, results in soil acification and ground water pollution.

Conventional tillage is environmentally non-sustainable.

** = PCO_2/PO_2 is the ratio of partial pressure of CO_2 and O_2 in the soil atmosphere*

Closed soil-plant system. This Soil-Plant system mimics natural soil eco-systems. It is more drought resistant; ensures highly efficient use of existing and, if required, added nutrients; it reduces contamination risks.

Due to intense biological activity, soil pore atmosphere is richer in CO_2 and has a lower PO_2/PCO_2 ratio. Soil temperature is also lower. Both conditions lead to reduced oxidation rate and accumulation of SOM.

Weed control is facilitated by plant cover (shade, allelopathy, low weed self-seeding due to smothering).

Permanent soil cover protects from rain drops' energy, increases water infiltration, hence drastically reduces water runoff and soil erosion risks.

Increased population of earthworms, insects and rodents and greater root development contribute to better soil aeration, and SOM distribution in the soil profile through biological macropores.

Efficient water and nutrient cycling, as a result of root development and stable biological porosity.

Clean water drained.

No Tillage is environmentally sustainable.

Photo 5. Forty-liter capacity manual sprayer (Chapeco, Brazil)

Photo 6. Felix Drupek and Vitorio Roik discuss the use of a roller-knife on the steep slopes of Cerro da ponta Alta community (Paraná, Brazil)

Soil cover

Permanent soil cover with a thick layer of plant residues is fundamental to the success of NT systems. As stated by Reeves (quoted by Derpsch, 2000), "we have concentrated too much and too long on not tilling the soil instead of concentrating on crop residues as the main tool for management". The presence of crop residues on the soil surface minimizes evaporation, and in regions of low rainfall can conserve water and increase crop water-use efficiency. Further, the change in infiltration and runoff rates can have major effects on the total water balance that is important in sustainable production systems. In Latin America, NT farmers aim to have at least 6-10 t/ha of dry matter from plant and crop residues each year. Sources of plant material can be diverse (Séguy, 2001a), and may include:

- residues from previous crops;
- dry residues of cover crops preceding or following the main crop. Favorable qualities of these crops include (i) rapid establishment; (ii) deep rooting; (iii) high biomass production and low decomposition rate; and (iv) low water requirements. The objective is to fully cover the soil, to 'tap' rainy-season humidity, restructure the soil, control weeds (through shade and allelopathy), recover and store nutrients not utilized by the main crop, and produce seeds;
- live mulch cover, i.e., perennial plants (through their seeds or underground organs) that can be controlled by low-rate herbicide application, are compatible with the main crop, control weeds, and have fodder value for alternate crop and livestock production; and
- external biomass sources such as from agroforestry shrubs, straw, etc.

Selection and management of plant cover is fundamental to the success and sustainability of NT systems so that it has the expected effects on the farm and associated agroecosystem (Photo 7). Beneficial effects include:

- mitigating extreme temperatures and soil moisture variations;
- controlling water run-off and reducing soil erosion;
- suppressing weeds (including *Striga* sp.);
- enhancing biological control of insect pests and diseases;
- stimulating crop growth (through active rhizosphere and nutrient recycling); and
- providing indirect benefits such as carbon sequestration and improved water quality.

There is abundant literature available on cover crops[15] best adapted to different regions, agroecological zones, and soils.[16] Information on cover crops also includes nutrient content, range of nitrogen fixed by legume cover crops, capacity to complement animal feed and/or human food (Calegari and Peñalva, 1994), as well as their capacity to control specific pests such as nematodes[17] and weeds (Table 1).

Some plants previously considered as noxious weeds such as *Brachiaria plantaginea* in Brazil, *Chromoloena odorata* in Côte d'Ivoire, or *Desmodium intortum* on Bourbon Island, are now successfully

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15. The earliest written information was for the sub-tropical and tropical zones of Latin America (see for example, Derpsch and Calegari, 1985; Monegat, 1991; Calegari et al., 1993) as well as the temperate zones of North America and Europe (Young, 1982; CTIC, 1997; INRA, 1992). However, in the mid 1990s knowledge on cover crops adapted to a wide range of environments increased considerably, including Southeast Asia (Boulakia and Enjalric, 2000); United States temperate climate (USDA, 1998); sub-humid and semi-arid zones of Africa with up to 5-6 months of totally dry season (Steiner, 1998; Buckles et al., 1998a); Charpentier et al., 1999; Séguy et al., 2001a), and tropical mainland and island mountain ecosystems (Buckles et al., 1998b); Rasolo et al., 1999).

16. In tropical zones some of the more common cover crops include legumes and grasses. Legumes include mucuna (*Stilozobium deeringianium, aterrimum, cinereum, niveum*), *Calopogonium mucunoides*, siratro (*Macroptelium atropurpureum*), kudzu (*Pueraria phaseoloides*), cowpea (*Vigna sinensis*), pigeon pea (*Cajanus cajan*), vetch (*Vicia sativa*, *villosa*), crotalaria (*Crotalaria juncea, spectabilis*), lupin (*Lupinus albus, angustifolius, luteus, mutabilis*), and jack bean (*Canavalia ensiformis, brasiliensis*). Grasses include sorghum (*Sorghum bicolor*), millet (*Pennisetum americanum*), *Eleusine coracana*, oats (*Avena strigosa, sativa, byzantina*), rye (*Secale cereale*), ryegrass(*Lollium multiflorum*), Brachiari spp *(B. decumbens, B. brizantha* and *B. ruziziensis*) and *setarias italica*.

17. *Crotalaria, Mucuna, Cajanus cajan,* alfalfa, oats, rye, and raygrass are among the well-known plants that help to control nematodes.

used as cover crops in NT systems. Finally, the most recent development in managing plant cover is to use crop rotation and intercropping for the cover crops themselves to improve soil fertility and regeneration, control insect pests and diseases, as well as to increase the nutritive value and production of fodder (such as black oats + vetch, or millet + pigeonpea or cowpea).

Crop rotation and integrated pest management

The increase in crop yields as a result of a sound crop rotation is well documented. Under NT systems, this positive effect is enhanced by the accumulation of soil organic matter, increased biological activity, better availability of nutrients, and increased nitrogen through symbiotic fixation by legume cover crops.[18] These processes better control soil erosion, lower the overall cost of crop production, and increase farm income (Séguy, 1996; Derpsch, 2000).

Table 1. Effect of selected cover crops on Striga in Côte d'Ivoire

Cover crop	*Maize plants infested by Striga (percent)*	*Yield (kg/ha)*
Pueraria phaseolides	2.8	2540
Calopogonium mucunoides	3.6	2260
Cassia rotundifolia	18.4	2310
Macroptilium atropurpureum	98.0	1250
Centrosema pubescens	100	1120
Tephrosia pedicellata	100	910
Control	100	730

Note: Pueraria is the best option to control Striga in northern Côte d'Ivoire
Source: Charpentier et al., 1999

In addition to improving plant nutrition, use of crop rotation and cover crops is key to managing weeds in NT systems. These strategies dramatically decrease the reseeding and emergence of weeds through the physical (smothering and shading) and biochemical (allelopathic substances from straw breakdown or root exudates) effects of the accumulation of straw and other plant residue cover on the soil surface. The practical effects on farm finances can be very significant, for example:

- 90 percent of the NT mechanized fields in Rio Grande do Sul state, Brazil, with about 6 t/ha of dry matter of black oat cover crop 'rolled down' on the soil surface with a roller-knife, no longer require herbicide applications (Roman 1990); and
- small-scale farmers in Paraguay controlled weed infestation using manual and animal traction NT systems over a 3-year period in wheat-soybean-cover crop systems, without herbicide applications.

18. The overall impact of NT systems, including crop rotation and permanent plant cover, is highly beneficial to soil microbiological activity and plant nutrition. For example, over a 9-year period in Paraná, Brazil, Calegari and Alexander (1998) measured an annual input of nitrogen equivalent to 90 kg/ha in a corn-soya rotation including cover crops such as blue lupin and hairy vetch.

Photo 7. Sunflower directly seeded into maize residue (Rosario, Argentina)

Farmers moving from conventional to NT agriculture need to drastically change the way they manage weeds, particularly during the transition phase. In order to manage this change, farmers need to improve their knowledge of weeds and their management (e.g., control self-seeding), herbicides and their application technology,[19] as well as alternative weed control methods (Box 2).[20]

Box 2. Effects of cover crops and rotations on reducing herbicide requirements

Over a 3-year period, farm experiments conducted in the state of Alto Paraná, Paraguay showed that:

- Traditional double-cropping of wheat and soybeans required **11 herbicide applications** for adequate weed control. Total cost of weed control was **US$ 208/ha**.
- In a 2-year rotation including cover crops (year 1: *Crotalaria juncea* L./wheat/soybean; year 2: *Lupinus albus* L. /maize), the cover crops were 'rolled' down with a 'knife roller' about 50-60 days after seeding so all biomass was on the ground. The next crop was seeded into the stubble with a no-till planter, and required only **4 herbicide applications** for adequate weed control. Total cost of weed control, including cost of cover crop seed and cover crop management was about **US$ 184/ha**;
- A 3-year crop rotation included a rotation of three cover crops (year 1: sunflower as a cover crop, black oats, lupin; year 2: sunflower/black oats/soybean; year 3: wheat/soybean, lupin/maize). **No herbicide applications** were required for adequate weed control. Total cost of weed control, including cost of cover crop seed and cover crop management was about **US$ 151/ha**.
- Other benefits not accounted for in the crop rotation/cover crop systems include (i) a significant increase in soil organic matter content;(ii) minimization of nutrient losses by surface run-off and from leaching, and (iii) presence of a healthy root system.

Source: Kliewer et al., 1998.

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19. Information is also required to apply herbicides efficiently and safely. The complex calculation of water volume to be applied, pressure, nozzle output, ground speed of application, tank capacity, and amount of product to be added to the water to follow the recommended application rate poses a difficult task for anyone trying to calibrate a manual, animal-drawn, or motorized sprayer. This is particularly true in warm tropical zones where water availability and quality (pH) can be an issue, along with other factors that influence use efficiency and sprayer requirements — solar radiation, air temperature (needs < 30º C), relative humidity (> 60 percent), and the absorption period required after spraying during which there must be no rain.

20. It is also critical for farmers and technicians to access easily understood and credible publications that describe available herbicides, their chemical and toxicological characteristics, long-term impact on weed populations, application rates, and species that can be efficiently controlled by each product. Publications that describe and show pictures of the most common weeds as seeds, seedlings, and adult plants are important for easy identification. In Brazil excellent manuals are available on weeds (Lorenzi, 1994) and herbicides (Rodrigues and Almeida, 1998). Both publications are now in their fourth edition. In the USA, the Sustainable Agriculture Network recently published *Managing Cover Crops Profitably,* with very detailed information (Sustainable Agriculture Network, 2001).

Key Features and Effects of No-Till Farming

No-till farming should not be seen as merely a set of technological packages, but rather it can be defined as a 'platform' based upon three pillars:

- community empowerment and farmer-led organizations that believe in the benefits of NT;
- entrepreneurial partnerships such as links with market forces; and
- NT farming practices.

On this platform, concrete improvements in the well-being of the rural poor can be erected, as well as achieving the goals of SLM/BLH and improving the environment. Such improvements are best achieved when conducive legal, institutional, and policy conditions are in place, including land-use security, administrative decentralization, community empowerment, and an effective open market economy.

The Brazil experience, however, demonstrates that changes can occur even if not all these conditions are met. The 'NT Brazilian platform' occurred in a rather constrained sociopolitical environment.[21] It is, nonetheless, important for decisionmakers to understand that the supportive environment created by favorable institutional and policy conditions will accelerate the process of change toward sustainable economic and social development with measurable effects. These favorable conditions are also critical to scale-up successful NT pilot projects.

Farmer-led organizations

The empowerment of farmer organizations and rural communities to address land management issues is a key condition for the successful implementation of NT farming. Fair prices for farm products is fundamental to good land husbandry.[22] As mentioned earlier, SLM and BLH can be seen as the 'art' of managing site specificity, and integrating biophysical and socioeconomic forces over time and scale.[23] No-till farming draws on the BLH principle that rural people, educated or not, have greater knowledge and ability than previously assumed by outsiders, and hence are equipped to lead the process of change toward SLM goals.[24]

Dedicated farmer organizations, specifically constituted to address land and crop management issues, are needed to foster this change, as historically demonstrated in some industrialized countries (Centre d'Etudes des Techniques Agricoles in France, sustainable agriculture farmers network in the USA, land care movement in Australia and New Zealand) and more recently in developing countries with farmer-led organizations such as the Friends of the Land Clubs in Brazil and the Regional Committee SLM-

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21. In the 1970s and early 1980s, many politicians opposed NT farming because they assumed it would be more polluting and adapted only to large, well-financed farms. Research and extension efforts were muted.

22. As pointed out by Pretty (1998), "Sustainable management of natural resources depends not just on the motivations, skills and knowledge of individuals, but on actions taken by local groups or communities as a whole". It also depends on profit.

23. "Standardization of land resource management and control of production processes have significant weaknesses in dealing with high level of biological integration in diverse production systems and/or with high level of social integration" (Harwood, 1995).

24. "Unless the poor have the power to participate in deciding which technology to use, they are unlikely to benefit from it" (IFAD, 2001).

Environment (Gestion Durable des Sols-Environnement) in Côte d'Ivoire. The most recognized strengths of producer organizations are:

- a better understanding of the **local interactions** among biological, technical, labor, and socioeconomic factors (at field, farm, community, and watershed levels);
- the competence to identify constraints, opportunities, and the **best local strategies** for transition toward BLH and NT farming;
- a position to facilitate a **cost-efficient transition** process, including farmer education, on-farm participatory technology development, farmer-to-farmer extension, information and knowledge dissemination, and networking;
- contributions to developing multi-scale **producer-led SLM institutions** (at community, watershed, terroir, and administrative unit levels),
- a position to address **local land conflict** issues (land tenure and land user rights, bush fire control, herder-farmer conflicts) because they are directly affected; and
- activities to best combine all the requirements for rural economic **growth**, **human health, social development, and environment management** (at field, farm, community, and watershed levels).

Devolution of the responsibility for natural resource management to producers has two advantages — increased accountability by those responsible for land and water management, and improved prospects to overcome lack of knowledge of local conditions.

Farmer organizations may differ in size, organizational framework, and scope, from small groups (fewer than 20 members) to land management committees at a watershed level, or larger administrative units. However, whatever the size, all successful production-oriented farmer organizations usually have common features (Box 3).

Entrepreneurial partnerships

In general terms, rural people respond to market opportunities when they see that they will be better off as a result of some specific action. No-till farming is an holistic approach that contributes to the ultimate goal of BLH in rural landscapes by developing locally-adapted farming practices. However, NT is eventually about increasing farmer income through marketing quality farm products grown in an environmentally friendly manner, including increased produce value through livestock integration (e.g., crops as animal feed) and agroprocessing (Cheatle, 1998).

Box 3. Common features of successful farmer organizations

Farmer organizations:

- are profit-motivated and oriented to solving problems;
- protect land assets through sustainable use of land resources; and
- are willing to develop alternative soil and crop practices that are not only profitable and productive, but offer less drudgery and fewer hazards to human health and the environment.

Farmer organizations acquire knowledge through:

- farmer education;
- interchange of experience;
- testing new practices; and
- field and farm visits.

Farmer organizations are:

- flexible;
- farmer managed (independent from external funding sources);
- recognized (legitimate and credible);
- have non-profit status; and
- transparent and democratic.

Although food security concerns may come first for poor rural smallholders, no farmer, poor or rich, will ever invest in BLH components such as NT in the absence of tangible, short- and long-term benefits.[25] Poor people also perceive entrepreneurship as a key strategy to escape poverty. Narayan (2000) said that "Development leaders or entrepreneurs are found at all levels in society. Their social energy creates momentum for an improved quality of life for poor people. Yet their scale and impact remains limited. Venture capital funds are needed for development entrepreneurs." To derive the full benefits expected from development of NT systems, however, it is essential to form fair partnerships (with compatible interests) among rural communities, farmer organizations, agribusinesses, and consumer groups.

Benefits and impacts

The benefits from adoption of NT farming can be assessed at three different levels — farm, community and watershed, and global (Box 4) (FAO and World Bank, 2000).

These benefits are increasingly being documented where conventional tillage systems have been replaced by NT systems, such as in Brazil and Paraguay.

Economic benefits

Increase in land and labor productivity, and consequently in farm income, are commonly experienced by NT practitioners, such as the World Bank-funded Land Management II-Santa Catarina Project in Brazil (Table 2).

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25. "To attract poor farmers, investment in land capital should not conserve at the expense of production, and preferably should itself be productive" (IFAD, 2001).

Box 4. Descriptive benefits and impacts of no-till farming

Farm Level	*Community Or Watershed Level*	*Global Level*
Labor, time, and farm power are saved through reduced cultivation and weeding requirements. Lower costs because both operations and external inputs are reduced. Mechanical equipment has a longer life span, lower repair costs, and consumes less fuel. Better movement in the field, less drudgery. More stable yields, particularly in dry years because more nutrients and moisture are available to plants. Labor savings provide opportunities for diversification (livestock, high-value crops, agro-processing). Yields are maintained or increased even as inputs decrease. Increased profits, in some cases from the beginning, in all cases after a few years as efficiency of the production system increases.	More constant water flow in rivers/streams, improved recharge of the water table with reemergence of dried up wells and water sources. Cleaner water because pollution, erosion and sedimentation of water bodies are reduced. Less flooding because infiltration increases; less damage from droughts and storms. Improved sustainability of production systems and enhanced food security. Increased environmental awareness and better stewardship of natural resources. Lower cost of municipal and urban water treatment. Reduced maintenance costs of rural roads. Increased associative activities. Improved rural livelihood and quality of life.	Improved carbon balance through reduced carbon emissions, lower fuel and energy consumption, and increased carbon sequestration in soil organic matter and biomass. Improved protection for biodiversity at the microflora and fauna levels (bird nests in NT fields, fish in streams and ponds, etc.). Stocks improve. Improved hydrological cycle at river basin and continental levels. Reduced risks of soil erosion and enhanced soil build-up improve efforts to combat desertification and land degradation. Recharging of aquifers through the capture and infiltration of rainfall. Recognition of the role of rural dwellers and farming activities in providing key environmental services to the society at large.

Table 2. Direct benefits — comparison of no-till with conventional tillage in Brazil

Farm type and crop	*Yield (kg/ha)*		*Yield increase (percent)*	*Decrease in hours/ha/year (percent)*		
	Conventional	*NT*		*Labor*	*Equipment use*	*Fuel consumption*
Mechanized						
Soya	2440	3100	27	-10	-27	-27
Maize	4500	5840	29.8	-51	-19	-19
Animal traction						
Maize	4000	4800	20	-55	-66	—
Bean	1460	2000	37	-59	-46	—

Source: World Bank, 1998a, 1998b

Denardin (1998) documented similar results in a comprehensive analysis of the socioeconomic impact of the adoption of NT systems in wheat and soya cropping systems in Rio Grande do Sul, Brazil. Reductions were substantial — 31 percent for labor, 41 percent for equipment use, 44 percent for fuel consumption, and 90 percent for soil erosion. As a consequence, over 3-5 years, and sometimes as early as the second year, the adoption of NT systems substantially increased net farm income. Based on a sample of 477 farms in Paraná, Bragagnolo et al. (1997) found that net farm income increased by 59 percent from its initial value five years after the beginning of the project. Subsequent improvements in rural livelihood were reflected by several indicators such as purchases for home improvements, an 8 percent increase in spending for electrical appliances, 10 percent more spent on farming equipment, and larger livestock and poultry numbers.[26]

Large mechanized farms in the Cerrado region of Brazil demonstrate that net farm income can even double in a few years (Séguy et al., 2001a). Similarly, small farms in Paraguay with a manual labor force and/or animal traction significantly increased their farm income as a result of adopting NT systems (Sorrenson et al., 1998) (Table 3).

Table 3. Comparison between conventional tillage and no till on a 12.1-ha farm in Paraguay

Parameter	*Conventional*	*NT*	*Difference (percent)*
Labor (person-day/farm/y)	237	209	- 12
Net farm income (US$/y)	1946	3454	+ 77
Return to labor (US$/day)	8.2	16.5	+ 108

Source: Sorrenson et al., 1998

The study also showed that net farm income and returns to labor increased significantly only two years after the introduction of NT systems, particularly on the small 5-ha farms. It should be noted that in this analysis, (i) the same inputs and product prices were used to evaluate the situation before and after NT introduction; (ii) full costs of growing cover crops were included; and (iii) farmers received free technical assistance.

In addition, saving labor creates opportunities to diversify activities, including higher-value crops or livestock, which pro-vides farmers with complemen-tary income sources. Subsistence farmers have an opportunity to become familiar with marketing strategies.[27]

Environmental and social benefits

Decreases in soil erosion and water losses through run-off are spectacular and are reported by many authors (Derpsch et al., 1991; Crovetto, 1992; CTIC, 1997; Saturnino and Landers, 1997). Table 4 compares soil and water losses under a soya/oats cropping system and different tillage practices on a 6 percent slope land in Campinas, Sao Paulo, Brazil.

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26. In Santa Catarina state, Brazil Land Management II Project, net farm benefits from the main crops which before project implementation varied from $250 to $14,850 increased to a range of $850 to $17,250 (all figures are U.S. dollars). On average, the net farm income of NT adopters increased by 59 percent over the 5-year period.

27. For example, after the second year of NT, tobacco was reintroduced on small Paraguayan farms. This profitable crop demands a higher level of soil fertility. Previously, tobacco was only 'viable' for one or two years after clearing a forest (Sorrenson et al., 1998). In Paraná, NT adopters on average have more livestock than non-adopters — 7 head of cattle compared to an average of 5; and 6.3 pigs compared to 3.6.

More detailed information is available, including data gathered in the World Bank ICR of the Land Management Projects in Paraná, Santa Catarina, and complementary studies (Bassi, 1999).[28] The studies demonstrate the impact of NT systems on reducing soil erosion; improving water infiltration and quality; and reducing water treatment costs. As a result, rural infrastructure is better protected. For example, the total amount of savings in rural road maintenance in the project area of Santa Catarina state from 1992 to 1999 was estimated at about $900,000.

Table 4. Effect of tillage practices on soil and water loss

Tillage equipment	*Soil loss (t/ha/y)*	*Water loss (mm/y)*
No till	*1.1*	*13.1*
Chisel plow	3.4	35.7
Disc plow	7.7	93.0
Heavy disc	9.0	109.5

Source: Castro et al., 1993

Another indirect environmental benefit generated by NT systems is decreased CO_2 emissions and higher carbon sequestration above and below the ground surface (Séguy et al., 2001). The decrease in CO_2 emissions is a direct consequence of improved crop residue management — not burning residues and not incorporating them into the soil. Also, NT farming practices decrease CO_2 emissions up to 80 percent compared to plowing the soil, a practice that stimulates the oxidation of soil organic matter (Table 5).

In addition, a significant decrease in CO_2 emissions is expected from fuel and energy consumption that is reduced by up to 70 percent by using NT farming practices.[29]

Table 5. CO_2 emissions over 19 days following different tillage methods

Tillage method	*Cumulative CO_2 lost (t/ha)*
Moldboard plow	*9.13*
Disk harrow	3.88
Chisel plow	3.65
No till	1.84

Source: Reicosky, 1998; Reicosky and Lindstrom, 1993

Carbon sequestration has been debated among experts as an opportunity to mitigate climate change (Watson et al., 1996), and now after several years of discussion, the parties to the international negotiations on climate change have agreed (Marrakech, Oct. 2001) on the list of land uses that are eligible in the Kyoto Protocol,[30] including improved agricultural practices. However, current data show a significant contribution from improved soil management, which leads to mitigation of the greenhouse effect (Lal et al., 1998). The range of the net carbon sequestration rate has been estimated from 0.2 t/ha/y to more than 1 t/ha/y, depending on climatic conditions, soil characteristics, and quality and quantity of the plant cover (Séguy et al., 2001b), including agroforestry systems (de Jong, 2000). Under an NT system as practiced in southern Brazil, the carbon sequestration rate for the top 40 cm layer of soil was 1 t/ha/y over a 22-year period (Sá et al., 2000). This potential for carbon sequestration attracts investors and companies such as Syngenta, Peugeot, and GEMCO, which are willing to compensate for their own emissions of greenhouse gases through application of the clean development mechanism of the Kyoto Protocol.

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28. Microwatershed Lajeado Sao Jose, Chapeco, Santa Catarina. The total surface area was 7,744 ha, average slope was 12.3 percent, annual rainfall was 2,039 mm (1969-1998), 38 percent of the farms were smaller than 10 ha, and 90 percent were smaller than 50 ha. A detailed environmental impact survey showed the effects of NT systems over a 9-year period (1988-1997): (i) increased water infiltration into the soil; (ii) decreased soil erosion and water turbidity from an average monthly value of 400 mg/l in 1988 to 112 mg/l in 1997; and (iii) improved water quality, with a subsequent decrease in potable water treatment costs due to lower consumption of the flocculating agent (28 g/m^3 of aluminum sulfate used in 1991, and only 15 g/m^3 used in 1996 (reported by Santa Catarina Water and Sanitation Company).

29. Fuel consumption decreased 70 percent (CTIC, 1997) and (Gentil, 1993) in USA and Brazil; 66 percent in Brazil (Derpsch et al., 1991); and 36 percent in Paraguay (Sorrenson, 1998).

30. Specifically, in addition to afforestation, reforestation, and deforestation (eligible activities under Article 3.3 of the Kyoto Protocol), revegetation, forest management, cropland management, and grazing land management become eligible activities (under Article 3.4), including improved agricultural practices, land degradation prevention, and watershed management.

The shift to NT farming cannot occur without changes in socioeconomic and institutional conditions. Farmer groups in southern Brazil developed to address rural landscape issues from the perspectives of both micro-watersheds and individual owners.[31] These groups focused on land management and encouraged the participation of other interested parties such as municipal authorities, road maintenance crews, and technical specialists. This also motivated group discussions and participatory actions, which in turn led to joint activities such as building water supply structures, establishing toxic waste deposits and liquid manure tanks, as well as reforestation of riparian areas. These actions contributed to the creation of new job opportunities in the service sector and agricultural machinery industry.

Farmer assessment of no-till farming

In a survey of small-scale farmers in Rio Grande do Sul, Brazil, Melo, (1997) documented the reasons for adoption of NT farming (Table 6).

Table 6. Reasons to adopt no-till farming

Reasons for adoption	*Farmer approval (%)*
Higher yields	*35*
Higher income	55
Erosion control	75
Time saving	90
Labor saving	100

Small farmers in Paraguay gave similar reasons for adoption (Sorrenson et al., 1998). For example, on one 8.5-ha farm three years after adoption, benefits from NT farming (using *Mucuna* as a cover crop) managed with animal traction and no purchased fertilizers and herbicides included:

- vastly reduced erosion;
- soil fertility rejuvenated;
- time and labor saved because there was no need for soil preparation;
- less time spent on weeding because *Mucuna* reduced the incidence of weeds;
- reduced work load, giving more time for other activities;
- increased income, with reduced reliance on cotton for income; and
- the farming system was sustainable.

Another farmer who managed a 9.2-ha farm with animal traction adopted NT farming some 6 years before an interview. He used five different cover crops, applied herbicides, but no fertilizer (Box 5).

Summary

In conclusion, farmers from Brazil and Paraguay, as well as in other countries mostly in Latin America, provide reliable evidence about the benefits of NT farming systems. They have the potential to provide profitable and environmentally sustainable approaches to meet the challenge of food security and help to alleviate rural poverty in resource-deprived tropical and sub-tropical environments.

An attractive aspect of NT is its potential to save labor, which would be of particular benefit in rural areas affected by HIV/AIDS. This disease is rapidly diminishing the able-bodied work force and creating labor shortages in rural areas.[32] Production systems that reduce the time and intensity of labor, particularly for

31. For example, from 2 in 1990 to 27 in 1997 in Lajeado San Jose watershed.

32. Time available for farming operations is further reduced because family members not affected by HIV/AIDS spend an increasing amount of time caring for their afflicted relatives.

women (e.g., at planting, weeding, and harvesting stages), could help to mitigate the devastating effects of the disease.

A summary of the SLM approach, including NT is presented in Figure 2. Indeed, NT systems are complex, and the conditions of their adaptability and transferability to other farming systems must be defined more comprehensively.

Box 5. Benefits and problems of no-till farming as observed by one Paraguayan farmer

Benefits

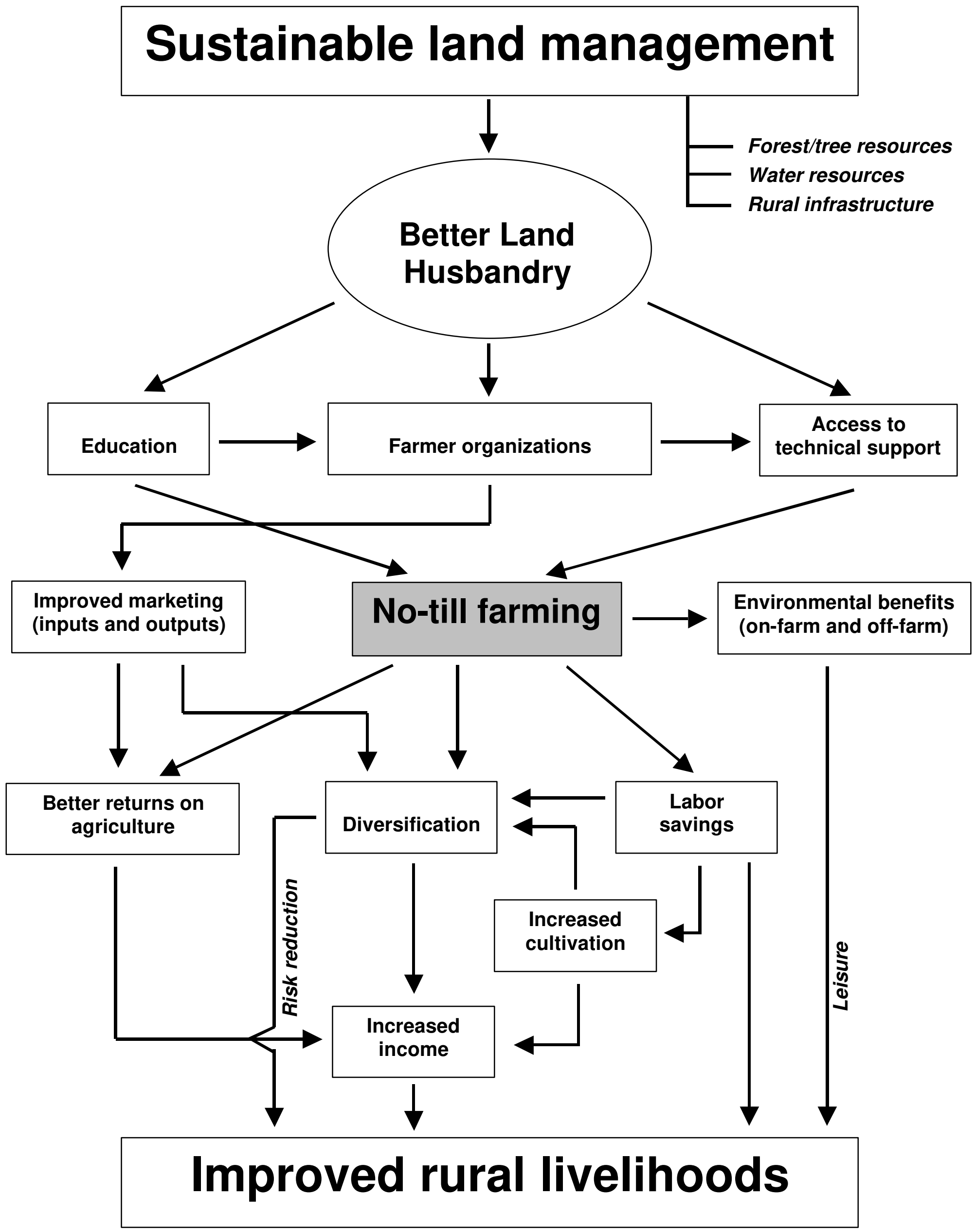
- Increased income and profit
- Reduced work load, more time available for fish production, home vegetable garden, better care of animals, community activities
- Soil is protected from erosion
- No need to hire a tractor anymore, only in rare occasions need to hire work oxen
- Increased soil productivity; crop yields increased and are more stable
- Now produces his own cover crop seeds and sells surplus (extra income)
- Cover crops have reduced the incidence of weeds; less time devoted to weeding
- Increased crop diversity/rotations have increased income and reduced incidence of insect pests and diseases
- Reduced reliance on soybean and cotton for income
- Sustainable production system reduces concerns about drought and heavy rains
- Investment in more permanent crop, including agroforestry trees, fish tanks, bee production
- Better standard of living (purchased motor cycle, electric water pump, refrigerator, and TV)

Problems

- Shortage of information on NT
- More complex system, technical assistance is required
- Long-term (5 year) credit is needed (but risky short-term credit is no longer necessary)
- Requires access to cover crop seeds
- Extra cost for herbicides
- Neighbors find the farm untidy; some have intentionally burned his crop residues

Source: Sorrenson et al., 2001

Figure 2. Impact of sustainable land management on rural livelihoods



Source: Adapted from Evers et al., 2001

Potential for Adoption of No-Till Agricultural Systems

To induce changes in farming practices is difficult, particularly because the current practices of a given farming system have evolved over many generations. This section discusses lessons learned, overcoming prejudices, and factors influencing the adoption of NT systems, particularly in tropical environments.

Lessons learned from Latin America (primarily Brazil)

There has been a rapid shift to NT farming in Latin America. From 1987 to 1997, NT practices experienced a 20-fold increase, while the increase in the USA was only 4.6-fold during the same period.[33] Until the early 1970s, Brazilian farmers did not use NT, but by 2000, 14 million ha were planted using NT farming. This significant turnaround provides a rich store of information (mostly in a tropical setting) on how this change from conventional tillage occurred.

Slow initial change. Change from conventional tillage to NT was initially slow. This change was much more than a simple switch from one technical package to another. Over a period of 25 years, the adoption of NT became the backbone of an integrated approach to sustainable rural development, including a collaborative effort on social mobilization, education and training, marketing and diversification, and environmental education. The adoption process also incorporated vital short-term improvements for the livelihoods of agricultural producers.

Driving forces. The two main driving forces behind the development and adoption of NT in Brazil were (i) the precarious situation of farmers associated mainly with acute and highly visible land degradation issues (Photo 8); and (ii) a handful of farmers who realized that radical changes in their farming systems were required to reverse the degradation trend and restore and secure their livelihoods. Through dialogue with technical specialists and private companies, these innovative farmers became aware of alternative technologies that could allow them to overcome high rainfall runoff and erosion on their tilled fields, while at the same time improving their income. At this point, however, the technologies were neither readily available nor validated.

Strategy. Finally, a complete NT development strategy (Box 6) created the conditions for expansion of the experience gained by the first agents of change (farmers, technical specialists, private input sector, and extension agents) through a network of diversified producer organizations established at local, communal, state, and federal levels. This network has now been established at the international level.[34]

The development of appropriate rural policies and support steadily became an important factor in the successful expansion of NT farming in Brazil. This included governmental and public institution support (research and education) in the 1980s, and from the early 1990s, financial

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33. However, in the USA, only 44 percent is truly no-till (Derpsch, 2000). The term used is 'conservation tillage', and includes other forms of reduced tillage such as minimum tillage and strip tillage. Commonly, conservation tillage practices in the USA are not combined with the use of cover crops and rotation of more than two cash crops, thus the full agroecological benefits of NT farming systems are not being realized.

34. The American Confederation of Sustainable Agriculture Associations was created in 1992 under the chairmanship of Mr. Victor Trucco, a pioneer of NT in Argentina. Mr. M. Pereira is the current president.

support from international funding agencies (e.g., Land Management I Project, Paraná, 1989-1997, financed by the World Bank). During that time, technologies were being adapted to local conditions, equipment tested and manufactured, and effects measured and validated. Lessons learned from projects that focused on land management issues have been essential for institutional development and use of financial instruments, particularly at the micro-watershed level. While subsidies were not provided to medium and large farms,[35] they were targeted to small- scale

Photo 8. Plowing and disking have led to soil compaction and erosion on large mechanized farms in the Cerrados (Goiás, Brazil)

35. The lack of commodity subsidies likely contributed to NT adoption by Brazilian farmers because they were looking for the most cost-effective alternative that was sustainable.

Box 6. No-till development support strategy — lessons learned from Brazil

The success of NT cannot be attributed to technical parameters alone. In conjunction with technical innovation, an effective participatory approach to adaptive research and technology transfer was adopted, which tied farmers to a development strategy suited to their specific requirements. Institutional support was demand-driven and concentrated on training and education that equipped participating farmers with the skills to adapt and refine NT on their own farms. The cornerstones of the development support strategy were:

- close collaboration among researchers, extensionists, the private sector, and farmers for the development, adoption, and improvement of NT systems;
- on-farm trials and participatory technology development (PTD);
- strengthening farmer organizations, creation of local Friends of the Land Clubs (FLCs), where farmers exchange information and experience, improve their access to extension or private technical assistance and other advisory services, as well as input and output marketing;
- close cooperation with existing and new cooperatives, concentrating primarily on marketing and training for diversification into livestock and vertical integration through processing;
- aggressive dissemination strategy of technical, economic, and environmental information through the media, written documents, meetings, and conferences, controlled and managed by producer organizations (FLCs) with emphasis on farmer-to-farmer exchange of experience;
- the national NT farmer organization FEBRAPDP, the tropical region's APDC, and the Rio Grande do Sul state Federation of FLCs played a significant role in advocating and supporting promotion of NT on large and small farms. No-till systems are complex to manage and require efficient farm management. An integral aspect of support to small farmers has been training in recordkeeping and a holistic understanding of farming system dynamics that considers, manages, and optimizes all links among the different components such as the use of biomass produced on the farm for fodder and soil cover;
- private-public partnerships, agro-input companies (Zeneca, Monsanto) supported demonstration projects on large and small farms through provision of inputs and extension services;
- targeted subsidies, short-term subsidies played a significant part in supporting small farmer adoption of no-till practices. In Paraná, Santa Catarina, and Rio Grade do Sul states, much of the hand-held or animal-drawn equipment was acquired with financial support from the State under development programs (mainly World Bank). Subsidized or free equipment is still made available to groups of farmers. Apart from economic constraints to adoption, the rationale for public subsidies has been the generation of off-site benefits from no-till adoption. In some instances, private companies provided equipment for small farmers;
- integration of crop and livestock, special attention has been paid to the incorporation of crop and livestock in NT systems, including integration of poultry, hog, and fish farming. A particular challenge is the development of rotational grazing patterns on cover crops that do not jeopardize the sustainability of NT systems; and
- incorporation of environmental considerations, correcting watershed degradation was a key reason for the adoption of NT farming practices. Raising environmental awareness among farmers led to central facilities for the disposal of pesticide containers, improved household sanitation, and replanting of gallery forests.

Source: Evers and Agostini., 2001

farmers and the rural poor, who from the mid-1990s have increasingly adopted manual and animal-drawn NT systems (about 500,000 ha in 2001). The lessons learned from projects supported by World Bank funding in southern Brazil include:[36]

- Successful investment in SLM must be based on changes in land use and land management that bring early benefits to farmers, e.g., labor savings and income.
- Farmers should be convinced that their land management practices are deficient and that viable technical alternatives exist.
- Farmer organizations such as Friends of the Land Clubs are essential to play a leading agent-of-change role (Box 7).
- When there are significant public good benefits, cost sharing may be justifiable to help resource-poor farmers adopt new land management practices. For example, Soil Conservation Funds, acting as a demand-driven incentive for change, proved to be a major instrument to implement changes.
- Public sector assistance is best where the planning unit is the micro-catchment because it ensures good cooperation among farmers who farm on any scale.
- Private sector assistance is essential in the form of machinery development, use of appropriate chemicals, and sponsorship of farmer organizations and activities.
- Participatory training, re-training, and shared learning are critical to 'adjust' the mindset of public- and private-sector support staff. Dynamic, well-trained extension agents are key to successful project implementation.

Box 7. Salient functions of Friends of the Land Clubs

Friends of the Land Clubs can function to:

- identify institutions or opportunities to learn and build capacity for NT farming practices (producers, front-line agents from agricultural services, decisionmakers);
- identify specialized technical capacity needs and opportunities in order to build an expanded group of knowledgeable NT practitioners;
- promote public-private cooperation on NT systems development;
- explore market opportunities, diversification opportunities, and market niches for 'sustainable agriculture' products and potential buyers;
- document effects of NT experience within the country and outside;
- promote NT results through available channels of communication; and network among NT groups, nationally and internationally.

- Adaptive research is essential to develop appropriate technological solutions to problems identified by farming communities at the micro-watershed level (for example, adaptation of NT machinery to the needs of smallholders and seed production for essential cover crops).
- Adequate socioeconomic and environmental monitoring activities that demonstrate external benefits can be used to encourage public incentives.

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36. Adapted from the implementation completion reports for the Santa Catarina and Paraná Land Management Projects (World Bank, 1998a, 1998b).

- Sustained political support at the regional and national levels and active participation by local authorities are important to successful NT development.

It is sometimes argued that the success of the Brazilian experience resulted from a factors that may not be commonly found elsewhere. Although Brazil is an important source of lessons learned, it is unlikely that this entire experience could be replicated.[37] However, most of these 'favorable factors' are not specific to Brazil and some are either misleading or erroneous.[38] Other countries such as Argentina and Paraguay have been adopting NT at an even quicker pace. Nonetheless, to assess the transfer potential of the Brazilian NT experience, it is important to separate common prejudices from genuine constraints, as well as opportunities to adapt this alternative land management strategy to other circumstances and conditions, particularly in Africa and Asia.

Overcoming prejudices

The most common prejudices against NT farming are discussed below. Generally, crtics argue that NT farming systems development is: (i) limited to deep soils and high rainfall conditions; (ii) suitable only to large mechanized farms; and (iii) results in increased herbicide use with adverse environmental effects.

Deep soil and high rainfall conditions

Based on current knowledge, NT farming practices can be adapted to a wide range of soils, deep or shallow, rich in clay or sand, under semi-arid or humid tropical or temperate climatic conditions. Under lowland tropical conditions, NT is better adapted in areas with an annual rainfall of about 800 mm, with less than a 5-month dry season. Under tropical highland and temperate conditions, lower rainfall may also be suitable. No-till farming is also suited to irrigated production systems (e.g., the wheat and rice systems in South Asia). The underlying principles of BLH remain valid under drier environments and adaptation of the NT components (particularly cover crops) to these conditions remain part of future research and development challenges.

Farm size and type

No-till farming systems have been implemented on medium and large mechanized farms in Brazil and in other countries such as Argentina, USA, and Canada. However, in the early 1990s, NT systems began to be developed on small farms in southern Brazil and Paraguay. Less than 10 years later, more than 120,000 farmers are using NT farming practices on about 500,000 ha. This development has been supported by public investment, mostly in research and technical assistance, which has allowed the NT farming approach to be adapted to manual and/or animal

37. Assertions about what made the Brazilian experience unique include: (i) devastating soil erosion convinced Brazilian farmers that change was inevitable; (ii) 'European tradition' of rural community actions; (iii) political support and commitment; (iv) higher level of farmer education; (v) favorable market forces and prices; (vi) well-structured communities and rural institutions; (vii) desirable physical conditions; and (viii) protection of huge Itaipu dam investment.

38. For example, Brazilian farmers practice NT farming on shallow and sandy soils and on steep slopes and lithic and gravelly soils (small farms in Rio Grande do Sul and Santa Catarina). Market prices have not been favorable and political support in Brazil came late. Pioneers of NT acknowledge that these improved farming systems were developed 'in spite' of the prevailing rural policy in the 1970s and the early 1980s.

traction farming conditions. Providing 'starter' credit to resource-poor farmers was also an important contributing factor. Close partnerships with private entrepreneurs made NT equipment for small farms available in local market places. Family farms with fewer than 10 ha on hilly areas and gravelly soils have successfully adopted NT farming practices in Brazil and Paraguay. These small-scale pioneers have set the stage for many other producers in both countries who are following their example.

Herbicide use and impact on the environment

Some critics argue that adoption of NT farming increases consumption of agrochemicals, whether herbicides or pesticides, and that NT systems would be 'herbicide-driven' with long-term, negative effects on soil, water, and air quality. The full adoption of NT practices (in particular cover crops, crop rotations, and integrated weed management) over a 2-5 year period reduces weed pressure, which especially in sub-tropical regions can be managed through mechanical and hand weeding. Practitioners generally claim that following the transition phase to NT farming, they use less herbicides (and other pesticides) than under conventional tillage systems. This concern is, therefore, a non-issue on NT farms where weed control is done through alternative technologies that reduce or even avoid the use of herbicides. Practitioners generally claim that following the transition phase to NT farming, they use less herbicides (and other pesticides) than under conventional tillage systems.[39] Successful NT users find that with improved skill and knowledge, in 3-5 years the need for and cost of herbicide applications generally decreases by up to 30 percent because of better weed control in comparison with conventional tillage (CTIC, 1997; Sorrenson et al., 1998).

The direct and long-term impact of herbicide use on soil biology and water quality remains a contentious issue. Although there is need for more extended and long-term studies on the impacts of NT on the environment, there is a growing consensus among the scientific community that NT practices are a better friend to the environment than conventional practices, for the following reasons:

Application timing. One factor that plays a significant role in water contamination is the use of soil-incorporated (pre-emergence) versus direct-contact (post-emergence) herbicides. Pre-emergence herbicides commonly used by conventional tillers need to have high solubility and relatively long half-lives, while post-emergence herbicides, sprayed directly on weeds are becoming the major choice for NT. The latter are generally less mobile, hence less likely to contaminate water, and less persistent in the soil. More soluble herbicides such as the non-selective systemic glyphosate are strongly adsorbed to the soil and rapidly degrade to relatively harmless products. This is enhanced under NT because there is more plant residue, organic matter, and microbial activity in the soil (Moldenhauer et al., 1995), and surface run-off and soil erosion are lower.

Biological activity in the soil. Soil microbiologists report that even if distribution among fauna categories is affected by herbicides, overall microbial activity in the soil may not necessarily be affected. Cultivation practices, either mechanical or chemical, affect microbial activity that needs to be assessed at a broad level (including bacteria, fungi, protozoa, nematodes, arthropods, and

39. Experience has shown that excessive reliance on herbicides in NT systems was generally caused by poor crop rotation (including monocropping) and lack of cover crops.

earthworms). No-till systems benefit soil fauna and microbial activity,[40] reflected in higher numbers of earthworms and most insect groups (Rombke and Forster, 1997; Boyer et al., 2001). These practices create a more undisturbed rhizosphere environment, which is highly favorable to symbionts such as *rhizobium* and or *mycorrhizal* fungi, and hence improve plant nutrition (particularly nitrogen and phosphorus) and lower fertilizer needs (Jackson et al., 1993).[41]

Biological pest control. Finally, farmer experience shows that NT farming practices aid biological pest control, and an increasing number of small- and medium-scale NT farmers are introducing aspects of biological farming to their NT systems, learning from organic farmers where a market for such organic products exists.

Despite unfounded claims that NT systems are more polluting than conventional systems and prone to herbicide overuse, NT practitioners must be aware of potential risks from improper use of herbicides and insecticides. New generations of more effective, cheaper herbicides regularly appear on the market and are likely to further reduce herbicide requirements under NT systems,[42] and NT farmers appear pro-active and keen to use new technologies (Derpsch, 2000). There is also evidence that NT farmers are quicker adopters of Integrated Pest Management (IPM) because they use rotations for both cash and cover crops.

Adaptability and transferability of no-till

Prospects to successfully implement the NT approach are influenced by several factors, particularly in tropical regions. Box 8 outlines the main factors that enhance or limit the adoption of NT farming practices in Sub-Saharan Africa.

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40. For example, Alvarez et al. (quoted in Clapperton, 1999) demonstrated a 300 percent increase of microbial biomass in the Argentinean NT soils.

41. On the C. Crovetto farm, Chile, where NT was introduced in 1978, a thorough monitoring of microbiological and macro fauna activity over 9 months (October 1991-August 1992 wheat crop) showed that NT fields have a much higher level of soil biological activity, and much better level of soil fertility (organic matter, phosphorus, nitrogen, potassium) compared to conventional tillage fields (wheat) that have received the same rate of fertilization (Crovetto, 1992).

42. These are highly specific to targeted species, and can be sprayed at very low application rates (below 100 g/ha of active ingredient sprayed with less than 100 l/ha).

Box 8. Enhancing and limiting factors that affect adoption of no-till systems

Enhancing factors

Institutional

- Farmers, technicians, and decisionmakers who believe in NT
- Willingness of governments to decentralize and empower rural communities and producer organizations
- Specific support programs for NT
- Legal framework and policies that facilitate budget allocations and support services required for changes in behavior, especially in land rental, grazing rights, and bush fire control
- Strong existing producer organizations or local rural development and/or catchment committees
- NT integrated in educational curricula at all levels
- Effective extension and research services with active on-farm, participatory methodology
- Willingness of countries to comply with international commitments such as Convention to Combat Desertification/Land Degradation

Socioeconomic

- Applicable NT technology exists
- High level of land security
- Field testing and/or adaptive research on machinery and cover crops or other aspects (if extrapolated from different agronomic or socioeconomic conditions) that leads to field-tested new technology which shows potential to increase net farm income or reduce farm labor demands per unit of product, as well as positive environmental effects
- Growing cash crops for available markets
- Shortage of labor or high wages
- Easy access to cover crop seeds, specialized NT machinery, and desiccant herbicides

Agroecological

- Precipitation over 800 mm/year, and/or at least 5 months of adequate rainfall leading to long or bi-modal growing season
- Soils not easily compacted
- Locally-tested cover crops

Limiting factors

Institutional

- Inflexible, top-down extension and research institutions with little user participation or control, low on-farm activity and/or poorly-trained personnel
- Lack of government authority or producer organizations (leading to increased role of traditional structures or addressed by institutional capacity building)
- Lack of prior history of producers cooperating with each other
- Lack of drive by POs to strengthen participatory approaches, marketing, bargaining power, bringing stakeholders together, networking, and lobbying
- Little support for SLM as a question of national security and survival of rural producers
- Entrenched resistance to change of public support services

Socioeconomic

- Strong demand for crop residues as animal feed
- Uncertain land use rights
- Lack of access to markets or credit
- Market preference for one crop mitigating against crop rotation
- Lack of funding for on-farm and related backup research
- No or little training in NT for technicians and rural producers
- Lack of stimuli for agribusiness growth in rural areas
- No motivation for farmers to take responsibility as equal stakeholders for NT
- No or limited availability of needed inputs, specialized tools, and machinery.

Agroecological

- Constraints on available producer resources
- Low precipitation, low biomass production
- Soils pre-disposed to compaction (e.g., silty sands)
- Short growing season (less than 5 months)
- Soils subject to waterlogging
- Monocropping with a low residue-generating crops
- · Burning crop residues or termites eating them
- · Snakes (and other dangers such as scorpions); possible use of trap or repellent crops

Source: adapted from Steiner, 1998

Institutional and policy constraints

Institutional inertia and resistance to change need to be overcome to provide the appropriate environment for adoption of NT farming. Generally, research, education, and development institutions have tended to disconnect tillage and mechanization from soil/land and crop management. This led staff to work in isolation, and became a disincentive to adequately integrate tillage and mechanization issues in a farming systems context. Moreover the effects of continuous tillage on farm productivity were seldom established, as if tilling the soil was a not an issue. Therefore, government and donor efforts to develop mechanization in developing countries have typically imported disc plows and harrows. Initial NT developments can be constrained by contradictory policy and development priorities when tilling implements continue to be promoted and possibly subsidized.

In Brazil, the resistance of research, academic, and extension staff to change was much greater than that of farmers. In the Brazilian Cerrados (in the 1980s), the following reasons were observed by Landers (1999):

- rejection of farmer-based experience (practice not proven experimentally);
- resistance to cost and effort of change;
- most research was on-station, and research generally not systems oriented;
- researchers not in close contact with farmers;
- rewards to researchers depended on publications not farmer impact;
- little or no farmer control over research priorities; and
- misconception that NT was only for large farms.

In terms of marginal satisfaction, adopting farmers saw immediate benefits over and above the cost of change, while scientific and technical agents saw a positive cost in the effort of change and no foreseeable economic benefits accruing to this extra effort. In Brazil, it has been notable that farmers on fertile soils (with higher gross margins from lower fertilizer costs) have been the slowest to adopt NT. Thus, needs of the farmer-client should be fully recognized.

Not all stakeholders[43] will react positively to the NT approach, and some will have their own agenda that may be at odds with what is good for the community as a whole. Alternative agendas may include political, financial, commercial, employment, landholding, religious, and tribal considerations.[44] For example, local hierarchies may feel threatened by bottom-up and demand-led principles and must be accommodated in the process (Chuma et al., 1998). Emphasis should be on the interactive and participative role of stakeholders[45] to raise awareness and create partnerships and willingness to change.

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43. The main stakeholders in NT farming practices include producers, (farmers, herders, hunters, fishermen), land owners, administration (local, governmental organizations), extension agencies, international research agencies, national research institutions, and the private sector (e.g., agribusiness, marketing organizations, etc.), civil society and NGOs, media, and donor/lending agencies (international, regional and bilateral).

44. It should not be denied that although in theory poverty alleviation and sustainable land use are generally compatible, some situations may require difficult tradeoffs by decisionmakers between short-term actions (shoot the wild animal, cut down the forest, and plant maize) and long-term solutions (conserve the ecosystem and empower local communities).

45. Decisions by *both* men and women farmers about adopting or rejecting 'improved' crop and pasture management practices are absolutely critical, as well as their perceptions of what is or isn't 'sound' land management (e.g., simple criteria such as 'it saves labor' or 'it does not pay').

Access to land

One key condition for successful NT development is secure land tenure, including water rights. This can take several forms — individual ownership, long-term land-use contracts with extension rights, and community control. When property rights are lacking or insecure, farmers lack the incentive to invest in sustainable land resource management practices, including NT. The resulting land degradation and soil loss threatens the livelihoods of millions of people as well as future food security, with implications for water resources and the conservation of biodiversity. To demonstrate the importance of land control at the local level, two ongoing projects of the World Bank can be cited —the Loess Plateau Watershed Rehabilitation project in central China, and the Gestion Des Terroirs approach applied in Burkina Faso (Box 9).

Box 9. Examples of land control by local communities

Loess Plateau Watershed Rehabilitation project in central China

The objective of this project was to increase agricultural productivity and income for more than 1 million poor rural people in nine watersheds of the Yellow River. It began in 1994. Reducing sediment flow and erosion, as well as more productive use of seasonable rainfall, were also project objectives. Prior to the project, land was managed by the government. A key feature of the project was to establish long-term leases (50 years) for family units, with the right of continuance. By the end of 2000, grain output was up by one-third, fruit production increased three-fold, and per capita income more than doubled. Reasons for success specified by stakeholders included, among others: (i) a participatory approach; (ii) rapid increases in productivity and income; and (iii) secure land tenure. The benefits of improved productivity and income accrued to family units and not the government. Previous attempts at economic development in the Loess Plateau were not successful because land was controlled by the state.

Project Gestion Des Terroirs, Burkina Faso

At the beginning of the project (1990), it was obvious to project managers and country officials that top-down management control of natural resources by the government was not working. Forests were fast disappearing for fuel wood and overgrazing by roaming herds was destroying annual plant life. The result was severe loss of topsoil and barren landscapes. Project objectives focused on ways to hand control of natural resources to local villages. Working with village leaders, foresters, herders, and farmers (both men and women), teams of community and technical specialists helped the villages to develop land-use maps for the various stakeholders. The Gestion Des Terroirs approach will eventually include 2,500 villages. The key is to empower each village with the right to plan and manage their own land and water resources. The villages identify ways to better capture and use their limited water resources, reduce conflicts with roaming herds, establish tree nurseries for reforestation, etc. This example shows that land tenure arrangements do not need to be at the individual farmer or family level to be successful. Success may partially depend on traditions and culture.

Socioeconomic constraints

There are a number of socioeconomic constraints that need to be addressed, particularly in Africa and Asia, for NT to be adopted. These issues call for a major effort on rural education, acknowledging the key importance of BLH and NT education programs designed for women, and strengthening farmer organizations (Maguire, 2001). They also include economic aspects related to funding the transition. The main socioeconomic constraints include:

- **Limited education** and literacy mean that farmers are less likely to participate in pro-active on-farm development in a partnership approach with researchers and extensionists, and to become on-farm researchers in their own right.
- In many rural societies, particularly in Africa, **women** are increasingly the main agricultural labor force and are even taking on plowing and other activities that were traditionally men's tasks. Because they already perform other time-consuming tasks such as weeding with a hoe — in addition to household tasks and wood and water collection — they would be the greatest beneficiaries of NT. However, despite their increased role, women often do not have an equal voice in decisions. The decisionmaking men might not value women's labor savings adequately and might place greater weight on potential risk factors associated with a transition to NT.
- Strong **farmer organizations** through which NT development strategies should be implemented are not very common and are often poorly organized.
- **Food habits and lack of market outlets** may hamper the transition to NT. Full crop rotation, such as switching 50 percent of the land in cereal to legumes (e.g., maize/bean, soybean/maize) is essential to a successful and sustainable shift to NT systems. This may be difficult to achieve if market opportunities for grain legumes are limited, which in turn may be related to food habits, poverty, and lack of agroprocessing industries and export outlets.
- The lack of **effective input/output marketing systems** (and infrastructure) can constrain NT development. Timely supply of inputs and equipment (and maintenance) and the sale of value-added production present significant challenges.
- **Funding** the shift to NT farming practices is very difficult for resource-poor farmers.[46] Many developing countries do not have fair lending policies for poor farmers, so some mechanism is required to make credit available at affordable levels. Experience gained in Brazil and Paraguay (Sorrenson, et al., 2002) shows that resource-poor farmers require a 5-7 year credit to finance capital costs when shifting to NT.[47] This change includes adoption of cover crops and crop rotations and assumes technical assistance is provided at no charge (Table 7).

Agroecological constraints

No-till agriculture is constrained in drought-prone areas, and particularly in the semi-arid tropics where annual rainfall is less than 800 mm, monomodal, and the dry season lasts more than 5 months. Large parts of Africa fall into these zones. While the principles of NT are also valid here, they may not be applied fully. The provision of a permanent ground cover is the main constraint. Biomass production is naturally limited because of low rainfall, and feeding livestock in the dry season competes with the principle of maintaining crop residues on the soil surface, while termites and bush fires can destroy most of this biomass. A range of technical options, summarized under the terms conservation tillage or conservation farming, have been developed in Africa (Biamah et al., 1999). The purpose of these techniques is increased water-use efficiency and reduced risk of crop failure due to drought. Examples are 'ripping' with animal draught power or

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46. On a 1999 study tour to Brazil, a group of poor hillside farmers (who were still using traditional tillage methods) were asked why they hadn't shifted to NT, knowing they would save labor and increase their net returns. They said that the main reason was a lack of available cash to purchase capital equipment, cover crop seeds, and inputs. When asked why they didn't use their land as collateral, they said they didn't trust financial institutions. In the past, small loans were used as excuses to expropriate farms. This situation clearly demonstrates the need for 4-5 years of credit at favorable rates because it takes that long to realize the full benefits of NT.

47. For a group of three farmers with technical options involving jab planter, animal-driven NT planters, and with or without motorized stationery threshers, capital costs were $770-2,933 per farmer depending on the option. The hand-planting option (two jab planters per farmer), valid for farms smaller than 10 ha, provides an opportunity for small-scale farmers to adopt NT.

tractors, or planting holes or basins, e.g. 'holey ground methods' in Zambia for manual cultivation, as well as 'zai' and 'demi-lune' systems in Niger and Burkina Faso

Table 7. Farmer investment costs in Paraguay to adopt no-till farming

Options	*Capital cost (US$)*
Machinery/equipment:	Unit cost
Jab planters	35
Two-row NT planter	3,500
200 -liter sprayer	1,500
Roller knife	600
Stationary motorized thresher	3,200
Cost per set of equipment if shared by three farmers	Cost per farmer
Jab planter without thresher	770
Jab planter with thresher	1,837
Animal-powered planter without thresher	1,867
Animal-powered planter with thresher	2,933

Source: Sorrenson (2001)

To rehabilitate degraded and compacted lands ('bad lands'), farmers dig a hole ('zai') of 30-40 cm diameter every 1 or 1.5 meter. The excavated earth is used both to create a small semi-circular ridge ('demi-lune' 10-12 cm high) around the hole to collect run-off water. The remaining friable excavated soil is mixed with cattle manure, and when available, rock phosphate, to create a favorable seed bed. In association with leguminous trees that provide nitrogen for crops and shade for small cattle, a degraded bare soil in a crop field is progressively rehabilitated.

Most tropical soils are suited to NT systems, but soils with poor drainage should be avoided, and gravelly and rocky soils will be suited only to NT manual systems (using manual planters). Acid soils with very low fertility might require initial correction of pH (liming) and nutrient deficiencies. Given adequate reaction time, there is no need to incorporate (plow in) liming products that can be broadcast on the soil surface to control aluminum toxicity and soil acidity within the soil profile.[48]

Soil compaction is a recognized issue that has been reported in NT fields under intensive mechanization (McGarry et al., 1998).[49] Although there are different views on this problem, under mechanized conditions soils rich in fine sands and silt are more prone to soil compaction than soils with a more balanced texture. Under NT systems, cover crops and crop rotations with different rooting characteristics are essential to prevent soil compaction.[50] A distinction must be made, however, between secondary compaction as a result of NT, and initial compaction (consolidation) that is increasingly reported under various conventional systems, including those using hand tools (Douglas et al., 1999). Where initial compaction prevails, technical options include the use of a chisel plow or sub-soiler for those farmers who have the finances and access to machinery. For a resource-poor farmer, a cover crop with a powerful root system such as *Crotalaria sp.* or pigeonpea can efficiently loosen the soil over a few years.

Maintenance of surface mulch can be a constraint, particularly in a tropical environment. Under warm humid conditions, the fast breakdown of plant residues and organic matter due to insect and soil biological conditions makes maintenance of permanent plant cover more difficult.[51] This constraint can be overcome —

48. For example, the combination of broadcast application of liming products and or phosphates and an adequate cover crop such as black oats or Crotalaria juncea will allow an efficient recycling of calcium and phosphorus through the root activity of these crops (Oliveira and Pavan, 1996).

49. See, for example, the recently launched environment strategy (World Bank, 2001)

50. Three NT pioneer farmers of southern Brazil reported that on their farms, ranging from 80 percent sand to about 80 percent clay, soil compaction was not an issue. They said that the best way to avoid compaction is an extensive cover crop and crop rotations, "so that root and biological activity as well as earthworms and insects loosen the soil" (Revista Plantio Direto, 1999).

51. Another biological constraint is rodents that graze and destroy leguminous cover or grain crops. Farmers use commercial or natural repellents such as Tephrosia, red or black pepper spray, and even human hair.

information is increasingly available about suitable cover crop(s) that have the capability to withstand the heavy rate of organic mineralization that prevails in the humid tropics, either as a sole crop or in association with other cover crops,.

In many parts of Africa and other continents, grazing rights, bush fires, roadside fires, or traditional burning in preparation for planting pose a major constraint to the maintenance of crop residues or soil cover, all of which lie outside the individual farmer's control. There are examples of overcoming uncontrolled fire, for example in Côte d'Ivoire with bush fire committees such as the Comité Cantonal de Lutte contre les Feux de Brousse de Yakasse-Feyasse.[52].

Finally, termites are a major challenge, and chemical control methods are costly for small-scale farmers. Initial observations show that improved soil fertility would significantly reduce termite infestation (e.g., in the Cerrado Region of Brazil), with recent work on trap or repellent crops such as *Tephrosia vogelii* in Uganda, Malawi, and Tanzania.

Livestock integration is a related issue, not only in terms of conflict resolution between herders and farmers, but as a farming systems option with potential conflict in the use of plant residues to meet the double goals of animal feeding and soil plant cover. No-till systems require that farmers control livestock access to crop land, whether through barbed wire fencing or live fencing with thorny shrubs (e.g., *Ziziphus mucronata, Haematoxylon brasileto, and Bauhinia rufescens*). In Africa, forestry tree species can provide animal feed alternatives to crop residues and cover crops, and agroforestry should be considered in development of NT farming systems. In Brazil, promising examples of livestock integration are documented,[53] demonstrating the capacity of mixed farming to increase both economic performance of NT systems and soil health (Lara Cabezas and Freitas, 2000).

Risks of imperfect adoption

In some instances, because conversion to NT is a slow learning process and full conversion takes several years, farmers have reverted to plowing to solve soil compaction caused by poor crop residue management or inadequate crop rotation. Other NT adopters do not fully adhere to the four key features of NT practices. At first, results

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52. What was the key? In the past, farmers had not planted trees on community land because it is a sign of ownership. This time, in cooperation with local chiefs and patriarchal landowners, farmers identified and acknowledged on paper the customary rights and agreements between owners and land users. With land tenure issues solved, farmers could plant protective shrubs, and their crops grew better. Similarly, they established an inter-village bush fire committee with commonly agreed rules, including a fine system and a voluntary enforcement brigade entirely controlled by rural communities. This proved to be extremely efficient and decreased the occurrence of bush fires in southeast Côte d'Ivoire by 95 percent.

53. For example, on one farm in Paraná, ryegrass was planted 25 years ago. Every year the pasture is desiccated (roller knife or herbicide) and maize is planted for about 120 days. The ryegrass is then allowed to recover for 60 days, after which cattle graze the ryegrass and crop residues for 120 days, and finally the ryegrass recovers 60 additional days before being desiccated, and then the cycle begins again. This system is reported to be profitable and has been sustained for 25 years.

might be encouraging even in imperfect systems, but incomplete adoption may not be sustainable and can lead to soil compaction and increased weeds, insect pests, and diseases in the medium and long-term.

A Road Map from Conventional to No-Till Farming

In countries where no-till systems have not yet been developed, the first step toward NT adoption would be to sensitize stakeholders to land issues and NT opportunities so as to create awareness and willingness to change. Thereafter, activities would initiate the change process, primarily to identify pathways of change, pilot NT farming, establish support for knowledge and information systems, and build capacity of local institutions and producer organizations.

Creating awareness and willingness to change

The objectives of these initial activities are:

- to sensitize key stakeholders on the root causes and adverse effects of land and soil degradation on farm productivity and the environment (from farm to watershed levels), and the relationship with increased poverty and food insecurity;
- to provide evidence to stakeholders that changes are urgently required, that opportunities for productive and sustainable land management exist, and that they have been successfully implemented by comparable farming communities elsewhere;
- to identify and begin to address specific inertia and resistance to change issues at national and local levels; and
- to identify a dedicated NT core group to start networking among stakeholders who are committed to change.

A good way to begin the change process is to make people aware of the potential benefits of NT systems by showing them fields that employ these techniques. Study tours, field visits, and farmer-to-farmer contacts are among the best triggers for a sequence of activities designed to capture interest and create willingness to change among individual farmers, front-line agricultural service providers, as well as high-level decisionmakers. Often, external specialists may be needed to create initial motivation and raise interest through presentation of successful experience elsewhere.

At the national level, information and sensitization should be targeted at policymakers and decisionmakers at the highest levels, concerned staff from research and development organizations, universities and other education institutions, the private sector, and donors. A key objective is to identify a few 'NT champions' and get their support for Sustainable Land Management/Better Land Husbandry (SLM/BLH) approaches and NT development in the rural sector development agenda. This approach would open a dialogue with government to review the policy framework, and as appropriate, make the required adjustments. Sensitization and lobbying at the national level would also ensure that NT development efforts are not undermined by contradictory government policies or donor strategies, such as continuing support for expanding agricultural mechanization using disk plows and harrows.

At the local level where NT development would be initiated, stakeholder involvement is essential to facilitate the process and promote socially acceptable and economically sound strategies for change. The stakeholder analysis should be designed to:

- enhance understanding of prevailing farming systems;[54]
- categorize different stakeholder interests (political, financial, landholding, employment, commerce, NGO, religious, tribal, etc.),
- elucidate gender issues in each stakeholder group;
- identify conflicts or convergence of interests with the NT development agenda;
- assess the level of awareness and demand for adopting the BLH approach and developing NT farming among each group; and
- characterize the non-resource-poor rural producers and landlords. Stakeholder understanding and expectations might be ascertained through discussions (Box 1).

At the end of this first round of awareness activities, a small informal group (so-called core group) of dedicated people, ideally including representatives of farmers, front-line agents (extensionists, NGOs, researchers), government institutions, donors, and the private sector would decide to network to plan further development of NT activities. Awareness and sensitization activities should not be seen as a one-time exercise, and should be adapted as needs arise during the NT adaptation and adoption process.

Participatory farmer-led identification of change

It is assumed that national SLM, BLH, and NT development plans would build progressively, starting from local and sub-national plans.[55] This second phase draws upon two concepts, 'gateway' and 'pathway of change', and a change strategy selected by

Box 10. Key issues for discussion ibn stakeholder consultations

- o Are sustainable farm productivity, food security, and income perceived as linked to the quality of land?
- o Do herders perceive that they need a sustainable forage supply as opposed to maintaining grazing rights?
- o Do farmers perceive elimination of erosion and soil fertility losses as vital to sustainability?
- o How do women and man perceive links between current farming practices and human health and other environmental issues?
- o What are the demands of other sectors of society to reverse land degradation and adopt SLM/BLH approaches (e.g., NGOs, urban communities, decisionmakers)?
- o Do farmers of different size farms and systems perceive SLM/BLH and NT farming differently, and what are the common denominators?
- o What is the range of financial investment within which individuals and producer organizations see the limits of their actions?
- o Is there a willingness to undertake joint actions to improve sustainability?

54. From available studies and specific surveys, e.g., using PRA methodologies.

55. In some cases, related plans have already been (or are being) formulated (e.g., through stakeholder consultation during the Soil Fertility Initiative (SFI) in Sub-Saharan Africa, or the formulation of CCD action plans). Where appropriate, advantage can be taken of already formed teams that could extend their activities to NT development.

farmers and their organizations. Ideally, they should drive the change process while other stakeholders are gathering momentum. Identifying pathways of change is achieved through piloting activities, initially with a few farmer groups in the most suitable and representative areas, so as to eventually allow expansion of successful achievements.

Gateway and pathway of change

A gateway is the critical and concrete first step that farmers make to overcome constraints that prevent adoption of NT farming. It cannot be assumed that farmers, although aware of this new opportunity, will automatically embrace NT because it is inherently beneficial. There must be locally appropriate triggering mechanisms that help producers and other stakeholders begin the transition to NT. This triggering mechanism is a gateway, and must be identified by the producers — an operational gateway is a producer decision. Examples of gateways include:

- direct planting on crop residues to prevent soil erosion in south Brazil;
- development of improved fallow with *Pueraria phaseoloides* in central Côte d'Ivoire to control an obnoxious weed (*Imperata cylindrica*) and to allow women farmers to cultivate yam in (initially) compacted soil; or
- development of live fencing in pastoral areas, and the establishment of an inter-village bush fire control committee in southeast Côte d'Ivoire.

When farmers select their own gateway, they are empowered to chart their own future, while at the same time providing workable solutions to critical issues (land tenure issues, customary rights) that may appear out of reach through an administrative top-down approach.

Identifying a gateway must be followed by enabling actions that permit pathways of change — roadmaps of staging points along the way to NT farming. The pathway of change concept recognizes that producers and communities vary, thus strategies geared toward NT farming need to be developed and customized to fit existing initial conditions. The pathway concept implies that there is no single approach nor prescriptive technical packages. On-the-ground realities determine the successful adoption of SLM/BLH and NT practices by communities. The pathway must be identified jointly by farmers and other stakeholders, but driven by farmers. This process should be flexible to allow for adjustments that consider experience gained by the farmers. This is critical to ensure that the strategy of change is tailored to local circumstances and farmers, risk averse, and perceived as feasible by potential beneficiaries.

In northern Côte d'Ivoire, cotton and cereal growers recently initiated a pathway of change that began by collecting seeds and seedlings to plant living fence (60 km were planted in less than 16 months by the farmers). In addition, they acquired cover crop seeds, tested no-till and direct seeding on the cover crop; had discussions with herder groups, patriarchal landowners, and producer associations; and made contractual agreements with extension agents and researchers to develop a cost-effective integrated production and pest management strategy to reduce fertilizer and pesticide needs. More advanced pathways of change developed through a participatory technology development (PTD) process in Paraná, Brazil are presented in Box 2.

Piloting

Piloting is required to start NT development actions in selected areas to be identified by stakeholders. The main objectives of piloting are to:

- develop suitable pathways of change — adapt, test, and validate improved NT farming practices by innovative farmer groups and support service providers;
- identify research priorities needed to support NT farming systems development;
- test the feasibility of new local institutional and funding arrangements and shared responsibilities, particularly between producer organizations and local government; and
- test partnerships among the various stakeholders, including the private sector.

These pilot efforts are also necessary to provide all levels of decisionmakers with facts on the qualitative and quantitative benefits of SLM/BLH and NT farming with a view toward expansion. The best argument is to present positive results.[56] An example of a pilot process for NT farming proposed for Sub-Saharan Africa is outlined in Figure 1 (FAO and World Bank, 2000).

Piloting is also needed to find an institutional home for the NT approach at a national level. Local momentum and enthusiasm created by the NT local core group during the awareness activities will not generate strong support for a nationwide strategy unless there is a highly visible project, government program, or an influential producer-led private institution that will support it. A dedicated and influential NT pilot group can be instrumental in overcoming institutional and policy constraints and create useful synergies among stakeholders.

Many countries may already have a geographical database or framework that would be useful to pre-select areas with a good potential to develop NT systems. This can be based on physical features (soil and climate), typology of production systems, and major rural landscape forms**.** To avoid using a top-down approach and ensure that farmer organizations are the major driving force, a complementary and pragmatic approach is to consult existing farmer organizations and the NT core group to select the areas with the best opportunity using the following criteria:

- explicit demand from rural communities to test new land management systems;
- presence of producer organization(s) capable of driving the change process; and
- on-going farmer group activities or programs consistent with BLH approach and interested in changing from conventional to NT systems.

56. In Brazil, the small pilot watershed of Ribeirão das Pedras, Santa Catarina, and the Santa Catarina Land Management II Project (World Bank, 1998) led to larger programs.

Box 11. Examples of smallholder no-tillage pathways of change in Paraná state

Small-scale farmers (maize and beans)

Main characteristics**. Use of animal traction, family labor, low use of inputs, subsistence, and market-oriented.**

Cropping system. Planting black oat *(Avena strigosa)* and field peas *(Pisum sativum)* in mid-May (120 days from planting to milking stage/full flowering). Biomass management with animal-drawn knife-roller in mid-August and planting maize in early September with animal-drawn no-tillage planter. Harvesting maize in April, management of crop residues with knife-roller and sowing rye (*Secale cereale)* in May, cover crop management and planting common beans in mid-September.

During the transition period. Runoff control with contour bunds built with animal-drawn moldboard plow and planting elephant grass (dwarf variety) on the contour bunds. During summer, this material can be cut twice for livestock (e.g., horses and dairy cattle for home consumption). In February, the last sprouting can be used to prepare a silage mixture (60 percent elephant grass + 40 percent maize).

Small-scale farmers (tobacco)

Main characteristics**. Use animal traction, family labor (in this system, labor is a strong constraint due to tobacco cultivation and processing), marketed-oriented.**

Cropping system. Sowing black oat in April/May (120 days from planting to milking stage). Biomass management with animal-drawn knife-roller in mid-August, furrow opening with animal traction and manual transplanting of tobacco in September. Manual harvesting of tobacco and planting beans in January. Manual harvesting of beans in April, sowing black oat and vetch (*Vicia sativa*) and biomass management in mid-August. Planting maize with animal-drawn no-tillage planter.

During the transition period. Runoff control with contour bunds built with animal-drawn moldboard plow and planting of *Phalaris hibrida* on the contour bunds.

Small-scale farmers (handicrafts and beans)

Main characteristics. Use of animal traction, family labor, low labor availability, low use of inputs, subsistence, and market-oriented.

Cropping system. Planting vetch (*Vicia villosa)* in April-May; planting sorghum for brush making; harvesting sorghum and planting black oat. Management of black oat with animal-drawn knife-roller and planting beans in mid-September. Harvesting beans by late December/January.

During the transition period. Runoff control with contour bunds built with animal-drawn moldboard plow and planting *Phalaris hibrida* on the contour bunds.

Small-scale farmers (dairy cattle and soybeans)

Main characteristics. Use of mechanical power (owned or hired), family labor, medium use of inputs, marketed-oriented.

Cropping system. Sowing black oat or ray grass (cycle of 150 days from planting to milky stage). Depending on soil and climate conditions, 2-3 controlled grazings beginning 40 days after planting. The biomass is used as pasture on a rotational basis. The last sprouting is left to produce soil cover for no-till. Biomass management with knife-roller only or knife-roller and herbicide depending on the amount of oat residues left and weed infestation. Planting soybeans in November, harvesting in February-March. Planting black oat and vetch *(Vicia villosa)* and controlled grazing. Biomass management in November and planting maize for silage. A dwarf variety of pigeon peas can be sown between maize rows 40 days after planting to replace part of nutrient extraction of maize harvesting, promote soil decompaction, and provide nitrogen to the system.

Source: Adapted from Ribeiro et al., 2000

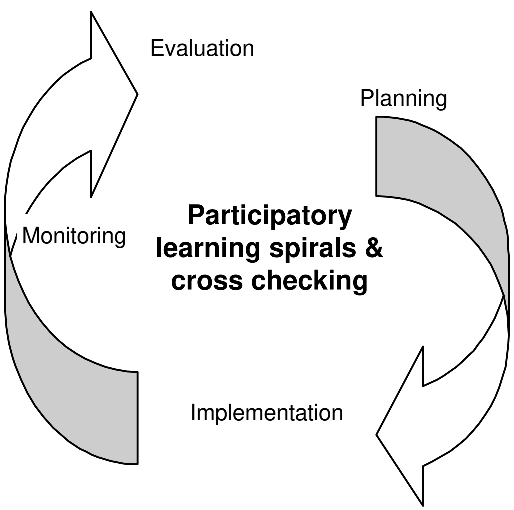
Figure 3. Example of a framework for piloting no-till farming

Preparatory activities. Information and sensitization; clarify NT farming systems development approaches and practices, selection of 'best opportunities areas', agreement with participating communities on objectives and expected outputs. Local meetings (organized by National Support Committee)

Piloting. Learning and training through community-based farmer groups, together with other stakeholders (testing, validation and adaptation of technical NT options)

Farmer group activities

(20 to 30 farmers per farmer group)
NT field development, PTD, provision of inputs and equipment, training, etc.



Continuing process for about 5 years, identify pathway of changes, and adaptation as needs arise

Technical support group

Developing tools, imple-ments, and equipment

- research/PTD
- blacksmiths
- tool makers
- manufacturers
- distributors
- retailers
- importers

Screening and multipli-cation of suitable cover crops

- research/PTD
- multipliers
- distributors

Backstopping group

(Technical assistance)

- local expertise
- Brazilian/Latin American NT experts
- regional networks
- CGIAR (e.g. ICRAF, CIMMYT, etc.)
- FAO
- NGOs

Monitoring and evaluation

Contracted to an independen t institution

Supporting activities

1. National Support Committee
2. Program assistant
3. Study tours
4. Farmer groups exchange visits
5. Research to address issues identified during the piloting process

Dissemination of findings, scaling up successful pilots, national and regional networking of NT practitioners

Source: Adaptedfrom FAO and World Bank (2000)

The *selected areas* must not be too small or large, preferably an identified administrative unit with common land management issues and with farmer-recognized individual *champions* (producers, technicians) or groups (producer organizations, NGOs). It would be advantageous to identify existing and dynamic farmer groups that are ready for new challenges such as participatory extension, technology development groups, or integrated production and pest management (IPPM) Farmer Field School (FFS) groups.[57]

Consultations with stakeholders to define SLM/BLH change strategies can be organized in the concerned areas, ideally by the producers themselves to agree on an action plan of action for NT pilot activities and a provisional institutional setup for their implementation.[58, 59] After this consultation process, activities would be coordinated by a local NT core team to:

- prepare a work program to implement the decisions taken during the local stakeholder consultations;
- develop monitoring and evaluation (M&E) indicators (Herweg et al., 1998);
- agree on partnership arrangements and shared responsibilities among participating stakeholders; and
- establish coordination and communication mechanisms among stakeholders, a schedule and funding mechanism, and support by pioneer farmers or rural communities already committed to NT adoption.

Local government support would be critical in poor communities and/or marginal areas during this phase, and probably more important than agribusiness links. This role should be part of a governmental participatory support strategy to:

- provide communities with technical support and facilitate land conflict resolution and agreement among producers,
- support SLM/BLH and NT information gathering and dissemination to help identify realistic pathways; and
- ensure that agreements among stakeholders consider the interests of diverse groups, particularly women and youth, and ensure that M&E arrangements are in place and will provide the expected information to document the outcome of pilot activities.

Knowledge and information systems

In the past, much agricultural knowledge and information came through pre-determined technology packages provided by technical experts working for public agencies. Much of the information was not used because it didn't meet the site-specific needs of the local growers. Today, many public agencies in agriculture are in the process of reform, encouraging local empowerment by producer groups to provide demand-driven extension and advisory services, with direct interaction with researchers to design

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57. Such as the IPPM/FFS groups in Kenya, Uganda, and Tanzania, established under the IFAD/FAO project on piloting FFS in Eastern Africa (1999-2002).

58. This has been successfully done in Côte d'Ivoire with a cotton grower association and coffee-cacao cooperatives. Where producer organizations are weak, such meetings would be better managed jointly with other stakeholders, such as extension and/or research services, NGOs, etc. In any case, a farmer organization must be the host or co-host, to clearly indicate that it is a farmer-led consultation.

59. In northern Côte d'Ivoire a Commission Régionale GDS (SLM Regional Committee) was created as a sub-committee of the Regional Committee for Rural Development. In southern Côte d'Ivoire a Commission Régionale GDS- Environnement (SLM-Environment Regional Committee) was similarly created, emphasizing the importance of linking SLM and environmental matters. Both committees are chaired and managed by farmer organizations, with support from the national extension service.

experiments that meet their specific needs. This emerging trend should provide a conducive environment for, and can be strengthened by, moving from conventional to NT farming.[60]

People and organizations that have a vested interest in a thriving agriculture-based economy should also be involved — local community groups, representatives of equipment and chemical manufacturers, and private and marketing cooperative specialists. They should respond to specific requests from farmers, and not merely promote their own agendas. This integrated agricultural knowledge and information system approach has been successful for the adoption of NT in Brazil, where the academic system has also become involved. For example, in 1983 the University of Ponta Grossa, Paraná, developed the first course on NT systems, which now is part of the rural development curriculum. Adjustments required for NT development would include:

- realignment of research programs with NT requirements;
- training practitioners in NT concepts; and
- development of a producer-centered communication strategy.

Realignment of research programs

No-till adaptive research also requires adopting appropriate on-farm methodologies, such as the Participatory Technology Development (PTD) approaches, and associated on-farm and on-station complementary research. Successful PTD would require working with farmer groups that have already been empowered through participatory extension and experiential learning activities, such as FFS. Synergies can be exploited by selecting PTD farmer groups from those involved in pilot activities. PTD methodologies are already used by international research organizations[61] and by some national agricultural research systems for land and soil management. Research and development on NT systems would need to adopt a farming systems approach where cross-cutting issues (e.g., land, soil, mechanization, weed management, socioeconomics) and new NT-specific challenges (e.g., cover crop screening and management) receive adequate priority in terms of human and budget resources. A major change may be required to move away from individual, isolated, largely commodity-based programs toward more collaborative work to address a specific development challenge. Indeed, these changes are generally not specific to SLM/BLH and NT, but are a condition for successful NT development. Box 3 presents possible priority domains for NT research.

Some NT research would occur on-station, particularly more basic research such as preliminary screening of cover crop species[62] and IPM issues, as well as the initial multiplication of cover crops. It is anticipated that research institute land would also be gradually converted to NT farming.[63]

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60. In Brazil, farmer organizations pressured state and federal governments for a higher priority on NT research. Today, the technical director of EMBRAPA (national research agency) has publicly declared that "there is no justification for any more research on conventional tillage". It took over 20 years for this to happen.

61. Such as CIRAD in Brazil, Côte d'Ivoire, and Madagascar; ICRAF in Western Kenya; AHI in the East African highlands; CIMMYT and IRRI in South Asia; CIAT in Uganda; IITA in Nigeria; and ICRISAT in Zimbabwe.

62. It should be noted that many cover crop species are generally available in the country, whether indigenous or already introduced for different purposes such as forage, green manure, improved fallow, etc. Therefore, an inventory of available species should be made prior to considering import of exotic species.

63. This would add credibility to NT development efforts and constitute a learning-by-doing exercise for research staff. In Tanzania, the Department of Research and Development agreed to start converting its land to NT farming as part of its NT activities (through the World Bank-funded Tanzania Agricultural Research Project – Phase 2) (United Republic of Tanzania, 2001).

In many developing countries, research and extension emphasize production. The BLH approach and NT systems emphasize the role of market forces in the adoption of these land management practices. This calls not only for increased expertise within research and extension bodies on how to produce quality products for the market, but also how to transport these products more efficiently and how to organize their marketing (Cheatle et al., 1998).

Box 12. Priorities for no-till adaptive research

Cover crops — collection of locally-available germplasm and introductions as appropriate, screening species with emphasis on elimination of herbicide applications; seed production (certified seeds).

Management of crop residues — on the field, both mechanical and with herbicides.

Integrated production and pest management (IPPM) — integrated insect pest, weed, and disease management (including soil-borne pests such as nematodes), herbicide evaluation, and soil fertility enhancement with crop rotations, including mixed cover crops, allelopathic effect of cover crops and nutrient recycling, associated with agroforestry systems, spatial field and crop pattern.

Fertilizer — (mineral, organic) requirements, liming across cover crops and in the crop rotation (needs, timing, and methods of application).

Machinery/tool adaptation — Adaptation and fine tuning of NT planters, knife-roller, sprayers, etc.

Integration of crops and livestock production — screening double-purpose cover crops; best crop rotations and cropping patterns; increase biomass, e.g., through agroforestry.

Pathways of change — on-farm test of pathways best suited to local/zonal typology of farming systems.

Land/soil benchmark — characterization of representative on-farm and on-station soils for future monitoring and evaluation activities and better understanding of interactions, e.g., among chemical, physical properties (including compaction and erosion) and soil biological diversity and activity.

Soil as a rooting environment — rooting depth, root distribution for crops and cover crops.

Socioeconomic studies — reasons for adoption and non-adoption; gender considerations; generation of production cost data; comparison between conventional and NT on-farm income; cost-efficient effects indicators, including socioeconomic and environmental effects.

Finally, the NT approach also provides an opportunity to implement new research and extension mechanisms promoted in several countries such as Brazil, Colombia, and Uganda by funding agencies such as the World Bank and IFAD, including competitive grants for delivery of services, and public-private cooperation.[64]

Management skills for no-till practitioners

Implementation of NT systems would require specific management skills, for example, cost-efficient weed management using crop rotations and cover crops possibly complemented by herbicides, and how to adjust planter and seed drill coulters under different soil moisture and residue cover conditions. Producers

64. Examples of public-private cooperation in Brazil include co-funding of on-station research (product-related); co-funding of on-farm research, demonstration, and training programs; participation in technical/promotional and training events; and co-financing of publications.

and support staff would have to acquire these skills and be able to transmit them to others. This requires specialized courses and on-the-job training.[65]

No-till practitioners also need to increase their knowledge of agroecosystem dynamics and farming systems management. Time saved from the adoption of NT systems may allow them to spend more time scouting their fields (above and below ground level) to observe and assess the effects of NT farming practices on plants, insect pest and disease relationships; recognize indicator weeds and insects; and assess soil biology activity. With time, NT practitioners would become experts on what constitutes soil and crop health and become increasingly committed to environmental and food quality issues.[66]

Communication strategy and networking

As repeatedly discussed in this paper, the adoption of a BLH approach and NT farming practices requires a profound change in mindset, perceptions, and behavior.[67] There is risk of failure if poorly-prepared or under-supported farmers embark on NT, which can set back adoption in an area for years. While education, learning, and capacity building should be integral parts of the change strategy, early communication among farming communities is equally important. Although not specific to NT, experience in many countries with all types of farmers has shown that farmer-to-farmer contact is the most cost-effective means of introducing new concepts. On-farm demonstrations and visits, field days around NT piloting and PTD activities, and farmer exchange visits and study tours are some of the common tools for communication.

A farmer-to-farmer communication strategy is a step to developing a comprehensive dissemination strategy, including rural radio and television, technical pamphlets, newsletters, and more comprehensive training courses. However, at an early stage of NT development, emphasis on farmer-to-farmer communication would lead to farmer networking and the possible creation by farmers themselves of SLM/BLH or NT associations, such as the Friends of the Land Clubs and land care groups that have proven to be foundations upon which institutions are progressively built from local to watershed and national levels. Networking among NT farmer groups and practitioners from public and private organizations would lead to developing a shared philosophy about NT farming and commitment to its development.[68] However, unless an institutional support framework is built in parallel, its achievement may prove difficult.

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65. In Brazil, the Friends of the Land Clubs at the municipal level reduced the learning period by promoting exchange of both positive and negative experience among farmers.

66. In 2000, the 7th National Symposium organized by the Brazilian Federation of NT farmers focused on Agriculture in Harmony with Nature: A Challenge for the 3rd Millennium. The symposium was attended by about 1,750 participants, of which 1,500 were producers.

67. Called by some Brazilian practitioners 'brain de-compaction'. It is not unusual to hear from non-NT practitioners that "NT fields are untidy" or "NT farmers are lazy". Besides, many regions or countries are proud of the quality of the agricultural products harvested from painstakingly managed land, and proud of the human values attached to farming activities. The deep man-nature bonds have been recorded, illustrated, and glorified by many European painters by showing the bounty of the land and the strength and courage that man needs to exhibit to tame nature. The plow epitomized this relationship between 'honest' man and fertile nature. An efficient strategy needs to be developed to counter the deep-rooted belief that tillage is the only way to create soil fertility. Selling such a strategy will not be an easy task or a short-term undertaking (Pieri, 2001).

68. For example, a network of over 100 Friends of the Land Clubs has been created in Brazil with private sector participation that supports state, regional, and national umbrella entities. Some of these clubs have evolved into research/extension foundations with highly interactive links to all sectors, others organize joint purchase of inputs, or establish cooperatives.

Building an institutional and incentive support framework

Countries that are decentralizing would be in a better position to develop institutional support to promote SLM/BLH approaches and NT farming, as well as farmer networking. Although more difficult, it may be possible to encourage local empowerment of rural communities in more centralized economies. For example, in the Loess Plateau Project in China, devolution of responsibility to, and strengthening of, local governments in an area improved support services necessary for NT farming adoption.

Two set of actions could be jointly developed to make this institutional support strategy effective:

- Local governments responsible for providing support services for SLM would need: (i) training for technical personnel; (ii) administrative strengthening; and (iii) establishment of easy communication channels with rural communities and producer organizations.
- Other supporting actions may include government service contracts for NGO and private sector or other independent organizations, and networking with education institutions and NGOs.

Sustained efforts should be made to spread and scale up SLM/BLH and NT activities from the farm to community, administrative, and watershed units by:

- establishing local commissions (administrative unit or watershed commissions), with representatives of key stakeholders;
- supporting reliable input and output produce markets;
- expanding NT producer-led institutional support groups such as producer associations, and NT networks/clubs with members from producers, research and extension, educational institutions, NGOs, business enterprises, etc; and
- raising funds and resources for community watershed actions.

Financing the transition from conventional to no-till farming

Funding is needed to support the NT farming development process and to directly assist smallholder farmers during the 3-5 year transition phase.

Funding the no-till development process

The independent funding mechanism developed by Friends of the Land Clubs with medium and large farms has proven to be successful for the adoption of NT systems in Brazil. For small-scale and subsistence farmers, however, alternative mechanisms would be necessary through financial support from programs and projects. By mobilizing and channeling funding, NGOs can also help by providing technical services and acting as intermediaries between government agencies and local groups. Funds would generally be required for sensitization, participatory rural appraisal and planning, NT piloting, and financial incentives for farmers, PTD and competitive research grants, training, study tours and exchange visits, communication and networking, M&E, and local and international technical support (from countries with NT experience).[69]

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69. This translates largely into equipment and materials, mobility, travel, allowances, honorariums, etc. It has been estimated that NT piloting and PTD involving 10 farmer groups over 5 years would cost about US$ 1 million.

No-till farming and SLM/BLH approaches would both contribute to increased agricultural productivity and rural development, and bring environmental benefits. Funding support from international financing institutions and other donor agencies could therefore be sought through one or more related entry points, such as:

- rural development and community driven development projects (CDD);
- watershed and river basin management;
- agricultural services support (education, research, extension/advisory);
- drought preparedness/fight against desertification (UN Convention to Combat Desertification);
- biodiversity conservation (UN Convention on Biological Diversity);
- climate change, reduction of gas emissions, and carbon sequestration (UN Framework Convention on Climate Change, Kyoto Protocol); and
- Integrated Planning and Management of Land Resources (Chapter 10 of Agenda 21 of the Rio Summit).

The promotion of NT in Brazil has built on intensive technical assistance to all participating farmers. Results have been encouraging where innovative and resourceful farmers met enthusiastic and committed research and extension teams. Following closure of the World Bank-supported micro-watershed management project in Santa Catarina, concerns were raised about sustainability of the system because a large number of support staff paid for by the project were now no longer available to assist farmers with NT development. Where the NT development is funded by external resources, careful consideration should be given to phasing out incremental support services, which is key to sustainability.

Farmer incentives

Experience in Latin America shows that while more advanced, large-scale farmers are generally able to finance their change toward NT farming,[70] financial incentives (subsidies) are needed for resource-poor farmers. Short-term subsidies played a significant part in supporting small-scale farmer adoption of no-till practices. In Paraná, much of the hand-held or animal-drawn equipment was acquired with financial support from the state in the context of development programs funded by the World Bank. In some instances, private companies (e.g., the tobacco industry) also provided equipment for small farmers. Such incentives, which should be linked to the transition process and phased out after a short period,[71] may include:

- acquisition of inputs such as cover crop seeds, soil amendments, or new equipment related to NT systems;
- one-time subsoiling for soil de-compaction;

70. One salient feature of the Brazil NT development experience is the lack of production subsidies. To survive with low commodity prices, the medium- and large-scale farmers had to find lower per-unit cost production methods. The combination of zero tillage with the use of cover crops and rotations reduced their cash outlays for fuel, labor, equipment depreciation, and purchased chemicals. This approach required more knowledge about how to maintain healthy soils, less dependence on quick fixes, and the patience of 3-5 years to allow the benefits to be fully realized. In Western Europe and the United States, these incentives do not exist because farmers are able to fall back on production subsidies that do not encourage lower-cost innovation. The situation in Brazil may be unique, but the NT innovators there (who primarily came from larger farms) worked with the private sector, extensionists, and researchers to develop equipment and know how for resource-poor farmers. In other countries, this rather egalitarian attitude may not exist, so some transition funds may be required for poor farmers.

71. For example, up to 3 years for production (equipment or inputs), and up to 5 years for other aspects such as training and technical assistance.

- contribution to decrease the cost of farmer access to information;
- on-farm adaptation of NT farming practices; and
- acquisition of specific NT farming skills.

A specific 'NT window' can be conveniently opened in existing social funds and/or community development funds to prevent the proliferation and costly management of specific funds. Several financial mechanisms may be considered, including: (i) grants and special credit lines for purchase of collective NT equipment or development of small rural infrastructure; (ii) matching grants, particularly to support piloting activities; and (iii) taxes rebates[72] or exemptions.

These public financial incentives would generally not be sustainable beyond a donor-supported project closure. There is therefore concern that production subsidies may distort the estimate of private benefits from NT that could lead to a backlash as farmers are suddenly confronted with full market prices. It would be economically justified to compensate farmers for environmental and other benefits that NT adoption generates outside their farms, but in that case a regular transfer system from beneficiaries to farmers should be developed. Subsidies for pre-defined, specific technologies should be avoided in order not to stifle innovation.

72. In Brazil, NT adopters benefit from a 1 percent point reduction in crop insurance premiums.

Conclusion — No-Till Farming and Sustainable Rural Development

The development of NT farming systems following SLM and BLH principles can contribute to improving food security and alleviating poverty, and therefore to the goals of sustainable rural development and environmental protection. Both are key priorities of the World Bank and partner agencies.

The main thrust of the Rural Development Strategy of the World Bank is to reach the rural poor (World Bank, 2002). The challenges addressed include persistent poverty (70 percent of the world's poor live in rural areas); slow growth in agricultural productivity; and natural resource degradation. The focus is on actions and outcomes and working with a wider range of sectors and stakeholders (including the private sector). The strategy also has three implementation thrusts:

- improve decisionmaking processes for the allocation of resources to and within rural space, and encourage client countries to assess their development needs;[73]
- improve the quality of operations to ensure that interventions are locally validated and adapted, and focus on poverty reduction, sustainability, and replicability; and
- scale-up successful approaches to states or provinces within a country, to the country as a whole, or to other countries.

The goal of the environment strategy of the World Bank (2001) is to "promote environmental improvements as a fundamental element of development and poverty reduction strategies and actions", with three interrelated objectives — improving quality of life, improving the prospect for and quality of growth, and protecting the quality of regional and global environmental commons. The strategy recognizes that environment and development are closely linked. In rural areas, major threats to livelihood are posed by the decline of natural resources, including land and soil degradation, especially in poor households that often depend on natural resource services for as much as 30-50 percent of their total income.

The implementation of SLM and BLH approaches and development of NT farming are fully in line with the above key strategies. There are, therefore, opportunities to support NT development through different investment programs or projects addressing both rural development and environmental goals. Financial support is needed both to launch the NT systems development process (in particular, piloting and research) and to scale-up successful pilots. As discussed earlier, major investments in human resource development are needed, from stakeholder sensitization to training and education on the pillars of successful NT development — community empowerment, effective farmer-led organizations, entrepreneurial partnerships, and market development, as well as the technical aspects of NT farming.

To be successful and sustainable, NT farming systems development must be considered as a long-term process whereby all stakeholders, particularly farmers, are actively involved. No-till farming is highly location-specific and must be adapted to specific farmer circumstances. It should therefore not be seen as a new quick fix or blueprint that would solve the low agricultural

73. These development needs are reflected in the Country Strategy (CS) and in Poverty Reduction Strategy Papers (PRSP).

productivity issues, for example, through a set of prescriptive technical packages. Depending on prevailing socioeconomic and agroecological conditions, the conversion from conventional to NT farming will take time, and full conversion to NT farming may not always be achievable, in particular in semi-arid and arid climates. What is most important is to adhere to the underlying principles of SLM/BLH and NT farming, and to adapt them to local circumstances in a flexible manner.

Introducing the concepts of NT farming will initially generate skepticism and resistance.[74] Indeed, adequate marketing of these new ideas among stakeholders is critical. The process of adapting NT farming to given circumstances will generate many socioeconomic and technical problems and challenges that will need to be addressed. However, successful NT developments in Latin America and elsewhere suggest that addressing these problems may bring higher and more sustainable benefits than attempting to address the problems arising from conventional tillage farming.

74. In 1943, the American agricultural expert Edward H. Faulkner stated in his small book *Plowman's Folly* "the fact is no one has ever advanced a scientific reason for plowing". This book was acknowledged by Time magazine as "one of the most revolutionary ideas in agricultural history". In spite of the unbelievable yields obtained by E. H. Faulkner, making his experimental plots commercially profitable, it took several decades (Phillips and Phillips, 1984) to get official recognition of his findings in the USA.

Appendix 1
The Voice of Farmers in Brazil

Brazil's successful adoption of no-till farming on 14 million ha was driven by many successful producer-led organizations (POs), with strong links and synergies among them (Fig. A1).

The inner ring of producer-led organizations[75] interacts with many different institutions where the producer traditionally has little or no control. The power of the cooperatives and specialized no-till NGOs has the most effect on federal and state government policies, but POs exercise considerable influence at the municipal level, obtaining significant financial support for NT systems, more specifically through World Bank-financed projects (in southern Brazil).

There is no *one* measure of success, and successful POs will vary from place to place. However, the successful POs always include rural producer leadership and interactive participation of all members. Pretty (1998) characterizes 'interactive participation' as:

- employing a methodology for collective learning;
- user-friendly, with quick inquiry and learning processes;
- multiple perspectives from diverse participants;
- external inputs from professionals with listening and facilitating skills;
- self-assessment leading to visions for the future; and
- enhanced individual and organizational capacity for action.

The Brazilian case shows that successful farmer-led NT diffusion systems include both internal and external factors.

Internal factors include:

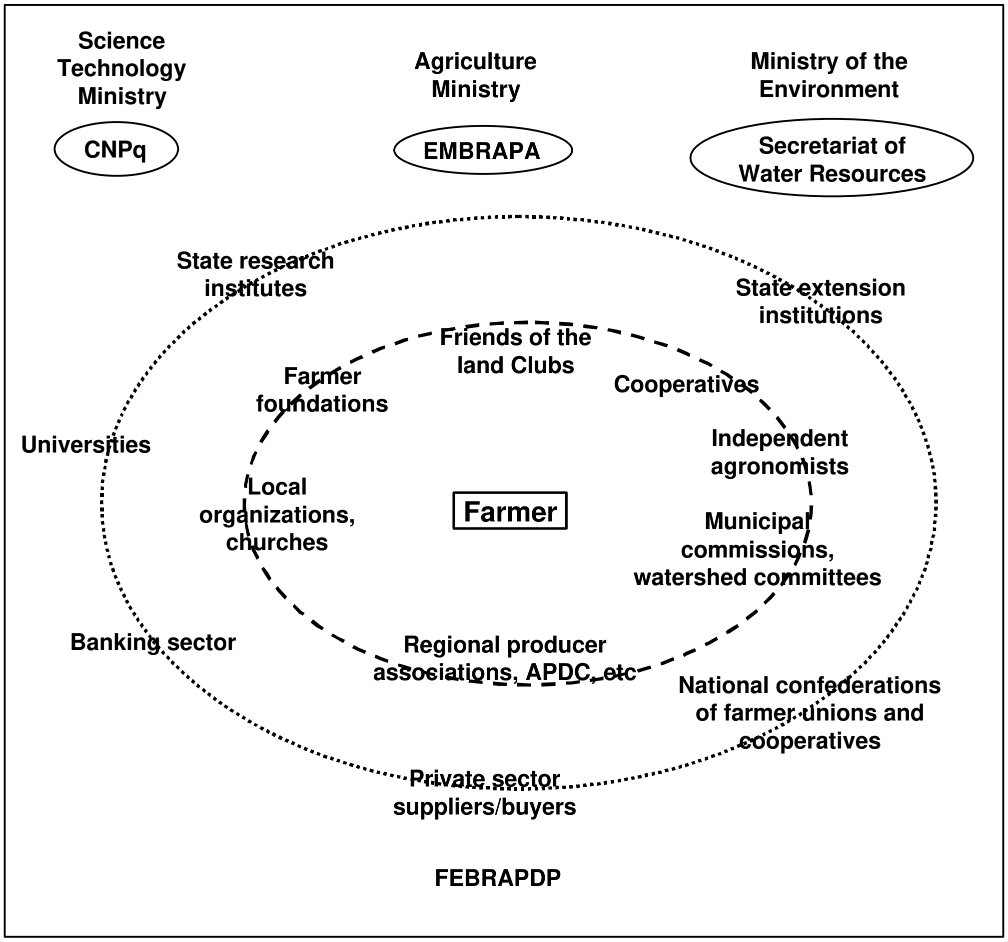
- PO officers with good leadership skills;
- good links to local administrators, politicians, traditional structures, and private sector;
- key technicians and directors who are amenable to change;
- financial and administrative support for activities;
- on-farm demonstrations and ad hoc applied research for all farm sizes;
- objectives that include good land stewardship;
- technical assistance available to members on an ad hoc or regular basis; and
- regularly scheduled meetings.

External factors include:

75. The inner ring include the following POs: Friends of the Land Clubs (FLCs); Cooperatives; Farmer research and advisory foundations, Small farmers' formal associations; Informal small farmer neighborhood groups; Farmer Field Schools for IPM; Machinery credit co-ownership groups.

- technical and/or financial support from the private sector;
- government organizational, technical, and credit support for small-scale farmers;
- full-time state or provincial and national program coordinators; and
- acceptance of the NT system by state or river basin and/or municipal/village development commissions (Box A1) comprising all rural and urban stakeholders, but with a clear majority of rural members.[76]

Figure A1. Institutions involved in no-till agriculture in Brazil, 1999



Source: adapted from Landers (1999)

76. In Paraná State, Brazil, the State Secretariat of Agriculture (1998) listed an example of the membership of a typical commission: agriculture representative of local council or local government; one representative of the locally elected political body; one representative of private advisory services (cooperative, private agronomist, foundation, agribusiness); two or three rural producers per micro-catchment; one representative of government extension service; and one representative of rural credit institutions.

Box A1. No-till producer-led organizations in Brazil

Micro-catchment level

Farmer micro-catchment groups or associations for community projects (all farmers)

Small-scale farmer credit groups (all farmers)

Municipal level

Agricultural Development Councils or Soil Commissions (farmer organizations and others)

Farmers' Unions (commercial farmers on any scale)

Rural Workers' Unions (small-scale subsistence farmers and farm workers)

Friends of the Land Clubs (small-, medium-, and large-scale farmers, NT adopters)

Specialized growers and livestock associations (all farmers, medium- and large-scale predominating)

Farmer Cooperatives (all farmers)

Multi-municipality level

Large cooperatives (input and food supply, credit, technical assistance, product marketing, research – all scales of farming)

Farmer foundations (applied research and technical assistance, medium- and large-scale farmers)

River basin level

Basin committees for all water users (incipient and based on operational funds derived from water tax, not yet implemented)

State or regional level

State Zero Tillage Associations (states of RS, PR, MS)

Cerrado Zero Tillage Association (APDC)

State Federations of Farmers' Unions

State Federations of Cooperatives

State Federations of Rural Workers' Unions

National level

Federação Brasileira de Plantio Direto na Palha (FEBRAPDP) Associações de Plantio Direto na Palha (FEBRAPDP)

Confederations of above organizations

Role of producer organizations in the NT adoption process

Table A1 outlines the activities of farmer organizations in Brazil at various stages of the NT adoption process —particularly the Friends of the Land Clubs. Critical factors to ensure effective development and functioning of farmer organizations for NT development include:

- strong leadership, usually from one farmer;
- support capacity from farmer cooperatives or foundations, the extension service, municipal authorities, and commercial companies (with reservations);

- development of second- and third-phase activities; and
- member representation on water resources and municipal development committees.

No-till PO activities engender feedback mechanisms and networks that are vital to signal changes and needs in the production system that sustains communities. These networks and mechanisms (e.g., ready and accessible markets for produce and inputs) that help lower the threshold levels for adoption and expansion of NT systems. An example is the network of over 100 Friends of the Land farmer/technician clubs in Brazil with active private sector participation, which supports state, regional, and national umbrella entities. The club denotes a special interest group with which both private sector and government can identify and supply specific support. Some of these clubs have progressed to research/extension foundations with highly interactive links with all sectors.

In addition, experience has shown that building NT system principles into a functional existing PO has a greater chance of success than starting a new one. However, associations formed merely to receive government incentives have not generally survived beyond that horizon. The adoption of NT systems is a challenge, and self-help is engendered through farmer-to-farmer contact that sustains PO actions.

Finally, the success of a small-scale farmer PO depends on it being anchored within a supportive (policy and institutional) context, whereas medium- large-scale mechanized farmer POs will prosper as long as economic benefits are continually generated through advances in technology.

Table A1. Activities of farmer organizations in Brazil

Adoption phase	Mature phase	Advanced phase
Basic instruction	Specialist seminars	Rural leadership courses
Farmer-to-farmer exchanges	Field days	Cost accounting
Short courses	Ad hoc on-farm research/data collection	On-farm research partnerships (new crops, varieties, fertilizer trials)
Lectures, farm visits/field tours	Links with universities	
Planter clinics for adoption	Planter clinics for trouble-shooting	Advanced management groups
	'Professionalization' of rural workers	Field tours

Friends of the Land Clubs — organizational rules

Experience with Brazilian Friends of the Land Clubs (FLCs) indicates that initial informal organization with regular group activities is a necessary process to identify and evaluate leaders who are capable and prepared to work on behalf of the group. This activity increases the chance of electing the right person to the right office.

Transparency and democratic change of officers

Brazilian experience indicates that the traditional system of elections in South American NGOs, i.e., pre-formed groups competing for an entire complement of board officers, can be prejudicial to member diversity and transparency. Replacing this procedure with one in which each office is filled by the individual receiving the most votes increases the chance for fair representation of different stakeholder groups in the governing body and hence more effective scrutiny of proxy decisions for the members.

Presidential power

There is a pragmatic need for one board member alone or in conjunction with one other to sign on behalf of the rural communities or PO. This should be stipulated in the statutes, but at the same time, a commission or committee of respected people should oversee the ethics of board actions and have the power of impeachment.

With more complex projects, POs needed support for project preparation. In the Rural Poverty Alleviation Project in northeast Brazil, use of matching grant funds is overseen by a local supervisory committee independent of the elected board.

Non-profit status

The selection of non-profit status allows the exclusion of commercial and political influences, which are divisive and detract from the singular purpose that self-help FLC engenders. Small-scale farmer FLCs are few because extension services historically formed small-scale farmer associations which served as the POs for interaction with technology transfer and credit. Experience of using FLCs for joint input purchases or joint sales of products have been abandoned since they compete against a broad spectrum of support from the private sector. Profit-oriented actions should require a change of statute or conversion from FLCs to, for example, an association or a cooperative. For example, the non-profit Rice Growers Zero Tillage/Minimum Tillage Club of Rio Grande do Sul in Brazil evolved to a cooperative, while the Earthworm Club of Paraná State evolved to a non-profit farmer foundation for research and extension services, now supported by three cooperatives and private agribusiness.

In terms of organization at the local level, there is no specific formula. However, it does not make sense to duplicate existing structures that could be adapted to fulfill the required role. In Brazil, FLCs have used the umbrella of municipal farmers' unions, obtaining office space and administrative support. In this way, political affairs are handled by the union, allowing the FLCs to concentrate on technology development and diffusion.

Eligibility of members

Membership is focused on producers, but allows for technicians, private sector agents, and others to join. Eligibility allows for as a wide and varied membership as possible but should strive to engender a sense of common purpose: the sustainable utilization and management of the land resources.

Adapted from J. Landers, presentation in Paraná, November 2000

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