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CONSERVATION FARMING IN ZAMBIA

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EXECUTIVE SUMMARY

Since 1996, a growing coalition of stakeholders from the private sector, government and donor communities has promoted a new package of agronomic practices for smallholders in Zambia. The conservation farming (CF) system they advocate involves:

- dry-season land preparation using minimum tillage methods (either ox-drawn rip lines or hand-hoe basins laid out in a precise grid of 15,850 basins per hectare);
- no burning but rather retention of crop residue from the prior harvest;
- planting and input application in fixed planting stations; and
- nitrogen-fixing crop rotations. The CF system enables farmers to plant with the first rains when seeds will benefit from the initial nitrogen flush in the soil. By breaking pre-existing plow-pan barriers, the CF basins and rip lines improve water infiltration, water retention and plant root development. The precise layout of grids and planting lines enables farmers to locate fertilizer and organic material in close proximity to the plants, where they will provide greatest benefits.

Results from a survey of 125 farms in Central and Southern provinces during the 2001/2 cropping season suggest that, on average, hand-hoe CF farmers produced 1.5 tons more maize and 460 kg more cotton per hectare than did farmers practicing conventional ox-plow tillage. Among maize farmers, 1.1 tons of this increase comes from the CF technology – 400 kg from early planting and 700 kg from water harvesting and greater precision in input use in the basins – while the remaining 400 kg stems from higher doses of fertilizer, lime and high-yielding variety (hyv) seeds. Because cotton farmers use standard packages of seed and pesticides, the great bulk of the observed gain under CF -- 430 of the total 460 kg gain -- stems from the water harvesting, precision and timeliness of the CF system. Erratic early season rainfall showcased the water-harvesting benefits of CF during the 2001/02 season. Since results will no doubt vary under different rainfall regimes, future monitoring will be necessary to evaluate impact over a series of production seasons.

CF involves additional costs for farmers, particularly additional labor at weeding time given that farmers till only about 15 percent of the soil surface during field preparation. Dry-season land preparation, though arduous in early years, becomes easier over time, and with CF basins land preparation time falls in half after about 5 years. The redeployment of field preparation labor and draft power to the off-season relieves peak-season labor bottlenecks, thus enabling early planting and early weeding.

Budget analyses, which compare the value of increased output with the increased input and labor costs, suggest that hand hoe conservation farming outperforms conventional tillage, generating higher returns to both land and peak season labor. In its animal draft variant, conservation farming with ox-drawn rippers likewise holds the potential to outperform conventional ox plowing, offering higher returns to peak season

labor and to land. When practiced properly, with dry-season land preparation, rippers offer the benefit of more timely planting, resulting in higher yields, as well as labor deployment out of the peak agricultural season and into the dry season when opportunity costs are low. However, the small sample of farmers we interviewed suggests that a significant portion of ADP farmers fail to use rippers properly. For them to achieve the benefits of dry-season ripping will require expanded extension and training support.

Though data on overall adoption remain fragmentary, available evidence suggests that between 20,000 and 60,000 farmers practiced some form of hand hoe conservation farming in basins during the 2001/02 season while an additional 4,000 used rippers. Numbers using basins have risen sharply in 2002/03 given the big push provided by donor cash and food aid which have financed input packs and dry season digging of basins for an additional 60,000 smallholders.

Incentives for adoption of water-conserving CF technologies prove strongest in Zambia's Agro-ecological Regions I and IIa, regions of erratic rainfall and extensive plow-pan damage where 420,000 Zambian smallholders currently farm. Among the 60 percent who practice hand hoe agriculture and the 25 percent who plow with borrowed or rented oxen, basins or dry-season rental of oxen and rippers remain the most attractive CF technologies. For the remaining 15 percent, those who possess adequate draft power of their own, properly executed ripping technology proves the most profitable choice.

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 for conservation farming and control plots across a broad range of geographic settings, crops and seasons.

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1. INTRODUCTION

SCOPE OF THE CASE STUDY

Conservation farming (CF), as applied in Zambia, 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 (Box 1). For hand hoe farmers, CF revolves around dry-season preparation of a precise grid of permanent planting basins (15,850 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 leguminous crop rotations such as soybeans, green gram and sun hemp complete the ladder of conservation farming technologies.

Conservation farming represents a local variant of traditional minimum tillage technologies adopted in many parts of Africa. Similar hand hoe planting basin systems have emerged across much of the Sahel as well as in Cameroon, Nigeria, Uganda, and Tanzania (Critchley et al. 1994; Reij 2001; Shapiro and Sanders, forthcoming).[1] Ox-drawn rippers have expanded recently in Tanzania, Kenya, Namibia and Mozambique while early work with tractor-drawn minimum till systems in Zimbabwe and South Africa provided much of

[1] To provide contrast and comparison, a companion paper in this series traces the rise, spread and impact of a technology very similar to Zambia's conservation farming -- the zaï system of planting basins that has grown rapidly across Burkina Faso, Mali and Niger over the past 20 years (Kaboré and Reij 2003).

the inspiration for recent transfer to ox and hand-hoe cultivation systems (Oldrieve 1989; IMAG 2001).

Even though local development and promotion efforts date back scarcely a decade, many local observers consider conservation farming an emerging “success story” in Zambia. Its promoters note that CF holds the potential to restore soil fertility to land damaged by years of excessive plowing and heavy applications of chemical fertilizer, and to improve on-farm yields and incomes with moderate input use. In years of low or sporadic rainfall, conservation farming offers important water harvesting benefits as well. Its most prevalent planting basin variant explicitly caters for small-scale hand-hoe farmers without reliable access to draft power. CF thus aims to improve not only efficiency and sustained soil fertility but also equity.

Unlike the conventional hand-hoe and plowing technologies they replace, CF moves only about 15 percent of the soil where crops will be planted. By breaking through pre-existing hardpan or plowpan layers, CF systems aim to improve water infiltration and root development, 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, greater precision in input use and gradual build-up of soil organic matter.

The impact of conservation farming on farm output and incomes has received scattered attention in the past. Indeed, given the high expense of data collection, particularly in low-density rural areas of Zambia, researchers have exhibited considerable ingenuity in exploiting available resources. Even so, available results fall short of definitive for several reasons.

Many impact studies of CF have failed to apply control groups. Most field trials, for example, have focused on comparing within conservation farming systems – CF with and without lime, CF with different dosages of fertilizer, CF with different crop rotations. Though they document high yields from conservation farming plots, most of these studies resort to comparisons with national average yields rather than comparing these outcomes to matched control groups of farmers and farming conditions.

A handful of studies have compared output differences between CF and conventional tillage plots (Arulussa 1997; ECAZ 1999; Langmead 2001 2002; Stevens et al. 2002). Most find substantially higher yields on CF plots – often double those achieved under conventional tillage. But this outcome is not surprising given that CF farmers often receive extra extension support as well as input packages of high-yielding variety (hyv) seeds and fertilizers to which most conventional farmers have not had access in the decade and a half following the collapse of Zambia's input supply and credit systems. Even under conventional tillage, higher fertilizer and hyv seed use will increase output. Yet in the few studies that provide control groups to measure output differences with and without CF, data limitations often prevent them from distinguishing which part of the incremental output stems from higher input use and which part results from different agronomic practices.

Many studies of CF have relied on small sample sizes. Keyser and Mwanza (1996) conducted a rapid appraisal of 28 Mumbwa farmers. Langmead (2001) evaluates output differences before and after CF adoption using a sample of 19 CLUSA farmers. Large samples such as those by Arulussa (1997), ECAZ (1999) and Langmead (2002b) prove to be the exception rather than the norm.

Quantification of adoption rates for various CF practices remains similarly elusive because of the high costs of fieldwork and because partial and incremental adoption by farm households makes precise measurement difficult. Likewise, we know of no existing studies of disadoption by CF farmers. Such a review, perhaps in conjunction with more work on unassisted adoption, could provide valuable lessons as to which types of farmers most readily practice CF and which will prove unlikely to stick with it.

CF farmers must normally apply more labor at weeding time, at least in early years of adoption, because field preparation leaves 85 percent of the land surface untilled and therefore unweeded during land preparation. So CF farmers apply both more labor and more purchased inputs to achieve their higher yields. Yet no study we are aware of has measured differences in profitability by comparing the value of differential output to the differential input costs.

This review aims to address several of these important gaps by investigating three key features of conservation farming in Zambia:

1. the process by which CF originated and spread,
2. its impact on crop output, input use, cost of production and farm income, and
3. the scale of CF adoption across household groups and regions.

DATA AND METHODS

Process

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 Institute of Agricultural and Environmental Engineering (IMAG) Project, Ministry of Agriculture and Cooperatives (MACO), Dunavant Cotton, the Cooperative League of the USA (CLUSA0, World Vision and various donors and researchers involved in CF promotion and development. We have supplemented these oral reports with written documentation from those agencies as well as reports by other agencies and researchers (ECAZ 1999; Ellwell et al. 1997; GART 2002; GOZ 2001; Keyser and Mwanza 1996; Langmead 2001 2002; Ndioyi 2002).

Impact

The few available studies attempting to measure the output effect of conservation farming under on-farm conditions have focused primarily on hand-hoe planting basins. Frequently based on small sample sizes or rapid appraisal techniques and reliant on farmer recall,[2] most conclude that output of maize increases by 50 to 100 percent compared to conventional tillage systems, by which most mean plowing (Langmead 2001; ECAZ 1999; Ellwell et al. 1999) Gains in cotton production prove lower and more variable, ranging from

[2] The Arulussa (1997) study of Lonrho cotton farmers proves the major exception. This study randomly selected 224 cotton farmers around Mumbwa and obtained actual Lonrho sales figures rather than relying on farmer recall.

5 to 45 percent (ECAZ 1999; Arulussa 1997). Assessment of ox-drawn rippers have been fewer. A recent study of 60 assisted farmers over 3 seasons suggests that use of rippers results in slight yield gains for maize in some years but no significant difference in other years (Stevens et al. 2002).

To supplement these available data, we conducted a field survey of randomly selected cotton and maize farmers in Southern and Central Provinces during March 2002. Stratifying by location, crop, tillage system and gender, we selected a sample of 205 maize plots and 105 cotton plots grown by 125 farmers in Central and Southern Provinces. The sampling strategy aimed to select a group of a representative CF plots together 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 outputs on all conventional plots farmed by the selected CF farmers. Annex A provides details of the sampling and methods used.

Due to time constraints and given the need to focus resources, the survey concentrated on two crops only – on maize, Zambia's most prevalent food crop, as well as on cotton, the country's most important cash crop and the one most widely associated with conservation farming. This two-crop focus should in no way be construed as suggesting that farmers limit their practice of CF to only these two crops. On the contrary, farmers and promotional agencies practice conservation farming with a wide array of additional crops, including groundnuts, sunflowers, green gram, pigeon peas, and soybeans. Given differences in plant physiology, responses to CF will likely vary by crop and indeed across varieties within crops. We leave it to others to fill in the record on crops beyond the two addressed in this paper.

The survey provided plot-level data on inputs and outputs on both conventional and CF plots, thereby enabling us to estimate the impact of individual practices while controlling for soil conditions, farmer experience, rainfall and differential input use. Analytically, we evaluated the impact of individual inputs and farming practices through regression analysis. We applied several specifications of the yield regression to estimate the impact of various factors on maize and cotton yield with the most general specification given as follows:

$$\begin{aligned} Yield \quad &= \beta_0 + \beta_1(plantdate) + \beta_2(fert) + \beta_3(hyv) + \beta_4(plotsize) \\ &+ \beta_5(experience) + \beta_6(gender) + \beta_7(basins) + \beta_8(ripper) \\ &+ \beta_9(hoe) + \beta_{10}(fert{*}basins) + \beta_{11}(fert{*}ripper) + \beta_{12}(fert{*}hoe) + e, \qquad (1) \end{aligned}$$

where *plantdate* indicates the planting date as measured by the number of days after November 1, *fert* is the quality of fertilizer applied in kilograms per hectare, *hyv* is an high-yielding variety seed usage dummy variable equal to one if the seed used is a high-yielding variety, *plotsize* is the plot size in hectares, *experience* is the farmer's experience with conservation farming measured in years, and *gender* is the dummy variable for the sex of the household head equal to one if male and zero otherwise.

Of the four tillage methods encountered in the survey – planting basins, ripping, conventional hand-hoe cultivation and conventional plowing – ox plowing proved most prevalent. Using ox plowing as the numeraire, the effect of the categorical variable "tillage method" was, thus, represented by three dummy variables, *basins*, *ripper* and *hoe*. For each of these, the value of the tillage dummy is equal to one if the household used the tillage method and zero otherwise. Because the basins and rip lines harvest water and because of known interactions between water and fertilizer, we have included interaction terms to capture the combined effect of fertilizer and tillage method. The last term in the estimating equation is the error term assumed to be independently and identically distributed with mean zero and constant variance.

Adoption

A large-scale survey by the LMCF project, covering roughly one-third of Zambia's smallholders operating in 100 agricultural extension camps where LMCF operates, offers an important glimpse into the prevalence of a variety of specific soil conservation techniques. In addition, we have accessed the four-year series of nationally representative annual post-harvest surveys undertaken by the Central Statistical Office's in order to measure tillage methods across all regions of Zambia.

To learn more about adoption patterns, we conducted a census of Dunavant cotton distributors in September 2002 in order to obtain information on tillage methods among their 75,000 cotton farmers operating across the heart of the potential water-conserving CF zone in Southern, Central and Eastern Provinces. Dunavant cotton farmers provide a valuable focus group since they represent the largest pool of spontaneous CF adopters in Zambia. Moreover, unlike other promotional agencies, Dunavant's provision of inputs is not tied to tillage method. So adoption by these farmers represents a clear choice based on the farmer's best assessment of what tillage system is in his or her best interest. Annex B describes the methods used in this census. Coupled with other available information, these data provide a valuable picture of the geographic dispersion of CF practice as well as important clues as to factors governing adoption.

2. DEVELOPMENT AND SPREAD OF CONSERVATION FARMING

KEY PHASES AND TURNING POINTS

Development and promotion of conservation farming have taken place in several key phases. Though any partitioning will prove somewhat arbitrary, it is useful to consider three main periods in the development and spread of conservation farming in Zambia.

Phase 1. Subsidized high-input maize production (1964-1991)

For the first two and a half decades following independence, Zambian agricultural policy focused squarely on the promotion of maize. Large-scale marketing support coupled with extensive fertilizer and input subsidies induced farmers to devote ever-larger areas to maize production (Wood et al. 1985; IESR 1999; Zulu et al. 2000). Tractor and plow credit and subsidized rental schemes encouraged expansion of cropped area via plowing. Maize marketing guarantees provided further inducement for farmer adoption of the high-input maize packages.

As a result of heavy application of chemical fertilizers and sustained extensive plowing, Zambian agriculture entered the 1990's with significantly declining land quality and productivity. Though many regions of Zambia, particularly the North, house naturally acidic soils, decades of heavy nitrogen fertilizer application in central and southern zones have exacerbated the soil acidity problem in these areas. Consequently, the epoch of high input and animal traction subsidies left Zambia with large tracts of seriously acidified and compacted soils, hampered by underlying impermeable plow-pans that stymie both root and water penetration (Figure 1). As one major recent review of declining land productivity concludes, "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).

Figure 1--Plow pan damaged land in Zambia

Decades of large-scale maize subsidies came to an abrupt end with the change of government in 1991. Farmers quickly responded by diversifying out of maize production and by reducing fertilizer use by over two-thirds as availability diminished and input prices jumped (Table 1). Further dislocation spurred innovation and change in Zambian agriculture. A serious drought rocked Zambian agriculture in 1992, while fuel prices soared with the floating of the Zambian kwacha. In rapid succession, a serious outbreak of corridor disease in the mid-1990's precipitated an approximately 16 percent slump in cattle population between 1995 and 2000 (Figure 2).[3]

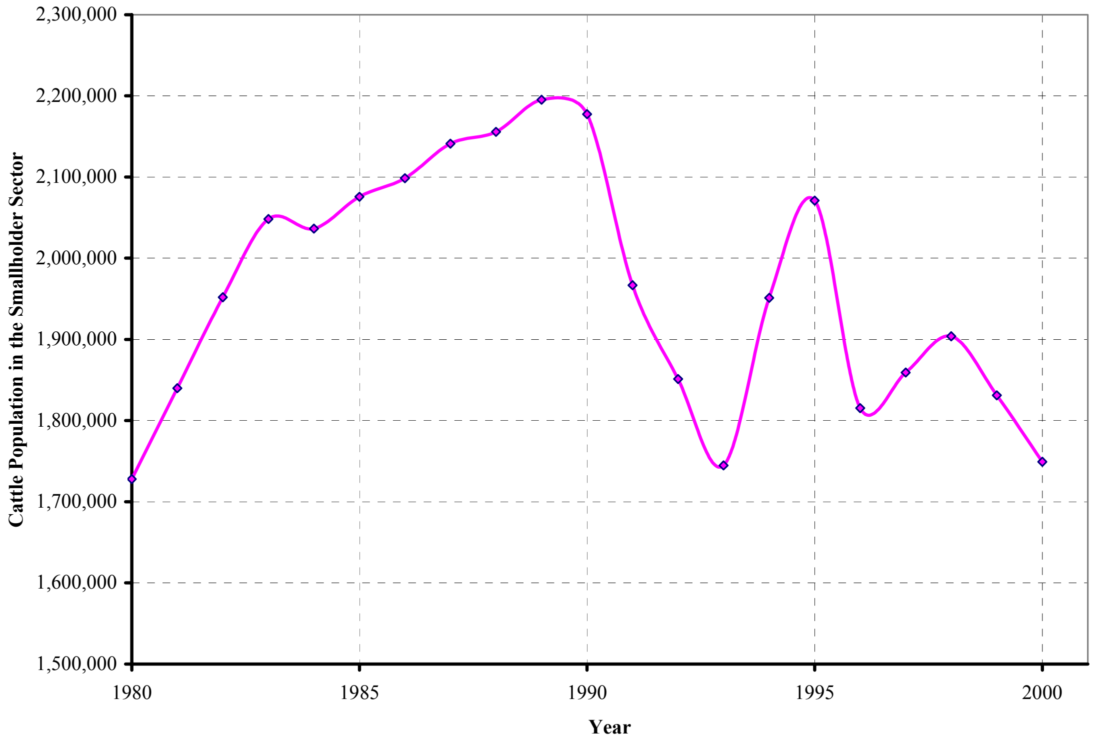
[3] Official figures, based on reporting by the Veterinary Services, suggest a modest 5% death rate. But reporting rates remain very low, and anecdotal evidence suggests far higher mortality rates, in the range of 20% to 50% in the affected regions.

Table 1--Trends in Zambian agriculture 1990-1999

Year	Maize: Production index	Maize: Share of cultivated land area (%)	Maize: Yield (tons/ha)	% of households with cattle	Average fertilizer use (kg/ha)	Rainfall (mm/year)
1990	100	67				579
1991	98	65	1.59	19	98	716
1992	43	66	0.75	20	69	469
1993	143	64	1.64	17	121	820
1994	91	63	1.28	14	79	700
1995	66	60	1.54	13	56	600
1996	126	63	1.89	13	59	925
1997	86	62	1.41	15	25	918
1998	57	42	1.24	13	27	846
1999	76	58				859
Mean	89	61	1.42	16	67	743

Source: IESR (1999); Zulu et al. (2000).

Figure 2--Trends in cattle population among Zambian smallholders, 1980-2000



Source: Data from the National Epidemiology, Livestock Information Centre (NALIC), Department of Research and Specialist Services, Animal Production and Health Sub-Program, Lusaka, Zambia.

Zambia's prior status quo -- input-intensive ox-plowed maize production -- has rapidly eroded in the face of these multiple shocks. As the scale of this land quality problem spread, it has triggered a series of parallel reactions, all aimed at finding ways of improving soil structure, organic matter and fertility.

Phase 2. Testing minimum tillage conservation farming technologies in a land-damaged landscape (1985-2000)

A series of actors emerged in the late 1980's and early 1990's to confront these twin problems of damaged soil and radically altered production incentives. Leading players in the technology development and dissemination have included the Conservation Farming Unit (CFU) of the Zambia National Farmers Union, the Institute of Agricultural and Environmental Engineering (IMAG) Project and the Golden Valley Agricultural Research

Trust (GART). Extension of the technology has attracted strong support from not only the CFU but also from the privately held Dunavant Cotton Company, the Cooperative League of the USA (CLUSA), GART, IMAG and the Land Management and Conservation Farming Project (LMCF) together with their partners at the extension service of the Ministry of Agriculture and Cooperatives (MACO), and NGO's such as the Catholic Archdioces of Monze, Development Aid from People to People (DAPP), CARE and Africare. Overall, four related strands of activity emerged as key players in Zambian agriculture responded to changing conditions by launching efforts to identify, develop and codify more sustainable production management systems.

Minimum tillage commercial farming

The Zambia National Farmers Union (ZNFU) has played a crucial role in the development and promotion of conservation farming technologies in Zambia. Initial interest began when several commercial farmers in the ZNFU traveled to Australia and the USA in the early and mid-1980's to learn about low-tillage systems. Extensive work and application by Zimbabwean commercial farmers and research at their privately financed 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. The parallel benefits of reduced soil compaction and improved soil structure soon 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.

Hand hoe CF package

Perhaps surprisingly, Zambia's commercial and medium-scale farmer organization, the ZNFU, became the prime mover in developing an appropriate minimum tillage package, not only for mechanized large-scale commercial farms but also for smallholder hand hoe agriculture. The hand hoe analog of minimum tillage systems was introduced to Zambia in 1995 by 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). In the course of this work, 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). Because of tension among farmers, researchers and the extension service in Zimbabwe, the planting basin technology never spread widely among smallholders there. Even so, given that the low tillage hand hoe methods appeared to be agronomically sound, and indeed well-suited to the damaged soil conditions and declining draft power availability in Zambia, the ZNFU elected to proceed in developing a hand-hoe analog to the minimum tillage animal and tractor-powered technologies under investigation for large farms (Figure 3).

Figure 3--Dry season digging of CF basins

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 (subsequently bought out by Dunavant), 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 with 395 farmers in their first cropping season of 1996/97, the CFU expanded to 800 onfarm demonstrations and trials in 2001/2 (CFU 1997). They conduct training and farm trials for government extension staff, Dunavant Cotton farmer distributors and have worked 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).

Agricultural engineering and development of the Magoye Ripper

Parallel efforts in agricultural engineering concentrated on development of ox-drawn ripping equipment to facilitate animal draft low tillage systems. In 1986, work began at the Ministry of Agriculture research station in Magoye under Dutch funding. This applied research resulted in development of the Magoye Ripper (Figure 4 and 5), an ox-drawn ripping tool tested locally at GART and now produced and exported to surrounding countries in Southern and Eastern Africa (GART 2001; 2002; IMAG 2001). LMCF, through MAC extension officers, actively promotes the Magoye Ripper.

Figure 4--The Magoye Ripper

Source: Piet Stevens, IMAG/GART.

Figure 5--Dry season ripping

Source: Piet Stevens, IMAG/GART.

Improved fallows

In 1985, at about the same time that minimum tillage work began in Central and Southern Provinces, the International Center for Research on Agroforestry (ICRAF) began research in Eastern Province of Zambia to explore prospects for soil rejuvenation via improved fallows. Given the scarcity of chemical fertilizer and their high price following subsidy removal in the 1990's, ICRAF aimed to find natural soil fertility enhancers that could provide significant nitrogen and organic material without cash purchase of inorganic fertilizers.

After a decade of research station, on-farm and often farmer-designed trials, ICRAF concluded that 2-year fallows with herbaceous shrubs proved most viable under typical farm conditions. Sesbania sesban and tephrosia vulgari have proven the most popular fallow species, though ICRAF and colleagues work with a range of other leguminous shrubs as well. Beginning in 1996, in concert with World Vision, LMCF and the Ministry of Agriculture, ICRAF began an aggressive program of seed distribution and extension support for improved fallows in Eastern Province (World Vision 2002; Franzel et al. 2002 and 2003).[4]

Soil conservation

Together with the Ministry of Agriculture and Cooperatives (MACO, then named MAFF), a Swedish funded Soil Conservation and Fertility Enhancement (SCAFE) project began in 1985 to promote a wide range of erosion control measures such as bunding, contour tillage, and vetiver grasses; soil fertility enhancement techniques including crop residue management, green manures, cover crops, mulching, improved fallows, and conservation tillage. Their efforts initially focused on Eastern Province but have expanded in the mid-1990's to include Central and Southern Provinces as well. The geographic scope of project activities has expanded as the name changed to what is now called the Land Management and Conservation Farming (LMCF) project. Working with the Ministry of Agriculture and Cooperatives (MACO) they have become large-scale promoters of conservation tillage via both basins and rippers as well as strong proponents of integrating crop rotations and of extension of a full menu of tillage options to farmers. Thus, the originally independent development and extension of hand hoe and ADP conservation tillage systems has gradually given way to cross-product promotion and extension links among the various promotional agencies.

[4] Two companion papers in the IFPRI "Successes in African Agriculture" case study series, by Place et al. (2003) and Franzel et al. (2003), examine these efforts in detail.

Phase 3. Scaling up extension (1998 on)

Early extension efforts

In addition to its technology development and testing, the CFU has engaged in direct extension efforts since its first full season of operation in 1996/97. They have conducted between 800 and 1,000 demonstrations and trial plots annually between 1997 and 2001. They supply inputs to farmers in return for their cooperation in carefully measuring inputs, response rates and outcomes of a variety of alternative crop rotations, intercrops, and input application rates. With a headquarters staff of two full-time professionals and an extension staff of about 30, the CFU runs demonstrations and field days as well as specialized training for MACO, Dunavant, CLUSA and other promotional agencies. They have produced radio broadcasts as well as a series of field manuals in different local languages to facilitate CF extension by their staff and others (CFU 1996 1998 2002a 2002b,2002c). The CFU has worked with a range of extension partners including the Catholic Diosces of Monze, DAPP, World Vision and Africare, though their two longstanding partners have remained Dunavant Cotton Company and CLUSA.

Dunavant Cotton Company runs a series of training programs each cropping season for their 1,400 group distributors. These are lead farmers, or farmer-entrepreneurs, through whom Dunavant distributes inputs, credit and information on key management practices to their roughly 80,000 cotton farmers. Through CFU participation at these distributor training sessions, the Dunavant small farm training personnel disseminate CF principles to their farmers (CFU 2002). Dunavant remains keenly interested in the CF management system because several features of CF coincide with best-practice management for cotton production:

- emphasis on dry-season field preparation enables timely planting, with the first rains, a key determinant of cotton yields,
- exact measurement of the CF basin grids and planting rows enables precise input application rates as well as placement in close proximity to the seeds
- precision layout of the grids enables optimal plant populations for both yield and plot management.

Because of these perceived benefits, Dunavant Cotton (and their predecessor Lonrho) has provided annual financial support to the CFU since its inception.

CLUSA's Rural Business Group Programme in Southern and Central Provinces has likewise emphasized CF planting basins in the field demonstrations and training session they run for their 6,000 to 8,000 farmers. To support these efforts, they have developed a training of trainers manual which covers CF extension methods. Following their first several years experience with CF, CLUSA conducted a rapid appraisal of farmer performance in 1997. From this review, they concluded that farmers planting with CF basins consistently outperformed other group members and most reliably repaid their input credits. So from 1998 onwards, CLUSA's operations in Central and Southern province required all its farmers to adopt CF planting basins as a condition for receiving group loans and marketing support.

The Ministry of Agriculture and LMCF implement a mandate far broader than simply extension of CF packages. Though starting out small and in Eastern Province (under the SCAFE Project), LMCF now operates in 100 agricultural camps (MACO extension offices) throughout Eastern, Central and Southern Provinces. Mandated to work with ministry extension services, LMCF areas serve 300,000 farmers, about one-third of all smallholders in Zambia (LMCF 2001). Their work includes extension staff development and planning support as well as work on general land management issues such as erosion control, testing and dissemination of improved fallow systems, testing of different cover crops and crop rotations, and tillage demonstrations.

GART, with support from the Dutch group IMAG, has inherited the mandate to conduct trials with mechanical and animal draft power (ADP) low-till equipment. As part of this effort, they have worked closely with local manufacturers of the Magoye Ripper. Since production began in the mid 1990's, local manufacturers have produced a total of about 5,000 Magoye rippers. Roughly 4,000 remain in use in Zambia while 1,000 have been exported to neighboring countries. GART and IMAG have ordered 2,000 more for distribution in the 2002/3 cropping season. Increasingly, to complement their on-station research, GART is moving to on-farm ripper trials (GART 2002; Stevens et al. 2002).

Regular interaction occurs informally across this broad consortium of CF practitioners. In 2001, the Ministry of Agriculture's Technical Services Branch established a National Conservation Farming Steering Committee to help coordinate information flows and facilitate collaboration.

Rapid scaling up

In 1998, the Ministry of Agriculture, Food and Fisheries (then MAFF, now renamed MACO) 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.[5] Consequently both MAFF and LMCF have devoted increasing attention to extending CF technologies. In addition to their ongoing work with ox-drawn rippers, LMCF and MACO have conducted trials with CF basins and expect to diversify their extension message in coming years to both hand hoe and

[5] The LMCF project operates administratively under the Ministry of Agriculture and Cooperatives (MACO), before 2002 known as the Ministry of Agriculture, Food and Fisheries (MAFF).

ox-plow CF systems. To facilitate these efforts, they have produced a series of written training materials as well as an instructional video (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 programs in Central and Southern Provinces have required all their farmers to plant in CF basins as a condition for receiving input credit and marketing support. Though testing and technology development continues, most agencies are now focused on extension of CF management systems. As a result of increasing farmer adoption and growing extension support from other agencies, beginning in the 2001/2 season the CFU has cut back its own on-farm demonstrations from 800 to 200 in order to devote more resources to extension support for other promotional agencies (CFU 2001).

The drought of 2001/2 accelerated interest in water-conserving conservation farming technologies – the hand hoe basins and rippers – developed for erratic rainfall zones of southern and central Zambia.[6]. Having observed the strong performance of CF basins during the erratic rainfall of the prior season, both farmers and government have substantially expanded their CF activities. Among farmers, our field interviews with Dunavant groups suggest an increase of about 70 percent in CF adoption between 2001/2 and 2002/3, from about 6,000 to 10,000 using basins and from 2,000 to 3,000 using rippers (Table 2). Donors such as SIDA, NORAD, FAO and WFP have spurred a major expansion of CF by funding

[6] 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 regions 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 the erratic rainfall Regions I and IIa.

the dry season digging of CF basins with Food for Work monies and then financing 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 (Table 3).

Table 2--Growth rates of conservation farming among Dunavant cotton farmers 2001/2 to 2002/3

Province	Basins			Rippers			Number of
	2001/2	2002/3	% change	2001/2	2002/3	% change	Observations
Central	2,879	5,206	81%	892	1,186	33%	466
Lusaka	225	296	32%	98	114	16%	43
Southern	1,075	1,561	45%	704	1,835	161%	241
Total number of farmers*	4,180	7,063	69%	1,719	3,160	84%	767

* Growth rates reflect changes anticipated among the two-thirds of distributors who had already visited group members prior to the start of the 2002/3 season. While we believe growth rates to be accurate, the total numbers of farmers listed in this table understate adoption by about one-third. During the 2001/2 season. 6,200 Dunavant farmers had adopted CF basins, while a further 2,2000 practiced ripping. See Table B.2 for details.

Table 3--Recent changes in the adoption of conservation farming basins in Zambia

Farmer Categories	Number of Farms Adopting CF Basins 2001/2	2002/3
Sponsored farmers whose input supplies are tied to use of CF basins		
CLUSA group members	6,000	28,000
CFU trials	1,000	450
other NGOs	4,000	32,500
subtotal	11,000	60,950
Spontaneous adopters		
Dunavant farmers	6,000	10,200
others	3,000 – 47,000	3,000 – 80,000
subtotal	9,000 – 53,000	13,200 –89,600
Total	20,000 – 60,000	75,000 – 150,000

Source: Post-harvest survey, Dunavant Distributors Survey

ADOPTION RATES

Changing incentives

The 1990’s ushered in key changes in farmer opportunities and incentives in Zambia. Subsidies on maize prices and key farm inputs evaporated overnight as a new government took office in 1991. Farm credit disappeared from the market as did subsidized tractor hire and rental schemes. A serious drought in 1992 reinstilled concerns about soil moisture retention and timeliness of planting. A legacy of damaged soils heightened awareness of problems of runoff, erosion, poor soil structure and low soil organic material (Figure 1). The epidemic of corridor disease has seriously weakened cattle herds throughout Zambia, while the drought of 2002 has reduced their already depleted numbers still further.

Individual farmers have responded by reducing input use, diversifying out of maize production, and seeking alternative tillage systems (Table 1). Collectively, farmer organizations, private companies, NGO's, specialized projects and MACO began to disseminate the CF technologies that emerged in response to the radically altered physical and policy environment.

Overall adoption rates

In response to these changes in their operating environment, how many farmers have adopted conservation farming practices in Zambia? The answer to this question requires considerable care, since many farmers adopt some of the recommended practices without adopting others (Arlusa 1997; ECAZ 1999; LMCF 2001).

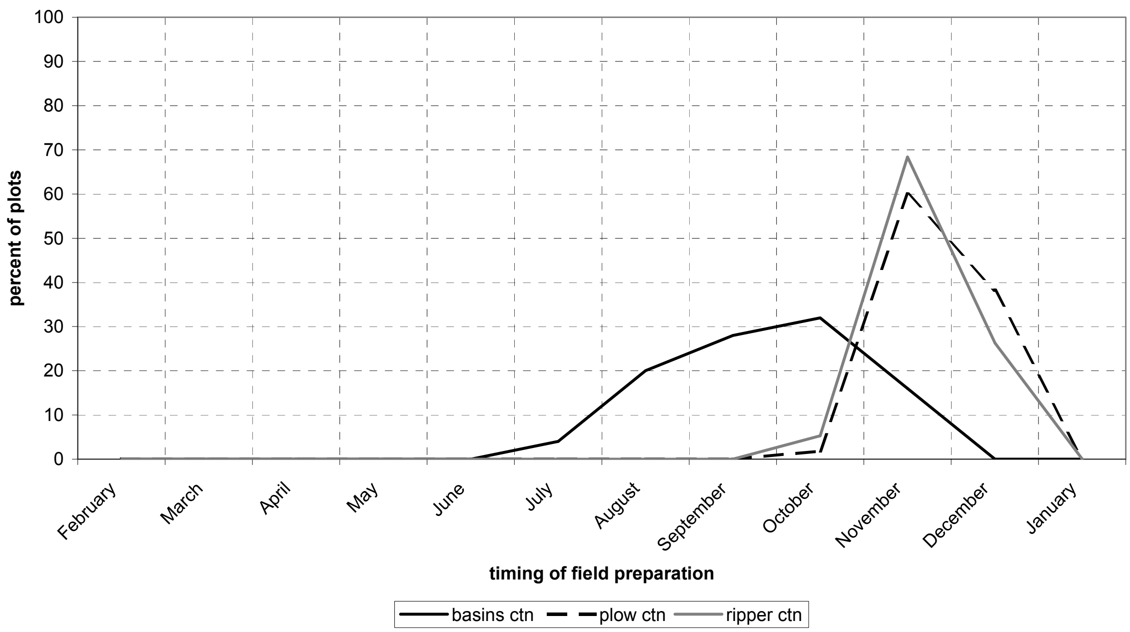
Looking purely at tillage systems, estimates of ADP rippers range widely. A large-scale sample survey of CF practices among the roughly one-third of Zambia's smallholder farmers indicate that about 22,000 farmers in those areas prepare land with animal-drawn rippers (LMCF 2001).[7] They identified a further 20,000 who use both rippers and basins. Even so, this estimate most likely overstates the prevalence of ripping in Zambia, particularly since only about 5,000 Magoye rippers have been produced in Zambia with 1,000 of these exported to Tanzania, Angola and other neighboring countries. Furthermore, our field data

[7] The zones covered include Southern, Central and Eastern Provinces. Since animal traction remains less prevalent elsewhere, particularly in northern zones of Zambia, it is difficult to extrapolate these figures to project national totals.

from Central and Southern Provinces suggest that even farmers who own rippers do not use them properly. They do not rip in the dry season (Figure 5), but rather use the ripper as a furrower or even as a plow after the rains have begun (Figure 6). Given the distribution of 2,000 more rippers in the 2002/3 season, adoption of ADP conservation farming more likely lies in the range of 4,000 to 6,000 farmers.

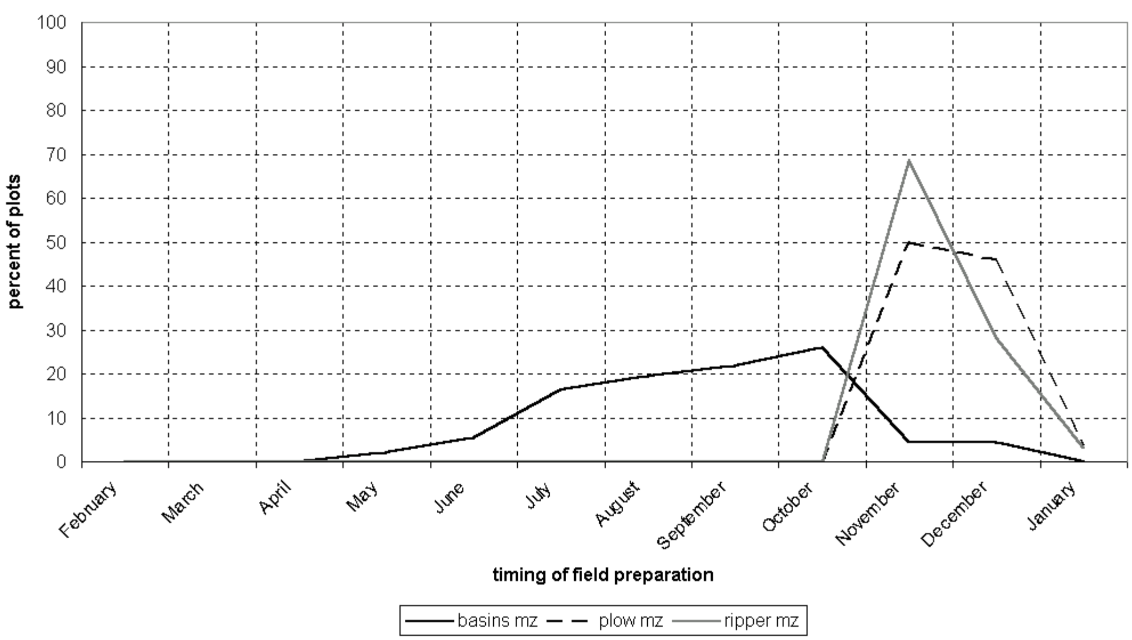
Figure 6 – Timing of land preparation, by tillage method

a. cotton plots



b. maize plots

Source: IFPRI/FSRP survey 2001/2.



For the hand hoe variant of conservation farming using basins, a nationally representative farm household survey covering small and medium scale farmers (those cultivating under 20 hectares) indicates that 63,000 small holders and about 3,000 medium-scale farmers nation-wide prepare land under some kind of basins (Table 4).

Table 4--Prevalence of conservation tillage practices in Zambia 199/2000

Agro-ecological region	Small-scale farms (0-5 ha)	Medium-scale farms (5-20 ha)
Planting basins (percent of farmers)		
Region I	4.4%	0.0%
Region IIa	8.7%	18.2%
Region IIb	18.0%	1.7%
Region III	5.2%	3.6%
Zambia		
percentage	7.8%	13.0%
numbers of farmers	63,350	2,868
Leave residues in the field (percent of farmers)		
Region I	50.8%	83.8%
Region IIa	52.0%	59.0%
Region IIb	51.0%	39.9%
Region III	45.6%	63.6%
Zambia		
percentage	49.2%	60.4%
numbers of farmers	397,940	13,370

Source: Post Harvest Survey.

According to these data, planting basins prove most prevalent in agro-ecological regions IIa and IIb. While the high adoption rate is expected in IIa, it is rather surprising in region IIb where prevalent sandy soils make water harvesting difficult. Given the generality of the Post Harvest Survey questions and possible ambiguities in wording of the survey questions, we expect that the PHS survey results likely overstate the use of planting basins for conservation farming. At a minimum, directly supported CF farmers totaled 11,000 in 2001/2 plus another 6,000 Dunavant cotton farmers as additional spontaneous adopters (Table 3). Numbers of other spontaneous adopters, however, remain highly impressionistic. A study by ECAZ suggests that unassisted farmers outnumber assisted CF farmers by about 2:1 (ECAZ 1999). If so, this suggests a ballpark figure of about 30,000 hand hoe CF farmers operating in 2001/2. Meanwhile, the PHS estimate offers an upper bound of about 60,000. Within this wide range of 20,000 to 60,000, given that many spontaneous users of basins do not adopt the full package of CF practices, we expect that actual hand hoe CF adoption lay near the lower end of the range during the 2001/2 season.

Spurred by possible back-to-back droughts, numbers of CF adopters have grown substantially in 2002/3, among both assisted and unassisted farmers. Among Dunavant cotton farmers -- unassisted in the sense that their receipt of inputs does not depend on what tillage system they adopt -- rates of increase between 2001/2 and 2002/3 averaged about 70 percent, with the highest gains in Central Province. These numbers suggest that about 10,000 Dunavant cotton farmers used CF basins during the 2002/3 season (Table 3). The drought of 2001/2 likewise induced a big government and donor push into water-conserving conservation farming for the 2002/3 season. Food for Work has financed the digging of two limas of CF basins on each of 60,000 small farms. A consortium of donors, including SIDA, NORAD, and FAO, has financed input packs for these 60,000 farmers, 1 lima (.25 ha) of maize and 1 lima of a legume, to be managed by CLUSA, CARE, the Programme Against Malnutrition (PAM), LMCF and the CFU. If the donors and NGO's meet these targets, this big push program will dramatically boost CF numbers this season to between 74,000 and 150,000. Again, we expect actual figures to lie towards the lower end of this range.

Scattered adoption

Adoption rates of CF basins and ripping vary dramatically across agro-ecological regions, provinces and even within individual districts. Among Dunavant cotton farmers, use of CF basins varies from 15 percent in Lusaka Province to not at all on the Copperbelt.

Ripping technology proves most popular in Lusaka Province and least popular in the East. Across agroecological regions, adoption of CF basins proves highest in Region IIa (at 10 percent) and Region I (at 3 percent), while none of the handful of cotton farmers interviewed in the higher-rainfall Region III applied CF basins in their cotton plots (Table 5).

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 percent at their Nangoma Depot to only 8 percent at Shinuma (Table 5). As this disparity suggests, though agro-ecological region clearly affects the feasibility of CF adoption, other factors are also at play.

Table 5--Tillage methods used by Dunavant cotton farmers 2001/2

Location	Agro-ecological region	Number of groups	Average group size	Percentage of farmers using each tillage method Plow	Ripper	Hoe	Basin	Total
Ranking by Agro-ecological								
Region I. Low rainfall (under 800 mm)		46	92	74%	2%	20%	3%	100%
Region IIa. Moderate rainfall (800-1,000 mm), clay soils		796	54	56%	3%	31%	10%	100%
Region IIb. Moderate rainfall (800-1,000 mm), sandy soils		0	-	-	-	-	-	-
Region III. High rainfall (over 1,000 mm)		8	28	74%	7%	19%	0%	100%
Ranking* by Province								
Lusaka Province		44	35	54%	6%	25%	15%	100%
Central Province		514	47	64%	4%	19%	13%	100%
Southern Province		249	77	77%	4%	13%	6%	100%
Eastern Province		462	66	31%	1%	63%	5%	100%
Copperbelt Province (Mpongwe)		8	28	74%	7%	19%	0%	100%
Total Zambia		1,272	59	54%	3%	35%	8%	100%
Ranking* by Depot								
Nangoma (Mumbwa District, Central Prov)	IIa	24	56	49%	4%	19%	27%	100%
Keembe (Kabwe District, Central Prov)	IIa	7	58	57%	6%	13%	24%	100%
Mulendema (Mumbwa District, Central Prov)	IIa	36	41	48%	5%	27%	20%	100%
Kapyanga (Mumbwa District, Central Prov)	IIa	46	46	62%	5%	14%	19%	100%
Lusaka (Lusaka Rural, Lusaka Prov)	IIa	13	44	48%	9%	24%	19%	100%
Muundu (Kabwe District, Central Prov)	IIa	6	60	64%	9%	11%	16%	100%
Choombwa (Mumbwa District, Central Prov)	IIa	19	58	68%	2%	15%	15%	100%
Moono (Mumbwa District, Central Prov)	IIa	15	51	61%	0%	25%	14%	100%
Mumbwa (Mumbwa District, Central Prov)	IIa	35	44	28%	2%	56%	13%	100%
Chadiza (Chadiza District, Eastern Prov)	IIa	31	49	52%	0%	36%	12%	100%
Myooye (Mumbwa District, Central Prov)	IIa	32	51	65%	7%	16%	12%	100%
Chongwe (Lusaka Rural, Lusaka Prov)	I & IIa	30	33	57%	5%	26%	12%	100%
Mkushi (Mkushi District, Central Prov)	I & IIa	7	78	72%	11%	6%	11%	100%
Lifwambula (Kabwe District, Central Prov)	IIa	19	41	58%	9%	22%	11%	100%
Kalichero (Chipata District, Eastern Prov)	IIa	37	61	12%	0%	76%	11%	100%
Mvumbe (Mumbwa District, Central Prov)	IIa	39	32	76%	2%	11%	10%	100%
Choma (Choma District, Southern Prov)	IIa	44	70	71%	6%	13%	9%	100%
Lundazi (Lundazi District, Eastern Prov)	IIa	46	60	35%	1%	55%	9%	100%
Chama (Chama District, Eastern Prov)	IIa	6	41	0%	0%	91%	9%	100%
Mgubudu (Chipata District, Eastern Prov)	IIa	44	59	17%	0%	75%	8%	100%
Likumbi (Kabwe District, Central Prov)	IIa	17	41	73%	3%	16%	8%	100%
Muchenje (Kabwe District, Central Prov)	IIa	25	37	72%	6%	14%	8%	100%
Shinuma (Mumbwa District, Central Prov)	IIa	40	42	75%	5%	13%	8%	100%
Chipata (Chipata District, Eastern Prov)	IIa	24	57	30%	0%	62%	7%	100%
Kalomo (Kalomo District, Southern Prov)	I & IIa	31	97	74%	4%	15%	7%	100%
Mazabuka (Mazabuka District, Southern Prov)	IIa	49	79	79%	5%	10%	6%	100%
Gwembe (Gwembe District, Southern Prov)	I	21	124	73%	2%	19%	5%	100%
Namwala (Namwala District, Southern Prov)	IIa	40	71	87%	1%	7%	5%	100%
Kabwe (Kabwe District, Central Prov)	IIa	5	61	92%	1%	3%	5%	100%
Monze (Monze District, Southern Prov)	IIa	37	56	78%	6%	11%	5%	100%
Katete (Katete District, Eastern Prov)	I & IIa	97	72	45%	2%	51%	3%	100%
Mfuwe (Chipata District, Eastern Prov)	I & IIa	26	50	1%	0%	96%	3%	100%
Makafu (Kabwe District, Central Prov)	IIa	23	31	85%	3%	10%	1%	100%
Masala (Chipata District, Eastern Prov)	IIa	27	74	31%	0%	68%	1%	100%
Mpongwe (Ndola Rural, Copperbelt Prov)	III	8	28	74%	7%	19%	0%	100%
Vulamkoko (Chipata District, Eastern Prov)	IIa	10	48	28%	0%	72%	0%	100%
Petauke (Petauke District, Eastern Prov)	I & IIa	66	89	31%	1%	68%	0%	100%
Sinezongwe (Sinezongwe District, Southern Prov)	I	25	64	76%	2%	22%	0%	100%

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

Partial and incremental adoption

Most farmers who adopt CF technology do not apply it 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 6). Because the hand hoe CF plots are smaller than plowed plots, the CF plots account for 10 to 20 percent 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 6).

Table 6--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.

Over time, proportions allotted to CF grow steadily. While first-year CF cotton farmers experiment with basins on only 1 percent 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 percent of their cotton holdings. Similarly with maize holding, the 10 percent area allotted to CF basins rises to about 30 percent among farmers with four or more years of experience (Table 6). Similarly with rippers, data over four seasons suggests that contact farmers practicing low tillage ADP increased the area they ripped from 1.3 to 2.4 hectares over that four-year period (Stevens et al. 2002).

But adoption rates rarely reach 100 percent. Conversations with experienced CF farmers suggest that they focus a portion of their labor resources on CF plots as insurance against drought and famine. They appear to view CF as providing portfolio diversification to ensure their family 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

Farmers continuously experiment with new technologies. One field survey suggests that among those farmers exposed to CF training, about 30 percent adopt the practice (ECAZ 1999). Anecdotal evidence from our survey indicates that after a period of time, some farmers disadopt the practices. Promotional agencies such as CLUSA, CFU and other agencies disqualify farmers who fail to rigorously maintain CF practices. The strict requirements of the CFU have led to disqualifications of as much as 50 percent, in a given year, particularly in the early years of CF extension (CFU 1998). 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.

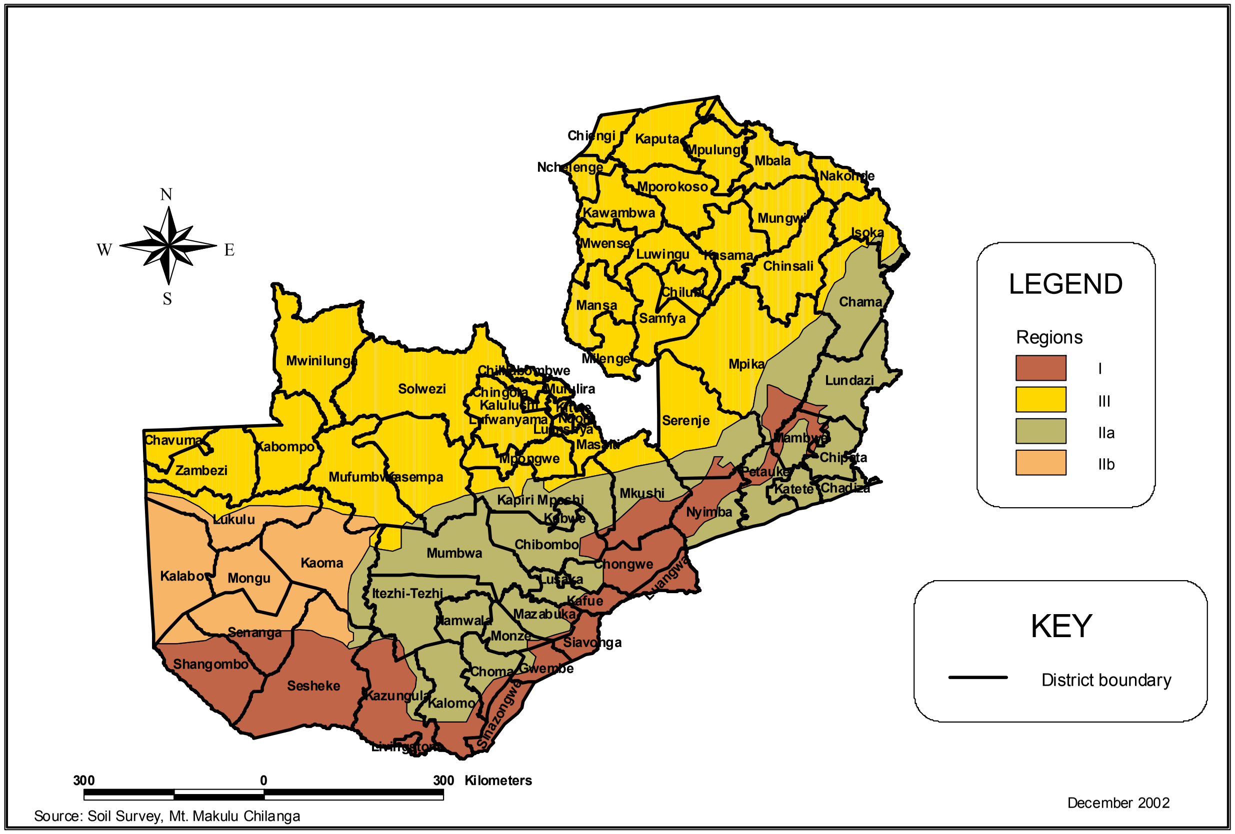
Disadoption has occurred at the institutional level as well. Early NGO partners of the CFU -- including World Vision, DAPP, Southern Province Household Food Security Programme (SPHFSP) and the Dioceses of Monze -- have all stopped their CF promotion efforts after a number of early experimental years. 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. The staff of these institutions apparently elected to devote their scarce manpower to other sectors and activities with which they felt more comfortable. Among institutions, as well as individual farmers, CF is a management intensive technology for which not all are well suited.

Spontaneous adoption of CF, of course, also occurs. Our census of cotton distributors offers tangible evidence of variable but potentially significant numbers of cotton farmers who have adopted CF basins in recent seasons. The acknowledged good performance of cotton farmers using CF basins during the erratic rainfall of the 2001/2 season has led to more conversions for the ensuing year (Table 2).

Factors influencing CF adoption

Agro-ecological region. The water-conserving CF technologies currently under widespread promotion – ADP ripping and hand hoe basins – are best suited to areas with low or scattered rainfall and clay or loamy soils. Hence Zambia's Agro-ecological Regions I and IIa are most suitable. Our census of Dunavant distributors suggests that about 10 percent of cotton farmers in Agro-ecological Region IIa use CF basins, while none in the higher rainfall AER III do (Table 5). Geographically, the CF basins appeal most where rainfall proves erratic and unreliable, particularly in Agro-ecological Regions I and IIa (Figure 7).

Figure 7 – Agro-ecological regions of Zambia



Extension support. Yet even within a given high-potential CF zone, adoption rates differ considerably. In Mumbwa District of Central Province, adoption of CF basins ranges from 27 percent at Dunavant Nangoma Depot to only 8 percent at Shinuma (Table 5). Access to extension support and ADP certainly influences farmer decisions. In Central District, areas of longstanding CFU, CLUSA and Dunavant extension support for CF yield higher rates of adoption than elsewhere. Similarly, ripper use appears higher in areas where extension demonstrations have occurred. Yet, even some areas of heavy extension support yield low adoption rates. Witness the low adoption of CF basins among cotton farmers in Southern Zambia, in spite of heavy and longstanding extension support there. Even strong extension cannot easily overcome longstanding traditions of cattle culture and preference for animal draft power.

Striking results from the census of Dunavant distributors suggest that the example set by the Dunavant distributor himself or herself strongly influences the behavior of his or her group members. Even in high-prevalence Mumbwa district, the share of basins rises sharply, from 16 to 24 percent, among groups whose distributor uses basins (Table 7). Our regression results bear out the importance of the role model provided by the Dunavant distributors (Table 8). Where distributors themselves farm with CF basins, we find 16 percent higher basin prevalence among their group members compared to groups whose distributors do not use basins. Similarly, when a distributor tills with a ripper, prevalence of rippers among his group members rises by 8 percent, even after holding location constant.

Table 7--Effect of cotton distributors' example on group member tillage methods

Distributor's tillage method	# groups	average group size	Percentage of farmers using each tillage method: plow	ripper	hoe	basin	total
All Zambia							
plow	806	60	**63%**	3%	28%	6%	100%
ripper	61	58	65%	**10%**	12%	12%	100%
hoe	269	60	23%	1%	**68%**	8%	100%
basin	117	51	53%	4%	19%	**24%**	100%
total	1278	59	54%	3%	35%	8%	100%
Mumbwa District							
plow	165	44	**68%**	3%	17%	13%	100%
ripper	25	49	63%	**9%**	17%	11%	100%
hoe	52	45	43%	2%	**43%**	12%	100%
basin	74	53	53%	4%	19%	**24%**	100%
total	327	47	58%	4%	22%	16%	100%

Source: Dunavant Distributor Survey, September/October 2002.

Table 8--What factors affect adoption of conservation farming (CF)?

Causal factors*	Increase in Farmers Practicing CF basins	rippers
Dealer practices conservation farming		
dealer uses basins	16.2%	0.0%
dealer uses ripper	6.7%	8.2%
Location (district)**		
Chadiza	10.6%	0.0%
Mumbwa	10.3%	0.0%
Mkushi	0.0%	7.6%
Lusaka	8.2%	4.1%
Chipata	7.8%	0.0%
Choma	7.5%	3.4%
Kalomo	6.5%	0.0%
Kabwe	5.5%	3.1%
Lundazi	4.8%	0.0%
Others	0.0%	0.0%
Sample size	1320	1320
Adjusted R-squared	0.15	0.08

Source: regression results based on Dunavant Distributor's survey, 2002.

* This table lists only factors that prove statistically significant at the 99% level as estimated from the following regression equation:
CF adoption = f(dealer's tillage method; district)

** District serves as a proxy for availability of cattle, soil and rainfall differences, and variations in extension support across locations.

Surprisingly, distributor use of rippers is also associated with a 7 percent increase in probability of group members using CF basins (Table 8). This parallels the findings of recent GART onfarm ripper trials indicating that one-fourth of their contact ripper farmers also dug basins on a portion of their land (Stevens et al. 2002) and may suggest that when a distributor is persuaded of the benefits of conservation tillage, he effectively communicates this to his group members. This evidence suggests that targeting extension support to these influential distributors may yield considerable spinoffs, for they apparently serve as highly persuasive agents of change among their group members.

Cattle ownership. Within a given region, asset holdings of individual farmers will clearly influence their adoption decision. Access to labor and cattle matter most. For CF basins, the most likely adopter categories include current hand hoe farmers, for whom CF basins represent a clearly superior alternative, and cattle-poor households who currently farm with borrowed or rented oxen but as a result plant late and produce meager output (Table 9). For animal draft CF with rippers, conventional ox-plowing households represent the clear client group. Extension support and clear demonstration of technical superiority seem to be requisite ingredients in effecting this switch.

Table 9--Distribution of cattle ownership among small- and medium-scale agricultural households (or smallholders) by province 1996/97-1999/00 averages

Province	Estimated number of smallholders	Proportion (%) of smallholders by cattle ownership category				
		No cattle	1-2 cattle	3-5 cattle	6-10 cattle	More than 10 cattle
Central	83,000	86.9	3.6	3.5	2.6	3.4
Copperbelt	38,000	97.9	0.8	0.5	0.1	0.7
Eastern	193,000	81.5	5.1	5.0	4.6	3.8
Luapula	120,000	99.4	0.2	0.3	0.1	0.1
Lusaka	21,000	91.4	1.5	3.1	1.7	2.3
Northern	162,000	93.5	1.6	2.1	1.4	1.5
Northwestern	56,000	94.8	1.6	0.8	1.4	1.5
Southern	117,000	68.6	7.2	8.7	7.5	8.1
Western	108,000	86.6	1.8	2.8	2.7	6.1
Zambia	898,000	87.2	3.1	3.4	2.9	3.4

Source: Data from four annual post-harvest surveys (1997-2000) by the Central Statistical Office.

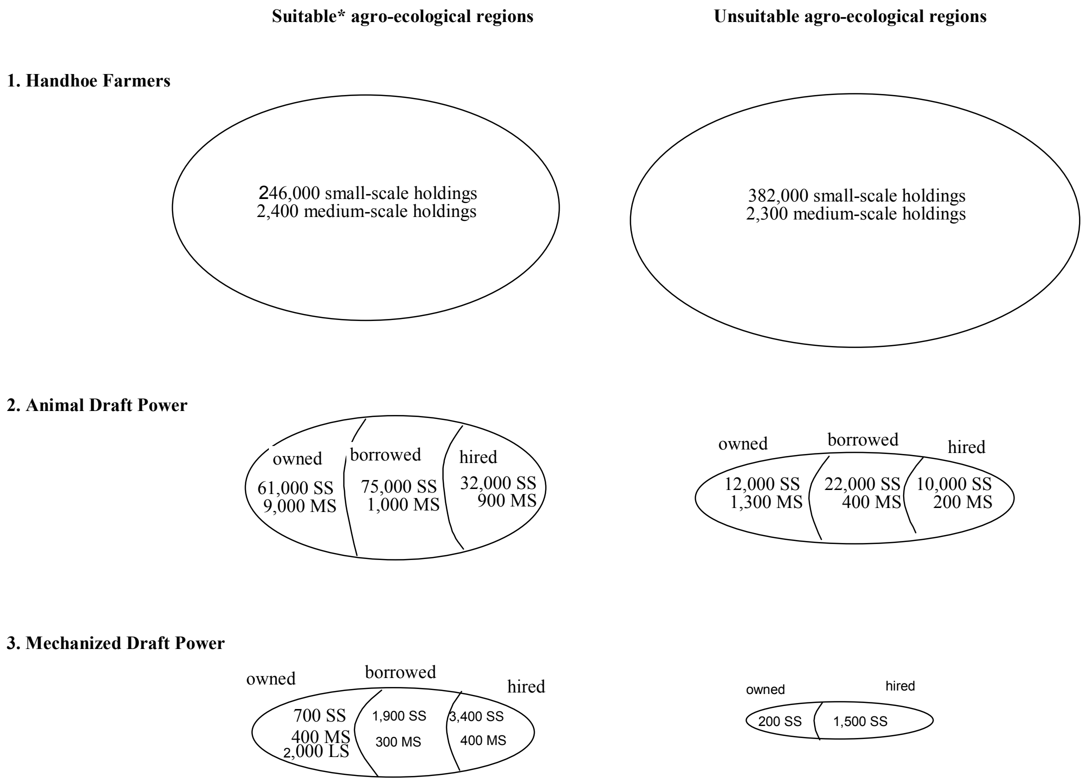
Personal characteristics. Personal characteristics of individual farmers likewise affect their adoption decisions. Conservation farming requires careful advance planning and meticulous, timely execution of key tasks. It requires a change of thinking about farm management under which the dry season becomes no longer a time primarily reserved for socializing but rather an opportunity for serious land preparation work. Anecdotal evidence from our field interviews suggests that retired schoolteachers, draftsmen and accountants make good CF farmers. Likewise cotton farmers, whose cash crop demands careful attention to planting date, regular weeding and spraying and repeated careful hand harvesting represent an important pre-selected group of farmers. Cotton production, like CF basins, requires a willingness to work hard. And because of the importance of intensive attention to detail and crop management, cotton farmers provide, in many ways, a self-selected group of farmers with the perseverance, planning, management and 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 CF. They share the planning skills and personality traits required to manage a precise system like CF. And they have proven willing to work hard to manage their crops.

3. RECOMMENDATION DOMAINS

Zambia's nearly 900,000 agricultural smallholders are a heterogeneous group in many respects. Significant differences occur because of widely varying socio-economic conditions, asset ownership, and agro-ecological conditions. Blanket agricultural recommendations rarely prove appropriate, and CF technologies are no exception to this rule. In an attempt to place the conservation farming discussion in context, two dimensions appear to be crucial in determining both the effectiveness and economic returns of conservation farming. First, agro-ecological region determines where water-conserving CF technologies[8] will prove most feasible. Second, access to draft power determines options, timing, cost and returns of ADP technologies for individual households within the appropriate agro-ecological regions. The following discussion and pictorial summary (Figure 8) partition Zambia's smallholders along these two dimensions.

[8] The CFU is in the process of developing a CF package for the high-rainfall northern regions of Zambia (Langmead 2002; CFU 2002). This paper treats only the water-conserving CF technologies originally introduced and disseminated since 1996, the hand hoe basins and the ADP rippers.

Figure 8—Recommendation domains for water-conserving conservation farming



* Suitable agro-ecological regions include low-rainfall areas with good soil structure (AER I and IIa)
** In this summary representation, all effectives over 5,000 have been rounded to the nearest thousand, those under 5,000 to the nearest hundred, while all cells under 50 have been dropped. For a more detailed breakdown, see Annex Figure C.1.

SS = small-scale farms (under 5 hectares)
MS = medium-scale farms (5 to 20 hectares)
LS = large-scale farms (over 20 hectares)

Source: Post-harvest surveys (CSO, 1997-2000) and Annex Figure C.1

AGRO-ECOLOGICAL REGIONS

Ministry of Agriculture staff has divided Zambia into three major agro-ecological regions using rainfall as the dominant climatic factor distinguishing the three regions (Figure 7). Region I includes the Luangwa-Zambezi rift valley and western semi-arid plains, including drought and flood prone valleys of Gwembe and Lunsemfwa, the central and southern parts of the Luangwa valley as well as the southern parts of western province. This region receives the lowest, most unpredictable and poorly distributed rainfall. With less than 800 mm per year, it offers farmers a short growing period of 80-120 days together with a wide range of physical and chemical soil properties which limit crop production (ECZ 1994). These constraints make this region a primary target for conservation farming practices, such as planting basins (for hand hoe farmers) and ripping (for those with access to ADP).

Region II covers the central belt of the country, comprising central, southern and eastern fertile platea. It receives moderate rainfall, between 800 and 1000mm, a longer growing season of 100 to 140 days and relatively fertile soils. The region is further sub-divided into two sub-regions, IIa and IIb. Sub-region IIa comprises the degraded plateau of Central, Southern, Lusaka and Eastern provinces while sub-region IIb includes the Kalahari sand plateau and the Zambezi flood plain. Although offering a more secure moisture regime than Region I, Region II suffers from moisture stress during drought years and from periodically scattered rainfall even during years of adequate overall precipitation. CF technologies developed for this region need to consider moisture retention due to this intermittent moisture stress. Although planting basins (potholes) perform well in region IIa, they are likely to collapse in the sandy soils of region IIb. Other forms of minimum tillage (such as ripping, or even zero tillage) may be used to spread labour and resource use and foster timeliness of planting and other field operations.

Region III, which constitutes 46 percent of the country, covers Copperbelt, Luapula, Northern and Northwestern provinces. This region is characterized by high rainfall with an annual average precipitation in excess of 1000mm distributed over a long

120 to 150 day growing season. The region enjoys relatively fertile soils and farmers widely practice a traditional shifting cultivation under "chitemene." Because moisture almost never constrains farm output, water-harvesting technologies are not appropriate here. Planting basins, for example, may lead to water logging. Ripping could be used but only for breaking hard pans. For this reason, the CFU has actively begun developing CF technologies more appropriate to the high-rainfall Agroecological Region III (Langmead 2002; CFU 2002).

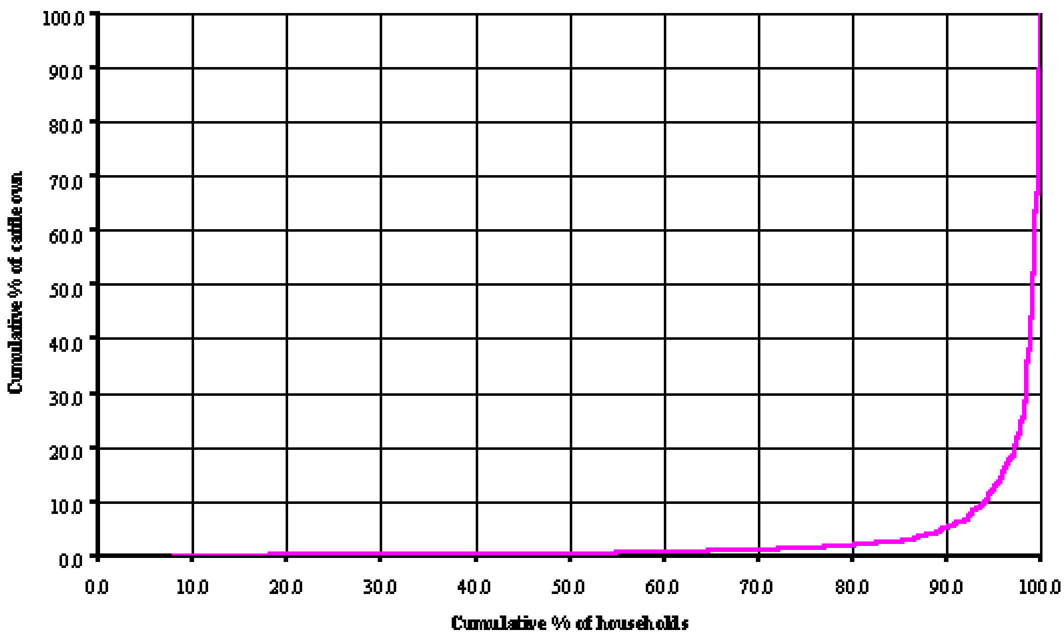
Figure 8 summarizes tillage recommendation domains according to agro-ecological conditions and farmer's access to draught power. Overall, about 435,000 Zambian small and medium holders farm in regions favorable for water-conserving CF technologies while an almost equal number live in areas where other technologies will be required (Figure 8).

ANIMAL DRAFT POWER

Distribution of ownership

Zambia's smallholder sector boasts about two million head of cattle, amounting to about 80 percent of the nation's total herd. Yet cattle ownership remains highly concentrated with 10 percent of the holdings accounting for 95 percent of the cattle (Figure 9; Table 9). Under these circumstances, the vast majority of smallholders must either cultivate with hand hoes or obtain oxen from neighbors via rental or borrowing.

Figure 9 – Concentration of smallholder cattle ownership in Zambia, 1996/97



Source: Post Harvest Survey, 1996/97.

Nationally, 10 percent (or 84,000 farmers) of Zambia's small- and medium-scale holdings use their own ADP (Figures 8), which is almost exactly equal to the number of households with at least three cattle (Table 9). Causes of low ADP ownership include low cattle numbers, high concentration of cattle ownership and limited access to the necessary implements.

In the agro-ecological regions suitable for water-conserving CF technologies (AER I and IIa), only 15 percent (or 65,000 farmers) own three cattle or more and conceivably own enough cattle to plow with their own oxen (Table 9). The remaining 85 percent of the region's smallholders (380,000 farmers in all) own two cattle or less, a number insufficient to support a working team of oxen.[9] They must, therefore, cultivate by hand hoe or by renting oxen from others. For this overwhelming majority of smallholders, the ADP rental market has a critical role to play in promoting draught-power-dependent technologies such as ripping.

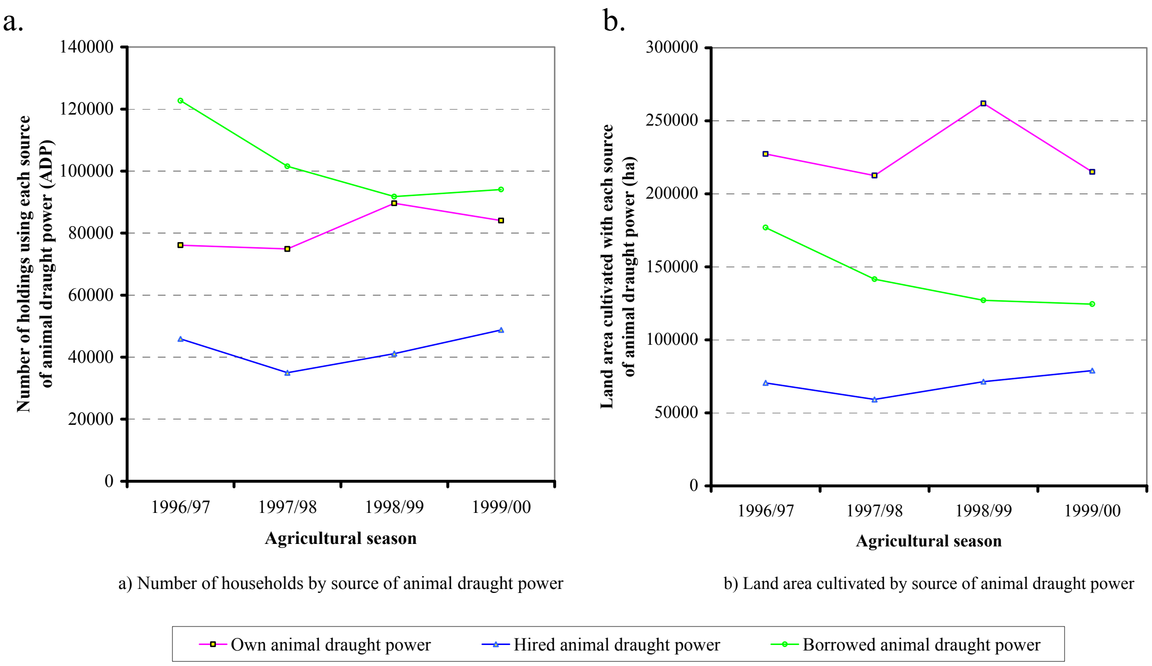
Rental markets

In the Zambian smallholder sector, 226,000 (or 26 percent) of the almost 900,000 small- and medium-scale holdings use animal draught power, while about 9,000 (or one percent) use mechanical power.[10] A four-season (1996/97-1999/00) average shows that the majority of animal draught power (ADP) users (64 percent) do not own the animals but borrow (45 percent) or hire (19 percent) from those that own some. While the importance of owning draught animals as a way of accessing ADP has remained largely the same (albeit with fluctuations) over the reference period, sources of draft power among non-cattle owning households have changed dramatically. Borrowing as steadily declined while hiring exhibits a striking and steadily upward trend (Figure 10). The upward trend in hiring as a method to access ADP shows that there is potential for the market to help foster ADP-dependent practices such as ripping.

[9] These calculations based on cattle numbers and ownership correspond almost exactly to actual sources of draft power reported by farmers and which are summarized in Figure 8.

[10] Almost 60 percent of mechanical power users access it by hiring. About 2,300 of the holdings that use mechanical power also use animal draught power (see Figure C.1).

Figure 10 – Trends in sources of smallholder draft power 1996/7 – 1999/2000



Source: Post-Harvest Survey 1996/7 – 1999/2000.

Notice that own draught animals and borrowed draught animals switch their hierarchical positions when total cultivated land area is used as the ranking criterion (Figures 10a and 10b). That is, although the number of holdings using own draught animals is less than the number of holdings using borrowed draught animals (Figure 10a), the total land area cultivated and planted by ADP owners is greater than that cultivated and planted with borrowed draught animals (Figure 10b). On average, a household that owns animal draught power (ADP) cultivates about 2.83 hectares annually, which is more than twice the area cultivated by households that use borrowed ADP (1.39 ha). A household that hires ADP cultivates about 1.64 hectares annually.[11] These findings support the hypotheses that i) ADP owners will first satisfy their own requirements before they can allow others to use their animals and that ii) preference and more time is given to households that hire than to households that borrow ADP.

ADP owners prefer to prepare their fields first before lending or renting their animals out. This implies that practices that relax the land preparation time constraint will increase chances of ADP hiring and borrowing holdings to cultivate large portions of land. Thus, ripping, which can be done over the entire dry season, presents greater opportunities for increasing total cultivated land area than conventional plowing, which is done at the onset or during the rainy (cropping) season. A Magoye ripper impact study conducted among 60 test farmers by the Golden Valley Agricultural Research Trust (GART) indicates that male farmers who were supplied with rippers have been able to increase cultivated land area by as much as 20 percent over a period of three seasons (Stevens et al. 2002). Because crop productivity is sensitive to time of planting, which in turn is a function of time of land preparation, spreading land preparation over the period before the cropping season has the potential to significantly increase farm productivity through more timely planting even without additional purchased inputs.

AGGREGATE NUMBERS

Taking these two criteria together – agroecological region and access to draft power – we calculate that about half of Zambia's small and medium holders (about 435,000 households) farm in agro-ecological regions suitable for water-conserving CF

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[11] On average, a household that uses ADP, regardless of how it accesses the ADP, cultivates at least 15 percent more land than a household that does not use ADP.

technologies.[12] Among them, more than half – about 60 percent of smallholders and 15 percent of medium-scale holding -- do not have access to draft power. They must, therefore, farm with hand hoes (Figure 8). Another 25 percent of those living in suitable agro-ecological regions (AER I and IIa) have access to ADP through hiring or borrowing of oxen. About 15 percent own herds sizeable enough to permit them to till their farms with their own animal draft power. Only 1.6 percent of the smallholder holdings in these regions have access to mechanical power.

The economics of conservation farming differ between among these various groups of farm households. Because owners of animal draft power choose their time of tillage and planting, they plant first, while households who must borrow or rent plant much later and suffer significant yield losses as a result. Therefore the following discussion explores both adoption and impact according to the recommendation domains described in Figure 8.

[12] Alternative CF technologies are under development for other zones.

4. IMPACT

ECONOMIC IMPACT

Output effects

Output differences between conservation farming and conventional tillage systems, as measured by our survey, are broadly consistent with earlier studies. For hand hoe farmers using conservation farming basins, maize yields roughly double those achieved by conventional ox-plow farmers (Table 10). This result holds for both farmer estimated output as well as physical crop cut measurements taken during the survey. Since most CF farmers receive hybrid seeds and fertilizer on credit from their sponsoring agencies (CLUSA or CFU) -- while most ox-plow farmers do not -- part of this difference undoubtedly stems from higher input use under CF. For this reason, the cotton comparisons provide a valuable contrast. All cotton farmers interviewed used standard seed and pesticide packages supplied by Dunavant Cotton. So any differences observed must stem from something other than higher input use. Though smaller than with maize, yield gains based on farmer and distributor estimates of cotton yields suggests that cotton farmers using CF basins achieved yield gains of about 60 percent over farmers using conventional plows.

Table 10--Yield differences across tillage systems, 2001/2

Tillage	Cotton Yield*			Maize Yield*
	farmer estimate	plot sample	farmer estimate	aggregate**
basins				
yield	1,278	2,934	3,023	3,054
st. dev.	717	1,694	1,541	1,711
(n)	(25)	(67)	(92)	(92)
hoe				
yield	986	2,125	4,549	3,062
st. dev.	563	-	638	1,326
(n)	(9)	(1)	(2)	(2)
ripper				
yield	557	2,486	1,373	1,727
st. dev.	284	1,097	1,286	1,244
(n)	(17)	(17)	(33)	(33)
plow				
yield	818	1,468	1,559	1,339
st. dev.	372	997	1,164	920
(n)	(47)	(43)	(77)	(77)
total sample				
yield	903	2,375	2,213	2,189
standard deviation	541	1,555	1,567	1,592
(n)	(99)	(128)	(205)	(205)

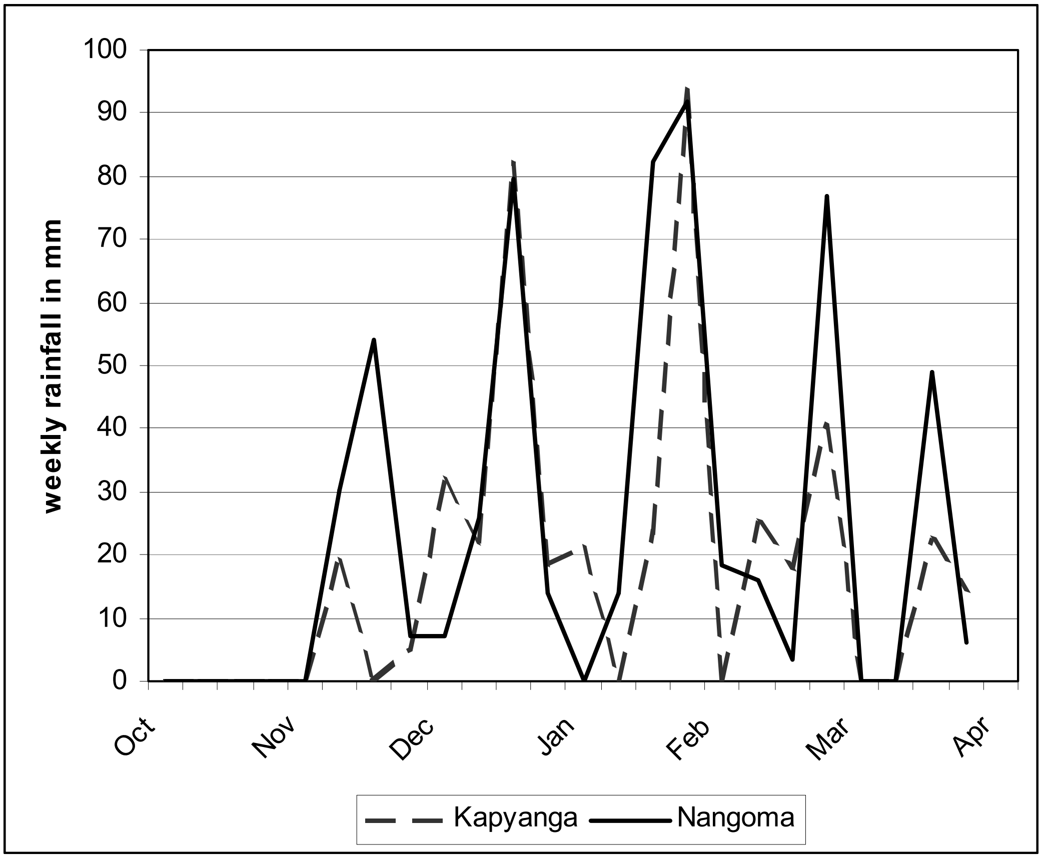
*yield in kilograms per hectare
**Aggregate yield represents our "best" assessment. It takes plot samples as best estimates where available. Where plot samples are not available, we use farmer, interviewer or Dunavant distributor estimates.
n = sample size
Source: IFPRI/FSRP survey.

The very scattered rainfall experienced during the 2001/2 season showcased the important water harvesting benefits of CF basins, as many farmers noted (Figure 11). In particular, the basins helped farmers bridge the several-week gap in rainfall early in the season (Figure 12). Given wide variations in the volume and distribution of rainfall from one year to the next, the water-harvesting benefits of conservation farming will surely differ across seasons. Indeed, evidence from similar planting basin technology in the Sahel suggests that yield gains due to planting basins can vary by a factor of two to ten, depending on rainfall (Table C.1). This suggests that monitoring over time will be an important part of solidifying our understanding of the impact of conservation farming in Zambia.

Figure 11 – Differences in plant establishment under basins (left) and plowing (right)*

* Basins on left were planted by this farmer 36 hours before the plowed field on the right.
Source: CLUSA.

Figure 12 – Rainfall distribution during the 2001/2 season



Source: Dunavant Cotton, Nangoma and Kapyanga Depots.

Surprisingly, the CF farmers using ox-drawn rippers performed more poorly than farmers using hand-hoe CF basins (Table 10). And compared to conventional plowing, the ripper results were ambiguous. Though differences were not statistically significant, the rippers slightly outperformed conventional plows in maize cultivation but on average performed more poorly with cotton. To some extent, the lesser performance of rippers under onfarm conditions may result from the slight loss in precision of both plant spacing and fertilizer application compared with CF basins. More importantly, however, we wish to highlight a deficiency in our survey execution that may account for this finding: we failed to insist that our enumerators ask if ripper farmers were actually using the Magoye ripper. Several specifically noted that they "ripped with a plow beam," that is they removed the plow share and then simply plowed using the beam itself without a proper ripper blade. In the analysis reported in Tables 10-15, we have therefore omitted these farmers from our results. Nonetheless, it remains possible that other farmers who indicated tillage with a ripper may have actually "ripped with a plow beam." So the ripper results must be interpreted with caution.

A second surprise emerged in the relatively strong performance of the handful of conventional hand hoe farmers we were able to locate. They performed better than animal-draft tillage systems and nearly as well as the CF basins. Because our sample of conventional hand hoe farmers is small – because they were so few in the areas we visited -- we cannot generalize this finding. Moreover, several of the hand hoe farmers we visited were indeed exceptionally careful farmers cultivating highly fertile river bottom land. So they did perform well but for reasons independent of tillage system.

What causes differences in output?

In general, many factors other than tillage contribute to output differences – notably differences in input application, soil fertility, plot history, planting date, weeding and other management practices. Controlling for these other differences, where possible, makes it possible to begin to evaluate the contribution of individual components of a management system to output.

Time of planting. Time of planting matters crucially to crop yields of both cotton and maize. Zambian maize breeders indicate that maize yields fall by 1-2 percent for every days delay in planting after the first planting rains (personal communication, Paul Gibson; Howard 1996). Standard rules of thumb from Zimbabwe suggest that maize yields decline by a similar 1.3 percent per day for every day past the first planting rains (Ellwell 1995). Cotton's longer growing season makes it even more vulnerable to late planting. Recent trials at the Cotton Development Trust in Magoye – during a short season on sandy soil -- found that cotton planted with the first rains yielded 1,500 to 1,700 kg per hectare, while cotton planted 14 days later yielded only 500 to 900. Cotton extension specialists with Dunavant estimate that farmers will lose 250 to 350 kilograms per hectare for each week planting is delayed (personal communication, Mike Burgess).

Indeed, in Zambia planting dates clearly differ among management systems (Table 11). On average, farmers planting in CF basins planted two weeks earlier than farmers using conventional ox-plows. Because plowing cannot begin until after the first rains, when the soil has softened enough to permit full inversion, plowing inevitably results in planting later than low-tillage systems where minimal soil movement can take place in the dry season. Our results suggest that this two-week advantage results in a gain of about 4 kg per hectare per day for cotton and about 25 kg per hectare per day for maize (Table 12).

Table 11--Planting date under different tillage systems

Tillage method	Cotton	Planting Date Maize	How much earlier do farmers plant cotton?*		
basins				cotton	maize
date	13-Nov-01	18-Nov-01	6 days	13-Nov-01	19-Nov-01
(n)	25	92	22	22	
hoe					
date	20-Nov-01	05-Nov-01	-	23-Nov-01	05-Nov-01
(n)	9	2		5	
ripper					
date	23-Nov-01	27-Nov-01	3 days	23-Nov-01	26-Nov-01
(n)	19	33	18	18	
plow					
date	28-Nov-01	02-Dec-01	4 days	28-Nov-01	02-Dec-01
(n)	50	78	43	43	
total sample					
date	23-Nov-01	25-Nov-01	4 days		
standard deviation	15	16			
(n)	105	205	83	83	

* Includes only households who plant both cotton and maize.
Source: IFPRI/FSRP survey.

Table 12--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

Table 12 -- Sources of yield gains in conservation farming (continued)

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
			(-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.

For households without cattle, and who must rely on rental of animal draft power, the delays in planting are far more severe. Farmers who plow with their own oxen plant one week after CF farmers. But farmers without adequate animal draft power (ADP) of their own must rent or borrow animals from others. They are the last served because they must wait until the cattle-owning households have finished preparing their own fields. In general, this means the households who rely on rented ADP will plant four weeks later than CF farmers, suffering substantial yield losses as a result.

Time of planting differences help to explain the poor performance by farmers using rippers. They plant 10 days later than the CF basin farmers and only about 5 days earlier than the ox plow farmers. Indeed, 20 percent of the ripper farmers in our sample planted after December 15th. This suggests that they are using the ripper (or plow beam) as they normally would a plow. Though moving less soil, they are not changing other management practices as required to fully benefit from the ripping technology. In part, these differences may stem from lack of extension support for ripper farmers. Farmers using CF basins benefit from strong management support by Dunavant Cotton, the CFU and CLUSA. We suspect that some sort of comparable extension support for tillage management under rippers will be required for these farmers to fully benefit from the ripper technology. Simple expanded distribution of the equipment appears not to suffice. Farmers need to be shown how and when to use the rippers most effectively. This suggests that expanded extension support for ox-drawn rippers would likely yield considerable gains via early field preparation and earlier planting. Dunavant distributors may offer one inexpensive yet effective means of demonstrating ripper technology to cotton farmers. Our census of distributors suggests that when distributors use rippers, group farmers are 50 percent more likely to do so as well (Table 7).

Fertilizer and hybrid seeds. Differential input use clearly affects yield. With maize farmers, use of hybrid seeds and fertilizer go hand in hand. It becomes difficult, consequently to separate out the effects of each independently. Nonetheless, regression results indicate that the combination of hybrid seeds and fertilizer strongly boost maize output – by about 800 kg per hectare compared to farmers who plant local varieties with no fertilizer (Table 12).

Normally, water availability strongly influences the effectiveness of fertilizer applications. Therefore, we expected a significant interaction between fertilizer use and CF basins, which help farmers to harvest water. Surprisingly, however, this interaction did not prove statistically significant among our sample farmers (Table 12). The importance of this relationship bears further investigation in coming seasons.

The cotton farmers we interviewed all use Dunavant-supplied seeds, though only about 15 percent apply fertilizer to their cotton plots. Those few who do use fertilizer generate output gains of 1.6 kg for each kg of fertilizer they apply. Given an approximate cost of 1,300 kwacha per kilogram for fertilizer and a cotton price of 860 kwacha per kilogram, the fertilizer application just covers its costs, generating 860 x 1.6 = 1,376 kwacha. Fertilizer trials underway by Dunavant and CFU will undoubtedly offer a more precise rendering of these fertilizer-induced output gains under differing field conditions. From our small sample, results suggests a small output contribution from fertilizer making it a marginal economic investment for cotton farmers.

Plot size and gender. We anticipated that smaller plots would permit closer management by farmers and thus higher yields. Indeed this holds true for cotton. For maize the same result emerges though it is not as statistically robust.[13] Gender appears to make no difference for maize production, though it matters substantially for cotton where male farmers produce 299 kg per hectare more than females, all other things equal (Table 12). The greater labor intensity of cotton production may explain this result. Likewise, the greater demands on female labor, for child rearing and household chores, may limit their flexibility in managing agricultural work.

Basins. The CF basins themselves offer many advantages in addition to the early planting they make possible. They improve water infiltration and harvest water, a particularly important contributor to output in years of sporadic rainfall such as the current cropping season. Over half of the CF farmers we interviewed specifically noted the importance of water harvesting this cropping season (Table 16).

The basins also permit greater precision in input application. Given the difficulty farmers have in estimating field sizes exactly, the precisely measured layout of CF basins (on a grid of 70 cm x 90 cm, for a total of 15,850 per hectare) ensures proper plant populations as well as fertilizer and seed application rates. It clearly facilitates management support and input supply by enabling support agencies to package inputs in standard one-lima packs. Our comparison of farmer estimates of field size with actual plot measurements suggests that slightly over half can estimate field size to within plus or minus 10 percent (Table C.2). But 25 percent estimate field sizes larger than they actually are. They waste purchased inputs by over applying them. The remaining 20

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[13] For maize larger plot size decreases yields by 111 kg for each hectare increase in size (Table 13). But this result is statistically significant only at the 15% rather than the normal 5% level.

percent understate field sizes. They underpopulate their fields with both seeds and other inputs.

The careful field measurement that results from the initial pegging out of the basin grid, thus, results in input economies for nearly half of all farmers. In addition, the permanent planting basins (or rip lines) ensure location of fertilizer and lime in proximity to the seeds they are to assist. They also permit concentration of soil organic matter and fertility investments over time in the root zone where future plants will grow. This, in turn, improves moisture retention and microbiological activity in the soil.

Additional inputs captured by the “basins” dummy variable include the additional weeding labor required by CF farmers due to their failure to invert soil during land preparation as well as the lime which is supplied as an input to most assisted CF farmers. Because of difficulties in accurately capturing plot-level labor inputs from a single retrospective interview, we are unable to do more than compute likely averages which we then apply in budget calculations. Lime input, used exclusively by CF farmers in our sample, proved highly collinear with basins, thus generating no independent effect of its own. Similarly, attempts to capture residual effects of prior leguminous plant rotations likewise yielded no significant effect on yield. Though we cannot separate the individual contribution of each, the “basins” dummy captures the sum of all these inputs. Likewise, the crop budgets reported in Tables 15 and 16 value these as additional costs.

The cumulation of these advantages results in significant yield gains from the basins themselves. With cotton, the basins contributed an extra 400 to 500 kg per hectare in output during the 2001/2 season. With maize, the gains stood closer to 700 kg per hectare (Table 12).

Rippers. Properly managed, ripping holds the potential to offer similar gains via early planting, water harvesting, improved infiltration and root development, and greater precision and location of inputs. But the ripper farmers we interviewed did not manage their plots properly. Consequently they did not achieve these anticipated gains.

What does it cost?

Higher input costs. CF basins offered clear output gains among farmers we interviewed. But to achieve these gains, they required greater purchased inputs (of fertilizer, seed and lime) as well as more labor time in both field preparation and weeding. Assisted CF farmers receive input packages from their sponsoring agencies. But even the unassisted farmers who use basins tend to apply hybrid seeds and fertilizer or manure in their basins. Over 90 percent of maize plots planted under CF basins received hybrid seeds compared to only 55 percent of conventionally plowed fields. About 85 percent of hand hoe CF farmers applied fertilizer compared to only 20 percent of conventionally plowed fields (Table 13).

Table 13--Differences in input use across tillage systems

Input Use	Cotton				Maize			
	basins	hoe	ripper	plow	basins	hoe	ripper	plow
Number of sample plots	24	9	16	45 94	95	3	40	87
Seed								
hyv %	100%	100%	100%	100%	93%	100%	85%	55%
kg/ha	30	23	20	26	20	18	18	24
Basal fertilizer								
percent who use it	33%	0%	0%	9%	85%	33%	55%	13%
kg/ha among users	80	0	0	76	131	205	163	126
average use	27	0	0	7	112	68	90	16
Topdressing								
percent who use it	0%	0%	0%	0%	87%	33%	45%	21%
kg/ha among users	0	0	0	0	142	205	175	139
average use	0	0	0	0	124	68	79	29
Manure								
percent who use it	4%	0%	6%	0%	5%	0%	8%	5%
kg/ha among users	1125	0	5600	0	1294	0	758	764
average use	47	0	350	0	68	0	57	35
Lime (kg/ha)								
percent who use it	21%	0%	0%	0%	82%	33%	35%	8%
kg/ha among users	77	0	0	0	198	205	142	134
average use	16	0	0	0	162	68	50	11
Pesticide (kwacha/ha)								
percent who use it	83%	78%	81%	91%	0%	0%	0%	0%
kwacha/ha among users	254,325	239,283	191,819	166,056	0	0	0	0
average use	211,938	186,109	155,853	151,296	0	0	0	0
Dry season land preparation								
share before Nov. 1	84%	22%	5%	2%	92%	50%	3%	0%
Labor (person days/ha)								
land preparation	66	59	7	7	70	50	10	8
planting	11	8	4	4	16	39	5	4
fertilizer application	1	0	0	0	18	8	8	2
liming	1	0	0	0	9	0	3	0
hand weeding	79	68	51	45	81	58	35	27
mechanical weeding	3	0	4	9	1	0	2	2
spraying	10	7	22	5	0	0	0	0
harvesting	47	22	35	26	16	21	14	6
total	219	164	124	96	211	176	77	48

Source: IFPRI/FSRP survey.

Increased labor. Labor data proved most problematic of all to collect. In a single visit, we asked farmers to recall how much time they had spent on each operation in each cotton and maize plot they cultivated. Given greater time and resources, multiple visits throughout the season would surely have improved the accuracy of farmer recall.

Nonetheless, we believe the average magnitudes reported offer at least broad guidelines as to labor input differences required across different tillage systems.

Higher labor requirements emerged clearly among plots managed under CF basins. Our empirical measurements suggest that both field preparation time and weeding increased compared to the other tillage methods. In cotton cultivation (where we have a more solid representation of conventional hand hoe farmers), CF farmers required 66 days for field preparation compared to about 59 days for conventional hand hoe and only 7 days for animal traction tillage systems. Weeding labor increased as well from about 70 days under conventional hand hoe to about 80 under CF basins. Similarly under ox-plowing, the full inversion of soil during plowing serves as a pre-season weeding tool. Consequently, plow farmers required only 45 days of weeding labor after planting. Under maize cultivation, results suggest similar increases in land preparation and weeding labor under CF basins (Table 13).

Farmers, when asked for their qualitative assessment of CF, likewise complained of higher labor requirements in both weeding and field preparation (Table 14). One farmer complained that labor demands under CF basins caused him to, "lose a lot of energy and grow thin." Another suggested that the hard labor of digging basins, "reduces the lifespan of an individual." Many noted that basins proved, "hard to dig unless done right after harvest." More experienced farmers qualified these observations by noting that both digging basins and weeding was, "very demanding laborwise *in the early years*."

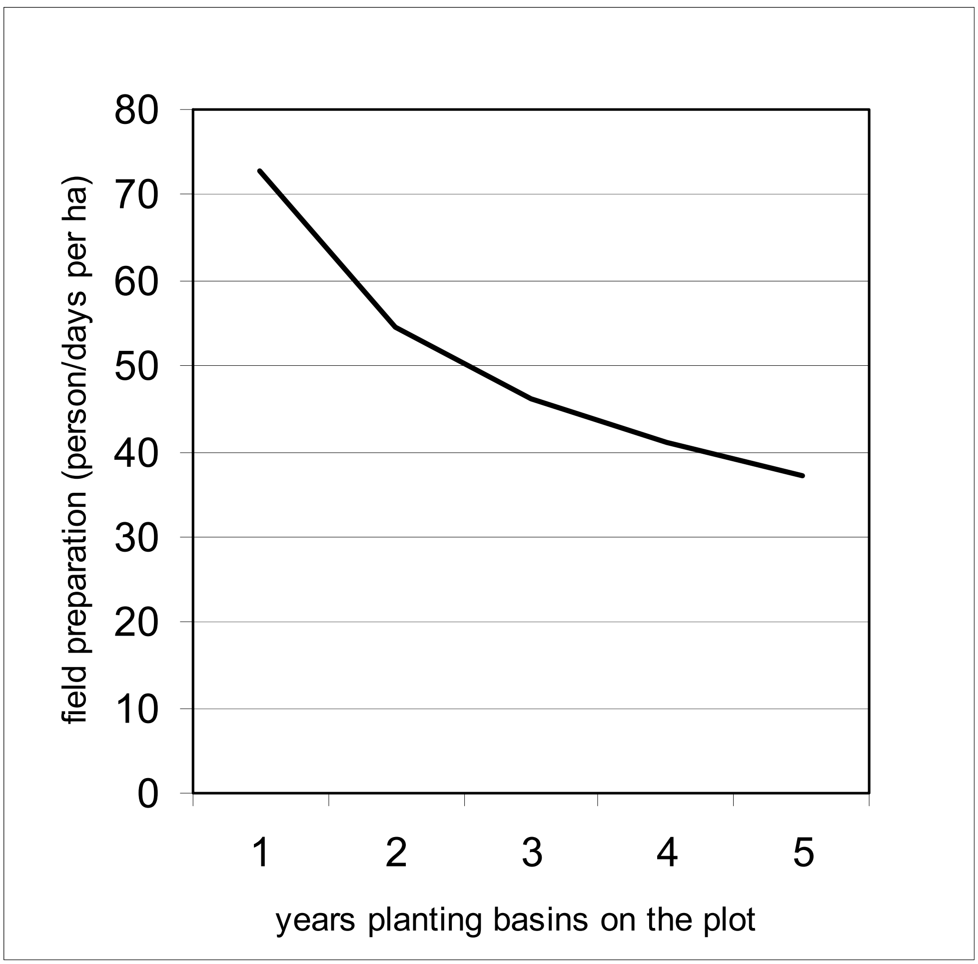
Table 14--Farmer assessments of conservation farming

	Responses	
	number	percent
1. How did CF plots compare with conventional tillage?		
a. CF produces higher yield	87	70%
b. CF gives bigger cobbs	15	12%
c. no difference	1	1%
d. conventional higher	1	1%
e. no response	21	17%
f. total	125	100%
2. Why did CF plots produce different results?		
a. enable early planting	77	62%
b. water harvesting	69	55%
c. focus fertilizer	49	39%
d. enable timely/early weeding	28	22%
e. early land preparation labor	27	22%
f. good germination	13	10%
g. total households	125	100%
3. Do you see any difficulties with CF technology?		
a. no difficulties	41	33%
b. heavy labor demand	48	38%
c. no response	36	29%
d. total households	125	100%
4. What improvements can you suggest?		
a. dig basins immediately after harvest	15	12%
b. farmers should get weedwipe	3	2%
c. no suggestions	107	86%
d. total households	125	100%

Source: IFPRI/FSRP Farm Survey, 2001/2.

This raises an important qualification necessary before interpreting these labor data – the time dimension. Conservation farming, whether with basins or rippers, represents a long-term investment in improved soil fertility and soil structure. Both farmers and promoters need to look at the system over a period of years. Clearly, farmers find digging basins difficult in the first year. But empirical measurement bears out the observation of the old timers, that land preparation labor declines substantially in later years. While first year farmers require an average of slightly over 70 person-days to prepare a hectare of basins, a fifth-year farmer requires about half that amount (Figure 13). By maintaining permanent planting basins, farmers not only concentrate soil fertility but also reduce land preparation labor in subsequent years.

Figure 13 – Declining labor requirements over time for digging CF basins



Source: IFPRI/FSRP survey 2001/2.

Reducing weeding labor. A key issue under investigation by the CFU and GART concerns means of reducing weeding labor. By failing to invert all soil during field preparation – effectively a pre-season weeding under conventional tillage -- CF technologies produce greater weed growth and demand more weeding labor during the crop season (Table 13). In later years, specialists believe weeding labor will decline as farmers remove the weed populations prior to their flowering time. However, documentation of this claim must await availability of time-series evidence on CF plots.

To reduce peak season labor bottlenecks at weeding time, the CFU advocates use of herbicides applied with a locally designed applicator called the weed wipe. Though raising cash costs for the equipment and herbicide, the weed wipe dramatically reduces weeding labor, from about 70 to 15 person-days per hectare. A reduction of this magnitude strongly influences returns to labor (Tables 15,16).

Redistribution of labor out of the peak season. Though CF technologies increase weeding labor time, and therefore total labor use, they compensate by redistributing the heavy field preparation work to the dry season when no other agricultural activities compete for household labor. Compared to conventional hand hoe maize farmers, first-year CF basin farmers *increase* total labor use by about 30 person-days, from 158 to 210 (Table 15). But because CF redistributes heavy field preparation labor to the dry season (Figure 6), the net effect is to *reduce* peak season labor demand by nearly 20 person-days. Since peak season labor – for planting, conventional tillage and early season weeding – frequently constrains farm output, this reduction in peak season labor represents a significant economic advantage of conservation farming.

Table 15--Options for smallholder farmers without draft power* living in zones favorable for water-conserving conservation farming**

	Hand Hoe Tillage					Animal Draft Power Tillage				
	Basins			Hand Hoe		Rent Ripper			Rent Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
Maize farmers	(250,000 farmers)					(110,000 farmers)				
Output (kg/ha)***	3,000	3,000	3,000	1,319	2,119	752	1,552	2,308	752	1,552
Planting Date****	18 Nov	18 Nov	18 Nov	25 Nov	25 Nov	Dec 16	Dec 16	18 Nov	Dec 16	Dec 16
Labor inputs (person days)										
peak season	124	58	58	124	142	53	53	44	53	53
harvest	16	16	16	16	16	10	10	10	10	10
dry season	70	70	35	0	0	0	0	9	0	0
total	210	144	109	140	158	63	63	63	63	63
Gross margin (K/ha)										
revenue	1,500,000	1,500,000	1,500,000	659,500	1,059,500	376,000	776,000	1,154,000	376,000	776,000
input costs	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325
gross margin	1,086,195	1,005,345	1,005,345	659,500	664,175	309,000	313,675	691,675	309,000	313,675
Returns to labor (K/person day)										
peak season labor	8,795	17,334	17,334	5,327	4,681	5,836	5,924	15,649	5,836	5,924
total labor	5,182	6,977	9,215	4,714	4,204	4,928	5,003	11,031	4,928	5,003
Cash costs										
Zambian Kwacha	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325
US dollars	$99	$118	$118	$0	$94	$16	$110	$110	$16	$110
Capital costs										
Zambian Kwacha	20,000	95,600	95,600	20,000	20,000	20,000	20,000	20,000	20,000	20,000

Table 15 -- Options for smallholder farmers without draft power* living in zones favorable for water-conserving conservation farming (continued)**

	Hand Hoe Tillage					Animal Draft Power Tillage				
	Basins			Hand Hoe		Rent Ripper			Rent Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
US dollars	$5	$23	$23	$5	$5	$5	$5	$5	$5	$5
Cotton farmers			(50,000 farmers)					(70,000 farmers)		
Output (kg/ha)***	1,280	1,280	1,280		850		795	868		795
Planting Date****	13 Nov	13 Nov	13 Nov		20 Nov		Dec 11	13 Nov		Dec 11
Labor inputs (person days)										
peak season	106	41	41		142		79	72		79
harvest	47	47	47		22		31	31		31
dry season	70	70	35		0		0	14		0
total	223	158	123		164		110	117		110
Gross margin (K/ha)										
revenue	1,075,200	1,075,200	1,075,200		714,000		668,136	729,288		668,136
input costs	214,445	295,295	295,295		214,445		323,445	323,445		323,445
gross margin	860,755	779,905	779,905		499,555		344,691	405,843		344,691
Returns to labor (K/person day)										
peak season labor	8,151	18,884	18,884		3,520		4,363	5,629		4,363
total labor	3,869	4,930	6,330		3,050		3,139	3,478		3,139
Cash costs										
Zambian Kwacha	214,445	295,295	295,295		214,445		323,445	323,445		323,445
US dollars	$51	$70	$70		$51		$77	$77		$77

Table 15 -- Options for smallholder farmers without draft power* living in zones favorable for water-conserving conservation farming (continued)**

	Hand Hoe Tillage					Animal Draft Power Tillage				
	Basins			Hand Hoe		Rent Ripper			Rent Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
Capital costs										
Zambian Kwacha	20,000	95,600	95,600		20,000		20,000	20,000		20,000
US dollars	$5	$23	$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.

Income gains

What do farmers gain in the end? Both outputs and input usage rise under CF. So it becomes necessary to value both to see where the economic incentives lie.

In doing so, it is necessary to distinguish between two categories of CF household: a) those with adequate draft power of their own, amounting to 70,000 farm households in AER I and IIa; and b) those without sufficient livestock of their own, the 360,000 small and medium holders who must till by hand or rent and borrow oxen in order to engage in ADP tillage. Given significant herd losses from corridor disease and drought, draft power has become clearly scarcer over the past decade. Currently about 250,000 of the households who do not own sufficient cattle till by hand hoe while 110,000 rent or borrow oxen for plowing (Figure 8). Even among users of ADP plows, only about 40 percent own sufficient draft animals to plow for themselves. The remainder must borrow or rent. The last served, they are most vulnerable to late planting and low yields.

The economics of ADP tillage differ substantially between the two groups. Households without adequate ADP of their own incur not only cash rental costs but also substantial yield losses due to late planting with other people's oxen. Maize farmers lose about 27 kg for each day they delay planting after the first planting rains (Table 12). The common practice of plowing with rented oxen implies that renting households will plant about 28 days later than under CF technologies. Hence households renting ADP will lose about 27x28=750 kg in maize output simply from late planting with rented oxen. Compared to hand hoes, the 7-day early planting advantage of CF technologies yields 7x27=200 kg increase in output. Since both outputs and input costs vary across the two household groups, the following discussion evaluates the economics of conservation farming separately for these two groups.

Smallholders without adequate ADP

Cotton budgets. Returns to land improve under conservation farming, compared to their conventional counterparts, because of the output gains achieved through early planting and water retention in the basins. Hand hoe CF with basins generates returns per hectare 70 percent higher than conventional hand hoe cultivation and 150 percent higher than conventional plowing (Table 15). Even compared with properly applied dry-season ripping, hand hoe CF more than doubles a farmer's returns to land. Where land constrains output, CF basins will prove most economically attractive for cotton farmers.

Returns to peak season labor also prove higher under CF. Because CF technologies redistribute land preparation labor out of the peak season and into the dry season, both ripper and basin variants of CF increase returns to peak season labor when compared to their conventional counterparts. Though the profitability of dry-season ripping surpasses that of conventional plowing, hand hoe CF generates 45 percent higher returns to peak season labor than do ADP rippers (Table 15). Under hand hoe basins, returns to labor more than double compared to those of conventional hand hoe farmers and they surpass ox-plow cultivators by about 90 percent.

Cash costs prove lowest for hand-hoe cultivation, about $50 per hectare, but rise by about 50 percent, to roughly $75, for ADP rental. Local cotton companies finance input supply for cotton farmers, though ADP rental requires either borrowing or a cash outlay by the farmer himself.

The weedwipe, because it substantially reduces peak season labor requirements, increases returns to peak season farm labor by 100 percent, from 8,000 ($1.75) to 19,000 ($4.20) Kwacha/day. To achieve these gains, farmers' cash requirements rise by a further $20 per hectare. Procurement of the necessary herbicide will, therefore, require additional input credit or farmer self-financing.

Overall, CF technologies clearly dominate their conventional counterparts. Hand-hoe CF basins unambiguously outperform conventional hand hoe tillage. CF ripping, if done as prescribed during the dry season, likewise outperforms conventional plowing.

Maize budgets. Yield gains due to early planting dominate results here. Both CF technologies significantly outyield their conventional counterparts because their dry season field preparation and permits planting one to four weeks earlier than hand hoe or oxen rental plow farmers.

As with cotton, CF technologies prove more profitable than their conventional counterparts. CF basins generate returns to land and to peak-season labor 60 to 90 percent higher than under conventional hand hoe tillage. Ripper rentals, when properly applied in the dry season, nearly triple returns to labor and more than double returns to land when compared to plow rental during the peak season (Table 15).

Given adequate input financing and sufficient land, dry season rental of rippers by cattle-deficit households theoretically holds the potential to increase household income most, since rented rippers would enable area expansion comparable to that of plows but with higher returns to both land and peak season labor. Even so, the lackluster performance of rippers on the farms we surveyed suggest that this prospective evolution from hand hoe CF to dry-season ripper rentals will be gradual and will require careful extension support to ensure that farmers realize the prospective gains from ADP conservation farming.

Smallholders with adequate ADP of their own

Cattle ownership significantly improves the viability of conventional tillage systems among small and medium holders. Since owners of oxen plow their lands first and plant only a week or two behind their CF counterparts, plowing loses much of its late-planting disadvantage by limiting yield losses.

Proper dry-season ripping retains an absolute advantage over plow farmers, though its edge becomes subtler than under rental conditions. With cotton, returns to land are only about 3 percent higher under ripping with returns to peak season labor 13 percent higher. Hand hoe CF, however, continues to dominate ox tillage, generating returns to peak season labor 30 percent higher and returns to land 70 percent higher than conventional plowing. Under maize cultivation, early planting with rippers produces a more decisive edge, 15 percent higher returns to land and 35 percent higher returns to peak season labor (Table 16).

Table 16--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			Hand Hoe		Ripper			Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
Maize farmers	(250,000 farmers)					(110,000 farmers)				
Output (kg/ha)***	3,000	3,000	3,000	1,319	2,119	1,319	2,119	2,308	1,319	2,119
Planting Date****	18 Nov	18 Nov	18 Nov	25 Nov	25 Nov	25 Nov	25 Nov	18 Nov	25 Nov	25 Nov
Labor inputs (person days)										
peak season	124	58	58	124	142	53	53	44	53	53
harvest	16	16	16	16	16	10	10	10	10	10
dry season	70	70	35	0	0	0	0	9	0	0
total	210	144	109	140	158	63	63	63	63	63
Gross margin (K/ha)										
revenue	1,500,000	1,500,000	1,500,000	659,500	1,059,500	659,500	1,059,500	1,154,000	659,500	1,059,500
input costs	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325
gross margin	1,086,195	1,005,345	1,005,345	659,500	664,175	592,500	597,175	691,675	592,500	597,175
Returns to labor (K/person day)										
peak season labor	8,795	17,334	17,334	5,327	4,681	11,190	11,278	15,649	11,190	11,278
total labor	5,182	6,977	9,215	4,714	4,204	9,450	9,524	11,031	9,450	9,524
Cash costs										
Zambian Kwacha	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325
US dollars	$99	$118	$118	$0	$94	$16	$110	$110	$16	$110
Capital costs										

Table 16--Options for smallholder farmers with adequate draft power* living in zones favorable for water-conserving conservation farming (continued)**

	Hand Hoe Tillage					Animal Draft Power Tillage				
	Basins			Hand Hoe		Ripper			Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
Zambian Kwacha	20,000	95,600	95,600	20,000	20,000	3,270,000	3,270,000	3,270,000	3,270,000	3,270,000
US dollars	$5	$23	$23	$5	$5	$779	$779	$779	$779	$779
Cotton farmers			(50,000 farmers)					(70,000 farmers)		
Output (kg/ha)***	1,280	1,280	1,280		850		850	868		850
Planting Date****	13 Nov	13 Nov	13 Nov		20 Nov		20 Nov	13 Nov		20 Nov
Labor inputs (person days)										
peak season	106	41	41		142		79	72		79
harvest	47	47	47		22		31	31		31
dry season	70	70	35		0		0	14		0
total	223	158	123		164		110	117		110
Gross margin (K/ha)										
revenue	1,075,200	1,075,200	1,075,200		714,000		714,000	729,288		714,000
input costs	214,445	295,295	295,295		214,445		323,445	323,445		323,445
gross margin	860,755	779,905	779,905		499,555		499,555	514,843		499,555
Returns to labor (K/person day)										
peak season labor	8,151	18,884	18,884		3,520		6,323	7,141		6,323
total labor	3,869	4,930	6,330		3,050		4,550	4,412		4,550
Cash costs										
Zambian Kwacha	214,445	295,295	295,295		214,445		323,445	323,445		323,445

Table 16--Options for smallholder farmers with adequate draft power* living in zones favorable for water-conserving conservation farming (continued)**

	Hand Hoe Tillage					Animal Draft Power Tillage				
	Basins			Hand Hoe		Ripper			Plow	
	1st year		5th year	local	hyv	local	hyv seed		local	hyv
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed	
US dollars	$51	$70	$70		$51		$77	$77		$77
Capital costs										
Zambian Kwacha	20,000	95,600	95,600		20,000		3,270,000	3,270,000		3,270,000
US dollars	$5	$23	$23		$5		$779	$779		$779

*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.

ECOLOGICAL IMPACT

Conservation farming aims to restore soil fertility and improve long-term productivity of farmers' soil. In areas where land has been severely damaged by long-term ox plowing and repeated heavy doses of inorganic fertilizer, investments in CF amount to reclaiming damaged farmland by restoring soil fertility. Similar efforts at land reclamation using planting basins swept across the Sahel following the great drought of the 1970's (Kabore and Reij 2003).

Over time, the aim and promise of conservation farming is to build up sustainable cropping systems on the same plots by improving soil structure, soil organic material and fertility. In order to assess these anticipated changes, long term monitoring trails by GART, CFU and others will be important in monitoring fertility profiles over time.

EQUITY IMPACT

Over 75 percent of Zambia's 870,000 farmers operate holdings of less than 5 hectares (Figure 8). Available evidence suggests that the overwhelming majority of hand hoe CF farmers operate small farms. NGO assisted small farmers all lie in this range, and PHS data indicate that 95 percent of farmers digging basins are small farmers (Table 4). The remaining 5 percent of hand hoe CF farmers operate on medium and even commercial farms. Field evidence assembled by CLUSA field staff suggest that larger-scale practitioners typically operate in the range of 1-2 hectares under CF, though sometimes these range as high as 15 to 20 hectares. A handful of commercial farmers has even experimented with CF basins because of the ease of managing farm labor on piece work.

Rippers, on the other hand, are more commonly used by medium-scale farmers who own 5 to 20 hectares of land, who own cattle and who require animal traction to farm such large areas. Large numbers of small farms likewise utilize animal draft tillage. Because ripping technology enables dry-season rental, unlike plowing, it can potentially enable smallholders to take advantage of the expanded area offered by ADP as well as the considerable yield gains offered by early planting. Given yield losses of 1-2 percent per day for maize, the normal 4 week delay in plow rental implies a 30 to 60 percent yield reduction for small farmer renters who plow with rented oxen. So the ripper opens up potentially important ADP prospects even for non-cattle-owning smallholders (Figure 8). In Agroecological Regions I and IIa, where water-conserving CF technology proves most appropriate, 60 percent of smallholders (246,000 households) currently farm with hand hoes while a further 25 percent (107,000 farms) till with borrowed or rented oxen and 15 percent (61,000 farms) own sufficient cattle that they are able to till with their own animals. CF hand hoe and ripper systems squarely target these 414,000 smallholders. Indeed, the Zambia National Farmers Union specifically launched the Conservation Farming Unit (CFU) in order reach Zambia's smallholder farmers, and they have targeted smallholders consistently since their inception.

5. IMPLICATIONS

Conservation farming has made significant progress in Zambia in a very short time. Remarkably, large-scale private actors sparked much of the initial interest and activity necessary in developing CF systems for smallholders. Commercial farmers leading the Zambia National Farmer's Union (ZNFU) launched their Conservation Farming Unit (CFU) to spearhead experimentation and extension in close collaboration with Dunavant Cotton and a network of religious and secular NGOs. Publicly funded tillage research and early government support for these initiatives proved important in moving that initial vision forward. Zambia's public sector has now fully committed to CF and it appears that between 20,000 and 75,000 Zambian farmers currently benefit from increased yield and incomes under conservation farming. As many as 440,000 overall stand to benefit from a successful scaling up of CF extension efforts.

Currently available evidence -- though based on small samples and most often on single seasons -- suggests that conservation farming packages outperform their conventional counterparts. CF basins appear to outperform hand hoe cultivation. Rippers, where properly applied, promise to outperform conventional plowing. Where improperly applied however -- using CF rippers as plows -- ripping does not confer economic benefits on adopting farmers. Given the current skewed distribution of draft animal ownership, an overwhelming majority of Zambian smallholders in suitable regions will most likely begin conservation farming via hand-hoe basins. However, as extension support for rippers improves in suitable regions, the 15 percent of smallholders who currently own draft power and another 25 percent that have access to ADP through hiring or borrowing will benefit by shifting from conventional plowing to ripping. Later, as onfarm performance with rippers improves and as ADP markets develop, hand-hoe smallholders can likewise aspire to move up the CF ladder to rental of oxen and rippers.

Our own limited 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 (0.25 hectares) of carefully managed CF basins could provide a bare bones food security safety net for a family of four. Two limas should 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.

For the future, we see several important operational issues that need to be addressed:

- *The time dimension.* How do outcomes vary across seasons, particularly in response to variable rainfall regimes? How do investment in basins and permanent rip lines pay off over time, in terms of improved soil fertility and reduced field preparation costs. The anwer to both questions will require long-term monitoring of CF and control plots.

- *Management of weeding bottlenecks in early years*. How can CF farmers most effectively address the weeding constraints that typically emerge in the early years of CF adoption? Both GART and the CFU have initiated important experiments with alternative weed management strategies, including herbicides and mechanical weeding. Yet our limited evidence suggests these practices are not yet widely practiced by farm households. In addition to continued experimentation and extension, on-farm monitoring and sustained interaction with the growing cadre of CF old-timers will help illuminate this important question.

- *Adoption and disadoption.* More detailed assessment of partial adoption and of disadoption by farm households would prove useful in targeting extension support to farmers most likely to benefit from CF and stick with it.

- *Animal-drawn CF rippers.* Animal draft CF extension appears to have received comparatively low priority in the past, though most major implementing agencies anticipate increased focus on ADP CF technologies going forward. As part of this effort, animal draft markets will need to be investigated more thoroughly. Follow up work will need to highlight bottlenecks to ADP use among both cattle owners and non-owners if ADP rental is to expand appreciably in Agro-ecological Regions I and IIa. Given the large potential benefits to dry-season ADP land preparation, we believe this effort merits higher priority than it has received in the past.

Box 1--What is conservation farming?

Conservation Farming in Zambia involves five principal practices:

1) retention of crop residues in fields, with no burning of residues
2) restricting land tillage and nutrient application to the 10-15% of surface area where crops are sown
3) completion of land preparation during the dry season
4) establishment of a precise and permanent grid of planting stations, furrows or contoured ridges within which successive crops are planted each year and within which purchased organic nutrients can be accurately applied
5) rotations with nitrogen-fixing legumes

To distinguish among a wide range of adoption practices, promoters define farmers who combine all five principles as practicing Conservation Farming (CF). They refer to farmers completing only the first four as practicing Conservation Tillage (CT), while farmers who persist in burning crop residues but who adopt practices 2-4 are said to practice Improved Reduced Tillage (IRT).

"The principal aim of this approach is to restore and maintain soil fertility in the 15% of surface area and associated root zone occupied by the planted crop. The intervening area (85% of inter-rows) can remain relatively infertile as this area is mainly occupied by competitive weeds." (CFU 2001)

Key agronomic and economic benefits of conservation farming include:

- land preparation during the dry season which, unlike conventional tillage, redeploys labor out of the peak agricultural season and into the normal slack season in Zambian agriculture; this early land preparation in turn enables
- early planting, with the first rains; plants consequently benefit from the nitrogen flush, early germination and root establishment
- water harvesting and improved water filtration via basins or rip lines which break through existing plow pans
- precise application of nutrients to plant location, where they will do the most good.
- restoration of soil fertility via crop rotations and residue retention in the field.

Conventional tillage, by contrast, includes an array of soil management practices. Soil inversion, by plow or hand hoe, involves movement of the entire surface soil on a field. Hand-hoe ridging, common in Eastern Province, likewise involves disturbing the entire surface of the field, usually by splitting the previous seasons ridges to form new ridges above the old furrow. Finally, some hand hoe farmers practice a form of minimum tillage, either by scratching planting lines or digging holes, after the planting rains, where the seeds will be sown. See CFU (1997) for a good description of these practices.

The CF "ladder" offers a progression of conservation farming technologies to Zambian farmers. For hand hoe farmers, CF basins typically prove most feasible. Those with adequate draft power begin with ox-drawn rippers, while farm households with access to tractors practice minimum-tillage mechanical systems.

Source: CFU (2001 2000 1997).

Box 2--A recent convert to CF basins

Wilson Mapiza of Mumbwa District in Central Province saw the high yields achieved by his friends who practiced CF with a CLUSA supported group nearby. Impressed by their results, he, too, asked to join.

In his first season as a group member, Mapiza has planted two limas maize and soybeans with inputs from CLUSA. In addition, he planted two limas of potholed maize purchasing fertilizer and seed with his own funds from the Food Reserve Agency. He grows one lima of paprika on ridges and has ox-plowed one hectare of maize. Because he prepared basins in the dry season, he planted his CF maize with the first planting rains on November 15th. Due to a late start and sporadic early season rains, he was unable to plow until December. He planted his one hectare plot of conventionally tilled maize on New Years' Day 2002, fully six week later than his potholed maize. The picture below demonstrates the striking difference in plant establishment. Mapiza reckons he will harvest 3 to 4 tons per hectare from his CF basins on the right. But from the plowed field on the left he will be lucky to harvest even one ton. Mapiza says that about three farmers a day pass by to ask how achieves such high yields

Box 3. A Six Year Veteran with CF Basins

John Manchinchi and his wife retired from school teaching in 1994. They returned to their home village of Nangoma to begin cultivating their three hectares of land. In 1995, they planted cotton and maize in furrows, tilling with ox-drawn plow.

Then in 1996, they became CFU demonstration farmers and devoted one lima of land to a CF rotation of maize, soya and green gram. Their five remaining limas remained under conventional ox-plow tillage and planted, as before, with cotton and maize..

Because of the striking difference in output from his CFU basins, Manchinchi planted an additional two limas in basins the following season, using his own resources to procure inputs. The remaining two limas remained under conventional tillage.

Each year, he brought additional land under CF basins. In the 2001/2 season, he cultivated all 12 limas of land in basins under a variety of CF systems. On some plots he applies chemical fertilizer; in others he applies manure from his kraal. Plot samples taken from one of his self-financed maize plots, the one he fertilized with kraal manure, register a 2.9 ton per hectare yield under CF with basins.

Now in his sixth years of conservation farming, Manchinchi emphasizes that his land preparation and weeding time have diminished substantially over time. As we prepare to leave, he asks about a new variety of cassava called Bangweula which he understands can yield over 20 tons per hectare. As it turns out, he is right.

Box 4—A cotton farmer adopts CF basins

Emmanual Mukwashi of Chisani Village is a Dunavant distributor. This is a responsible position for this 27 year-old father of five. He assumes responsibility for input distribution and loan repayment by his 62 group members. Following each of the half dozen seasonal training sessions run by Dunavant and the CFU, he visits his farmers to show them what he has learned.

Two seasons ago, Mukwashi began to experiment with CF basins. He saw results from his neighbors who were achieving unusually high yields on their cotton and maize. This season, he has planted 5.4 hectares in all, with all labor supplied by himself, his wife and his two oldest children. He farms 1.4 hectares of cotton in three separate plots, 1 hectare under conventional ox-plow tillage and .4 hectares in basins. This season, he estimates that his cotton planted in basins will yield double what he harvests from his adjacent conventionally plowed field. This year, the rains have been scattered and irregular. Eight of his 62 group members currently plant cotton in basins. But because of the drought, they have seen that farmers with basins will harvest much more than those who plow.

Even though he owns five cattle, Mukwashi intends to plant more land in CF basins next season. And 32 of his group members have asked for training so they too can switch to CF planting basins next season.

Box 5—Effective onfarm application of CF ripping

Moses Mulinga farms 15 hectares outside of Lusaka. A former driver, he retired to begin farming in 1995. To feed his 14 family members, including 7 children still in school, he needed a productive farm. Yet he fared poorly during his first three years. Imitating his neighbors, he used an ox-plow and chemical fertilizers. But as a beginner, he did not knowing proper input rates, crop combinations or rotations or how to market his product.

In 1998, he learned about the Magoye Ripper during a demonstration at the Casisi Agricultural Mission nearby. Inspired by what he saw, Mulinga devoured all the written material he could find on conservation tillage and began switching to animal draft power conservation farming.

By 2002, his hard-working family has converted their farm into a living textbook on conservation tillage. One hectare remains in natural woodlands, percolated with bee hives, while another two limas houses a series of onfarm trials with leguminous shrubs such as sesbania sesban and tefrosia as well as experiments with various citrus trees and catchment basin. The Mulinga family crops the remaining 14 hectares with a Magoye Ripper drawing draft power from among their 8-cattle herd. Last season, they devoted two hectares to the testing of two different varieties of sunhemp, an annual legume that will prepare the soil for maize production next season. In addition to 2 hectares of maize, they have planted fields of velvet beans, green gram and cowpeas. Mr. Mulinga no longer applies any chemical fertilizers. Instead, through his various crop rotations he achieves maize yields of 3 to 4 tons per hectare. His neighbor, across the road, produced stunted maize this season, with meager shriveled cobs that yielded barely one ton per hectare. Uprooting several large weeds from the neighbor's field reveals a pronounced L-bend in the root structure suggesting that both maize and weed roots failed to penetrate the plow pan built up over years of ox plowing. Mr. Mulinga shakes his head knowingly as he proceeds to show us his compost pile.

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ANNEX A. FARM SURVEY METHODS

A. Objectives

This survey aims to measure differences in

- input use,
- output produced, and
- income

between conservation farming and conventional tillage systems. Since most farmers practice conservation farming on only a portion of their plots, this requires plot-level input-output data on both outputs and inputs.

Output differences. Though several prior studies have evaluated differences in output between CF and conventional systems, none that we are aware of has separated out from the CF tillage practice the portion of gains due to differential input use (both purchased inputs and labor) and time of planting, both of which materially influence output levels. Since many CF farmers receive HYV seed and fertilizer packages, at least part of their higher output stems from higher levels of input use. One primary objective of this study was to isolate the effect of the CF agronomic practices from their higher input use.

Input and income differences. Conservation farming often involves greater labor input than conventional tillage systems, particularly at weeding time. Because CF farmers practice minimum tillage, both with the ripper and hand hoe basins, they invert less soil during field preparation and thus generate higher weed growth, at least early in the season and in early years of CF adoption. Assisted CF maize farmers (though not cotton farmers) receive input packages that typically include higher fertilizer and lime than conventional farmers. These additional input costs need to be valued in evaluating income gains.

B. Sampling

Provinces. To achieve geographic dispersion, the survey sampled farmers in two provinces, Central and Southern. In order to capture insights into how labor use and productivity of CF systems change over time, the survey selected zones within each province where farmer groups have the longest experience with conservation farming. This resulted in the selection of Mumbwa District in Central Province and Choma and Mazabuka Districts in Southern Province.

Commodities. The survey focused on two commodities, maize and cotton. The first is Zambia's principal food crop, while the second is the cash crop whose farmers have the most extensive experience with conservation farming. Since the impact of conservation farming undoubtedly differs across crops, the study aimed to explore some of this diversity by evaluating its impact on the two principal commodities produced under CF.

Group selection. Within each selected district, the team stratified all CLUSA farmer groups according to years in the CF program, and gender of the group members. They then randomly selected six 1st year groups, three 2nd year groups, seven 3rd year groups including 3 female-only groups.

A shortage of cotton farmers among the CLUSA groups led the Mumbwa team to sample Dunavant cotton groups as well. After taking an inventory of the 16 Dunavant groups closest to the Dunavant sheds in the survey area, the team randomly selected 5 groups to interview.

Farmer selection. For each selected group -- both Dunavant and CLUSA --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 and female). The team then randomly selected farmers from each category. The paucity of ripper and conventional hand hoe farmers required selection of a 100 percent sample of these farmers from the selected groups.

This procedure generated a representative sample of 125 farmers with 205 maize and 105 cotton plots.

Table A.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 A.2--Characteristics of survey households

	Tillage system			
	basins	hoe	ripper	plow
Plot size (ha)				
cotton	0.44	0.57	1.1	1.1
maize	0.32	0.60	1.1	1.2
maize and cotton	0.34	0.57	1.1	1.2
Cattle ownership				
average number owned	3.8	1.5	4.3	5.8
% owning 0 cattle	52%	73%	29%	44%
% owning 1-2	15%	9%	18%	18%
% owning 3-5	15%	0%	27%	13%
% owning 6-10	8%	18%	12%	12%
% owning 11 or more	10%	0%	14%	13%
	100%	100%	100%	100%
Household labor units*	4.6	3.5	5.1	5.1
Education of household head	7.7	5.8	7.4	7.8
Number of plots sampled	116	11	51	128

* Labor measured in adult equivalents, where an active adult male = 1,
an active adult female = .8, children between 10 and 18 = .6.
Source: IFPRI/FSRP survey.

Plot selection. The survey team obtained input-output information for all cotton and maize plots cultivated by each of the selected farmers.

C. Calendar

The survey took place in the second half of March and the first half of April 2002, just at the end of the maize cropping season. This timing proved necessary in order to cut maize plot samples from the selected fields before the farmers harvested their crop.

D. Measurement

Plot size. Some farmers had previously measured their fields with a tape measure. This occurred principally with farmers planting in CF basins. Because of the precise 70 by 90 cm grid adopted as the CF standard, interviewers simply asked the number of basins planted and computed area from this measure. On plots for which farmers offered only ocular estimates, the field team physically measured plots with a tape.

Output. Interviewers asked each farmer to estimate ouput from each sampled plot. In addition, for cotton plots, Dunavant distributors gave their estimate as well.

The team took a physical sample from a 10 x 10 meter subplot at the middle of each maize plot. They paid the farmer the market price of 660 Kwacha per kg for maize on the cobb. This enabled the team to bag each plot sample, transport it to Lusaka, dry and weigh each under uniform conditions. The team took moisture readings from all physical samples and adjusted output to 14 percent moisture content. In all, the team succeeded in procuring physical samples for 128 out of 205 maize plots.

Because the cotton harvest occurs much later than maize and takes place over four to six weeks, physical sampling was not possible. We did, however, ask each distributor to keep separate weights from sampled plots in order to compare the physical weight with the prior estimates. This procedure did not prove satisfactory, for three reasons. First, some farmers failed to segregate their harvest by individual plot. Secondly, several sample farmers experimenting with basins grew subplots in basins surrounded by plowed cotton lines, making it difficult for them to supervise hand picking and separate output from the CF and conventional plots. Finally, significant levels of side-selling and poaching by other textile companies led, in some areas, to underweight reporting at the Dunavant sheds.

ANNEX B. DUNAVANT DISTRIBUTOR SURVEY: SEPTEMBER AND OCTOBER 2002

A. Objectives

Dunavant cotton farmers constitute the largest group of spontaneous adopters of conservation farming in Zambia. Unlike CFU and CLUSA farmers, Dunavant farmers do not plant basins or rippers as a condition for receiving their inputs. They only adopt CF practices if they perceive it to be their best 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, their farmers offer a unique opportunity to examine CF adoption rates among 75,000 smallholders across most of Zambia's agroecological regions 1 and 2.

Because Dunavant conducts quarterly extension meetings with all their distributors, these convocations offer an important opportunity to inexpensively gain broad information on CF adoption. Therefore, with the gracious cooperation of Dunavant's management and their extension specialist, we interviewed all 1,400 distributors who attended the pre-season extension meetings in September and October 2002. All distributors filled out a simple half-page questionnaire which aimed to document two things:

- distributor's tillage method
- group members' tillage methods in 2001 and in 2002.

B. Sampling

We conducted a 100 percent census of all 1,400 distributors who attended the 2002 pre-season extension workshops. Table B.1. describes the locations and numbers interviewed.

Table B.1 -- Dunavant Cotton Distributors Survey, 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

C. Calendar

These 23 meetings took place between September 23 and October 15 2002.

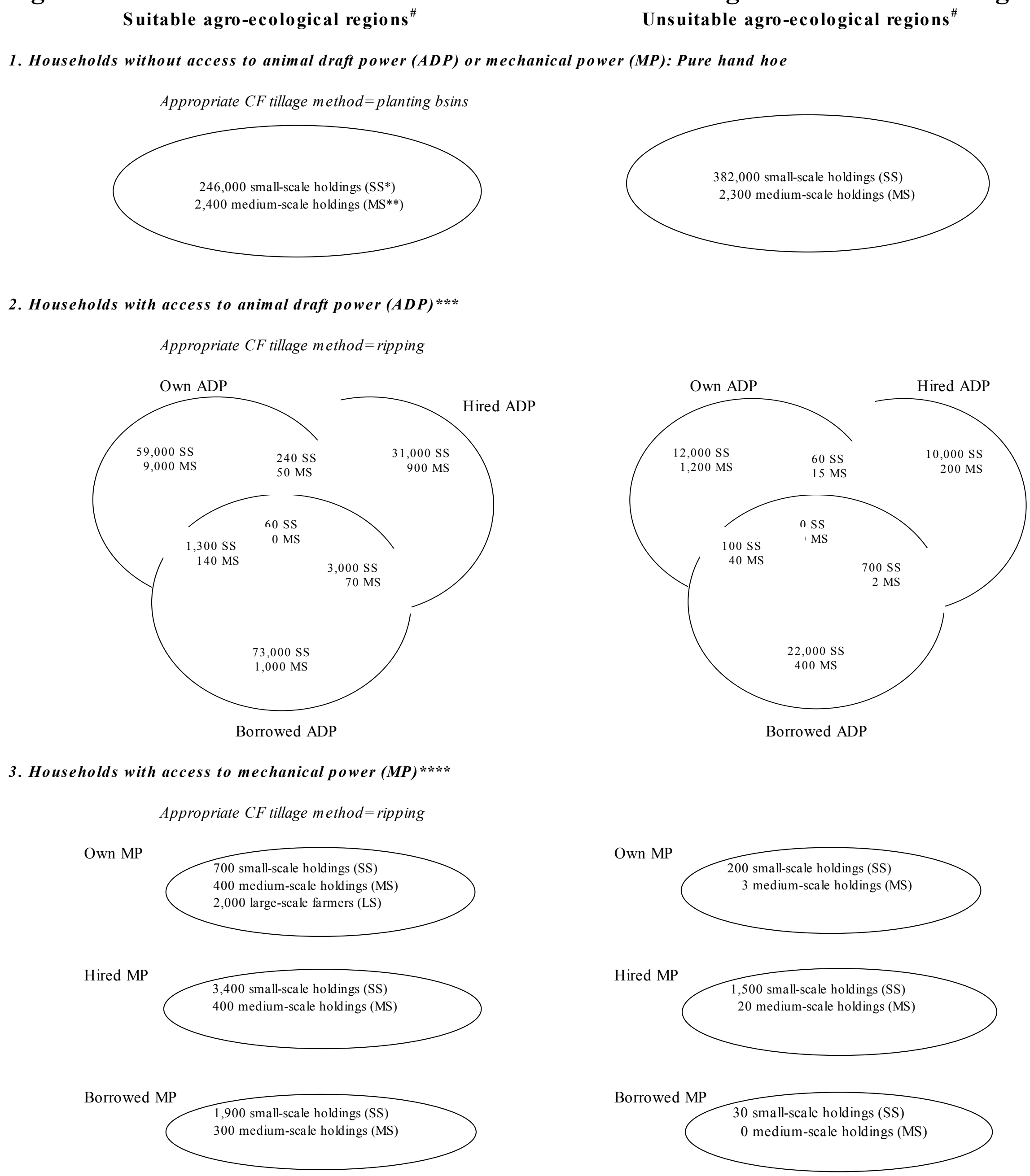
Table B.2 -- Tillage methods used by Dunavant distributors and cotton farmers, 2001/2

	Distributors		Farmers	
Tillage method	Number	Percent	Number	Percent
Plowing				
plow only	880	64%		
plow plus basins, hoes or rippers	125	9%		
total plowing	1,005	73%	40,410	54%
Ripper				
ripper only	27	2%		
ripper plus plow	35	3%		
ripper plus basins or hoes	8	1%		
total using rippers	70	5%	2,167	3%
Hoe				
hoe only	278	20%		
hoe plus plow	24	2%		
hoe plus basins or rippers	8	1%		
total using hoes	310	23%	26,639	35%
Basins				
basins only	52	4%	4,535	6%
basin plus plow	63	5%		
basin plus hoe or rippers	13	1%	1,681	2%
basin total	128	9%	6,216	8%
Total	1,374	100%	75,432	100%

Source: Dunavant distributor survey, September and October 2002.

ANNEX C. SUPPLMENTARY FIGURES AND TABLES

Figure C.1–Recommendation domains for water-conserving conservation farming



#Suitable agro-ecological regions include low-rainfall areas with good soil structure that can hold the basins and rip lines

*SS = Small-scale agricultural holdings cultivating not more than 5 ha per year

**MS = Medium-scale agricultural holdings, cultivating 5-20 ha per year

LS = Large-scale agricultural holdings, cultivating more than 20 ha per year

***ADP farmers used a range of ADP sources, hence the venn diagrams with intersections

****Typically, each mechanical draft power farmer used only one source of MP

Source: Data from post-harvest surveys (CS0 1997-2000).

Table C.1 -- Yield variations in planting basins across seasons in the Sahel

	Location and year						Average
Millet yields in Illela, Niger	1991	1992	1993	1994	1995	1996	
Rainfall (mm per year)	726	423	369	613	415	439	452
Millet yields (kg/ha)							
a. control	-	125	144	296	50	11	125
b. basins + manure	520	297	393	969	347	553	513
c. basins + manure + fertilizer	764	494	659	1486	534	653	765
Absolute gains							
b-a	-	172	249	673	297	542	388
c-a	-	369	515	1190	484	642	640
Percentage gains							
(b-a)/a		138%	173%	227%	594%	4927%	310%
(c-a)/a		295%	358%	402%	968%	5836%	511%

Sorghum yields in Burkina Faso	Pouyango shallow altisols		Taonsongo deep brown soil		Average
	1992	1993	1992	1993	
Rainfall (mm per year)	706	632	563	466	
Sorghum yields (kg/ha)					
a. control	63	22	150	3	60
b. pit only	150	29	200	13	98
c. pit + leaves	184	83	395	24	172
d. pit + compost	690	257	654	123	431
e. pit + mineral fertilizer	829	408	1383	667	822
f. pit + compost + fertilzier	976	550	1704	924	1,039
Absolute gains					
b-a	87	7	50	10	39
c-a	121	61	245	21	112
d-a	627	235	504	120	372
e-a	766	386	1233	664	762
f-a	913	528	1554	921	979
Percentage gains					
(b-a)/a	138%	32%	33%	333%	65%
(c-a)/a	192%	277%	163%	700%	188%
(d-a)/a	995%	1068%	336%	4000%	624%
(e-a)/a	1216%	1755%	822%	22133%	1281%
(f-a)/a	1449%	2400%	1036%	30700%	1645%

Table C.1 -- Yield variations in planting basins across seasons in the Sahel (continued)

	Location and year		Average
Sorghum yields in Mali	1992/3	1993/4	
a. plowed fields (yield in kg/ha)	397.2	280	339
b. zai pits plus manure (kg/ha)	1494.4	620	1,057
Absolute gain (b-a)	1097.2	340	719
Percentage gain (b-a)/a	276%	121%	212%

Source: Roose, Kabore and Guenat (1993), Hassane, Martin and Reij (2000), Wedum et al. (1996).

Table C.3--Cotton budgets for survey farmers

	Input usage under alternative tillage systems				
	Basins	Hand hoe	Ripper	Plow	Price
Output quantity (kg/ha)	1,278	986	557	818	840
Planting Date	13-Nov	20-Nov	23-Nov	28-Nov	
Purchased input quantities					
seed (kg/ha)	30	23	20	26	1,750
basal fertilizer (kg/ha)	27	0	0	7	1,376
topdressing (kg/ha)	0	0	0	0	1,239
manure (kg/ha)	47	0	350	0	65
lime (kg/ha)	16	0	0	0	92
pesticides (kwacha/ha)	211,938	186,109	155,853	151,296	140,000
Animal traction (hectare)					
land preparation	0	0	1	1	67,000
weeding	0	0	0.5	1	42,000
Labor inputs (person days)					
dry season (July-October)	55	13	0	0	
peak season (Nov-Feb)	116	129	88	70	
harvest (March-June)	47	22	35	26	
total	219	164	124	96	
Gross margin (K/ha)					
revenue	1,073,520	828,240	467,880	687,120	
purchased input costs	305,831	226,009	213,078	206,116	
animal traction costs	0	0	88,000	109,000	
gross margin	767,689	602,231	166,802	372,004	
Returns to labor (K/person day)					
dry season labor (July-Oct)	13,847	0	0	0	
peak season labor (Nov-Feb)	6,609	4,671	1,899	5,341	
harvest labor (March-June)	16,369	27,499	4,725	14,145	
total labor	3,513	3,677	1,351	3,871	
Capital costs (Kwacha)					
Zambian Kwacha	20,000	20,000	3,000,000	3,000,000	
US dollars	$5	$5	$714	$714	4,200
Sample size	24	9	16	45	

* imputed at rental cost.

Source: IFPRI/FSRP survey.

Table C.4--Maize budgets for survey farmers

	Input usage under alternative tillate systems (per hectare)						Price
	Basins	Hand hoe	Ripper	Plow			
				all	local	hyv	
Output quantity (kg/ha)	3,054	2,125	1,727	1,339	983	1,620	500
Planting date	18-Nov	5-Nov	27-Nov	2-Dec	4-Dec	30-Nov	
Purchased input quantities (kg/hectare)							
seed, hyv	18	18	15	13	0	22	2,730
seed, local	1	0	3	11	29	0	0
basal fertilizer	112	68	90	16	3	23	1,239
urea	124	68	79	29	6	39	1,239
manure	68	0	57	35	0	55	65
lime	162	68	50	11	0	31	92
Animal traction (hectare)							
land preparation	0	0	1	1	1	1	67,000
weeding	0	0	0	0.3	0	0.5	42,000
Labor inputs (person days per hectare)							
dry season (July-October)	64	25	0	0	0	0	
peak season (Nov-Feb)	130	130	63	43	43	43	
harvest (March-June)	16	21	14	6	4	7	
total	211	176	77	48	47	49	
Gross margin (K/ha)							
revenue	1,527,000	1,062,500	863,500	669,500	491,500	810,000	
purchased input costs	361,534	223,987	258,409	95,407	11,065	142,958	
animal traction cost*	0	0	67,000	77,500	67,000	88,000	
gross margin per hectare	1,165,466	838,513	538,091	496,593	413,435	579,042	
Returns to labor (K/person day)							
dry season labor (July-Oct)	18,137	33,608	0	0	0	0	
peak season labor (Nov-Feb)	8,955	6,458	8,541	11,657	9,728	13,529	
harvest labor (March-June)	72,389	40,508	38,435	90,290	98,437	87,734	
total labor	5,537	4,778	6,961	10,324	8,853	11,721	
Capital costs (Kwacha)							
Zambian Kwacha	20,000	20,000	3,270,000	3,270,000	3,270,000	3,270,000	
US dollars	$5	$5	$779	$779	$779	$779	4,200
Sample size	95	3	40	87	33	54	

* imputed at rental cost.
Source: IFPRI/FSRP survey.

Table C.5 -- Options for Smallholder Cotton Farmers Without Draft Power* Living in Zones Favorable for Water-Conserving Conservation Farming**

	Hand Hoe Tillage (50,000 farmers)				Animal Draft Power (70,000 farmers)			
	Basins			Hand Hoe	Rent Ripper		Rent Plow	Price (kwacha)
	1st year		5th year		late	early		
	hand weeding	weedwipe	weedwipe		prep	prep		
Output (kg/ha)***	1,280	1,280	1,280	850	795	868	795	840
Planting Date****	13 Nov	13 Nov	13 Nov	20 Nov	Dec 11	13 Nov	Dec 11	
Purchased input quantities								
seed, hyv (kg/ha)	25	25	25	25	25	25	25	2,730
basal fertilizer (kg/ha)	5	5	5	5	5	5	5	1,239
manure (kg/ha)								65
lime (kg/ha)	0	0	0	0	0	0	0	92
herbicide (liter/ha)	0	25	25	0	0	0	0	3,234
pesticides (1 ha pack)	1	1	1	1	1	1	1	140,000
Animal traction (hectare)								
land preparation					1	1	1	67,000
weeding					1	1	1	42,000
Labor inputs (person days)								
peak season (Nov-Feb)	106	41	41	142	79	72	79	
harvest (March-June)	47	47	47	22	31	31	31	
dry season (July-October)	70	70	35	0	0	14	0	
total	223	158	123	164	110	117	110	

Table C.5 -- Options for Smallholder Cotton Farmers Without Draft Power* Living in Zones Favorable for Water-Conserving Conservation Farming (Continued)**

	Hand Hoe Tillage (50,000 farmers)				Animal Draft Power (70,000 farmers)			
	Basins			Hand Hoe	Rent Ripper		Rent Plow	Price (kwacha)
	1st year		5th year		late prep	early prep		
	hand weeding	weedwipe	weedwipe					
Gross margin (K/ha)								
revenue	1,075,200	1,075,200	1,075,200	714,000	668,136	729,288	668,136	
purchased input costs	214,445	295,295	295,295	214,445	214,445	214,445	214,445	
animal traction costs					109,000	109,000	109,000	
gross margin	860,755	779,905	779,905	499,555	344,691	405,843	344,691	
Returns to labor (K/person day)								
peak season labor (Nov-Feb)	8,151	18,884	18,884	3,520	4,363	5,629	4,363	
harvest labor (March-June)	18,353	16,629	16,629	22,811	11,191	13,177	11,191	
dry season labor (July-Oct)	12,297	11,142	22,283			29,409		
total labor	3,869	4,930	6,330	3,050	3,139	3,478	3,139	
Cash costs								
Zambian Kwacha	214,445	295,295	295,295	214,445	323,445	323,445	323,445	
US dollars	$51	$70	$70	$51	$77	$77	$77	4200
Capital costs								
Zambian Kwacha	20,000	95,600	95,600	20,000	20,000	20,000	20,000	
US dollars	$5	$23	$23	$5	$5	$5	$5	4,200

* Includes farmers who do not own sufficient draft animals to plow with their own oxen. See Figures 13 and C.1 for detailes by farm size and region.

** Agroecological Regions I and IIa.

*** Estimated from the regression coefficients in Table 5 using the observed 1,280 kg/ha in CF basins as a base, then deducting yield for late planting, no hyv and no basins

**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey.

Table C.6 -- Options for smallholder maize farmers without draft power* living in zones favorable for water-conserving conservation farming**

	Hand Hoe Tillage (250,000 farmers)					Animal Draft Power Tillage (110,000 farmers)					
	Basins			Hand Hoe		Rent Ripper			Rent Plow		Price
	1st year		5th year	local	hyv	local	hyv seed		local	hyv	(kwacha)
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed		
Output (kg/ha)***	3,000	3,000	3,000	1,319	2,119	752	1,552	2,308	752	1,552	500
Planting Date****	18 Nov	18 Nov	18 Nov	25 Nov	25 Nov	Dec 16	Dec 16	18 Nov	Dec 16	Dec 16	
Purchased input quantities											
seed, hyv (kg/ha)	20	20	20		20		20	20		20	2,730
seed, local (kg/ha)				20		20			20		0
basal fertilizer (kg/ha)	125	125	125	0	125	0	125	125	0	125	1,239
topdressing (kg/ha)	150	150	150	0	150	0	150	150	0	150	1,239
manure (kg/ha)	0	0	0	0	0	0	0	0	0	0	65
lime (kg/ha)	200	200	200	0	0	0	0	0	0	0	92
herbicide (liters/ha)	0	25	25	0	0	0	0	0	0	0	3,234
Animal traction (hectare)											
land preparation						1	1	1	1	1	67,000
weeding						0	0	0	0	0	42,000
Labor inputs (person days)											
peak season (Nov-Feb)	124	58	58	124	142	53	53	44	53	53	
harvest (March-June)	16	16	16	16	16	10	10	10	10	10	
dry season (July-October)	70	70	35	0	0	0	0	9	0	0	
total	210	144	109	140	158	63	63	63	63	63	
Gross margin (K/ha)											
revenue	1,500,000	1,500,000	1,500,000	659,500	1,059,500	376,000	776,000	#######	376,000	776,000	
purchased input costs	413,805	494,655	494,655	0	395,325	0	395,325	395,325	0	395,325	
animal traction costs						67,000	67,000	67,000	67,000	67,000	
gross margin	1,086,195	1,005,345	1,005,345	659,500	664,175	309,000	313,675	691,675	309,000	313,675	
Returns to labor (K/person day)											

Table C.6 -- Options for smallholder maize farmers without draft power* living in zones favorable for water-conserving conservation farming**

	Hand Hoe Tillage (250,000 farmers)					Animal Draft Power Tillage (110,000 farmers)					
	Basins			Hand Hoe		Rent Ripper			Rent Plow		Price
	1st year		5th year	local	hyv	local	hyv seed		local	hyv	(kwacha)
	hand weeding	weedwipe	weedwipe	seed		seed	late prep	early prep	seed		
peak season labor (Nov-Feb)	8,795	17,334	17,334	5,327	4,681	5,836	5,924	15,649	5,836	5,924	
harvest labor (March-June)	67,466	62,444	62,444	40,963	41,253	31,692	32,172	70,941	31,692	32,172	
dry season labor (July-Oct)	15,517	14,362	28,724					79,049			
total labor	5,182	6,977	9,215	4,714	4,204	4,928	5,003	11,031	4,928	5,003	
Cash costs											
Zambian Kwacha	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325	
US dollars	$99	$118	$118	$0	$94	$16	$110	$110	$16	$110	4200
Capital costs											
Zambian Kwacha	20,000	95,600	95,600	20,000	20,000	20,000	20,000	20,000	20,000	20,000	
US dollars	$5	$23	$23	$5	$5	$5	$5	$5	$5	$5	4,200

* Includes farmers who do not own sufficient draft animals to plow with their own oxen. See Figures 13 and C.1 for detailes by farm size and region.

** Agroecological Regions I and IIa.

*** Estimated from the regression coefficients in Table 5. Using the observed 3,000 kg/ha in CF basins, yield deducted for late planting, no hyv and for no basins.

**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey.

Table C.7 -- Options for smallholder cotton farmers with adequate draft power* living in zones favorable for water-conserving conservation farming**

	Hand Hoe Tillage (few farmers)				Animal Draft Power (70,000 farmers)			
	Basins			Hand Hoe	Ripper		Plow	Price
	1st year		5th year		late	early		(kwacha)
	hand weeding	weedwipe	weedwipe		prep	prep		
Output (kg/ha)***	1,280	1,280	1,280	850	850	868	850	840
Planting Date****	13 Nov	13 Nov	13 Nov	20 Nov	20 Nov	13 Nov	20 Nov	
Purchased input quantities								
seed, hyv (kg/ha)	25	25	25	25	25	25	25	2,730
basal fertilizer (kg/ha)	5	5	5	5	5	5	5	1,239
manure (kg/ha)								65
lime (kg/ha)	0	0	0	0	0	0	0	92
herbicides (liters/ha)	0	25	25	0	0	0	0	3,234
pesticides (1 ha pack)	1	1	1	1	1	1	1	140,000
Animal traction (hectare)								
land preparation					1	1	1	67,000
weeding					1	1	1	42,000
Labor inputs (person days)								
peak season (Nov-Feb)	106	41	41	142	79	72	79	
harvest (March-June)	47	47	47	22	31	31	31	
dry season (July-October)	70	70	35	0	0	14	0	
total	223	158	123	164	110	117	110	
Gross margin (K/ha)								
revenue	1,075,200	1,075,200	1,075,200	714,000	714,000	729,288	714,000	
purchased input costs	214,445	295,295	295,295	214,445	214,445	214,445	214,445	
animal traction costs					109,000	109,000	109,000	
gross margin	860,755	779,905	779,905	499,555	499,555	514,843	499,555	
Returns to labor (K/person day)								

Table C.7 -- Options for smallholder cotton farmers with adequate draft power* living in zones favorable for water-conserving conservation farming** (continued)

peak season labor (Nov-Feb)	8,151	18,884	18,884	3,520	6,323	7,141	6,323	
harvest labor (March-June)	18,353	16,629	16,629	22,811	16,219	16,716	16,219	
dry season labor (July-Oct)	12,297	11,142	22,283			37,307		
total labor	3,869	4,930	6,330	3,050	4,550	4,412	4,550	
Cash costs								
Zambian Kwacha	214,445	295,295	295,295	214,445	323,445	323,445	323,445	
US dollars	$51	$70	$70	$51	$77	$77	$77	4200
Capital costs								
Zambian Kwacha	20,000	95,600	95,600	20,000	3,270,000	3,270,000	3,270,000	
US dollars	$5	$23	$23	$5	$779	$779	$779	4,200

* Includes all households who plow with their own oxen. See Figures 13 and C.1 for detailed breakdown by farm size and region.

** Agroecological Regions I and IIa.

*** Estimated from the regression coefficients in Table 5. Using the observed 1,280 kg/ha in CF basins, yield deducted for late planting, no hyv and no basins.

**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey.

Table C.8-- Options for smallholder maize farmers with adequate draft power* living in zones favorable for water-conserving conservation farming**

	Hand Hoe Tillage (few farmers)					Animal Draft Power Tillage (70,000 farmers)					
	Basins 1st year hand weeding	weedwipe	5th year weedwipe	Hand Hoe local seed	hyv	Ripper local seed	hyv seed late prep	early prep	Plow local seed	hyv	Price (kwacha)
Output (kg/ha)***	3000	3000	3000	1319	2119	1319	2119	2308	1319	2119	500
Planting Date****	18 Nov	18 Nov	18 Nov	25 Nov	25 Nov	25 Nov	25 Nov	18 Nov	25 Nov	25 Nov	
Purchased input quantities											
seed, hyv (kg/ha)	20	20	20		20		20	20		20	2730
seed, local (kg/ha)				20		20			20		0
basal fertilizer (kg/ha)	125	125	125	0	125	0	125	125	0	125	1239
topdressing (kg/ha)	150	150	150	0	150	0	150	150	0	150	1239
manure (kg/ha)	0	0	0	0	0	0	0	0	0	0	65
lime (kg/ha)	200	200	200	0	0	0	0	0	0	0	92.4
herbicide (liters/ha)	0	25	25	0	0	0	0	0	0	0	3234
Animal traction (hectare)						1	1	1	1	1	67000
land preparation						0	0	0	0	0	42000
weeding											
Labor inputs (person days)											
peak season (Nov-Feb)	123.5	58	58	123.8	141.9	52.95	52.95	44.2	52.95	52.95	
harvest (March-June)	16.1	16.1	16.1	16.1	16.1	9.75	9.75	9.75	9.75	9.75	
dry season (July-October)	70	70	35	0	0	0	0	8.75	0	0	
total	209.6	144.1	109.1	139.9	158	62.7	62.7	62.7	62.7	62.7	
Gross margin (K/ha)											
revenue	1500000	1500000	1500000	659500	1059500	659500	1059500	1154000	659500	1059500	
purchased input costs	413805	494655	494655	0	395325	0	395325	395325	0	395325	
animal traction costs						67000	67000	67000	67000	67000	
gross margin	1086195	1005345	1005345	659500	664175	592500	597175	691675	592500	597175	

Table C.8-- Options for smallholder maize farmers with adequate draft power* living in zones favorable for water-conserving conservation farming

Returns to labor (K/person day)											
peak season labor (Nov-Feb)	8795.101215	17333.534	17333.534	5327.1405	4680.5849	11189.8	11278.09	15648.76	11189.8	11278.09	
harvest labor (March-June)	67465.52795	62443.789	62443.789	40962.733	41253.106	60769.23	61248.72	70941.03	60769.23	61248.72	
dry season labor (July-Oct)	15517.07143	14362.071	28724.143					79048.57			
total labor	5182.228053	6976.7176	9214.8946	4714.0815	4203.6392	9449.761	9524.322	11031.5	9449.761	9524.322	
Cash costs											
Zambian Kwacha	413805	494655	494655	0	395325	67000	462325	462325	67000	462325	
US dollars	98.525	117.775	117.775	0	94.125	15.95238	110.0774	110.0774	15.95238	110.0774	4200
Capital costs											
Zambian Kwacha	20000	95600	95600	20000	20000	3270000	3270000	3270000	3270000	3270000	
US dollars	4.761904762	22.761905	22.761905	4.7619048	4.7619048	778.5714	778.5714	778.5714	778.5714	778.5714	4200

* Includes all households who plow with their own oxen. See Figures 13 and C.1 for detailed breakdown by farm size and region.
** Agroecological Regions I and IIa.
*** Estimated from the regression coefficients in Table 5. Using the observed 3,000 kg/ha in CF basins, yield deducted for late planting, no hyv and for no basins.
**** Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.
Source: IFPRI/FSRP survey.

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