Early Evidence on Conservation Farming in Zambia

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ABSTRACT:

Conservation farming (CF) offers a set of sustainable agronomic practices for Zambian smallholder farmers using either hand hoe or animal draft tillage. The CF package includes dry-season land preparation using minimum tillage methods (hand hoe basins or ADP ripping), crop residue retention, precision input application (in a precise grid of planting basins or along rip lines), and nitrogen-fixing crop rotations. These practices aim to improve soil structure and water retention and reduce the need for chemical fertilizers while at the same time increasing crop yield. Yet CF also increases weeding labor, at least in the early years following adoption. Using survey data from the 2001/2 cropping season, this paper evaluates yield gains against input usage increases in order to assess financial incentives for farmers to switch from conventional to CF tillage systems.

Results suggest that in 2001/2 CF basins proved financially more attractive to hand hoe farmers than conventional hand hoe tillage in in Zambia's Agro-ecological Regions I and IIa, regions of erratic rainfall and in areas with extensive plow-pan damage where 440,000 smallholders currently farm. Animal draft powered conservation farming using rippers promise still further gains, though realization of this potential will require improved extension support to ensure effective off-season land preparation. Overall, roughly 75,000 Zambian smallholders farmed CF plots accounting for approximately 3% of cultivated area in applicable regions during 2002/3. Of these, about 15,000 are spontaneous adopters while the remaining 60,000 practice CF as a condition for receiving their inputs. Adoption rates prove highest in regions of sporadic rainfall, with strong extension and input supply systems. At a personal level, CF requires highly disciplined farmers who are able to execute precisely and plan well in advance of the cropping season.

Evidence from similar technologies in other parts of Africa suggests that the effectiveness of conservation farming will vary not only across regions but also across crops and over time, due to variations in weather and rainfall. In addition, many of the benefits of CF -- including improved soil structure, gains from nitrogen-fixing crop rotations and reduced field preparation labor -- occur gradually and over time. Therefore, it will be important to establish long-term monitoring efforts to assess the effectiveness of conservation farming, across a broad range of geographic settings, crops and seasons.

JEL CLASSIFICATION CODE:

KEYWORDS: agriculture, conservation, Zambia

1. INTRODUCTION

Farmers apply a vast array of low-input, ecologically friendly agricultural technologies across the globe. Recent reviews have cataloged literally hundreds, referred to variously as “agro-ecological”, “low external input” or “sustainable” farm technologies (Pretty and Hine, 2001;Reij, Scoones and Toulmin, 1996). Most assessments of these technologies report substantial increases in farmer yields, often double those achieved by conventional methods (Pretty and Hine, 2001). Yet achievement of these substantial gains in output typically require additional inputs, most particularly increased use of labor to prepare compost, for mulching, manure application and weeding. So farmer incentives for adoption hinge critically on the availability and opportunity cost of labor.

This paper examines one such technology from Zambia. Introduced to smallholders in 1996, conservation farming involves a package of several key practices: dry-season land preparation using minimum tillage systems; crop residue retention; seeding and input application in fixed planting stations; and nitrogen-fixing crop rotations. Through crop rotations and build up of soil organic material, CF recommendations cut chemical fertilizer use to roughly half of historical conventional norms. For hand hoe farmers, CF revolves around dry-season preparation of a precise grid of 15,600 permanent planting basins per hectare. For farmers using oxen, CF technology involves dry-season ripping, normally with the locally developed Magoye Ripper. For commercial farmers, mechanized minimum tillage methods with leguminious crop rotations such as soy beans, green gram and sunhemp complete the ladder of conservation farming technologies.

By breaking through pre-existing hardpan or plowpan layers, CF systems aim to improve water infiltration and root development, thus enabling farmers to begin reclaiming portions of the estimated xx% of Zambia’s cultivated land rendered infertile by decades of soil organic matter depletion. Organis matter depletion is, in part, a byproduct of heavily subsidized inorganic fertilizer application, and the widespread build-up of impenetrable plow and hoe pans that form as plow and hoe blades seal off soil pores, much like a trowel, during rainy season plowing of clay soils (IESR, 1999). The CF basins and rip lines harvest water in years of sporadic rainfall and ensure the precise application of fertilizer and other inputs next to the plants where they will do the most good. By reallocating land preparation to the dry season, in advance of the rains, conservation farming redistributes heavy labor as well as animal and mechanized draft requirements out of the peak planting period. This enables farmers to sow with the first rains when their plants will benefit from the initial nitrogen flush in the soil. Under CF systems, farmers enjoy the benefits of timely planting, improved water retention and infiltration, good root development, soil investment and greater precision in input use.

CF involves additional costs for farmers, particularly additional labor at weeding time, at least in the early years, given that farmers till only about 15% of the soil surface during field preparation. Dry-season land preparation, though arduous in early years, succeeds in reducing peak-season labor demands on small farms. And given permanent basins and ridge lines, tillage becomes easier over time. Economically, CF technologies boil down to trading off-season labor and draft power for higher crop output.

The rapid growth of interest in conservation farming invites inquiry as to its potential impact – on both individual farmers and on the environmental sustainability of Zambian agriculture. Evidence available to date suggests substantial increases in farmer yields under CF basins, often in the range of 25% to 100% (ECAZ, 2001; Keyser, 1996; Langmead, 2001). But since NGO-supported CF farmers frequently enjoy access to more hyv seeds and fertilizer than conventional farmers, given the recent collapse of rural credit system, the question becomes to what extent the higher output stems from higher input use as opposed to improved cultural practices. A few studies have computed gross margins, thus comparing the value of the increased output with the cost of additional purchased inputs (Arlussa, 1997; Elwell et al., 1999). These, too show an increase of 50% to over 100% in returns per hectare under CF. No studies, however, have evaluated output gains against the higher labor costs of CF at weeding time. Nor have they attempted to evaluate questions of spontaneous adoption, partial adoption, disadoption, and scale of conservation farming practice. This paper aims to fill those gaps.

This paper traces the origins of conservation farming in Zambia as well as its impact on farmer yields, input use and incentives. It aims to determine farmer adoption patterns, the geographic spread of conservation farming and its potential for reversing the accumulated damage of three decades decline in Zambia's soil fertility.

2. CONCEPTUAL FRAMEWORK

Tracking the sustainability of agricultural systems requires a dynamic model of agricultural growth and evolution. It likewise requires a framework that relates individual farmer decisions to aggregate changes in the natural environment. Individual farmers, as they take decisions based on individual incentives and opportunities, collectively shape changes in national production, market prices, soil fertility, water quality and pesticide levels that in turn trigger mutation in pests, diseases and other features of the natural environment.

We have found the D-E-A-R framework, in Figure 1, to be a useful heuristic model for thinking about how the farmer decision-making environment (DE) shapes on-farm actions (A) in one period and how these produce collective results (R) each season along all three dimensions of the critical triangle of output, equity and sustainability (IFPRI, 2001). As the natural environment evolves along with changing prices and government policies, the farmer's decision-making environment likewise changes in the next period, launching an iterative sequence of decisions, actions and results. The resulting time path of agricultural growth (Figure 2a) will prove "sustainable" only if farmers can maintain established levels of performance over long periods of time without degrading the natural resource base (Figure 2b).

4. DATA AND METHODS

4.1. Data

This study draws on three original data sources. First, the authors launched a small but focused farm survey of 125 farmers in Central and Southern Provinces of Zambia during the 2001/2 cropping season. The survey aimed to measure differences in both output and input use on CF and conventionally tilled plots, a topic surprisingly unaddressed in the available secondary literature. Because many CF maize farmers receive input packs from their promotional sponsors -- the Conservation Farming Unit (CFU), the Cooperative League of the USA (CLUSA) and others -- available reports of higher yield under CF occurs, at least in part, as a result of higher applications of hyv seeds, fertilizer and lime. Though prior studies have frequently found yields in CF plots 25% to 100% higher than conventional plots, none has related this higher output to the higher input use. Nor have they compared the total cost of the additional inputs, including labor, with the higher output. This farm survey aimed to fill that important gap.

Details of the research design and sampling as well as full questionnaire are available in Haggblade and Tembo (2003). In a nutshell, the survey strategy aimed to compare representative CF plots with a carefully matched set of conventional plots as controls. To match soil types, rainfall, farmer aptitude and experience as closely as possible, the survey measured inputs and outcomes on all conventional plots farmed by the selected CF farmers. By selecting controls this way, the survey aimed to avoid standard fixed effects problems. In order to capture insights into how labor use and productivity of CF systems change over time, the survey focused on three districts of Central and Southern Provinces where farmer groups have the longest experience with conservation farming. The authors stratified farmer groups in those areas by years of experience and gender and then randomly selected groups to interview. For each selected group, the study team compiled a list of all group members and stratified them according to crop cultivated (cotton and maize), tillage system used (basins, conventional hand hoe, ripper and plow), and gender (male or female). The team randomly selected farmers from each category and then visited each farmer to obtain plot-level information on all cotton and maize plots. The survey team measured maize output using crop cuts. Because of differences in harvest dates, cotton yield and all input measurements depended on farmer recall. The final sample included 21 farmer groups, 16 supported by CLUSA and 5 by the Dunavant Cotton Company. At the plot level, this procedure generated a sample of 125 farmers with 205 maize and 105 cotton plots (Table 1).

Second, in collaboration with Dunavant Cotton Company, the authors conducted a census of the 1,400 farmer group distributors supported by Dunavant during their pre-season round of extension meetings in September and October 2002. This effort focused on Dunavant cotton farmers because they constitute the largest group of spontaneous adopters of conservation farming in Zambia. Unlike farmers supported by other promotional agencies, such as the Conservation Farming Unit (CFU) and CLUSA farmers, Dunavant farmers do not plant basins or use rippers as a condition for receiving their inputs. They only adopt CF practices if they perceive it to be in their interest. Since

Dunavant has worked closely with the CFU since its inception in 1996, and since they operate across most of Southern, Central, and Eastern Provinces, they offer a unique opportunity to examine CF adoption rates among Dunavant's 75,000 smallholder cotton farmers across most of Zambia's low and moderate rainfall agroecological regions (Regions 1 and 2a). Because Dunavant conducts quarterly extension meetings with all their distributors, this round of extension briefings offered a unique opportunity to inexpensively gain broad information on CF adoption across Zambia (Table 2). A simple half-page questionnaire asked each distributor only two questions. What tillage method did the distributor himself use? And what tillage methods did his or her group members use in 2001 and in 2002?

Finally, this study analyzed four-year data from Zambia's nationally representative annual post-harvest surveys (1996/97-1999/00), each with a sample of 8,000 small- and medium-scale holdings. Post-harvest survey (PHS) data enabled us to evaluate tillage methods as well as ownership and access to animal draft power. The Central Statistical Office (2002) and Jayne et al. 1999) provide details of sampling, questionnaires and methods used in post-harvest surveys.

4.2 Methods

To document the origin and spread of conservation farming, we have relied primarily on interviews with key actors involved in its development and diffusion. These have included past and present staff at the Zambia National Farmer's Union (ZNFU), the Conservation Farming Unit (CFU), Land Management and Conservation Farming (LMCF) Project, the Golden Valley Agricultural Research Trust (GART), the IMAG Project, Ministry of Agriculture and Cooperatives (MAC), Dunavant Cotton, CLUSA, World Vision and various donors and researchers involved in CF promotion and development. We have supplemented these oral interviews with written documentation from those agencies as well as reports by other local and international agencies and researchers.

To determine the impact of various conservation farming inputs, we have adopted standard regression techniques. Because CF farmers often use higher – or at least different – input levels on their CF plots, we have measured plot-level inputs and outputs, for maize with physical crop cuts. In addition, we asked about planting dates for each plot. Because CF shifts field preparation to the dry season, it enables early planting with the first rains. Conventional tillage, which cannot take place until after the first rains, results in inevitable planting delays. Zambia's plant breeders insist that for both cotton and maize, farmers will lose 1% to 2% yield per day they delay planting after the first rains (Howard, 1996; Arlussa, 1997; Gibson, 2002). Thus one crucial advantages offered by conservation is early planting. Hence, our yield equations regress yield as a function of planting date, fertilizer quantities used, a dummy for hyv seeds, plot size, years of experience with CF, tillage system used and gender. Because the basins and rip lines harvest water, and because of known interactions between water and fertilizer, we have included an interaction term capturing the combined effect of fertilizer with basins and fertilizer with rippers. Various regression models were estimated using the ordinary least squares (OLS) provisions in Stata (Table 4).

Many observers believe that peak season weeding labor determines area planted as well as household farm income (Arlussa, 1997, p.2). Returns to peak season labor, then, become the crucial determinant of profitability of alternate tillage systems. These returns vary considerably depending on a farmer access to draft power. Those who own cattle enjoy lower costs and higher yields since they plow and plant first and thus enjoy the considerable benefits of early planting. Conversely, farmers who depend on borrowed or rented draft power plow and plant last, often one month later than oxen owners themselves. For them, returns to ADP technology prove lower. Because of this important difference, budget comparisons were made to help distinguish between the two groups of smallholders.

5. FINDINGS

5.1. Origins of conservation farming

5.1.1 Influences from conservation tillage worldwide

Conservation farming in Zambia – at least in its predominant hand hoe package -- represents a local variant of traditional minimum tillage technologies adopted in many parts of Africa (Critchley et al., 1994; Reij, 2001; Shapiro and Sanders, forthcoming). Yet unlike the largely indigenous development of smallholder planting basin systems in Cameroon, Nigeria, Tanzania, Uganda and across the Sahel, Zambia's conservation farming movement has emerged as a byproduct of international technology transfer by large-scale commercial farmers. After importing minimum tillage systems for their own use, the commercial farmers subsequently became strong exponents and supporters of scaled down versions for Zambia's 440,000 smallholder farmers living in low and medium rainfall regions (Oldrieve, 1989; IMAG, 2001).

For large commercial farmers worldwide, the USA has spearheaded research and policy interest in soil conservation technologies. Devastating recurrent droughts during the 1930's, which converted the nation's breadbasket into a dust bowl and launched and massive emigration out of the farming heartland of America, resulted in the formation of the Soil Conservation Corps and an ongoing program of research into alternative methods for combating soil erosion. Spurred by this experience (Anderson, 1984; Beinart, 1984) and fresh from the memory of the South African drought of the 1920's, British colonial authorities imposed a set of mechanical soil conservation interventions – soil bunds, ridging, countour plowing – across much of British Africa, through the 1950's (Reij, Scoones and Toulmin, 2001). Widely resented, these African colonial schemes largely collapsed after independence, while the US-based efforts, in contrast, continued to gain strength. By the 1960's, US researchers and farm equipment manufacturers had produced a successful package of mechanized low-tillage equipment and agronomic practices (Hudson, 1981).

Successive oil price shocks during the 1970's significantly boosted farmer interest in minimum tillage techniques in the US and elsewhere. In addition to diminished compaction, soil erosion and improved water infiltration, the mimimum tillage techniques succeeded in cutting fuel costs by 50% to 80% (Witmuss, Olson and Lane, 1975; Epplin et al, 1982; Baker and Rouppet, 1996). Stimulated by six-fold increase in oil prices, minimum tillage agriculture expanded rapidly in the USA during the 1970's and 1980's, reaching over 35% of total area and up to 80% for crops such as soybeans (ECAF, 2001; Doane, 2001). Sparked by two major changes in their decision-making environment – catastrophic drought-induced soil erosion in the 1930's and a six-fold increase in oil prices during the 1970's -- US farmers, researchers and farm equipment manufacturers have invested heavily in minimum tillage farming techniques. As a result, the USA has became a major research center and exporter of minimum tillage technology and equipment.

In South America and Southern Africa, commercial farmers and associated national and international agricultural research institutes caught the second wave of global interest in conservation farming during the 1970's, spurred by advances in the USA and the breathtaking increase in world oil prices. Brazil quickly become a leader in South America, establishing conservation tillage research programs in Parana and Rio Grande do Sul during the 1970's and expanding thereafter to central and western Brazil. Currently; Brazilian farmers cultivate nearly one-third of their cropped area under conservation tillage (Derpsch, 1999; Alonso, 2001) South African and Zimbabwean commercial farmers visited the USA and also launched research programs of their own during the 1970's and 1980's (Ellwell, 1995). Zimbabwe's Agricultural Research Trust (ART) proved particularly influential among Zambian commercial farmers, who also sent farm delegations to the USA for study and commercial contacts during the mid-1980's.

5.1.2 Emergence of conservation farming in Zambia

Radical change in their decision-making environment confronted Zambian farmers in 1990's. Three decades of heavy subsidies for maize, fertilizer, tractors and plows came to an abrupt end following the bankruptcy of Zambia's key agricultural parastatals and the collapse of world copper prices, which had financed the Zambian government for decades (Wood et al., 1985; IESR, 1999; Zulu et al., 2000). The continuous high-input maize monocropping left Zambian soils seriously degraded throughout the low to moderate rainfall zones of Central, Southern and Eastern Provinces. Heavy application of nitrogen fertilizers, coupled with little attention to organic material, led to serious soil degradation – erosion, acidification, reduction in soil organic material and the build of plow pans across much of Zambia's maize belt. Commenting on Zambia's declining land productivity, one major recent review of Zambian agriculture concludes that, "The underlying causes relate to inappropriate farming practices, excessive erosion, increasing levels of fertilizer-induced acidity and soil compaction due to excessive and repeated cultivation." (IESR, 1999).

Further dislocation accelerated incentives for innovation and change in Zambian agriculture. A serious drought rocked Zambian agriculture in 1992, while a serious outbreak of corridor disease in the mid-1990's precipitated an approximately 16 percent slump in cattle population between 1995 and 2000. Meanwhile, fuel prices soared with the floating of the Zambian kwacha.

Zambia's commercial farmers responded by sending several members of the Zambia National Farmers Union (ZNFU) to Australia and the USA in the early and mid-1980's to learn about low-tillage systems. Extensive research, privately financed by Zimbabwean commercial farmers through their Agricultural Research Trust (ART) further stimulated local interest in low-till technologies (Vowles, 1989). High fuel costs in Zambia spurred interest in these systems, as Zambian farmers discovered low-till cultivation could enable them to reduce fuel consumption from 120 to 30 liters per hectare, dramatically improving profitability of mechanized maize production. Parallel benefits of reduced soil compaction and improved soil structure became apparent to early adopters (Hudson, 1995; The Farmer, 1995). As in Zimbabwe and South Africa, a significant share of commercial farmers in Zambia have now adopted minimum tillage techniques.

Smallholders, defined in Zambia as those farming less than 20 hectares, quickly responded by diversifying out of maize production and by reducing hyv seed and fertilizer use by over two-thirds as availability diminished and input prices jumped. Average maize yields fell as a result, from 1.6 to 1.2 tons per hectare between 1900 and the end of the decade (IESR, 1999). Farmers reduced maize area by 20% and shifted land to roots, tubers, legumes and cotton as the rural credit system collapsed and the previously ubiquitous maize subsidies disappeared.

In this environment, ZNFU created two institutions to spearhead development and extension of minimum tillage technologies for smallholder farmers -- the Conservation Farming Unit (CFU) of the ZNFU and the Golden Valley Agricultural Research Trust (GART), modeled on Zimbabwe's ART. A Zimbabwean farm manager, brought in as a consultant to the ZNFU to help set up low-tillage farm trials at the newly established Golden Valley Agricultural Research Trust (GART), first introduced the hand hoe analog of minimum tillage systems to Zambia in 1995 . In the course of his work in helping to define the mandate at GART, he related his success in applying a system of permanent planting basins for hand hoe farmers on the estate he managed in Zimbabwe (Oldrieve, 1988). Inspired by the notion of six to eight ton maize yields under hand-hoe cultivation, the ZNFU established a Conservation Farming Unit (CFU) in late 1995 to adapt the hand hoe basin system to Zambian conditions and to actively promote it among smallholders. With modest early funding from a variety of supporters, including the World Bank and Lonrho Cotton Company, the ZNFU's Conservation Farming Unit moved rapidly to develop guidelines and conduct onfarm trials with maize and cotton farmers in Central and Southern Provinces. Starting in the 1996/97 cropping season, the CFU has conducted between 800 and 1,000 demonstration and trial plots annually between 1996 and 2001. They conduct training and farm trials for Dunavant Cotton farmer distributors and work with a shifting coalition of NGOs including CLUSA, DAPP, World Vision and the Catholic Dioceses of Monze (see CFU 1996,1997,1998,1999,2000,2001).

During their early years, the CFU has focused largely on a conservation farming system for Zambia's 440,000 hand hoe smallholders living in the arid and moderate rainfall zones of Zambia (Agroecological Regions I and IIa), while GART, with support from the Institute of Agricultural and Environmental Engineering (IMAG) Project has concentrated on animal draft powered rippers. In more recent years, the CFU and GART have both worked with hand hoe and ADP variants of conservation farming research and extension.

5.1.3 Expansion

Extension of the conservation farming technology has attracted strong support from not only the CFU but also from the privately held Dunavant Cotton Company (the successor to Lonrho and the largest cotton company in Zambia), the Cooperative League of the USA (CLUSA), the Land Management and Conservation Farming (LMCF) Project together with their partners at the extension service of the Ministry of Agriculture and Cooperatives (MAC) and other NGO's such as the Catholic Archdioces of Monze, Development Aid from People to People (DAPP), CARE and Africare.

In 1998, MACO (then Ministry of Agriculture, Food and Fisheries or MAFF) formally embraced conservation farming as an official policy of the Zambian government (GART 2002; MAFF, 2001). Their partners at LMCF have likewise stepped up promotional efforts for both CF rippers and hand hoe basins. Consequently both MAFF and LMCF have devoted increasing attention to extending CF technologies (Burgess and Oscarson, 2002; Jonsson and Oscarsson, 2002; Oscarsson, 2002). Following its recent restructuring in 1998, Dunavant Cotton expanded its commitment to CF in its farmer training and support programs. Similarly, since 1998, CLUSA operations in Central and Southern Provinces has required all its farmers to plant in CF basins as a condition for receiving input credit and marketing support.

The drought of 2001/2 stimulated a surge of interest in the water-conserving conservation farming technologies – the hand hoe basins and rippers – developed for erratic rainfall zones of southern and central Zambia[1]. Donors such as SIDA, NORAD, FAO and WFP have funded a major expansion of CF by funding food for work digging of CF basins coupled with the financing of 60,000 input packs – one lima of maize and one lima of a legume – distributed to CF farmers by CARE, CFU, CLUSA, LMCF, the Programme Against Malnutrition (PAM) and World Vision.

5.2. Farm-level Incentives

[1] Early conservation farming work in Zambia has focused on water-conserving CF technologies suitable for the low and moderate rainfall areas, that is, Agro-ecological Regions I and IIa. The CFU has subsequently begun work on a comparable CF package appropriate for AER III, the high rainfall zones of northern Zambia (see CFU, 2002a; Langmead, 2002). Because this package is still under development, it has not yet seen large-scale extension support or on-farm adoption. This paper, therefore, focuses exclusively on the water-conserving conservation technologies developed for Regions I and IIa.

Yields proved higher in CF basins than in conventional plowing; roughly double among maize plots and 60% higher for CF cotton (Table 3). Higher applications of fertilizer, lime and hyv seed explain at least part of the higher yield on CF maize plots. In contrast, since cotton farmers, regardless of agronomic practices, use standard input packs supplied by Dunavant, the full 60% yield gain stems from cultural practices or at the very least from something other than differential input use. Early planting, for example, proves an important determinant of both maize and cotton yields. Since CF farmers prepare their basins in the dry season, they are able to plant with the first rains, on average two weeks earlier than animal traction farmers who must await the rains before they begin field preparation (Table 3). In years of sporadic rainfall, their field preparation frequently stalls, as farmers must wait for several weeks between showers to complete their ADP tillage. Though few in number, the ripper farmers in our sample failed to use their rippers properly for dry-season land preparation and subsequent early planting. Instead, they prepared land and planted on dates comparable to the conventional plow farmers.

In order to separate out the effects of planting date and differential input use from cultural practices, Table 4 presents regression results that attempt to separate influences of each factor independently. The results suggest that the use of hyv seeds and fertilizer account for about 800 kg of the yield gain in maize cultivation. Tight collinearity between hyv seed and fertilizer in this sample prevents us from assessing the independent effect of increased fertilizer applications. Since most farmers planting in CF basins use hyv seed and fertilizer compared to only about half of conventionally plowed plots; this suggests that higher input use accounts for roughly 300 to 400 kg of the observed maize yield gains in CF basins. Planting date, at 27 kg per day times 15 days, accounts for a further 400 kg gain. About 700 kg of the gain stems from CF cultural practices themselves – the retention of crop residue, the build-up of soil organic material and concentration of nutrients in the basins, and the water harvesting effects of the basins during the sporadic rainfall of the 2001/2 season.

For Zambia's 260,000 smallholders who do not own sufficient ADP of their own, budget comparisons suggest that CF technologies generate higher returns to land and to peak season labor than do their conventional tillage counterparts (Table 5). Hand hoe CF farmers, who plant in basins, achieve returns to peak season labor 65% higher than conventional hand hoe or plowing. Use of herbicides, which cut peak season weeding labor dramatically from 79 to 15 person days per hectare, boost returns to peak season labor a further 50%. If farmers used rippers properly for dry-season field preparation, they could take advantage of early planting as well as other benefits of low-til technology and earn the highest returns of all to both peak season labor and land. Yet most farmers in our small sample did not rip in the dry season. For them, achievement of the potential gain to ADP rippers will require additional extension support and training.

Returns for the 120,000 smallholders who do own adequate draft suggest that, if applied properly, ADP conservation farming with animal-drawn rippers offers the benefits of early land preparation and planting which in turn lead to returns to land 15% higher and returns to peak season labor 35% higher than conventional plowing (Table 6).

5.2 <u>Adoption</u>

Regional differences. The water-conserving CF technologies currently under widespread promotion – ADP ripping and hand hoe basins – are best suited to zones with low or scattered rainfall and clay or loamy soils. For this reason, adoption rates prove highest in Zambia's Agroecological Regions 1 and 2a. Our survey of Dunavant distributors, for example, suggests that about 15% of cotton farmers in moderate rainfall zones (AER 2a) of Lusaka and Central provinces use CF basins, while none in the high rainfall Copperbelt (AER 3) do (Table 7).

Extension support and role models. Even within a given high-potential CF zone, adoption rates differ considerably. In Mumbwa District of Central Province, the heart of Zambia's cotton zone, adoption of CF basins ranges from 27% at the Nangoma Dunavant Depot to only 8% at Shinuma (Table 7). Access to extension support and ADP certainly influences farmer decisions. And results from the census of Dunavant distributors suggests that the example set by the Dunavant distributor strongly influences behavior of his or her group members. Regression results suggest that when a distributor farms with CF basins, prevalence of basins among his group members rises by 16% (Haggblade and Tembo, 2003). Similarly, when a distributor tills with a ripper, prevalence of rippers among his group members rises by 8%, even after holding location constant.

Personal traits. Personal characteristics of individual farmers likewise affect adoption decisions. Conservation farming requires careful advance planning and meticulous, timely execution of key tasks. It requires a change of thinking about farm management under which the dry season becomes no longer a time primarily reserved for beer parties and socializing but rather an opportunity for serious land preparation work. Anecdotal evidence from our field interviews suggests that retired school teachers, draftsmen and accountants make good CF farmers. Likewise with cotton farmers -- whose cash crop demands careful attention to planting date, regular weeding, constant spraying and insect monitoring, as well as repeated careful hand harvesting – harbor the necessary management traits that make good CF farmers. Because of the importance of hard work, intensive attention to detail and crop management, cotton farmers constitute, in many ways, a self-selected group of farmers with the perseverance, planning, management and agronomic skills necessary to excel at CF. We believe it is no accident that cotton farmers prove to be among the largest group of spontaneous adopters of conservation farming.

Partial adoption. Most farmers who adopt CF technologies do not apply them to all of their plots. On average, the 125 farmers we surveyed in Central and Southern Provinces apply CF basins on about one-fourth of their cotton plots and about one-half of their maize plots (Table 5). Because the hand hoe fields are smaller than those that are plowed, the CF plots account for 10% to 20% of area cultivated. Adoption rates likewise vary by group, crop, gender and length of experience with CF. Women, for example, apply CF to a greater proportion of their holdings than men (Table 5).

Incremental adoption. Over time, for farmers who stick with conservation farming, proportions allotted to CF grow steadily. While first-year cotton farmers experiment with basins on only 1% of their cotton area -- often placing a few lines of basins as a test run -- those with four or more years of experience apply basins to over 40% of their cotton holdings. Similarly with maize holdings, the 10% area allotted to CF basins among first-year CF farmers rises to about 30% among farmers with four or more years of experience (Table 8). Likewise with rippers, data over four seasons suggests that contact farmers increased their ripped area from 1.3 to 2.4 hectares over that four-year period (Stevens et al., 2002).

Risk diversification. Adoption rates rarely reach 100%. Conversations with experienced CF farmers suggest that they do not have sufficient resources to manage their entire farms under CF basins but that they focus efforts on CF plots as insurance against drought and famine. They appear to view CF as providing portfolio diversification to ensure their household food security. As a woman farmer in Chongwe says conservation farming, "is a farming method for people who do not want to starve." (IRIN, October 17, 2002).

Disadoption. Anecdotal evidence from our survey indicates that after a period of time, some farmers disadopt the practice. Promotional agencies such as CLUSA, CFU and other agencies likewise disqualify farmers who fail to rigorously maintain CF practices. These can amount to as much as 20%, in a given year. Some farmers probably enter promotional programs purely to receive inputs on credit, which with the demise of major farm credit agencies they find difficult to obtain in any other way. Graduation of these farmers off of the input credit will offer the only real proof of how significant their numbers are.

Disadoption has occurred at the institutional level as well. Early NGO partners of the CFU -- including World Vision International, the Development Aid from People to People (DAPP), the Southern Province Household Food Security Programme (SPHFSP) and the Dioceses of Monze -- have all stopped their CF promotion efforts after a number of early experimental years. Though we have not been able to visit with all these groups, we sense that this institutional disadoption stems, in part, from the rigorous management and agronomic skills required by the staff of these promotional agencies. For non-agricultural institutions, the very exacting agronomic practices required by CF became difficult for their generalist staff to backstop and sustain. Among institutions, as well as individual farmers, CF is a management intensive technology for which not all are well suited.

Spontaneous adoption. Spontaneous adoption of CF, of course, also occurs. Our census of Dunavant distributors offers tangible evidence of the variable but potentially significant numbers of Dunavant farmers who have adopted CF basins in recent seasons. The acknowledged good performance of cotton farmers using CF basins during the 2001/2 season has led projected 70% to 80% increase in the number of cotton farmers using CF basins and rippers for the 2002/3 season (Haggblade and Tembo, Table 4).

5.3. Aggregate Impact

Best-guess estimates suggest that about 75,000 Zambian smallholders practice conservation farming in 2002/3, up dramatically from about 20,000 in the 2001/2 season because of the 60,000 starter packs issued as a drought-relief measure by a consortium of donors. How durable these 60,000 newcomers will prove once the starter packs dry up, however, remains open to serious question. Nonetheless, of the 75,000 smallholders practicing during the2002/3 season, about 15,000 are spontaneous adopters while the remaining 60,000 practice CF as a condition for receiving their inputs (Haggblade and Tembo, 2003, Table 6).

Estimation of total cropped area under conservation farming requires extrapolation based on limited on-farm sample surveys coupled with sometimes widely varying estimates of overall adoption rates. These projections, therefore, remain subject to large margins of error. Using a plausible range of estimates, we expect that CF adoption among cotton farmers accounts for somewhere between 1% and 5% of area planted in cotton, with the probable level tending toward the lower end of that range. With maize farmers, estimates become firmer because of the standard 1-lima (.25 hectare) input packs supplied by many support agencies and because of survey evidence for more experienced CF practitioners suggesting plot sizes in the range of .33 hectares per household. Using these figures, we estimate that Zambian smallholders planted about 4% of total maize area under conservation farming during 2002/3, 3% due to first-year farmers with starter packs and 1% from ongoing practitioners. Including a provision for soybeans and other legumes cropped in CF rotations, we estimate that smallholders planted roughly 22,00 hectares under CF in 2002/3. This accounts for 3% of total cropped area in agroecological regions suitable for water-conserving conservation farming, 1% of this from the ongoing practitioners plus another 2% from the first-year cohort of starter pack farmers.

Where sustained on the same plots over many seasons, the CF technology offers clear potential for improving soil quality, crop yields and financial returns to farmers. Yet we remain at the early stages of conservation farming promotional efforts and necessary time-series evidence is not yet available. CF promotion has operated for only the past seven years, with limited extension support in the early years. What the time-path of future adoptions will look like, only the future will tell. Likewise, a full understanding of the environmental impact of conservation farming will require time-series monitoring of soil fertility, soil structure, organic material and water tables as well as undoubted variability in yield gains from year to year.

6. CONCLUSIONS

Zambia’s old system of heavily subsidized, high-input agriculture has collapsed both financially and ecologically. It cannot continue. Despite a small population, growing pressure has reduced natural fallows (Franzel et al., 2002) and natural capacity to reconstitute Zambia’s soil. Therefore, farmers and researchers must find cost-effective means of breaking up plow pans, cracking sealed infertile surfaces, rejuvenating soil organic matter and reclaiming damaged farmland.

Conservation farming offers one promising and potentially sustainable technology for Zambia's low and moderate rainfall zones. Currently available evidence -- though based on small samples and mostly on single seasons -- suggests that conservation farming packages outperform their conventional farming counterparts. For farmer, without ADP of their own, CF basins appear to outperform hand hoe cultivation. For farmers with adequate draft power, the CF system that uses the ripper offers the promise of a more profitable and sustainable progression, though achieving this potential will require training to improve current on-farm practices.

The switch to conservation farming requires careful planning by farmers, changes in their dry-season lifestyle and work schedule. Effecting such change will require strong extension support, particularly to establish proper practices among ADP rippers. Indeed, not all farmers are willing to make these changes. But many have proven that they are. Private sector extension via Dunavant distributors appears to work well and to offer powerful CF role models among cotton farmers. For other crops, farmers will depend on support from the CFU, GART, government extension officers and NGOs in order to establish proper management procedures. And to benefit fully, farmers will require resuscitation of Zambia's rural credit and input supply systems, since access to key inputs such as hyv seeds, fertilizer and herbicides considerably improve incentives for adoption of conservation farming.

Our field research suggests that most farmers who adopt CF do so incrementally and partially. Partial adoption may, in fact, represent a useful food security and extension strategy. One lima (.25 hectares) of carefully managed CF basins could provide a bare bones food security safety net for a family of four. Two limas would generate cash surpluses. Given that the benefits of CF increase over time, early partial adoption may well offer the best vehicle for expanded adoption in the future.

Overall, the early evidence on conservation farming appear promising. Yet we know from similar experience elsewhere that onfarm results will vary tremendously across seasons. Likewise many of the anticipated gains under conservation farming -- declining field preparation and weeding labor, soil organic matter build-up, and the nitrogen gains from crop rotations -- will only become fully apparent over time. Therefore, both farmers and policy makers will benefit from the establishment of long-term monitoring over time-series on a larger-scale to more definitively assess the gains to conservation farming across geographic settings, crops, and seasons.

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Table 1 -- Conservation Farming Survey Sample

	Province		Total
	Central	Southern	
1. Groups selected			
CLUSA	7	9	16
Dunavant	3	2	5
total	10	11	21
2. Households interviewed			
CLUSA	34	48	82
Dunavant	32	11	43
total	66	59	125
3. Plots selected			
cotton	63	42	105
maize	109	96	205
4. Tillage system			
basins	59	61	120
hand hoe	11	0	11
ripper	9	45	54
plow	93	42	135

Table 2 -- Dunavant Cotton Distributors Census, September 2002

	Province					Total
	Central	Southern	Eastern	Lusaka	Copperbelt	
Distributors interviewed	549	273	518	52	8	1,400
Total group members	24,129	19,222	30,340	1,561	222	75,474

Table 3 -- Differences in Outpus and Input Use Across Tillage Systems

	Cotton					Maize			
	basins	hoe	ripper	plow		basins	hoe	ripper	plow
Number of sample plots	24	9	16	45	94	95	3	40	87
Yield (kg/ha)	1278	986	557	818		3054	3062	1727	1339
Timing									
field preparation befor	84%	22%	5%	2%		92%	50%	3%	0%
average planting date	13-Nov	20-Nov	23-Nov	28-Nov		18 Nov	5-Nov	27-Nov	02-Dec
Input use									
hyv seeds	100%	100%	100%	100%		93%	100%	85%	55%
inorganic fertilizer (kg/l	27	0	0	7		236	136	168	45
manure (kg/ha)	47	0	350	0		68	0	57	35
lime (kg/ha)	16	0	0	0		162	68	50	11
pesticides('000K/ha)	212	186	156	151		0	0	0	0

Source: IFPRI/FSRP survey.

Table 4 -- Sources of Yield Gains in Conservation Farming

Factors affecting yield	Cotton Yield Regressions				Maize Yield Regressions			
	1. Date only	2. Basic factors	3. Extended list	4. Fertilizer interaction	1. Date only	2. Basic factors	3. Extended list	4. Fertilizer interaction
planting date	-9 **	-2.6	-4.2	-4	-41.4 ***	-23 ***	-27 ***	-28 ***
(# days after November 1)	(-2.2)	(-.7)	(1.1)	(-1.2)	(-6.2)	(-3.5)	(-4.0)	(-4.0)
hyv seed (=1, local=0)						781 ***	800 ***	816 ***
						(3.2)	(3.3)	(3.2)
fertilizer use (kg/ha)		2 ***	1.6 ***	6.2		0.0	-0.1	0.004
		(3.1)	(2.6)	(1.6)		(-.2)	(-.4)	(.01)
tillage method (plow=0)								
basins		412 ***	513 ***	398 ***		1109 ***	692 **	595 *
		(3.1)	(2.8)	(2.3)		(4.7)	(2.3)	(1.8)
hand hoe		159	52	69		90	-28	-92
		(.9)	(.3)	(.5)		(.07)	(-.02)	(-.07)
ripper		-316 **	-176	-94		59	-251	-46
		(-2.3)	(-1)	(-.6)		(.2)	(-.7)	(-.1)
gender (male=1, female=0)			299 ***	249 ***			-207	-216
			(2.8)	(2.5)			(-.9)	(-.9)
years practicing conservation farming			-49	-52			115	125
			(-1.3)	(-1.5)			(1.5)	(1.6)
plot size (in hectares)			-191 ***	-189 ***			-111	-119 *
			(-2.8)	(-2.9)			(1.6)	(1.7)
fertilizer interaction with conservation farming								
basins x fertilizer				-0.8				0.1
				(-.2)				-0.09
ripper x fertilizer				-5.9				-0.9
				(-1.5)				(-.9)
adjusted R squared	0.04	0.26	0.35	0.44	0.16	0.32	0.33	0.33
number of observations	95	95	95	95	200	200	200	200

( ) t ratios are listed in parentheses underneath the regression coefficients.

*** Statistically significant at the 99% confidence level.
** Statistically significant at the 95% confidence level.
* Statistically significant at the 90% confidence level.

Source: IFPRI/FSRP survey.

Table 5 -- Options for Smallholder Farmers Without Draft Power* Living in

	Hand Hoe Tillage			Animal Draft Tillage			
	Basins		Conventional	Rent Ripper		Rent Plow	
	1st year, hyv seed		hyv	hyv seed		local	hyv
	hand weeding	weedwipe	seed	late prep	early prep	seed	
Maize farmers	(260,000 farmers)			(120,000 farmers)			
Output (kg/ha)***	3,000	3,000	2,119	1,552	2,308	752	1,552
Planting Date****	18 Nov	18 Nov	25 Nov	Dec 16	18 Nov	Dec 16	Dec 16
Labor inputs (person days)							
peak season	124	58	142	53	44	53	53
harvest	16	16	16	10	10	10	10
dry season	70	70	0	0	9	0	0
total	210	144	158	63	63	63	63
Gross margin (K/ha)							
gross margin	1,086,195	1,005,345	664,175	380,675	649,675	267,000	271,675
Returns to labor (K/person day)							
peak season labor	8,795	17,334	4,681	7,189	14,699	5,042	5,131
Cash costs	$99	$118	$94	$94	$120	$26	$120
Capital costs	$5	$23	$5	$5	$5	$5	$5
Cotton farmers				(70,000 farmers)			
Output (kg/ha)***	1,280	1,280	850	795	868		795
Planting Date****	13 Nov	13 Nov	20 Nov	Dec 11	13 Nov		Dec 11
Labor inputs (person days)							
peak season	106	41	142	79	72		79
harvest	47	47	22	31	31		31
dry season	70	70	0	0	14		0
total	223	158	164	110	117		110
Gross margin (K/ha)							
gross margin	860,755	779,905	499,555	344,691	405,843		344,691
Returns to labor (K/person day)							
peak season labor	8,151	18,884	3,520	4,363	5,629		4,363
Cash costs	$51	$70	$51	$77	$77		$77
Capital costs	$5	$23	$5	$5	$5		$5

* Includes all households with two or fewer cattle.
** Agroecological zones 1 and 2a.
*** Estimated from the regression coefficients in Table 5.
**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey; Appendix Tables C.5 and C.6.

Table 6 -- Options for Smallholder Farmers With Adequate Draft Power* Living in Zones Favorable for Water-Conserving Conservation Farming**

	Hand Hoe Tillage			Animal Draft Power Tillage				
	Basins		Conventional	Ripper			Plow	
	1st year, hyv seed		hyv	local	hyv seed		local	hyv
	hand weed	weedwipe	seed	seed	late prep	early prep	seed	seed
Maize farmers					(120,000 farmers)			
Output (kg/ha)***	3,000	3,000	2,119	1,319	2,119	2,308	1,319	2,119
Planting Date****	18 Nov	18 Nov	25 Nov	25 Nov	25 Nov	18 Nov	25 Nov	25 Nov
Labor inputs (person days)								
peak season	124	58	142	53	53	44	53	53
harvest	16	16	16	10	10	10	10	10
dry season	70	70	0	0	0	9	0	0
total	210	144	158	63	63	63	63	63
Gross margin (K/ha)								
gross margin	1,086,195	1,005,345	664,175	659,500	664,175	758,675	659,500	664,175
Returns to labor (K/person day)								
peak season labor	8,795	17,334	4,681	12,455	12,543	17,165	12,455	12,543
Cash costs	$99	$118	$94	$0	$94	$94	$0	$94
Capital costs	$5	$23	$5	$719	$719	$719	$719	$719
Cotton farmers					(70,000 farmers)			
Output (kg/ha)***	1,280	1,280	850		850	868		850
Planting Date****	13 Nov	13 Nov	20 Nov		20 Nov	13 Nov		20 Nov
Labor inputs (person days)								
peak season	106	41	142		79	72		79
harvest	47	47	22		31	31		31
dry season	70	70	0		0	14		0
total	223	158	164		110	117		110
Gross margin (K/ha)								
gross margin	860,755	779,905	499,555		499,555	514,843		499,555
Returns to labor (K/person day)								
peak season labor	8,151	18,884	3,520		6,323	7,141		6,323
Cash costs	$51	$70	$51		$51	$51		$51
Capital costs	$5	$23	$5		$719	$719		$719

* Includes all households with two or fewer cattle.
** Agroecological zones 1 and 2a.
*** Estimated from the regression coefficients in Table 5.
**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey; Appendix Tables C.7 and C.8.

Table 7 -- Regional Differences in Tillage Methods Used by Dunavant Cotton Farmers, 2001/2

Location	# groups	average group size	Percentage of farmers using each tillage method				
			plow	ripper	hoe	basin	total
Ranking by Agro-ecological zone							
Zone 1. Low rainfall (under 800 mm)							
Zone 2a. Moderate rainfall (800-1,000 mm), clay soils							
Zone 2b. Moderate rainfall (800-1,000 mm), sandy soils							
Zone 3. High rainfall (over 1,000 mm)							
Total	1,272	59	54%	3%	35%	8%	100%
Ranking* by Depot within Mumbwa District, Central Province							
Nangoma	24	56	49%	4%	19%	27%	100%
Mulendema	36	41	48%	5%	27%	20%	100%
Kapyanga	46	46	62%	5%	14%	19%	100%
Choombwa	19	58	68%	2%	15%	15%	100%
Moono	15	51	61%	0%	25%	14%	100%
Mumbwa	35	44	28%	2%	56%	13%	100%
Myooye	32	51	65%	7%	16%	12%	100%
Mvumbe	39	32	76%	2%	11%	10%	100%
Shinuma	40	42	75%	5%	13%	8%	100%
Total Mumbwa District	327	47	58%	4%	22%	16%	100%

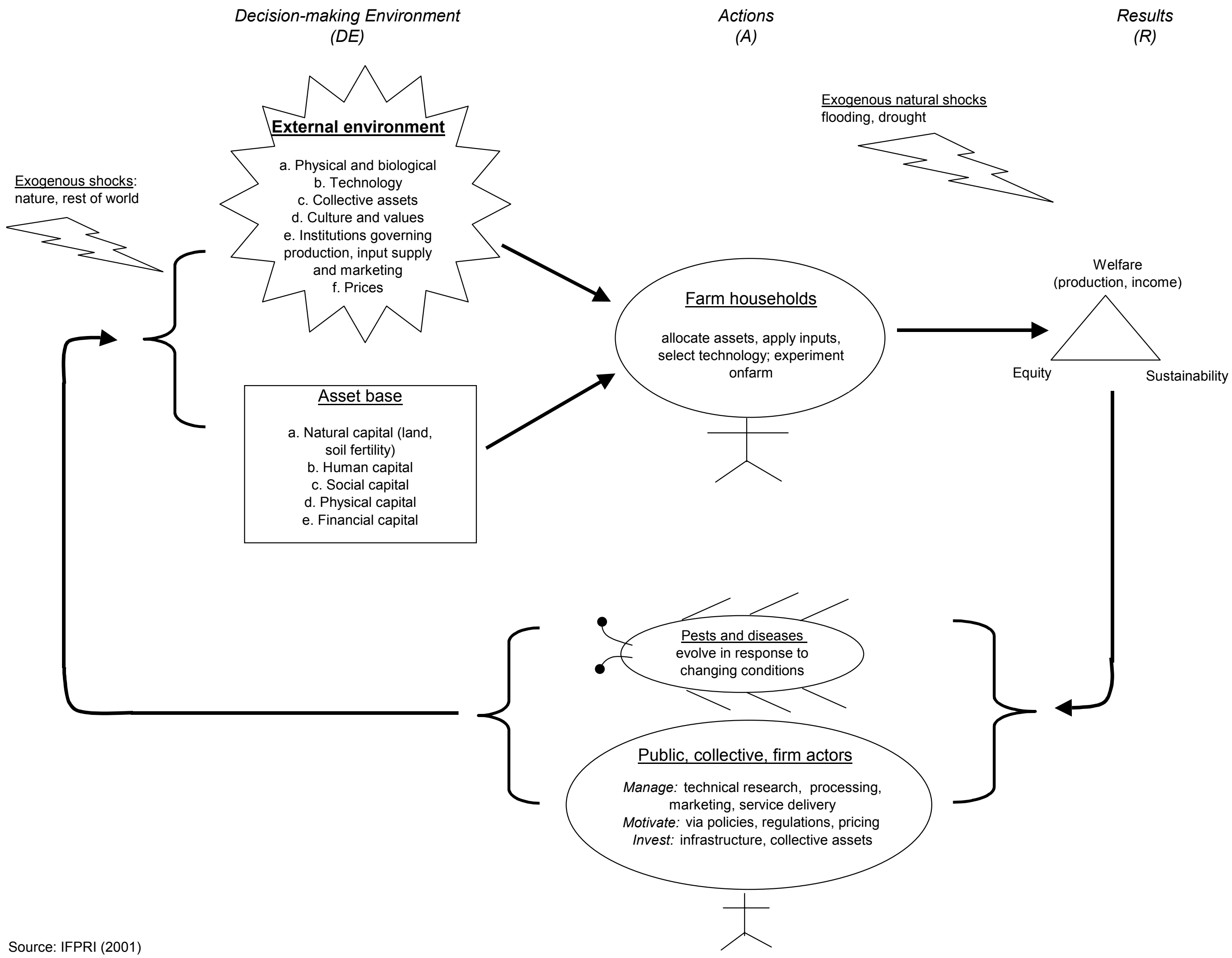
* Ranked in order of prevalence of conservation farming basins.
Source: Dunavant Distributor Survey, September/October 2002.

Table 8 -- Partial Adoption by CF Households

	Share of CF Basins in Total Household Plots			
	cotton		maize	
	% plots	% area	% plots	% area
Group membership				
CLUSA	13%	3%	48%	20%
Dunavant	31%	18%	34%	13%
total	24%	12%	45%	18%
Gender				
male	18%	7%	41%	14%
female	39%	33%	60%	49%
Years of experience with CF basins				
1	5%	1%	39%	11%
2 - 3	5%	22%	47%	25%
4 +	61%	44%	56%	31%

Source: IFPRI/FSRP survey.

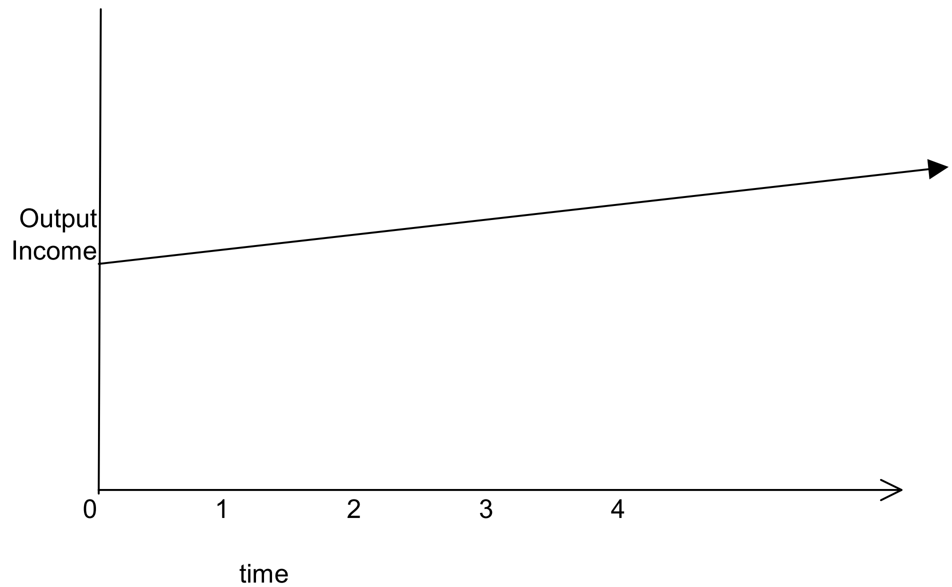
Figure 1 -- The Dynamics of Agricultural Change: The DE-A-R Framework



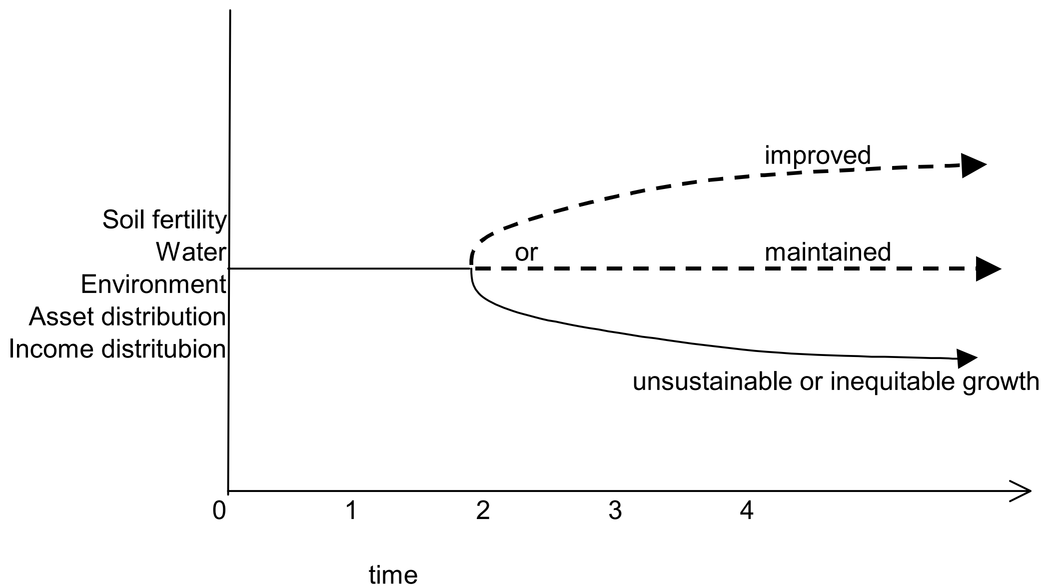
Source: IFPRI (2001)

Figure 2 -- Definition of "Sustainable" Agriculture

A. Steady performance



B. While maintaining or improving the asset base



Source: IFPRI (2001).