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IMPACT of No-Till Technologies in GHANA

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CIMMYT

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Abstract: In the 1990s, no-till with mulch, a sustainable agricultural alternative, was introduced to Ghanaian farmers through a joint program between the Crops Research Institute in Kusami, Ghana, Sasakawa Global 2000, and the Monsanto Company. The package was disseminated to farmers in the Forest, Transition, and Guinea Savannah Zones, and rapidly adopted. In 2000, it was estimated that 100,000 small-scale farmers practiced no-till on 45,000 hectares of land. This study examines the impact of no-till on farmers who adopted the technology in the three zones, and to a lesser extent, the reasons for non-adoption. The impact of no-till among agrochemical dealers was also evaluated. The report found that no-till brought important changes to farmers using the technology and expanded the market for agrochemicals. It calls for more research on machinery for the technology, crop rotations, and the dynamics of diseases and weed and pest populations. More research on the organization and performance of agrochemical markets is also needed to identify bottlenecks that hamper the dissemination of no-till.

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Acronyms

CIDA	Canadian International Development Agency
CIMMYT	The International Maize and Wheat Improvement Center
CRI	Crops Research Institute
GGDP	Ghana Grain Development Project
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IITA	International Institute for Tropical Agriculture
MOFA	Ministry of Food and Agriculture
SG 2000	Sasakawa Global 2000

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Executive Summary

In the 1990s, no-till with mulch, a sustainable agricultural alternative, was introduced to Ghanaian farmers through a joint program between the Crops Research Institute in Kumasi, Ghana, Sasakawa Global 2000, and the Monsanto Company. The package was disseminated to farmers in the Forest, Transition, and Guinea Savannah Zones and rapidly adopted. It is estimated that in 2000, no till was used by 100,000 small-scale farmers in 45,000 hectares of land. This study examines the impact of this technology on farmers who adopted the technology, and to a lesser extent, the reasons for non-adoption. The impact of no-till on agrochemical dealers was also evaluated. In the remainder of this summary, no till refers to no-till with mulch.

In contrast to other countries, the no-till package in Ghana responded to the needs of small-scale farmers. Adoption was facilitated by low-input agricultural practices prevalent in the study areas – the Forest, Transition and Guinea Savannah Zones - and the fact that few farmers have animals (other than some chickens). There was no need to develop no-till planters, which were major obstacles in other countries where no-till was introduced, because planting is traditionally done with a stick or cutlass (machete). This, however, was a limitation to widespread adoption among large-scale and mechanized farmers who need adequate machinery to adopt the technology.

Two surveys were carried out, a farmer survey and an agrochemical dealer survey. Three types of farmers were included in the farmer sample: farmers who are currently using no-till (NT users), farmers who used and later abandoned the technology (abandoned NT), and farmers who have never used the package (never used NT). A total of 146 farmers were interviewed: 97 farmers who used the technology, 18 farmers who used and abandoned the technology, and 37 farmers who never used no-till. The last two categories were included to obtain information on reasons for non-adoption. The number of farmers who abandoned no-till was small because no other farmers in this category could be identified in surveyed villages. A total of 28 agrochemical dealers in both survey villages and district capitals were interviewed.

In general, it was found that there were no differences between male and female farmers in wealth indicators (availability of water and electricity, ownership of a bicycle, car, tractor or different types of livestock), access to technical advice, and agricultural practices. However, on average, women farm about half the area as men and obtained lower maize yields. Only 21% reported trying new things in their fields against 43% of men. These differences can be explained by differences in nonagricultural employment. Women generally have nonagricultural occupations (work at home or trade activities); they tend to be part-time farmers and go to the field later in the day. This affects the efficiency of some agricultural practices (like spraying) that should be done early in the morning.

Farmers who used no-till applied the package recommended by research/extension agents. Most users of no-till (78%) did not change crops they planted after no-till adoption. This may reflect lack of market opportunities, inadequate technologies for current production patterns or inadequate information channels that permit farmers to learn about new crops. Adequate research and extension programs can solve some of these problems and increase the impact of no-till.

While there were active markets for agricultural services in the study areas, the performance of these markets can be enhanced by training contractors. Forty-eight percent of farmers contract planting and rent a knapsack, while 18% contract spraying. Economic considerations seem to be a restriction for 25% of no-till users and 51% of farmers who never used the technology. Difficulties in finding adequately trained contractors for planting or spraying were mentioned by 24% of no-till users, 56% of farmers who abandoned no-till, and 30% of farmers who never used the technology. Understanding the package was a problem for 23% of farmers who abandoned no-till and 30% of farmers who never used it.

Impacts of No-Till

Farmers in all three categories reported that the use of no-till is prevalent in their villages and that the number of users is increasing, although the perception is lower among those who abandoned no-till. Farmers in all groups said no-till users were of average wealth— in other words, no-till is not perceived as a technology for rich farmers. Also, farmers in all groups felt that income and food availability in households that use no-till was increasing.

In normal years, no-till farmers obtained maize yields that were 16% higher than farmers who abandoned no-till and 45% higher than farmers who never used this technology. But in a dry year such as 2000, the yield advantages of no-till were 38% and 48%, respectively. No-till improved moisture conservation and reduced the risk of crop failure in dry years, a particularly important feature in much of sub-Saharan Africa.

Male family labor was reduced by 31% after adoption; reductions in female and child family labor were not statistically significant. The overall family labor saving was 27%. The reason for the difference in male and other labor savings is that no-till simplified tasks that are usually reserved for men: land preparation (including slashing and burning), planting, and chemical weed control.

No-till reduced labor requirements for land preparation and planting by 22%. Labor for weed control fell by 51%, from an average of 8.8 man-days/ha to 4.3 man-days/ha. There was, however, a slight increase in labor for harvest from 7.6 man-days/ha to 8.6 man-days/ha. This was largely a consequence of higher yields obtained. Ninety-nine percent of no-till users reported that no-till was less physically demanding than the traditional technology and that labor requirements in critical moments were reduced, thus simplifying labor management.

When farmers were asked to identify the three most important changes that no-till brought to farming activities, a majority mentioned reduced investments in cash and labor and higher yields. Other important impacts were easier weed control and saved time for farmers. Less frequently mentioned changes were expansion of area farmed and improved soil fertility.

Three risk factors were also reduced with no-till: the soil cover increased water availability in dry years, the reduced turnaround time permitted planting of the second crop closer to the optimal date, and the presence of a larger number of beneficial insects facilitated pest control. When asked if they still get something in bad years, 84% of users responded affirmatively. Reduction of the downside risk is especially important for small-scale farmers who have little savings to weather a bad harvest.

Among the most important changes that no-till brought to their families, adopters mentioned increased food availability, more time for other activities, and reduced labor and effort. Nineteen percent of farmers mentioned the ability to promptly pay school fees, thus securing their children's education. Eighty-three percent started other income-generating farming or trading activities.

The dealers' survey showed that the market for agricultural inputs, especially herbicides, has expanded. There are currently two complementary marketing channels: formal dealers, located mostly in district capitals, and research/extension agents[1] who have closer contact with farmers in villages. As most farmers use small volumes of agrochemicals, it is not worthwhile for them to travel to cities to purchase them. Research/extension agents reduce the cost to farmers by bringing these inputs to villages.

The interaction between formal dealers and research/extension agents was only discovered in the analysis of farmer surveys and was not analyzed further. Formal dealers were also surveyed to assess the impact of no-till on their businesses. Almost half (43%) opened their businesses after 1996. Between 1998 and 2001, herbicide sales doubled for 57% of dealers, tripled for 7% and increased by only 50% for 14% of them. Finally, during the same period, 82% of dealers expanded the range of products they offered.

Markets for inputs are not well integrated. Only 29% of dealers know herbicide prices in Accra, and 57% know herbicide prices in other villages. This share is substantially smaller than that of no-till farmers who know prices in neighboring villages. Sixty-four percent of dealers said herbicides are easily available when needed. Only 11% receive credit from commercial banks and 21% from suppliers. On the other hand, 57% of dealers give credit to selected farmers.

The report concludes with some recommendations to ensure that no-till remains sustainable in Ghana. These include the introduction of machinery for both small- and large-scale mechanized farmers, such as the knife-roller for slashing, planters for manual, draft, and mechanized planting, and multi-line sprayers. Crop rotations (including cover crops) can help improve soil cover at flowering, increase fertility, ease weed control, and reduce potential buildup of aggressive weeds and pests. Research on diseases and weed and pest populations will also help to identify potential threats and develop remedies before they become a limiting constraint.

The development of a no-till package for crops that presently can only be planted with conventional till would also broaden the universe of potential adopters. Many of these needs have already been solved in other countries; Brazil and Paraguay in particular have many technologies for small-scale farmers that could be transferred into Ghana with minor adaptations. Establishing strong links with researchers and institutions in other countries is an efficient and cheap way to fill knowledge gaps.

While the survey showed that research and extension services worked efficiently, there were indications that the extension effort may be weakening and some activities have been scaled down. New institutional arrangements should be sought to compensate for these changes.

Finally, research on the organization and performance of research/extension agents and formal dealers and the interaction between them may help identify bottlenecks that hamper the dissemination of no-till. Programs to help dealers improve business management and better infrastructure can also reduce transaction costs and help expand no-till practice.

1 A formal dealer is someone who has an established shop and whose primary activity is selling agricultural inputs. Research/extension agents, on the other hand, provide mostly research and extension services and trade in herbicides on the side.

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Introduction

No-till has been practiced in Ghana for centuries. The practice is very much associated with shifting cultivation, in which vegetation is slashed and burned (known as bare no-till, essentially no-till without mulch or other soil cover) and crops are planted with minimal disturbance to the soil. Plots are farmed for 2-3 years and left to fallow for 5-10 years. However, growing population pressure has led to intensification of agricultural production and shortening of the fallow period. In recent decades, mechanization has also become a common feature in the Transition and Guinea Savannah Zones. Both bare no-till and mechanized agriculture are having negative economic and environmental consequences in Ghana, where farming is characterized by soil erosion, low soil fertility, high labor demand (especially for land preparation and weed control), low yields, and low income.

In the 1990's, the Crops Research Institute (CRI) in Kumasi, Ghana, teamed up with Sasakawa Global 2000 (SG 2000) and the Monsanto Company to develop a sustainable agricultural package—no-till with mulch—for farmers in the Forest, Transition, and Guinea Savannah Zones. This study examines the impact of this technology on small-scale farmers who adopted the technology in these three zones, and to a lesser degree, the reasons for non-adoption of the technology. The impact on agrochemical dealers was also evaluated.

No-till with mulch (henceforth referred to as no-till) is a sustainable technology that improves the physical and chemical characteristics of the soil and facilitates weed and pest control. These benefits arise in part from more active biological activity in the field. However, since the environment is a dynamic system that evolves in response to agricultural practices, the sustainability of the no-till package may be threatened by increased incidence of new weeds, pests or diseases. A sustained research effort must be maintained to provide early solutions to new threats that may arise.

In Ghana, the CRI-Sasakawa-Monsanto no-till package was presented to farmers in the Forest, Transition, and Guinea Savannah Zones and rapidly adopted. It is estimated that in 2000, no-till was used by 100,000 small-scale farmers on 45,000 ha.

Unlike other countries, the no-till package in Ghana responded to the needs of small-scale farmers, as a package for large commercial and mechanized farmers was not developed. Adoption was facilitated by the low external input agricultural practices prevalent in the three zones and because there was little competition from livestock production (farmers generally have only a few chickens). For example, because planting is traditionally done with a stick or cutlass (machete), there was no need to develop or introduce no-till planters, which required considerable experimentation and adjustment before adoption could proceed in other countries where no-till was introduced. Admittedly, the focus on small-scale farmers was a limitation to widespread adoption of no-till by large-scale and mechanized farmers, who need adequate machinery to adopt the technology.

Three types of farmers were surveyed: farmers who are currently using no-till (NT users), farmers who used and later abandoned no-till (abandoned NT), and farmers who never used the package (never used NT). The last two categories were included to obtain information on reasons for non-adoption. An agrochemical dealers' survey that included dealers in both survey villages and district capitals was also carried out.

In the absence of a reliable baseline data, it was not possible to calculate precise quantitative measures of the impact of no-till. Based on farmers' qualitative estimates, we obtained an estimate of some of the benefits of no-till, such as reductions in labor requirements for different agricultural tasks.

The next section of this report looks at general characteristics of agriculture in Ghana and the study area. This is followed by a discussion on the development and dissemination of no-till in Ghana.

Data collection procedures are then explained. Analyses of farmers and dealers surveys are then presented in subsequent sections. The report ends with a discussion of the impacts of no-till on farmers and agrochemical markets and the conclusion. (For information on the development of no-till internationally and features of the technology, please refer to Ekboir, 2002[1]).

Agriculture in Ghana

Ghana has a total land area of about 24 million hectares, of which agricultural land area constitutes about 14 million hectares. Ghana is basically an agricultural country with over 50% of its population working in agriculture. Small-scale farmers predominate. The principal agricultural produce are cocoa, oil palm, coconut, cotton, coffee, and tobacco; starchy staples include cassava, cocoyam, plantain, yam, maize, rice, millet, and sorghum; fruits and vegetables are pineapple, citrus, banana, and cashew. Of lesser importance are papaw, mangoes, and tomatoes. Maize is the most important cereal crop grown by a majority of farmers in all parts of the country except the Sudan Savannah in the far north.

In 2000, the area under cultivation was 5.8 million hectares (MOFA 2001). The area planted with the most important crops increased steadily in the 1990s, with the exception of sorghum (Table 1). The mean annual growth rate of the area under cultivation over the 1992 to 2000 period is 1.4% for maize, 3.9% for cassava, 1.06% for sorghum, and 3.98% for rice.

Table 1. Area under maize, cassava, sorghum, and rice cultivation, 1992-2000, Ghana ('000 ha).

Year	Maize	Cassava	Sorghum	Rice
1992	607	552	307	80
1993	637	532	310	77
1994	629	520	299	81
1995	669	551	335	100
1996	665	591	314	105
1997	652	589	324	118
1998	696	630	332	130
1999	697	640	312	105
2000	695	660	289	115

Source: MOFA (2001).

In the land use pattern, bush fallow and other uses cover about 60,000 km^2 and savannah woodland cover 71,000 km^2. These together form about 55% of Ghana's total land use area. Annual crops cover 12,000 km^2 or 5% of the total land area in Ghana. Tree crops cover 17,000 km ^{2} (7%) of total land area.

In the Northern Region, most households (81%) have more than 1.2 ha of land, whereas in the Ashanti and Brong Ahafo Regions, most households have holdings of less than 1.2 ha.[2]

Population density is 131 persons/km^2 in the Ashanti Region, 46 person/km^2 in Brong Ahafo, and 26 persons/km^2 in the Guinea Savannah (Ghana Statistical Service 2001). Apart from the Ashanti Region, population density is generally low; however because of poor soils, particularly in the Northern Region, pressure on natural resources is strong.

A particular characteristic of Ghanaian agriculture is that women frequently manage their own agricultural plots, contribute an important proportion of overall labor, and exercise complete discretion over the disposal of harvest and the cash obtained from it (Morris et al. 1999).

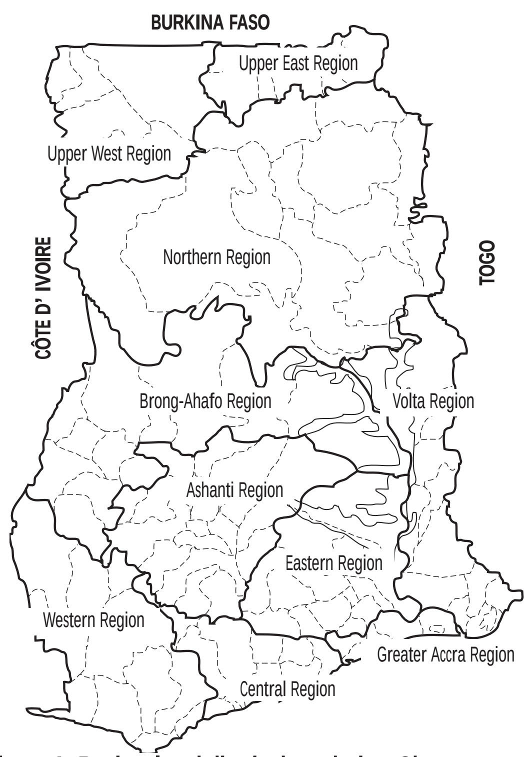

Figure 1. Regional and district boundaries, Ghana.

[1] This report is also available at http://www.cimmyt.org/Research/Economics/map/facts_trends/wheat00-01.html.
[2] A small-scale farmer in any region of Ghana has less than 5 ha.

The Study Area

Ghana has four major ecological zones: Coastal Savannah, Forest, Transition, and Guinea Savannah. This section describes the Forest, Transition, and Guinea Savannah Zones where this study was conducted.

Soils in the three zones are mostly acidic low in organic matter. Consequently, soil nutrient status is very low. Traditional slash and burn practices and the yearly indiscriminate bush burning further compound the problem of soil fertility. Soil improvement practices common in other countries with similar acid soil problems (such as liming) are not used in Ghana.

Forest Zone

This zone covers much of the Western, Ashanti, Brong Ahafo, and Eastern Regions of Ghana. It lies inland immediately after the Coastal Savannah Zone. Rainforest covers the southwestern part of the region, and elsewhere a semideciduous forest is prevalent. Soils in this zone are generally more fertile than other ecological zones and consist of well-drained forest ochrosols or forest oxysols that may leach because of high rainfall, particularly in the southwestern part of the zone. The annual rainfall is about 1,500 mm and has a bimodal distribution, which define a major and a minor agricultural season. Important weeds are *Chromolaena* spp., *Penissetum purperum* (elephant grass) and *Euphobia sp*. Cocoa and palm oil are cultivated for cash. Maize is grown in scattered plots and usually intercropped with cassava, plantain, and/or cocoyam. Maize and cowpea are the most important crops in the minor season.

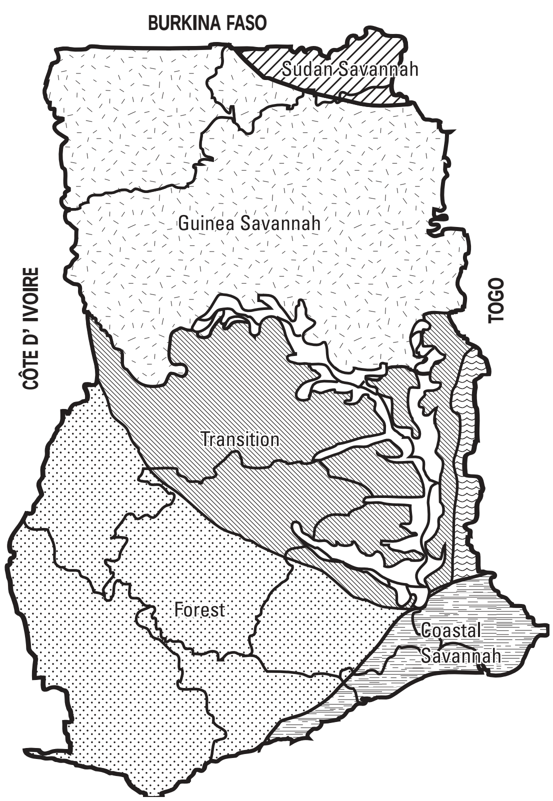

Figure 2. Agroecological zones, Ghana.

Transition Zone

There is no clear boundary between the Forest and the Transition Zones, which stretches across the center of the country from east to west and immediately north of the Forest Zone. Soils are deep and friable but well drained, and there is less dense forest cover. Trees are shorter with thick bark and interspersed with grasses. Important weeds are *Panicum maximum* (Guinea grass) and *Imperata cylindrica* (spear grass). Rainfall is bimodal and averages about 1,300 mm per year. Because of the favorable climate and less dense vegetation, the Transition Zone is extensively cultivated and an area of commercial farming, especially for grain production. Plowing with tractors is relatively common. Maize is planted in both the major and minor seasons, usually as a monocrop or with yam and/or cassava.

Guinea Savannah Zone

The Guinea Savannah Zone is the largest ecological zone in Ghana. It occupies more than half the country, covering 149,800 km^2. The Guinea Savannah has savannah ochrosols and groundwater laterites (poorly drained loams). Rainfall is unimodal, starting in April or May and ending about October. The mean annual rainfall is 1,100 mm. Vegetation is largely grassland with sparsely distributed short trees; dawadawa, acacia, baobab, and shea trees are predominant. Farming is the main occupation. Dominant crops are sorghum, millet, cowpea, groundnut, rice, and maize. Cotton is also grown in some areas. Tractor services are available although most farmers plant with a cutlass or a stick.

Common Agricultural Practices in Study Zones

As mentioned earlier, no-till without residue cover has been practiced by most farmers in the Forest and Transitional Zones for centuries. The practice is very much associated with shifting cultivation, especially the slash and burn system, in which farmers slash existing vegetation with a cutlass, leave residues to dry for a few days, and then burn them. Often the slashed vegetation is not burned completely, and farmers spend a substantial amount of time and labor gathering unburnt debris to burn again for a clean field. This activity is labor intensive and comes at a time when labor is scarce. Planting is done with a dibbling stick or cutlass for seeds and cutlass and hoe or earth chisel for propagated crops. The land is cultivated for 2-3 years and allowed to fallow for 5-10 years. Fallowing depends on the productive capacity of the land. Fertilizer use (organic and inorganic) has been minimal or absent. Fertility restoration depends on the length of fallow, natural vegetation, and the rate at which soil nutrients are taken up by fallow vegetation from the subsoil. According to Akonbundu (1987), slash and burn is a tradition that was handed down as a practice that is beneficial to crop production. According to most farmers, burning gets rid of excess vegetation that hampers planting and seedling emergence.

Slash-mulch (popularly called "proka" in the local Akan language) is also a no-till land preparation method, practiced mostly by tree crop farmers. In slash-mulch, the forest is cleared of undergrowth and unwanted trees are felled and chopped without burning. Seeds or seedlings are planted through the mulch. To ease planting, some farmers prepare the land one year ahead of planting to allow decomposition. No herbicides are used. Slash-mulch declined when farmers realized that they needed to burn slashed vegetation to plant vegetables and other food crops alongside tree crops.

Demand for arable land in many parts of the country has increased in recent years in response to increasing human population. This situation is gradually moving the emphasis from resting fallow to continuous and intensive cropping.

A recent study found that in the Transition Zone, 68% of farmers used modern maize varieties and 29% used fertilizers; in the Guinea Savannah Zone, 66% used modern maize varieties and 36% used fertilizers; and in the Forest Zone, 38% used modern maize varieties and 9% used fertilizer (Morris et al. 1999). Less fertilizer is used in the Forest Zone because of the higher fertility of soils there. The no-till with mulch package developed for Ghanaian farmers is becoming popular with farmers in the Forest and Transition Zones as an effective means of reducing production costs and conserving soil and water in more intensive agricultural systems. This technology is described below.

Animal densities are low (relative to feed availability) in all three zones. Livestock production is more important in the Guinea Savannah than the Forest Zone. In the Guinea Savannah, animals graze freely, while in the Southern Regions grazing is controlled. In spite of a lack of fencing, animals are closely watched during cropping seasons. Animals are allowed to graze freely in the stubble between crop cycles. Animals trespassing into no-till fields have not been a problem for surveyed farmers, but further research is needed about the interaction between livestock and no-till, especially in the north.

Markets for agricultural inputs are used extensively in all three zones, especially for agricultural labor and special services. A large proportion of farmers contract labor or contractors for planting and weeding.

Some farmers prepare land for planting either with tractors or animal-pulled implements. This is more common in the Guinea Savannah. Animal-pulled planters are rare. The most common practice for land preparation is still slash and burn, a technique used by both small- and large-scale farmers.

No-Till in Ghana

Early Developments

Research on no-till in Ghana started almost simultaneously with early developments in Europe and the United States. In Ghana, however, these efforts were conducted by local individual researchers with little interaction with agrochemical companies or foreign researchers. The earliest research on no-till started in the late 1960s (Ofori 1973) and was boosted by Mensah-Bonsu and Obeng (1979) who reported the beneficial effects of no-till on soil and water conservation. These first researchers controlled weeds with paraquat.

In the 1990s, the no-till research effort was concentrated in CRI and the Ghana Grains Development Project (GGDP).[3] Roberto Soza, an agronomist from the International Maize and Wheat Improvement Center (CIMMYT) working with the

[3] The Ghana Grains Development Project was a collaborative effort that involved the Crop Research Institute, the Grains and Legumes Development Board, the Ministry of Food and Agriculture, CIMMYT and the International Institute for Tropical Agriculture (IITA), with funding from the Government of Ghana and CIDA.

GGDP, organized no-till research from 1990 until 1996. Originally, funding came from the Canadian International Development Agency (CIDA). In 1991, the GGDP adopted the no-till system for planting maize and grain legumes on five research stations. The system was also tested extensively in farmers' fields across the country.

In 1993, SG 2000, Monsanto, the GGDP at CRI in Kumasi, and the extension service from the Ministry of Food and Agriculture (MOFA) teamed up to promote no-till in the Transition and Forest Zones. The program received strong political support from the government (Findlay and Hutchinson 1999).

From 1993, Monsanto assisted the CRI to evaluate the efficacy of herbicide glyphosate in the powder form for no-till on farmers' fields with maize and beans.[4] Trial protocols and guidelines were established by Monsanto and discussed with CRI researchers, who implemented the trials with financial support from SG 2000.

The results showed that powder glyphosate was very effective for controlling weeds before planting, and since 1995, it has been the driving force behind increased adoption of no-till among small-scale farmers. Later, liquid glyphosate was introduced.[5] The main advantage of glyphosate over paraquat is greater efficiency in weed control.

After the first experiences, several experimental themes were developed around tillage— herbicide use, cover crops, and mulches—but the main thrust was weed control. The emphasis on weed control was different from other countries where substantial efforts were made to develop adequate machinery (i.e., planters and mechanized sprayers) (Ekboir 2002). This was the consequence of the weakness of the research effort in Ghana and the fact that most farmers in the Forest Zone do not use planters.

The experiment results were used to train extension service field officers who carried out their own demonstrations in farmers' plots. Initially the demonstrations were concentrated in the high rainfall areas of Ashanti and Brong Ahafo, but later expanded to the northern Guinea Savannah, where the program is administered by the University of Development Studies at Tamale, and implemented by extension services supported by SG 2000 and Dizengoff Ghana Ltd., a local distributor of fertilizers and pesticides (Findlay and Hutchinson 1999).

From an institutional point of view, the research effort, measured by the number of researchers and public resources committed, was weak. Since most of the research was conducted by a CRI agricultural engineer pursuing a Ph.D. (with support from extension agents), efforts were concentrated on weed control. Attempts were made to strengthen the network by enlisting the collaboration of other professionals (e.g. adapting a Brazilian jab planter to Ghana) but were not successful. Even today, public research institutions do not have formal research programs in conservation tillage. Despite this limitation, a few motivated and innovative researchers have recently joined the development effort.

Today, MOFA extension agents and CRI researchers work closely, following a participatory approach, to the point that farmers cannot distinguish between research and extension staff. Some rural banks and district assemblies have also joined in the promotion of no-till farming by providing credit to selected farmers.

Current no-till research at research institutes, universities, and projects like the Sedentary Farming Systems Project of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) centers on residue management, planting equipment, pest and disease control, cover crops, and rotations. The GTZ program is active in the Forest and Transition areas of Brong Ahafo.

The major challenges for no-till research in Ghana now hinge on the development of planting mechanisms, crop rotations adapted to farmers' objectives and resources, integration of cover crops in the no-till system, and introduction of slash practices that reduce labor requirements.

Dissemination of No-Till

Demonstration plots that were large enough to show the advantages of no-till under farmers' conditions were established. For direct comparison, demonstration plots were at least 1,000 m^2, both for farmers' "standard practice" plot and the no-till plot. The size was also convenient for the calibration of the

4 A water-dispersible granule presentation containing 420 g of glyphosate per kilogram.
5 A liquid presentation containing 360 g of glyphosate per liter.

15-liter sprayer. The package included the use of certified seed, herbicides, and fertilizer. The no-till technology transfer program focused on the elimination of burning, increase in organic matter on the soil surface, maintenance of soil structure (i.e., no soil inversion), and reduction in hand labor/time input. Activities included pre-season farmer training, on-farm demonstrations, field days, field tours, workshops and seminars, and distribution of fact sheets and production guides.

Pre-season training

Before the planting season, farmers and village agricultural extension agents were offered training that included a review of the no-till concept, sprayer calibration, time and rate of herbicide application, spraying technique, planting through mulch, fertilizer application, follow-up weed control, maintenance of crop residues after harvest, and rotations.

Pre-season training was participatory. Farmers who had command of the technology often led demonstrations. Each training session had between 5 and 20 participants. The number of farmers that were trained yearly is shown in Table 2.

Table 2. Number of farmers trained, Forest, Transition, and Guinea Savannah Zones, Ghana.

Year	Farmers trained
1996	43
1997	210
1998	547
1999	366
2000	350

Source: Boa (2000).

On-farm demonstrations

No-till demonstrations were routed through farmer groups from the already established Extension Test Plot program of the MOFA, SG 2000, and Agricultural Development Bank, several rural banks, and district assemblies. The recommended system included the use of certified seed, fertilizing at planting and as topdress, pre-planting weed control with herbicide, manual or chemical in-crop weed control, and harvesting with the objective of leaving crop residues on the field. Farmers were involved in all activities from site selection through to herbicide application to harvesting. Table 3 shows the annual number of no-till demonstration plots.

Table 3. Number of no-till demonstration plots, Forest, Transition, and Guinea Savannah Zones, Ghana.

Year	Demonstration plots
1996	170
1997	261
1998	321
1999	266
2000	440

Source: Boa (2000).

Demonstration plots were located at strategic points such as major footpaths, roads linking villages/towns, and major highways. Farmer demonstration fields were usually used for farmer field days.

Field days

Field days were organized at critical stages of the no-till farming process and served as a forum for interaction between researchers, extension agents, farmers, and input sellers. During a field day, the host farmer played the leading role in presenting the activity of focus. Collaborating research and extension staff assisted farmers to answer questions and clarify issues. A field day can have up to 50 farmers. The annual number of field days is shown in Table 4.

Table 4. Number of field days, Forest, Transition, and Guinea Savannah Zones, Ghana.

Year	Field days
1996	30
1997	30
1998	25
1999	40
2000	80

Source: Boa (2000).

Field tours

Field tours were organized within cluster areas to give host farmers the opportunity to show other farmers what was happening in their fields. Often host farmers discussed problems and how they were solved. This gave farmers an opportunity to learn from each other. There were both formal and informal field tours. Formal tours were those planned with the collaborating research and extension staff and had a larger number of participants. Informal tours were undertaken by farmers and usually involved a smaller group of farmers (up to five). The program also established links with the Sasakawa Center at the University of Cape Coast in Ghana, where final year agricultural students were conducted around farmers' no-till fields at the end of their soil conservation course.

Workshops and seminars
Workshops and seminars were organized occasionally for all stakeholders (farmers, research and extension staff) and input dealers to exchange ideas on no-till farming. Workshops and seminars are the only activities held outside the farm.

Distribution of fact sheets and production guides
Fact sheets highlighting the key components of the technology were distributed to extension agents and farmers. Production guides were also prepared with some detail to guide the extension staff involved in the program. The number of no-till fact sheets and production guides distributed is shown in Table 5.

Table 5. Number of fact sheets and production guides distributed, Forest, Transition, and Guinea Savannah Zones, Ghana.

Item	Copies
Fact sheet	2,500
Production guides	150

Source: Boa (2000).

The No-Till Package in Ghana

Initially, the farmer slashes the vegetation with a cutlass. This operation is very demanding in terms of time and effort. The labor required depends on whether clearing is done in a plot that was left fallow or already under cultivation. A plot that was left fallow will have a secondary forest and consequently requires more labor and effort to clear. A cultivated plot usually has only grasses and broadleaf weeds, and clearing is easier. In the traditional system, the farmer can farm a recently fallowed plot for about three years before it loses its fertility and the soil deteriorates. At this point, the farmer has to clear a new plot. Since fertility and most soil characteristics are maintained in the no-till system, the farmer can plant the same plot indefinitely.[6]

In the traditional system, farmers burn slashed vegetation. In the no-till system, weeds are allowed to grow to between 30 and 40 cm and then controlled with glyphosate; the recommended dose is 3 l/ha, but if more aggressive weeds like *Imperata cylindrica* are present, higher doses are required. On the other hand, farmers have found that efficient control can be achieved with lower doses of herbicides, especially in plots that have been cultivated with no-till for several years.

Table 6 compares the costs of land preparation and weed control for slash and burn and no-till. The clearing of forest is common to both technologies in the first year. Subsequently, it has to be done every three years in slash and burn. In the two intermediate years weeds are slashed in both slash and burn and no-till. In the former, the farmer still has to burn residues, while in the latter, the farmer applies herbicide. Slashing becomes easier with the number of years a plot remains under no-till.

In two out of three years, the cost advantage of land preparation under no-till compared with slash and burn is US$ 12.21/ha. In the third year, when a new plot has to be cleared, the cost advantage increases to US$ 49.71/ha.

Table 6. Cost of land preparation and weed control with slash and burn and no-till for a 1 ha plot in production, Forest, Transition, and Guinea Savannah Zones, Ghana.

		Cost (US$/ha)	
Operation	Quantity/ha	Slash and burn	No-till
Clearing	15 man-days	15	
Felling and chopping	10 man-days	10	
Burning	2.5 man-days	2.5	
Gathering	10 man-days	10	
Total of forest clearing (every 3 years)		**37.5**	
Slashing weeds	10 man-days	10	
Slashing weeds	7 man-days		7
Pre-plant herbicide spray†	0.5 man-days		0.5
Herbicide	3 liters		19.29
Hauling water	1 man-day		1
In-crop weeding†	40 man-days	40	
In-crop weeding†	10 man-days		10
Total cost every year		**50**	**37.79**
Cost difference			**12.21**
Total cost every 3 years		**87.5**	**37.79**
Cost difference			**49.71**

Note: US$ 1 = 7,000 cedis; cost of labor = US$ 1/man-day.
†From Findlay and Hutchinson (1999).

[6] However, intensification of agriculture would require the use of fertilizers to compensate for the higher rate of nutrient extraction.

Herbicide is applied with a knapsack sprayer with a 15-liter capacity. Initially, spraying was done with a high volume technique, which required 300 liters of water per ha. In recent years, a low volume/low pressure spraying technique, which required only 150 liters of water per ha, was introduced. In addition to increasing herbicide efficiency, the low volume technique saved substantial amount of labor used for carrying water from the source to the plot. To switch to the new spraying technique, a low volume nozzle is substituted for a high volume nozzle. Using this technique, a farmer has to walk 6.7 km when applying herbicide to one hectare.[7] On the other hand, a farmer has to walk 10 km and bend to hand weed one hectare with a hoe.

Since the herbicide cannot be seen on plants immediately after application, farmers were advised to use visual devices (e.g., ropes or a sighting pole) to keep track of where they needed to spray. However, most farmers still do not use these devices. This system of application may leave patches of untreated areas, so farmers were advised to delay planting for at least one week after applying glyphosate to identify untreated spots. Dead weeds are left on the ground and not incorporated into the soil.

Planting is done with a cutlass or dibbling stick directly through the mulch. Even though planters for mechanized and nonmechanized small-scale farmers have been developed in other countries (e.g., Brazil), these technologies have not been introduced in Ghana.[8] The cutlass and stick are also used when mulch is not used. For this reason, no special techniques for applying fertilizer with mulch are needed. After planting, weeds are usually controlled by hand. In some cases, farmers use pre-emergence herbicides, like alachlor + atrazine[9] or atrazine alone. Harvesting techniques are not affected by no-till.

The no-till package in Ghana includes improved seeds and fertilizers. Farmers were told that the full benefits of no-till could be obtained only with the whole package. These two practices were also promoted for conventional tillage under the GGDP.

Even though it would be possible to isolate the impact of no-till from the impact of using improved seed and fertilizer, it was decided not to do so because no-till is not just a weed management practice but a new farm management system. The adoption of improved seed and fertilizer gave better results with no-till (as will be seen later).

Methodology and Data Collection

This study focused largely on the impact of no-till technology on farmers who adopted the technology; the reasons for nonadoption were studied in less detail. The impact of no-till on formal herbicide dealers[10] was also evaluated. Farmers' level of adoption was not estimated because of budget constraints. Two surveys were conducted, one with farmers and the other with input dealers (namely formal herbicide dealers). The farmer sample included three categories of farmers – those who were using the technology (NT users), those who used and abandoned it (abandoned NT), and those who never used the technology (never used NT). The dealer sample included input dealers in both villages and district capitals.

Data collection

For the farmer survey, a two-week planning session was held from 10-25 October 2000 with scientists from CIMMYT, CRI, and MOFA at CRI headquarters in Kumasi. During the session, questionnaires were developed and pre-tested, and enumerators were trained in the use of questionnaires. Six teams, each made up of two enumerators were organized. All enumerators were CRI technical staff with a university diploma. Training included discussion of survey objectives, review of survey questionnaire, and role-playing.

The field survey was conducted in November and December 2000. One enumerator conducted the interview while the other recorded responses. Each interview lasted an hour for NT users and half an hour for those who abandoned NT and never used NT. The input dealers survey was conducted on July and early August 2001. Each interview lasted about half an hour.

[7] Older nozzles have a 1 m swath. Presently most farmers use a nozzle with a swath of 1.5 m and some 2 m. Our calculation is based on a 1.5 m swath.

[8] Small-scale farmers in Brazil can be large-scale farmers in Ghana. A farmer is small in Brazil if he farms less than 50 ha.

[9] Alachlor + atrazine is known by its commercial name, Lasso-atrazine.

[10] A formal dealer is someone who has an established location and whose primary activity is selling agricultural inputs. Research/extension agents, on the other hand, provide mostly research and extension services and trade in herbicides on the side

Sampling procedure
The farmer survey was conducted in the Ashanti, Brong Ahafo, and parts of the Northern Region, where no-till technology was demonstrated. A two-stage sampling procedure was used. Thirty villages were randomly chosen. These consisted of 25 villages in the Ashanti and Brong Ahafo Regions that had no-till demonstrations; to get information on peri-urban agriculture, two villages near Kumasi were also included. Only three villages in the Northern Region were selected because of lack of time and resources.

In each selected village, a list of farmers using no-till was collected from extension agents. From this list, and depending on the number of no-till users, 3-4 farmers were randomly chosen from each village. In total, 91 farmers were interviewed. It was not possible to prepare a similar list of farmers who used and abandoned no-till because almost all farmers who tried it never returned to conventional tillage. Consequently, in all villages, extension agents and farmers were asked to identify farmers who fell into this category. Only 18 cases were identified.

Since it was not possible to compile a list of farmers who never used no-till, one or two houses (depending on the size of the village) in each village were selected randomly, and farmers who fell into this category were interviewed; 37 farmers who never used no-till were interviewed.

The total sample size was 146. A summary of the sampling procedure is presented in Table 7. The location of the sampled villages and districts is given in Appendix 1.

Table 7. Sampling procedures, Forest, Transition, and Guinea Savannah Zones, Ghana (no.).

Category of user	Villages	Sample unit	Expected sample size	Actual sample size
NT users	30	3-4	91	91 (62.3%)
Abandoned NT	30	1	30	18 (12.3%)
Never used NT	30	1-2	30	37 (25.3%)
Total	30	5	150	146 (100%)

The dealer survey was carried out in the same villages as the farmer survey. In villages where there were no dealers, a nearby village where dealers were available was sought. As most input dealers are found in district capitals, both input dealers in villagers and district capitals were interviewed.

In total, 28 smallholder input dealers were interviewed—15 in Ashanti, 8 in Brong Ahafo, and 5 in the Northern Region. Twenty-two dealers were located in district capitals and 6 were located in non-district capitals. The sample included 8 district capitals and 5 towns that had no administrative functions. The list of cities and villages included in the survey and the number of dealers in each location is given in Appendix 2.

Characteristics of Sample Farmers

Characteristics of sample farmers are shown in Table 8. There was little difference among the various categories of farmers for the majority of variables in the table. Most farmers were married; however, unmarried farmers (both male and female) constituted a larger percentage of farmers who never used NT. Two-thirds of NT users and those who never used NT, and half of those who abandoned NT are natives of the region. There were more illiterate people among farmers who never used NT.

Household sizes were also not significantly different for all categories. On average, each family had 2.6 adult males, 2.5 adult females and 3.7 children under 16. Wealth indicators (availability of water and electricity, ownership of bicycle, car, tractor or different types of livestock) were also similar for all groups.

Differences Among Sample Farmers by Ecological Zones

Table 9 shows descriptive statistics for the aggregate of the three groups of farmers in each of the three zones. The small sample size in some ecological zones prevented the analysis of fully disaggregated data, i.e., the analysis of nine separate groups (three farmer types in three zones). Thus the analyses were based only on the three categories of farmers already defined (NT users, abandoned NT, and never used NT). Even though some information is lost in this aggregation, the effects are relatively minor.

Differences between farms in the three zones were not statistically significant. We found no explanation for differences in the number of pigs and distance to an agrochemical dealer between farmers in the Forest and Transition Zones, or the difference in years of schooling between farmers in the Forest and Guinea Savannah Zones.

The majority of farms in the Forest and Transition Zones have expanded because of the combined action of public extension service in collaboration with SG 2000, Monsanto, and a strong program financed by GTZ that promotes sedentary agriculture and no-till in the Brong Ahafo Region. The greater expansion in the Transition Zone reflects the relative ease of clearing grasses and bushes compared to trees in the Forest Zone.

Table 8. Characteristics of sample farmers, by farmer type, Forest, Transition, and Guinea Savannah Zones, Ghana.

Characteristic	NT user	Abandoned NT	Never used NT	Difference between NT users and those who abandoned NT	Difference between NT users and those who never used NT
Male (%)	86	83	65	NS	S
Female (%)	14	17	35	NS	S
Marital status (%):					
Married	84	94	70	NS	S
Others	16	6	30		
Age (yr):					
Minimum	21	26	20	NS	NS
Maximum	75	65	75		
Mean	42.6	41.8	40.2		
Residence status in the region (%):					
Native	64	56	65	NS	NS
Settler	36	44	35		
Formal education (%):					
None	17	17	24	NS	NS
1-5 yr	12	6	3		
6-10 yr	49	56	53		
>10 yr	22	21	20		
Mean (yr)	8.3	8.3	7.7	NS	NS
Adult males (no.)	2.8	2.2	2.2	NS	NS
Adult females (no.)	2.6	2.3	2.2		
Children <16	4	4.2	2.8		
Number of observations	(91)	(18)	(37)		

Note: NS = not significant; S=significant at the 95% confidence level.

Table 9. Characteristics of sample farmers, by zone, Forest, Transition, and Guinea Savannah Zones, Ghana.

Characteristics	Forest	Transition	Guinea Savannah	Difference between Forest and Transition Zones	Difference between Forest and Guinea Savannah Zones
Farm size (ha)	2.0	3.2	1.9	NS	NS
Cattle (no.)	0	0.24	2	NS	NS
Pigs (no.)	0	0.87	0	S	NS
Sheep/goats (no.)	4.2	4.5	9.9	NS.	NS
Bullocks (no.)	0	0	1	NS	NS
Chicken (no.)	12	18	28	NS	S
Distance to main herbicide supplier (km)	35	53	26	S	NS.
Age (yr)	41	42	47	NS	NS
Schooling (yr)	9	8.6	3	NS	S
Adult males in household (no.)	2.3	2.7	2.9	NS	NS
Adult females in household (no.)	2.3	2.4	3.1	NS	NS
Children <16 in household (no.)	3.9	3.3	5.9	NS	NS
Increased area in last 5 years (% farmers)	63	84	23	S	S
Area remained the same in last 5 years (% farmers)	26	5	78	S	S
Decreased area in last 5 years (% farmers)	12	11	0	S	S
Number of surveys	114	19	13		

Note: NS = not significant; S = significant at the 95% confidence level.

Gender Issues

As pointed out earlier, male farmers predominate in all three groups. However the proportion of women is larger among those who never used no-till (Table 10). Other studies of Ghanaian agriculture have found that the proportion of female farmers is about 30%, similar to that of female farmers who never used no-till (Morris et al. 1999).

On average, women farm about half the area as men and seem to be less innovative. Only 21% of women reported trying new things in their fields against 43% of men. Maize yields obtained by female farmers were also lower. These differences can be explained by the fact that more women have nonagricultural occupations. While they are not formally employed, women work at home and/or are traders. Hence, they tend to be part-time farmers who go to the field later in the day. This affects the efficiency of some agricultural practices such as spraying, which should be done early in the morning.

Other indicators showed no significant difference between male and female farmers. Both groups had similar patterns of interaction with research/ extension agents, grew the same crop combinations, had the same years of schooling, and tried to simplify soil preparation. There were also no differences in wealth.

Table 10. Gender differences in selected variables, Forest, Transition, and Guinea Savannah Zones, Ghana.

Variables	Male	Female	Difference
Maize yield in 2000 (t/ha)	1.4	0.8	S
Normal maize yield (t/ha)	1.6	1.1	S
Years of schooling (mean)	9.0	7.0	NS
Tried new things in field (%)	43.0	21.0	S
Tried to simplify soil preparation (%)	35.0	24.0	NS
Total land farmed (ha)	3.0	1.6	S
Employed off-farm (%)	8.0	0	S
Employed in nonagricultural job (%)	6.0	0	S
Remittances (%)	1.0	7.0	S
Sale of animals (%)	7.0	3.0	S
Poultry sales (%)	9.0	0	S
Trading (%)	13.0	28.0	S
Sale of prepared food (%)	0	7.0	S

Note: NS = not significant; S = significant at the 95% confidence level.

Most farmers made their own decisions irrespective of gender and thus have equal rights to decision-making (Table 11). A particular characteristic of Ghanaian agriculture is that women frequently manage their own fields, contribute an important proportion of overall labor, and exercise complete discretion over farming activities, such as the disposal of harvest and cash (Morris et al. 1999).

Table 11. Decision-making on largest no-till field among male and female farmers, Forest, Transition, and Guinea Savannah Zones, Ghana (%).

	Decision-making		
Practice	Male	Female	Difference
Selecting crop	90	92	NS
Planting	97	92	NS
Fertilizer	71	54	NS
Weeding method	96	92	NS
Pesticide use	82	85	NS
Residue management	90	85	NS
Selling grain	90	92	NS
Use of cash from sale	86	77	NS

Note: NS = not significant.

Both women and men farmers who used herbicides were aware of agrochemical prices in other villages. In other words, both groups have the information to participate equally in the market. However, a larger share of female farmers do not use herbicides.

Attitude Towards Innovation

Compared to five years ago, 69% of NT users and 72% of those who abandoned NT increased their farming area, whereas only 30% of those who never used NT increased their farming area (Table 12). The reason for the expansion is that no-till users and farmers who abandoned NT are more innovative than farmers who never used no-till. A larger percentage of NT users and those who abandoned NT reported trying new things in their fields, trying to simplify land preparation, and talking to an extension agent at least once a month.

No-till users and those who abandoned NT have more farming experience than those who never used NT. On average, NT users have been making their own decisions about farming for 14 years, those who abandoned NT for 13 years, and those who never used NT for 9 years. Furthermore, NT users have worked continuously on the same land for 6 years, those who abandoned NT for 7 years, and those who never used NT for 4 years.

Table 12. Changes in area planted among NT users, those who abandoned NT, and those who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Changes	NT users	Abandoned NT	Never used NT	Difference between NT users and those who abandoned NT	Difference between NT users and those who never used NT
Increased land	69	72	30	NS	S
Land remained same	23	22	49	NS	S
Decreased land	8	6	22	NS	S
Tried new things in field	47	39	16	NS	S
Tried to simplify soil preparation	36	44	18	NS	S
Talked to an extension agent at least once a month	63	56	40	NS	S

Note: NS = not significant; S = significant at the 95% confidence level.

Income Sources

Agriculture was the main source of income for all sample farmers (Table 13).

Table 13. Income sources, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Income source	NT users	Abandoned NT	Never used NT
Agriculture	92	94	95
Nonagriculture	8	6	5

The most important cash crops, in order of importance, are maize, vegetables, and yam for NT users; maize, cassava, plantain, and vegetables for those who abandoned NT; and maize, plantain, vegetables, cassava, and rice for farmers who never used NT. Seven crops were mentioned by NT users, two by farmers who abandoned NT and five by farmers who never used NT, as important cash crops. The information indicates that those who abandoned NT are more specialized than the other two groups.

Maize is the most important crop for all three categories of farmers; 83% of NT users, 94% of those who abandoned NT and 65% of those who never used NT mentioned maize as a major crop, followed by cowpea and cassava. Plantain comes far below as the second crop and is only mentioned by farmers who abandoned NT. Farmers who abandoned NT and those who never used NT also mentioned vegetables. Adoption seems to be linked to crops grown, since no-till technologies for plantain and vegetables have not yet been developed in Ghana.

Input Use, Input Sources, and Extension Services

Markets for agrochemicals are developing fast in response to the expansion of no-till. There are currently two parallel channels for distribution of agrochemicals: formal dealers and research/extension agents (see below). Both channels seem to work well in the surveyed zones and different types of farmers appear to prefer each of these channels. Seventy-four percent of NT users know herbicide and fertilizer prices outside their village compared to 45% of farmers who abandoned NT and 5% of farmers who never used NT. This finding reinforces the picture that users and those who abandoned NT are more resourceful and innovative than those who never used no-till, because they not only are better farmers but also use markets better.

The mean distance from a farmer's home to the main agrochemical purchase point was 22 km. Differences in mean distances for all three groups were not statistically significant. Sixty-six percent of NT users and 67% of those who abandoned NT were able to get agrochemicals when needed. On the other hand, 30% of users and 11% of those who abandoned NT had difficulties in timely access to agrochemicals. Ninety-five percent of those who never used NT did not use agrochemicals, and only 5% were able to get fertilizers on time.

No-till users have closer contact with extension/research agents than farmers in other groups. Even though NT users and those who abandoned NT see extension/research agents as often, NT users interacted more closely with them. No-till users get more seed and herbicide through research/extension than the open market (Table 14). Forty-two percent buy certified seed of improved maize varieties through research/extension agents or cooperatives compared to 17% of those who abandoned NT and 14% of those who never used NT. Also, 33% of NT users get agrochemicals through research/extension agents who also provide technical advice. Only 12 farmers in the whole sample mentioned herbicide dealers as a secondary or tertiary source of information on herbicide use, but none mentioned them for other information. If carefully managed, the dual role of research/extension agents as technical advisers and input dealers could be the base for the development of a private extension system.[11]

Farmers who abandoned NT buy more seed and herbicide from the open market and other non-certified sources. Farmers who never used NT get seed from neighbors and do not use fertilizer.

Agrochemical dealers sell on credit to a small proportion of farmers; only 17% of NT users and 11% of those who abandoned NT obtained credit for agrochemicals from dealers in 2000.

Herbicide prices do not seem to be a major hurdle for farmers who adopted the technology. Only 3% of NT users complained about rising herbicide prices against more than 50% of farmers who never used the technology.

Even though there is an active market for planting services, its performance could be improved by training contractors. Forty-eight percent of NT users contract planting, 50% find it difficult to find a contractor to plant on time, and a similar proportion find it hard to get a well-trained contractor. This problem is more acute for small- and large-scale farmers (75% of NT users with less than 0.4 ha and 50% of farmers with more than 5.6 ha).

There is also a market for services for weed control. Only 34% of farmers own a knapsack sprayer to apply herbicides, 48% rent one (implying that they apply the herbicide themselves), and 18% contract for herbicide application. Most farmers (90%) who contract for spraying do not find it difficult to find a well-trained service provider.

More farmers contract for planting than spraying because planting is more demanding. More farmers complained about the cost of contracting for planting than spraying. This finding highlights that planting

Table 14. Source of inputs among NT users, those who used and abandoned NT, and those who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Input sources:	NT users	Abandoned NT	Never used NT	Difference between NT users and those who abandoned NT	Difference between NT users and those who never used NT
Maize seed					
Research/extension	40	17	14	S	S
Seed dealer	29	39	24	S	S
Own farm	23	17	16	S	S
Neighbor	4	0	39	S	S
Market	2	28	5	S	S
Cooperative	2	0	0	S	S
Other	0	0	3	S	S
Herbicide					
Chemical dealer	61	67	NA	S	S
Research/extension	33	11	NA	S	S
Cooperative	3	0	NA	S	S
Sprayer contractor	1	0	NA	S	S
Other	2	22	NA	S	S
Fertilizer					
Chemical dealer	33	56	3	NS	S
Research/extension	21	6	0	NS	S
Cooperative	1	0	0	NS	S
Other	3	6	5	NS	S
Not applicable	42	32	92	NS	S

Note: NS = not significant; S = significant at the 95% confidence level; NA = not aplicable.

[11] A discussion of the structure of extension systems in developing countries is beyond the scope of this project. We must stress, though, that the development of a private extension system is not synonymous with complete technical and financial withdrawal of the public sector.

is one of the major obstacles to further diffusion of no-till while spraying does not seem to be a major problem.

There is an active market for land; 28% of farmers in all categories rent land. In general, farmers use the same plot for several years, irrespective of the technology they use. Since long-term contracts allow farmers to recoup the benefits of improvements (including no-till), land tenure does not seem to be a problem for diffusion of no-till.

Management of the Most Important Maize Field

The management of maize was assessed in detail because of its relevance in Ghanaian agriculture. Since most farmers grow their crops on more than one plot, questions were concentrated on farmers' most important maize plot. Differences in land tenure and differences in the size of farmers' first maize field were not statistically significant among all three groups of farmers (Table 15).

There is, however, a significant difference in maize varieties planted. A higher proportion of NT users and those who abandoned NT planted the most modern variety (Obatanpa), while farmers who never used NT planted old varieties that were no longer recommended by research/extension services. The use of older varieties by these farmers indicates little contact with extension agents for advice or help. This strengthens the assertion that farmers who never used NT are less resourceful and innovative than the other two groups.

Table 15. Characteristics of most important maize field among NT users, those who abandoned NT, and those who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Characteristic of most important maize field:	NT users	Abandoned NT	Never used NT	Difference between NT users and those who abandoned NT	Difference between NT users and those who never used NT
Size of field (ha)	2.9	3.7	2.3	NS	NS
Land tenure (% farmers)					
Own	66	47	61	NS	NS
Sharecropping	7	12	14		
Rent	22	29	22		
Other	5	12	3		
Maize variety used (% farmers)					
Obatanpa	47	59	22	NS	S
Old improved	26	23	59		
Local	28	18	19		
Main intercrop with maize (% farmers)					
None (monocrop)	39	28	14	NS	NS at the 95%
Cassava	26	44	59		confidence level
Plantain	15	18	8		S at the 90% confidence level
Land preparation (% farmers)					
Spraying (no-till)	74	0	0	S	S
Slash and burn†	22	83	78		
Ridge/mound	1	6	3		
Tractors	1	6	6		
Not applicable	2	5	13		
Planting pattern (% farmers)					
Lines	79	59	53	NS	S
Ridges	7	18	3		
Random	14	23	44		
Maize yields (t/ha)					
Actual	2.2	1.6	1.4	S	S
Normal	2.9	2.5	2.0		

Note: NS = not significant; S = significant at the 95% confidence level.

†Slash and burn reported for NT users is a controlled burn to reduce residues left on the soil (see text for a full explanation).

The difference in the use of intercrops between NT users and those who abandoned NT on the one hand, and those who never used NT on the other, is marginally significant. Researchers recommend increasing the density of maize plants which reduce the possibility of intercropping. Again, farmers who never used NT used traditional farming practices. Crops most commonly intercropped with maize were cassava and plantain.

Differences in land preparation methods between the groups were statistically significant. Some NT users (22%) practice partial burning, a form of slash and burn that reduces the volume of mulch after slashing to facilitate planting. Plant residues are burned a few days after a heavy rain. Since only the top cover is dry, the fire does not damage residues at the bottom. Residues left on the ground are enough to keep the soil properly covered. Weeds are then allowed to grow and are controlled with herbicide.

The percentage of farmers in the sample who used tractors for land preparation is lower than in the general population, reflecting a biased sample. Mechanized no-till is not feasible without adequate planters, but planters are not available in Ghana. As the survey focused on farmers who used no-till, most farmers who used tractors would not have tried it and were less likely to be interviewed.

The traditional planting method is random, while the practice recommended by research and extension is to plant in lines or on ridges. There was little statistical difference in planting methods between NT users and those who abandoned NT, while the difference between NT users and those who never used NT was statistically significant. This is again another indication that farmers who never used NT are less innovative than farmers who used NT.

Yields were below normal in 2000 because the major season was dry. When asked about yields in the 2000 crop season and in a normal year, NT users reported higher yields in both compared to the other two categories of farmers. Since no-till improves moisture conservation, higher yields in users' fields were expected. Yield reductions due to drought was lower for NT users (24%) than for those who abandoned NT (36%) and never used NT (30%). In short, no-till increased yields and reduced the risk of bad crops in dry years, a particularly important feature in Africa.

No-Till Among Survey Farmers

Knowledge/perception

Farmers in all three categories felt that most or several farmers in the village used no-till (Table 16). Similarly, all three groups (NT users, 88%; abandoned NT, 61%; never used NT, 70%) think that the number of NT users is increasing although the perception is lower among those who abandoned NT. The majority of farmers in all groups thought NT users were of average wealth. In other words, no-till is not perceived as a technology for rich farmers. Also, farmers in all categories thought that income and food availability in households that use no-till is increasing. This perception is highest among NT users and lowest among those who never used NT. The difference in perception may arise from different personal experiences with no-till. As will be seen later, NT users actually mentioned that their income increased after adopting no-till.

A greater share of NT users and their families have a good opinion about no-till than the other two groups. A large majority of those who abandoned NT and their families also considered no-till a good technology. The large share of those who never used NT who had no opinion reflects lack of knowledge about the technology. Extension programs targeted to this group could accelerate adoption.

Diffusion of No-Till in Study Area

A pattern of dissemination of no-till was constructed from farmers' responses about the year in which they first used no-till. Farmers were also asked if they gave land for demonstration plots, and if the answer was affirmative, the year in which the demonstration occurred.

Table 17 shows the rate of diffusion of no-till in the three zones studied. Diffusion was slow during initial years, accelerated in the early 1990s, and stabilized in the late 1990s; demonstration plots show a similar pattern. The last three years show no clear trend. In the period of expansion, extension services received support from the National Agricultural Extension Project.

This diffusion pattern could have two alternative explanations over which the sample can shed no light: adoption has reached saturation as most potential adopters are already using the technology or, alternatively, extension efforts were reduced in the late 1990s, exposing less farmers to the technology.

Table 16. Perception of no-till among NT users, those who abandoned NT, and those who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

	NT users	Abandoned NT	Never used NT	Difference between NT users and those who abandoned NT	Difference between NT users and those who never used NT
How many farmers in village use no-till?					
Most	37	39	27	NS	NS
Several	42	39	35		
Few	20	17	35		
Not applicable	1	5	-		
How wealthy are farmers who use no-till?					
Rich	18	11	14	NS	NS
Average	74	83	76		
Poor	8	0	0		
Not applicable	0	6	10		
Do farmers who adopt no-till have more income than before adopting?					
Yes	98	72	65	S	S
No	0	6	0		
Cannot tell	2	22	35		
What is your spouse's opinion about no-till?					
Good	87	78	30	S	S
No good	1	17	5		
No opinion	12	5	65		
What is your relatives' opinion about no-till?					
Good	97	83	43	S	S
No good	2	11	11		
No opinion	1	6	46		
How is no-till viewed in your village?					
Good	99	89	65	S	S
No good	1	6	3		
No opinion	0	5	32		

Note: NS = not significant; S = significant at the 95% confidence level.

Table 17. Diffusion of no-till among farmers in the Forest, Transition, and Guinea Savannah Zones, Ghana (no.).

Year	Farmers who tried no-till for the first time	Demonstration plots
1980	1	1
1981	1	0
1982	1	0
1988	1	0
1990	1	0
1991	1	0
1992	3	1
1993	3	1
1994	7	2
1995	15	2
1996	20	4
1997	9	6
1998	15	3
1999	11	5

The number of potential adopters is a function of the technology available. As was discussed before, the availability of planters could make the technology suitable for mechanized farmers. Further research is needed to clarify this point.

Learning About No-Till

The first experience with no-till determines the probability of using or abandoning the technology. Most farmers (NT users as well as those who abandoned NT) received help during the first trial (about 40% from research and 20% from a neighbor). Seventy-two percent of NT users first learned about no-till from a research or extension agent, while 21% learned from another farmer. For those who abandoned NT, only 36% learned from a research or extension agent while 56% learned from another farmer.

The proportion of farmers who used both herbicides and manual weed control in the first trial is higher among those who abandoned NT (Table 18). These statistically significant differences may indicate that those who abandoned NT did not receive proper training in no-till or herbicide use. Most NT users (98%) and those who abandoned NT (88%) left residues on the ground after harvest during the first trial.

About 60% of NT users and those who abandoned NT planted their first trial with a cutlass and did not use animals or machinery. Most NT users had excellent result with the first trial, and 2% had a good first trial. In contrast, only 39% of those who abandoned NT reported an excellent first trial; 16% had a good first experience and 16% a fair one.

The opinion of neighbors on the appearance of no-till fields relative to the clean slash and burn fields was not a problem for 83% of farmers in the sample. The opinion of neighbors was a major obstacle for farmers in other countries (Ekboir 2000). Currently, research and extension services continue to be the most important source of information on no-till as 79% of NT users and 83% of those who abandoned NT obtained information from them. Only 11% of NT users and 17% of those who abandoned NT mentioned other farmers as their main source of information. Twenty-seven percent of NT users gave land for no-till demonstrations. Of these, 20 plots (83%) were used for maize.

Seventy percent of NT users and 56% of those who abandoned NT received some training from research and/or extension agents, a statistically significant difference. More than 70% of NT users were trained in herbicide use, weed management, and planting; 31% were trained in residue management, and 35% in fertilizer use. The proportion of NT users trained in soil management, rotation planning, certified seed use, and organic matter use is very low (less than 10% for each category). These categories reflect the emphasis of past research efforts. Based on international experience with no-till, it seems reasonable to conclude that increasing the sustainability of the no-till package will require broadening the research and training portfolio.

Table 18. Results of first no-till experience among NT users and those who abandoned NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

First no-till experience	NT users	Abandoned NT	Difference
Weed management			
Herbicide	43	21	S
Manually	47	50	
Herbicide and manually	10	29	
What was the result of the first trial?			
Excellent	74	39	S
Very good	23	28	
Good	3	17	
Fair	0	16	
Bad	0	0	

Note: NS = not significant; S = significant at the 95% confidence level.

Only 48% of NT users belong to a no-till discussion group. Seventy-two percent of those who abandoned NT do not belong to any discussion group and may find it hard to get advice on the use of the technology. In South America, stable discussion groups have been very effective in helping farmers solve problems with no-till (Ekboir, 2000).

Farmers Who Used No-Till

The vast majority of NT users (84%) practice continuous no-till, which is recommended to reap long-term economic and environmental benefits. The longest period of uninterrupted use of no-till was 10 years. Most farmers used no-till uninterruptedly for 3 to 6 years. Seventy-five percent practiced no-till during both major and minor seasons, and 9% of users practiced no-till during one cropping season (because the rainfall pattern allows only one season). Only 16% of farmers used no-till once in two seasons.

The number of farmers who do not use no-till continuously because they are learning is very low (4%), indicating that they do not have major problems finding information and advice on no-till. However, 30% of NT users reported that they have problems controlling weeds and occasionally revert to slash and burn.

Forty-three percent of NT users do not use no-till on all their land. Of these, 11% mentioned that no-till is not good for some crops, indicating that research on no-till has concentrated on a few crops such as maize and cowpea. To expand the use of continuous no-till there is a need to broaden research to other crops. Twenty-two percent of farmers also mentioned financial restrictions to expansion of no-till.

Compared to other countries, in Ghana, the no-till package represented a less dramatic change from conventional agricultural practices. This explains why 65% of NT users reported that it was not difficult to gain command of the package; 77% realized benefits in the first season and 94% within two seasons (Table 19).

Table 19. Number of seasons it took NT users to notice benefits of no-till, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Seasons	NT users	Cumulative
One	77	77
Two	17	94
Three	2	96
More than three	4	100

No-till users were also asked about problems associated with no-till (Table 20). Learning something totally different from what they used to do was mentioned by 88% of farmers; however, only 31% found learning the package difficult. This difference indicates a divergence between the *a-priori* perception of the difficulty of the package and the actual degree of complexity, which can be reduced with information programs.

It is usually claimed that small-scale farmers spend more money on commercial inputs with no-till than conventional tillage. However, only 33% of NT users mentioned this as a problem. As will be seen later, a large proportion of farmers contract several tasks and no-till greatly reduces labor requirements for many of these operations. In other words, for most NT users in Ghana, no-till changes the inputs that have to be purchased (substitutes herbicides for labor) and results in lower expenses per unit of land.

No-till users' responses to problems they faced with no-till confirm earlier findings. The biggest agricultural problems are planting (28%) and plant survival (24%). These problems could be greatly reduced with the introduction of planters.

Table 20. Opinions of NT users on problems with no-till, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Problem	Strongly agree
Different from what we used to do	88
Difficult to learn the package	31
I have to buy more inputs	33
No-till works in other fields but not mine	10
Planting is difficult	28
Difficult to keep soil covered	11
Difficult to manage herbicides	20
Fewer plants survive	24

In general, innovative abilities are found in only a minority of individuals, and Ghanaian farmers are no exception; only 10% of NT users admitted modifying the recommended package. All tried to reduce the dosage of herbicide. The fact that these farmers only tried alternative dosages for herbicides reflects two facts; first, that herbicides are a major expense and farmers are trying to save on this, and second, even though there are other tasks where farmers could save labor (e.g., slashing) or improve yields (e.g., planting), they have not been exposed to solutions developed in other countries.

Farmers tend to stay on the same plot for several years (Table 21), thus allowing for the attainment of long-term no-till benefits. Eighty-three percent of NT users who rent land did not have problems renewing their lease after adopting no-till.

Table 21. Number of years NT users stay on the same plot, Forest, Transition, and Guinea Savannah Zones, Ghana.

Years	Years on the same plot (frequency)	Percentage	Length of contract (frequency)	Percentage
1	5	15	5	19
2	6	18	3	11
3	9	25	5	19
4	4	12	2	8
5	3	9	5	19
6	0	0	1	4
7	1	3	0	0
9	1	3	0	0
10	3	9	2	8
15	0	0	1	4
20	1	3	2	8
30	1	3	0	0

Agricultural practices

More than 80% of NT users follow the recommended no-till package. Seventy-five percent controlled weeds with glyphosate before planting, while 5% controlled weeds by hand; 16% used alachlor+atrazine, indicating a lack of knowledge about herbicide use (Table 22). After planting, 44% of farmers controlled weeds by hand, while 39% used atrazine or alachlor-atrazine. The proportion NT users using only atrazine is slightly higher than alachlor-atrazine. If weeds are sparse, farmers can control weeds with only one application using glyphosate or glyphosate + alachlor-atrazine or atrazine immediately after planting; this practice was used by 12% of NT users.

Table 22. Pre- and post-planting weed control methods of NT users, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

	Farmers	
Method	Pre-planting	Post-planting
Glyphosate	75	9
Alachlor-atrazine	16	18
Manual	5	44
Slash/burn	3	0
Mechanically with tractor	1	1
Atrazine	0	21
Paraquat	0	4
Glyphosate + alachlor-atrazine	0	3

Most farmers (70%) used less glyphosate than recommended by researchers (3 l/ha); a large proportion used 1.8 l/ha and 2.5 l/ha (Table 23). This is because farmers use a milk tin of 180 ml per knapsack of 15-liter capacity (150 liters spray volume per ha) as a unit of measurement. One milk tin results in using 1.8 liters of herbicide per hectare, and 1.5 tins result in 2.5 liters per hectare. Most farmers use less herbicide than the recommended dose because weed control becomes easier the longer no-till is used. Thus, the dose actually needed by farmers who have been using no-till for a few years may be lower than the recommended one. Further research on this topic is needed.

Table 23. Glyphosate dose used by NT users for pre-planting, Forest, Transition, and Guinea Savannah Zones, Ghan.

Glyphosate dose (l/ha)	Farmers applying dose (%)
<1.8	16
1.8	23
>1.8, but <2.5	7
2.5	24
3 (recommended)	4
>3	7

The most prevalent weeds are grasses, which 86% of farmers reported controlling. Even though broad-leaf weeds are present, they are not a major problem. Only 14% of farmers reported that they had to control them.

Farmers also followed other recommended no-till practices. For example, 87% of farmers sprayed at the recommended weed height of about 40 cm and used a clean water source (Table 24).

Table 24. Other no-till recommended practices adopted by NT users, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Recommended practice	Farmers adopting
Weed height	87
Water quality	87
Spraying technique	80

Eighty percent of farmers keep the soil adequately covered at planting but 37% do not have adequate cover at flowering because residues decompose too fast. Many farmers (45%) add some organic matter. Problems caused by the rapid decomposition of residues could be solved by adequate research to identify acceptable rotations or new plant varieties that decompose less rapidly.

Low animal density and lack of draft animals aided the dissemination of no-till in Ghana. There were no complaints about animals eating stubble because, unlike other countries, demand for plant residues for livestock in Ghana is small. Finally, burning by neighbors also was not a problem for the vast majority of NT users in the sample.

Sixty-seven percent of NT users reported seeing a change in weed species after a few years of using no-till; weed control was actually easier for 70% of NT users. They reported no increase in pest pressure in terms of quantities and/or species (Table 25). Actually, 57% of users found pest control easier under no-till.

Table 25. Pest pressure observed by NT users, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Pest pressure:	Farmers
Sees more pests of the same type as before adopting	16
Sees different pests today	20

Most NT users in the Peri-urban (100%), Transition (69%) and Guinea Savanna (100%) used fertilizer. Only 30% used it in the Forest area because of greater fertility in the area. The Peri-urban area has similar ecology to the Forest area but the land is used more intensively and replenishment of nutrients is needed (Table 26).

Table 26. Fertilizer application in no-till fields, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Ecology	Farmers using fertilizer
Forest	30
Peri-urban	100
Transition	69
Guinea Savannah	100
All ecological zones	49

Most NT users (78%) did not change the crops they planted with adoption of no-till. Only 30% used rotations. The most common rotations are maize-cowpea (20%) and maize-cassava (9%). Only one farmer (1%) used maize-tomato. These practices reflect lack of market opportunities, lack of adequate technologies that fit into current production patterns, or lack of information channels that permit farmers to learn about new crops. Adequate research and extension programs can solve some of these problems and increase the impact of no-till.

Farmers Who Used and Abandoned No-Till

When a farmer switches to no-till, the dynamics of the agricultural system adjust to the new management practices. In particular, weed populations and soil, flora, and fauna change dramatically. It generally takes three years for these changes to occur before a major response is required by the farmer. If the farmer succeeds in adjusting the no-till practices to the new environment, he or she will be able to continue using it. Some farmers, however, never succeed in finding the appropriate practices and revert to conventional tillage.

Farmers in the sample who tried no-till and then abandoned it used it for a mean of 3.1 years. One-third of them used the technology for four years before abandoning it, while only 17% abandoned it in the first year (Table 27).

Table 27. Number of farmers who used no-till before abandoning the practice, Forest, Transition, and Guineas Savannah Zones, Ghana.

Years farmers practiced no-till before abandoning it	Percentage of farmers who abandoned NT
1	17
2	28
3	11
4	33
5	6
7	5
Mean (yr)	3.1

Poor access to adequate contract planting (not available on time or too expensive) was the main reason for reverting to slash and burn for 56% of farmers in this group; 6% mentioned that the soil was too compact; and 23% had problems understanding the package (could not control weeds, received inadequate advice, or required additional work). One farmer (6%) mentioned that no-till did not work on his soil. These reasons reinforce a previous finding that planting is the major technical problem faced by Ghanaian farmers who wish to use no-till.

When asked what they required to use no-till again, 78% mentioned financial support and 22% cheaper herbicides. However, when asked why they used no-till occasionally, only 5 out of 18 farmers (28%) mentioned lack of cash as a problem. The rest mentioned technical problems. As seen earlier, financing seems to be a problem for about 25% of farmers.

Access to technical advice is not a problem for 83% of these farmers. Seventy-seven percent had access to researchers or extension agents and 11% to other farmers.

Farmers Who Never Used No-Till

More than half (56%) of farmers who never used no-till knew about the technology. Some (41%) heard about the technology from other farmers. Only 8% heard about it from a researcher or extension agent (Table 28).

Table 28. Information sources about no-till among farmers who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana.

Information source	Frequency	Percentage
Neighbor	7	18.9
Relative	3	8.1
Another farmer	5	13.5
Herbicide seller	1	2.7
Research/extension	3	8.1
Field day	1	2.7
Not applicable	17	45.9

Most farmers who never tried no-till learned about the technology in the same year that the number of demonstration plots was highest. However, only one farmer mentioned going to a field day. The correlation between the number of demonstration plots and the year in which farmers learned about the technology shows that extension efforts had a multiplier effect. In other words, farmers who never used NT heard about it from neighbors who probably visited a demonstration plot.

The main reasons mentioned by these farmers for not using no-till were economic - either that herbicide was too expensive or more cash was required compared with current practices (Table 29). About 30% mentioned difficulties in contracting planting or spraying. This reason was also important for farmers who had abandoned NT. The complexity of the technology and lack of access to technical advice were important for about one-third of respondents in this category. This strengthens the idea that these farmers are less innovative than the other groups. The fact that technical issues are not ranked as very important reflects lack of practice with the technology.

Seventy-six percent of farmers who never used no-till visited farmers who used no-till and 73% had access to technical advice. Exposure to the technology is therefore not a problem. Also, concerns about neighbors' opinion of the appearance of no-till fields relative to clean fields was not an issue for 84% of these farmers.

Agrochemicals Markets

One of the key findings of this research was the identification of two complementary groups of suppliers (extension/research agents and formal dealers). This report only examines the impact of no-till on formal dealers, because the importance of extension/research agents was only discovered from the analysis of farmers' responses.

As mentioned earlier, markets for inputs are not well integrated. Only 29% of dealers knew prices of herbicides in Accra and 57% knew the prices in other villages, a share substantially smaller than that of no-till farmers. Knowledge of local markets is highly correlated with the size of business; dealers with more than three employees were more aware of prices in neighboring villages than dealers with less than four employees. However, there is no clear association between knowledge of prices in Accra and the number of employees. This pattern of information dissemination indicates high transaction costs.

Most dealers are close to a distributor; 61% travel 30 km or less and 68% travel less than 100 km to pick up supplies. There is no correlation between distance to suppliers, the size of business or agroecological zone. In other words, dealers buy from the same suppliers irrespective of size or location.

Only 64% of dealers said herbicides are easily available when needed, a proportion similar to farmers. A similar percentage has supplies delivered to them. Other inputs that are easily available are seeds and fertilizers: 75% of the dealers indicated that seeds and fertilizers are available when needed.

Only 11% of dealers receive credit from commercial banks and 21% from suppliers. On the other hand, 57% provide credit to selected farmers.

Table 29. Reasons for not using no-till among farmers who never used NT, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Reason:	Very important	Important	Not important	Not applicable
Cannot control weeds	16	3	35	46
The herbicide is too expensive	49	2	3	46
Do not have access to timely contract planting or it is too expensive	27	3	24	46
Cannot maintain the soil covered	16	5	32	47
Knapsack sprayer not available	22	5	27	46
Cannot manage residues properly	13	8	30	49
Cannot control pests	19	3	32	46
Soil is too compact	14	6	30	50
Too difficult	19	11	24	46
Cannot get adequate advice	19	14	19	48
Requires additional work	14	5	32	49
Does not work on soil	8	8	32	52
Not good for the crops I grow	14	8	30	48
Requires more cash than I normally invest	32	5	14	49

Characteristics of Formal Dealers

Most formal dealers are fairly young. More than half (61%) are below 40 years (Table 30). They are also relatively well educated; except for one who had only one year of schooling, the rest had more than 8 years of formal education. However, very few had college education (71% had between 9 and 12 years of schooling). Males predominate (71%); this percentage is similar to that of males in the farmer sample.

Table 30. **Characteristics of formal dealers, Forest, Transition, and Guinea Savannah Zones, Ghana.**

Characteristics	Minimum	Maximum	Mean	Standard deviation
Age	23	55	37.3	9.2
Years in school	1	18	11.44†	3.2
Years selling inputs	1	21	7.9	5.1
Years selling herbicides	1	21	6.7	5.3
Number of employees	0	20	2.4	3.7

Note: †The smallest observation excluded.

Business Characteristics

Most dealerships are small. Eighty-six percent have less than 4 employees. Larger dealers (more than 3 employees) have been in business for more than a decade (Table 31).

Table 31. **Agrochemical dealership size and years in business, Forest, Transition, and Guinea Savannah Zones, Ghana.**

Years selling	No. of employees								
inputs	0	1	2	3	4	5	6	20	Total
1			1						1
2			1						1
3		7		1					8
4		1							1
5		1							1
8		1							1
9		4		1					5
10		1						1	2
11		1							1
12			1	1	1				3
15	1	1					1		3
21						1			1
Total	1	17	3	3	1	1	1	1	28

Business Facilities

Most businesses are poorly equipped (Table 32). Although 79% of dealers have electricity, only 25% have telephones. None of the dealers has a computer or fax, and only 4% have access to the Internet. Thirty-nine percent have vehicles.

Table 32. **Business facilities of agrochemical dealers, Forest, Transition, and Guinea Savannah Zones, Ghana (% businesses).**

Facility	Dealers
Electricity	79
Telephone	25
Internet access	4
Computer	0
Fax	0
Bicycle	21
Motorbikes	7
Cars or trucks	32

Training

Some training is required for safe handling of agrochemical. In the sample, 93% of dealers received some training (Table 33). However, only 79% used safety equipment. More than half received training from extension agents.

Table 33. **Training sources among agrochemical dealers, Forest, Transition, and Guinea Savannah Zones, Ghana (% businesses).**

Source	Dealers trained
Extension agent	57
Suppliers	21
Research	11
Supplier and research	4
No training	7

Fifty-seven percent of dealers received business management training (Table 34); 32% were trained by the government and 11% by suppliers.

Table 34. **Sources of business management training among agrochemical dealers, Forest, Transition, and Guinea Savannah Zones, Ghana (% businesses).**

Source	Dealers trained
Government	32
NGOs	11
Supplier	11
Others	4
No training	43

Even though all dealers offered some training to their customers, only 43% organized field days to demonstrate the use and effect of herbicides.

Dealers' Perception of No-Till Use Among Farmers

When dealers were asked about the number of farmers using no-till in the village, 89% saw increases, 7% could not tell and 4% said it was decreasing (Table 35).

Table 35. Agrochemical dealers' perception of number of farmers using no-till, Forest, Transition, and Guinea Savannah Zones, Ghana.

Dealers response:	% indicating
Most	39
Several	50
Few	4
None	4
Cannot tell	3

The majority of dealers said that few farmers own a knapsack; most farmers either rent sprayers or contract herbicide application (Table 36).

Table 36. Farmers' who own, rent or contract spraying according to agrochemical dealers, Forest, Transition, and Guinea Savannah Zones, Ghana (% businesses).

Dealers' response	Own sprayers and spray	Rent sprayers	Contract spraying
Most	7	32	14
Several	32	36	39
Few	47	21	25
None/ Don't know	14	11	22

Sixty-four percent of dealers mentioned that farmers who spray have average wealth, while 14% think these farmers are rich, 7% believe they are poor, and 14% cannot tell.

Seventy-nine percent of dealers think that farmers who spray have increased their income, 18% cannot tell, and 4% said farmers did not have larger income. Also, 86% of dealers said that farmers who adopted no-till have more food than before.

Maize was the most frequently mentioned crop under no till by dealers (68%); vegetables (14%) and rice (11%) were other crops mentioned.

As indicated in Table 37, most dealers think that the demand for herbicides is moderately responsive to prices.

Table 37. Expected response of demand for herbicides to price changes, Forest, Transition, and Guinea Savannah Zones, Ghana.

Percentage price increase	Percentage decrease in sales (Mean)	(Minimum)	(Maximum)
10	8	0	50
25	23	0	70
50	41	0	90

Impacts of No-Till on Farmers

As stated earlier, it was not possible to estimate the extent of adoption because of limited resources. For this reason, the sample was directed specifically to users of no-till. Additionally, since there is no prior information on distribution of several important variables (e.g., wealth or land tenure) among farmers in the survey zones, it was not possible to assess whether the sample is representative and, consequently, to make inferences about population parameters. When no-till was introduced in Ghana, no baseline survey was conducted to collect data on the target population. Without such benchmark information, it is impossible to make a quantitative estimate of the technology's impact. However, it was possible to obtain qualitative assessments for most impacts and a quantitative estimate on labor savings. This estimate, though, should be considered a rough approximation of the true impact of no-till and cannot be used to make inferences about its impact on all Ghanaian farmers using the technology. Despite these limitations, the survey enabled identification of important impacts of no-till on several aspects of adopters' lives: quality of life, income, maize yields, input markets, occupation patterns, and use of labor.

The most important impact of no-till on small-scale farmers is the reduction in the amount of labor per unit of agricultural output. Farmers used this extra time to undertake other activities while still producing the same amount of food as they did before adopting no-till. These activities resulted in higher income and higher standards of living.

Labor Savings

The reduction in male family labor after adopting no-till was 31%; reductions in female and child family labor were not statistically significant (Table 38). The overall family labor savings is 27%. The reason for the difference in male and female and child labor savings is that no-till simplified tasks usually reserved for men, such as land preparation (including slashing and burning), planting, and chemical weed control.

Table 38. Average number of family members who work in no-till fields, Forest, Transition, and Guinea Savannah Zones, Ghana.

Activity	Adult males	Adult females	Children	Total
Before adopting no-till	3.6	1.8	1.9	7.3
After adopting no-till	2.5	1.6	1.6	5.3
Difference (%)	31	11	16	27
Significance	Significant	Not significant	Not significant	

No-till reduced labor requirements for land preparation and planting by 22% and labor requirements for weed control by 51%, from an average of 8.8 man-days/ha to 4.3 man-days/ha (Table 39). There was a slight increase in labor requirements for harvest from 7.6 man-days /ha to 8.6 man-days /ha as a consequence of higher yields under no-till.

Work should not be measured only in hours but in the effort required to complete a particular task. For example, with traditional techniques, farmers have to walk bent over 10 km to weed one hectare of land. To weed with no-till, they only walk 6.7 km in an upright position. Less physical effort increases farmers' ability to start new activities and results in a higher quality of life. Ninety-nine percent of NT users reported that with no-till agricultural work was less physically demanding; the same percentage said that it reduced labor requirements in critical moments, thus simplifying labor management.

In short, no-till reduced the labor and effort required to perform the same tasks and simplified labor management. The introduction of simple technologies used in other countries (e.g., knife-roller or jab planter) could increase these impacts substantially.

Impact on Agricultural Practices

Farmers were asked an open-ended question on the three most important changes that no-till brought to farming activities (Table 40). A majority of farmers mentioned reduced cash and labor investment and higher yields; other important impacts were easier weed control and saving in time. Less frequently mentioned were farm expansion and improved soil fertility.

Farmers were also asked whether they agreed or disagreed with a list of statements about the benefits of no-till (Table 41). A majority of farmers indicated that no-till increased production, reduced costs, reduced risk in bad years, and facilitated agricultural production. In particular, 67% of NT users reported a change in weed and pest species after adoption, and 70% found controlling new weeds easier. Pest control was also reported to be easier for 57% of NT users.

Normal maize yields were 16% higher for NT users compared to farmers who abandoned NT and 45% higher than farmers who never used NT. The yield differences in 2000, a dry season, were 38% and 48%, respectively. This means that the yield reduction caused by drought was 24% for NT users, 36% for those who abandoned NT, and 30% for farmers who never used NT. In other words, no-till reduced the water stress of maize plants.

Three risk factors are reduced with no-till: soil covered with mulch has greater water availability in dry years; the reduced turnaround time between harvesting one crop and planting another permits planting the second crop closer to the optimal date; and the presence of a larger number of beneficial

Table 39. Average man-days/ha required for selected farming activities before and after adopting no-till, Forest, Transition, and Guinea Savannah Zones, Ghana.

	Farming activities (man-days/ha)			
Activity	Land preparation and planting	In-crop weeding	Harvesting	Total
Before adopting no-till	9.4	8.8	7.6	25.8
After adopting no-till	7.3	4.3	8.6	20.2
Difference (%)	22	51	-13	22
Significance	S	S	S	S

Note: S = significant

Table 40. Most important changes that no-till brought to farming activities, Forest, Transition, and Guinea Savannah Zones, Ghana.

Change	Percentage of farmers who mentioned this effect†
Good crop growth	15
Less cash and labor investment	69
Easier weed control	41
Time saving	32
More income	19
Higher yields	62
More crops grown	7
New or expanded farm	18
Increased soil fertility	18
New knowledge	4
Stopped burning farm	6
Increased interest in farming	5
Now plant in lines	5

Note: †Total percentage is more than 100% because of multiple answers.

Table 41. NT users' responses about benefits of no-till, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Benefits of no-till:	Agree
Makes it possible to expand planted area	94
In bad years, I still get something	84
Reduces soil erosion	87
Improves soil water availability for the plant	99
Reduces need to use fertilizer	87
Improves soil structure	89
Reduces time between harvest and planting next crop	80
Facilitates weed control	96
Facilitates pests control	97
Yields are less affected by late or early planting	80
Increases yields	99
Reduces production costs	97

insects facilitates pest control. When asked if they still get something in bad years, 84% of NT users responded affirmatively. Reduction of the downside risk is especially important for small-scale farmers with little savings to weather a bad harvest.

Sixty-nine percent of farmers who used NT and 72% of farmers who abandoned NT expanded their farming area compared to 30% of farmers who never used NT. Even though most farmers indicated that no-till allows work on more land, in this case the expansion seems to be linked to the fact that NT users and those who abandoned NT are more innovative than farmers who never used NT. More research is needed to understand this phenomenon.

Impact on Families

As in the previous section, farmers were asked about the three most important changes that no-till brought to their families (Table 42).

Table 42. Impact of no-till on families, Forest, Transition, and Guinea Savannah Zones, Ghana.

Change	Percentage of farmers affected†
Increased income	87
More time for other activities	48
Increased food availability	51
Reduced labor and effort	43
Reduced child labor	5
Financially independent	8
Farm expansion	7
Built house/ acquired building plot	6
Prompt payment of school fees	19
Purchase home appliances	10
Purchase milling machine	3
Improved health	3

Note: †Percentages do not add to 100% because of multiple answers.

A majority of farmers (87%) reported higher incomes. Other important changes were increased food availability, more time for other activities, and reduced labor and effort. Nineteen percent of farmers mentioned the ability to promptly pay school fees, thus securing their children's education.

No-till users who reported new activities were requested to mention them (Table 43). Eighty- three percent of respondents started other income-generating activities, mostly other farm activities or trading.

Table 43. New activities resulting from the use of no-till, Forest, Transition, and Guinea Savannah Zones, Ghana (% farmers).

Activity	Farmers
Trading	35
Other farm activities	38
Leisure/rest	8
Livestock/poultry	4
Time to preach	6
Transport	2
Oil/gari processing	4
Household chores	2

No-Till Impact on Agrochemical Market

The data gathered indicates that formal dealers and research/extension agents provide different services. Formal dealers are generally located in larger cities (especially district capitals) and are often beyond the reach of many small-scale farmers who do not have the means or do not find it worthwhile to travel long distances to buy small volumes of herbicides. Farmers' lack of credit and atomized demand also make it unprofitable for formal dealers to open branches in villages.

On the other hand, research/extension agents are in contact with both farmers and formal dealers. Anecdotal evidence indicates that in the early years of no-till development some farmers gave money to extension agents to buy herbicide for them. Eventually, some extension agents started to trade in herbicides on their own. In short, extension/research agents occupy a market niche created by the atomized demand and relatively high transportation costs.

Unlike formal dealers, extension/research agents also offer technical advice and training. On the other hand, formal dealers offer a larger range of products, especially safety equipment. Understanding the interactions between these two marketing channels is crucial to increase the efficiency of input markets. The crucial issues that should be analyzed further are: What is the profitability of each segment? What is the efficiency of each segment? What type of relationships these segments establish with their suppliers, in particular, wholesalers and financial institutions? How can transaction costs in the herbicide market be reduced?

Growth and Sale of Agricultural Inputs

Figures 3 and 4 show that the market for commercial agricultural inputs has grown in the last five years. In that period, 12 dealers (43%) started operations; 8 dealers opened for business 3 years ago. The expansion of the herbicide trade is even more striking; 61% of dealers started selling herbicides after 1996. In other words, a number of input dealers with many years in the business started to sell herbicides only recently.

Even though no data on the profitability of sales of agricultural inputs and herbicides are available, the high increase in the number of dealers indicates an expanding market.

The expansion of the herbicide market is illustrated by sales performance. Compared to three years ago, 57% of dealers doubled the amount of herbicides they sold each year, 7% tripled it and 14% increased it by 50% (Table 44).

Table 44. Change in herbicide sales compared with three years ago, Forest, Transition, and Guinea Savannah Zones, Ghana.

Change	Percentage
Same	11
Increased 50%	14
Doubled	57
Tripled or more	7
Decreased	11

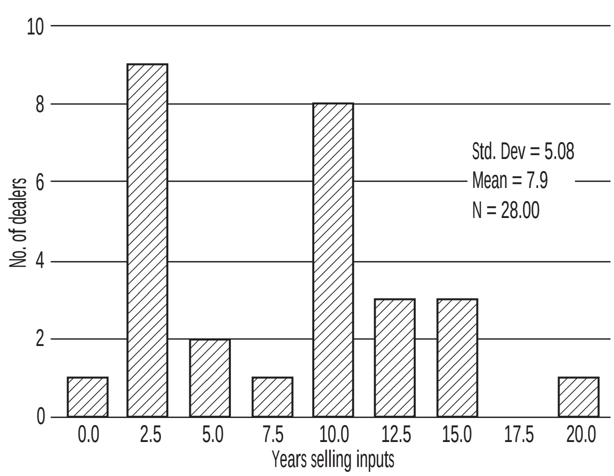

Figure 3. Years in input market, Forest, Transition, and Guinea Savannah Zones, Ghana.

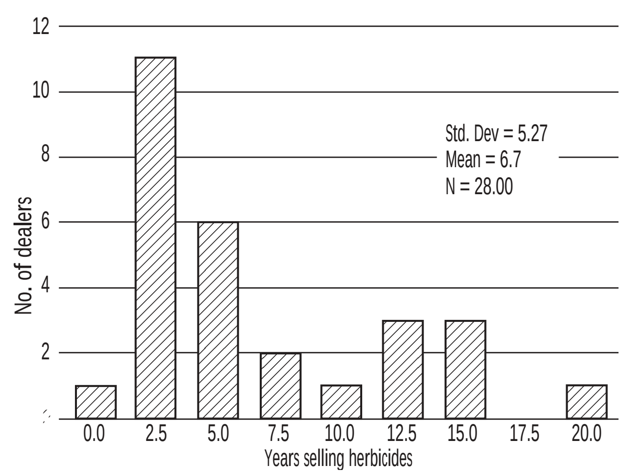

Figure 4. Years in the herbicide market, Forest, Transition, and Guinea Savannah Zones, Ghana.

The expansion of the input market is not confined to herbicides. Most dealers (82%) reported that they expanded the range of inputs sold (Table 45).

Table 45. Changes in the range of inputs sold, Forest, Transition, and Guinea Savannah Zones, Ghana.

Change	Percentage
Now sell more	82
Same	7
Sell less	11

In 2000, herbicides were the first or second line of product sold by 96% of dealers (Table 46). Seeds, pesticides, and fertilizers were less important. Veterinary products and tools were less common.

Table 46. Product lines sold by formal dealers, Forest, Transition, and Guinea Savannah Zones, Ghana, 2000.

	Dealers selling (%)					
Product	1st line	2nd line	3rd line	4th line	5th line	6th line
Herbicides	46	50	0	0	0	0
Seeds	43	21	11	7	4	0
Pesticides	4	11	43	29	7	0
Fertilizers	7	14	18	39	14	11
Knapsacks	0	4	21	4	7	0
Veterinary products	0	0	0	0	7	0
Tools	0	0	0	0	7	7
Other products	0	0	0	0	4	0
Not applicable	0	0	7	14	54	79

Dealers who have been longer in the business sell a more diversified range of products. Less than half of the dealers sell protective materials; 75% of those selling protective materials have been in the business for more than 8 years. More than half of the dealers who sell knapsacks (55%) mentioned that sales of these implements are increasing.

Table 47. Dealers' suppliers of agricultural inputs, Forest, Transition, and Guinea Savannah Zones, Ghana.

Supplier	Dealers (%)
Kumasi (Kajetia) Input Dealers	43
Dizengof	18
Sefa & Jane	11
Chemico	7
Kusiwaa Agro-chemicals	4
Wienco	4
Techiman market	4
Ministry of Agriculture (MOFA)	4
Ivory Coast	4
Togo	4

The major wholesalers of agricultural inputs are Kumasi (Kajetia) Input Dealers, Dizengof, and Sefa & Jane Agro Company. The wholesale trade is very concentrated. Seventy-five percent of dealers buy from these three firms (Table 47).

Sale of Herbicide Types

In the beginning of no-till dissemination efforts, farmers were advised to buy Roundup in sachets because they contained the exact amount required for a knapsack, even though it was more expensive than other presentations. As farmers became more familiar with no-till, they switched from sachets to the cheaper liquid presentation. At the time of the survey, 71% of dealers mentioned that the presentation they sold most was the 1-liter form; only 29% mentioned the sachet. The proportions in 1997 were 61% for the 1-liter and 36% for the sachet.

This pattern of starting with a sachet and then switching to liquid presentations seems to continue today. Dealers in the Guinea Savannah (the last region where no-till was introduced) reported that sachets are still the most sold presentation, while in regions where farmers have been practicing no-till longer the 1-liter form is most sold. In addition to changing the presentation they prefer, individual farmers are buying more herbicides, as reported by 79% of dealers.

Roundup is the most important herbicide for 71% of dealers, reflecting its key role in the no-till package (Table 48).

Table 48. Herbicides sold by dealers, Forest, Transition, and Guinea Savannah Zones, Ghana (% dealers).

	Dealers		
Herbicide	1st	2nd	3rd
Roundup	71	14	0
Atrazine	11	46	18
Rilof	11	4	4
Calliherbe	4	4	7
Propanil	4	4	0
Gramoxone	0	11	25
Lasso + Atrazine	0	7	7
Stomp	0	7	0
Cottonex	0	0	7
Chemocide	0	0	7
Satunil	0	0	11
Not applicable	0	4	14

Conclusion

Adoption of no-till (estimated in 2000 at 100,000 small-scale farmers on 45,000 ha) was facilitated by the low-input agricultural practices prevalent in the three study zones in Ghana, and the fact that few farmers have animals (other than a few chickens). Limited livestock production has prevented the creation of a market for crop residues, allowing farmers to maintain proper soil cover at planting. In addition, there was no need for no-till planters, an issue that was a major obstacle in other countries where no-till was introduced, because planting is traditionally done with a stick or cutlass. The lack of planters, however, prevented most large-scale commercial farmers from switching from conventional till to no-till. This feature of the Ghanaian experience is unique, because in other countries, large-scale farmers were the first to develop and adopt the technology.

In general, no differences were found between male and female farmers in wealth, access to technical advice, and agricultural practices. However, on average, women farmed about half the area as men, obtained lower maize yields, and were less inclined to try new things on their fields. These differences can be explained by the fact that more women have nonagricultural occupations and tend to be part-time farmers. They go to the fields later in the day and this affects the efficiency of some agricultural practices (like spraying) that should be done early in the morning.

Farmers who used no-till applied the package recommended by research/extension agents and did not change the crops they grew after no-till. This may reflect lack of market opportunities, lack of adequate technologies that fit into current production patterns, or inadequate information channels that permit farmers to learn about new crops. Adequate research and extension programs can solve some of these problems and increase the impact of no-till.

There were active markets for agricultural services. Almost half of all farmers contracted planting or rented a knapsack sprayer. More than half of farmers who never used no-till and a quarter of no-till users said economic considerations were a restriction to using agricultural services. Difficulties in finding well-trained contractors for planting or spraying as well as understanding the package were also mentioned. Training contractors in no-till can improve the performance of these markets.

No-till had many important impacts on the lives of adopters. These impacts can be categorized into two groups: agricultural practices and quality of life.

Impacts on agricultural practices

Among the important changes that no-till brought to farming activities, farmers mentioned reduced investment in cash and labor, higher yields, easier weed and pest control, and saved time for farmers. Less frequently mentioned changes were farm expansion and improved soil fertility.

Overall family labor was reduced by one third. Reductions in female and child family labor, however, were not significant because no-till simplified tasks usually reserved for men: land preparation, planting, and chemical weed control.

A majority of no-till users also reported that less effort was required for agricultural tasks. No-till also reduced labor requirements in critical times, simplifying labor management. The reduction in labor requirements more than compensated the cost of herbicide, resulting in reduced production cost. Cost reduction combined with higher yields increased the profitability of grain production.

In both normal years and dry years, as was the case in 2000, maize yields obtained by no-till farmers were higher than those obtained by farmers who abandoned no-till, and by farmers who never used the technology. No-till also reduced agricultural risk: most no-till farmers said they still received something in bad years. The reasons for the better results obtained with no till are: soils covered with mulch conserve more water in dry years, the reduced turnaround time permits planting the second crop closer to the optimal date, and the presence of a larger number of beneficial insects facilitates pest control. Reduction of downside risk is especially important for small-scale farmers with little savings to weather a bad harvest.

Although most users of no-till used it continuously, almost half did not use it on all their land. Among the reasons mentioned for this were cash restrictions and that no-till is not good for some crops. The latter indicates that research on no-till has concentrated on a small number of crops.

Most users reported a change in weed species and easier weed control. There was no increase in pest pressure in terms of population and species. Actually, more than half found pest control easier under no-till.

Impacts on quality of life
No-till users reported higher incomes, increased food availability, and more time for other activities because of the technology. Many started other income generating farm activities or trading. Some farmers also mentioned the ability to promptly pay school fees, thus securing their children's education.

The increase in the purchase of commercial inputs was not a problem for most users. A large proportion of farmers contracted several tasks and no-till reduced labor requirements for these operations. In other words, for most users, no-till changed the inputs that had to be purchased (substituted herbicides for labor) and resulted in lower expense per unit of land.

A characteristic of no-till is that the agricultural system has a higher level of biological activity. This more dynamic system facilitates weed and pest control as beneficial insects and plants are allowed to proliferate. Inadequate management, however, may also facilitate the appearance of new weeds and pests.

Further development of the no-till package in Ghana and its sustainability will depend on further research, particularly in three areas:

1) *adequate machinery,* to reduce labor requirements for small-scale farmers (increasing the profitability of the system) and make the system adequate for large-scale mechanized farmers; major savings can be made in slashing (probably with the introduction of the knife-roller), planting (including planters for manual, draft power, and mechanized planting) and spraying (with the introduction of multiline sprayers);
2) *crop rotations (including cover crops)* to improve soil cover at flowering, increase fertility, ease weed control, and reduce the potential for the buildup of aggressive weeds and pests; and
3) *dynamics of diseases and weed and pest populations* to identify potential threats and develop remedies before they become a limiting constraint.

Development of a no-till package for crops that currently can be planted only with conventional tillage would also broaden the universe of potential adopters. Many of these needs have already been solved in other countries; Brazil and Paraguay in particular have many technologies for small-scale farmers that could be transferred into Ghana with minor adaptations. Establishing strong links with researchers and institutions in other countries is an efficient and cheap way to fill knowledge gaps.

Lastly, the survey showed that while research and extension services have worked efficiently until now, there were indications that the extension effort may be weakening and that some activities have been scaled down. New institutional arrangements should be sought to compensate for these changes.

Impacts on agrochemical dealers
There are two complementary marketing channels for agrochemicals: research/extension agents and formal dealers. No-till has expanded the market for both. These two marketing channels offer different services but their interactions are not well understood. Further research on the organization and performance of these markets should be conducted to identify bottlenecks that hamper further dissemination of no-till.

The survey of formal dealers showed that more than half are young and relatively well educated. About half (43%) started operations after 1996; in addition, 61% started to sell herbicide after that year. Most dealers are small operations and have difficulties in obtaining credit and following markets outside their villages. Programs to help dealers improve business management and better infrastructure can reduce transaction costs and help the dissemination of no-till.

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Appendix 1. Location of survey districts and villages, Ghana.

Region	Village	District	Ecological zone
Ashanti	Afari	Atwima	Forest
	Toase		
	Nkaakom		
	Amanchia		
	Asuoyeboa	Kumasi	Peri-urban
	Quarters	Metropolitan	
		Assembly (KMA)	Forest
	Abrankese-Swedru	Bosomtwe-Atwima-	Forest
	Beposo	Kwanwoma (BAK)	
	Nkyensedaho	Ahafo Ano-South	
	Nyameadom		
Brong Ahafo	Goaso zongo	Asunafo	Forest
	Nkaseim	Asutifi	Forest
	Dormaa		
	Ata –ne-Ata	Tano	Forest
	Afrisipakrom		
	Tanoso		
	Susuansо		
	Yamfo	Wenchi	Transition
	Wenchi		
	Akete		
	Ofuman	Techiman	Transition
	Nyasuaka		
	Brahoho	Nkoranza	Transition
	Nsuatre		
	Esereso	Sunyani	Forest
	Fiapre		
	Dumasua		
Northern	Gbun	Salaga	Guinea Savanna
	Bihinayili	Savelugu-Nanton	
	Langa		

Appendix 2. Location of dealers' survey districts and villages, Ghana.

Villages / Towns	Dealers interviewed (No.)	District	District capital
Toase	1	Atwima Nwabiagya	
Nkawie	2	Atwima Nwabiagya	Nkawie
Kumasi	8	Kumasi Metropolitan Assembly	Kumasi
Mankranso	1	Ahafo Ano South	Mankranso
Biemso I	1	Ahafo Ano North	
Ampabame	1	Atwima Kwanwoma	
Asaman	1	Agona	
Bechem	2	Tano	Bechem
Tanoso	2	Tano	
Awisa	1	Wenchi	Wenchi
Techiman	2	Techiman	Techiman
Nkoranza	1	Nkoranza	Nkoranza
Tamale	5	Tamale Municipal Assembly	Tamale

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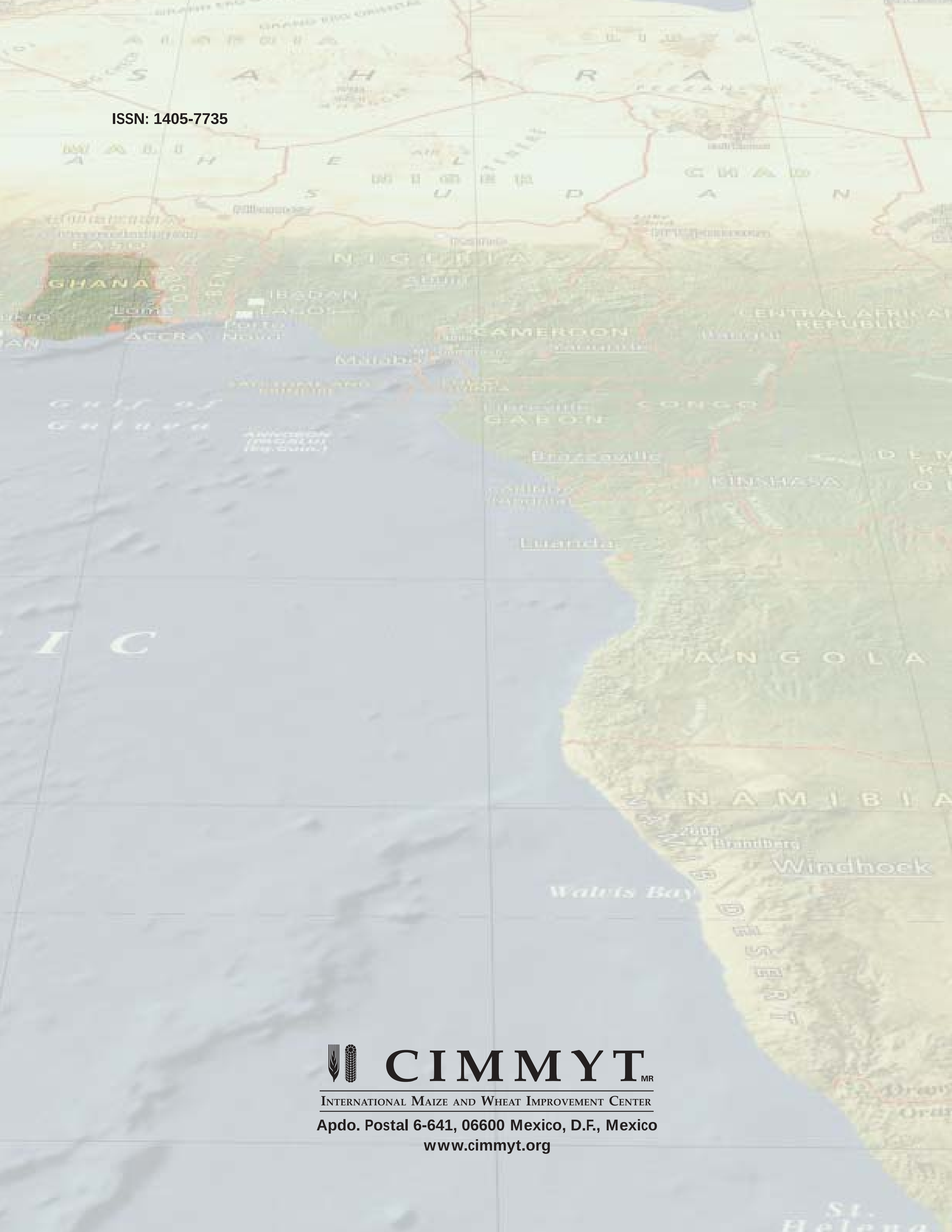

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