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Steven Haggblade[1] **and Gelson Tembo**[2]

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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 substantial yield gains in both maize and cotton. Among maize farmers, 400 kg of the increase comes from early planting and 750 kg from water harvesting and greater precision in input use in the basins. Hybrid seed also results in over 800 kg maize yield gains. Because cotton farmers use standard packages of seed and pesticides, the great bulk of the observed gain under CF stems from the water harvesting, precision and timeliness of the CF system, with planting basins, gender of the responsible person (male=1) and plot size being statistically significant. 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% 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% who practice hand hoe agriculture and the 25% 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%, 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. OVERVIEW

1.1. Scope of the Case Study

The study reported in this paper measures differences in profitability between conservation farming (CF) practices and conventional agriculture by comparing the value of differential output with the differential input costs. The main objective is to address and fill several important knowledge gaps by investigating three key features of conservation farming in Zambia:

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

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. 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 soy beans, 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).[3] 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 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.

[3] 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).

Unlike the conventional hand-hoe and plowing technologies they replace, CF moves only about 15% 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[4] 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 has 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.

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[4] The term "water harvesting" refers to conservation farming's inherent ability to reduce run-off and hold water near the plant, where the latter is needed most.

Quantification of adoption rates for various CF practices remains similarly elusive because of the high costs of field work 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 adoptions, because field preparation leaves 85% 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.

1.2. Data and Methods

1.2.1. 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; Ndiyoi, 2002).

1.2.2. 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[5], most conclude that output of maize increases by 50% to 100% 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 5% to 45% (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).

[5] 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.

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. The survey's main objective was to determine differences in input use, output produced and returns between conservation tillage and conservational tillage systems. 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.[6]

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 on yield through regression analysis (modeling details in Annex B.1; yield regression results in Table 11).

1.2.3. 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 (19,222), Central (24,129) and Eastern (30,340) Provinces. Other provinces serviced by Dunavant, but on a much smaller scale, include Lusaka (1,561) and Copperbelt (222). 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

[6] See Annex A in Haggblade and Tembo for details of the sampling and survey methods used.

farmers represents a clear choice based on the farmer's best assessment of what tillage system is in his or her best interest.

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, and the number of group members that had used each alternative tillage method in 2001 and in 2002. Tillage methods included in the questionnaire included plowing, ripping, conventional hand hoe, planting basins only, and basins in mixture with other tillage methods (see Annex B of Haggblade and Tembo for more details). Coupled with other available information, these data provided a valuable picture of the geographic dispersion of CF practice as well as important clues as to factors governing adoption.

Censored regression analysis (or Tobit model) was used to quantify and understand further the pattern and degree of spontaneous adoption of planting basins and rippers, using the distributor as the observation unit and the proportion (%) of farmers using CF tillage methods (basins, or rippers) as the dependent variable. Modeling details and results of these spontaneous adoption regression models are presented in Annex B.2 and Table 7, respectively.

2. DEVELOPMENT AND SPREAD OF CONSERVATION FARMING

2.1. 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, are characterized by 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 C.2). 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). The decades of large-scale maize subsidies came to an abrupt end with the change of government in 1991.

Table 1 shows selected agricultural trends to show the time path of and shifts in strategy and production methods brought about by this policy shock. For example, as is clear from Table 1, the 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.

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 1)[7].

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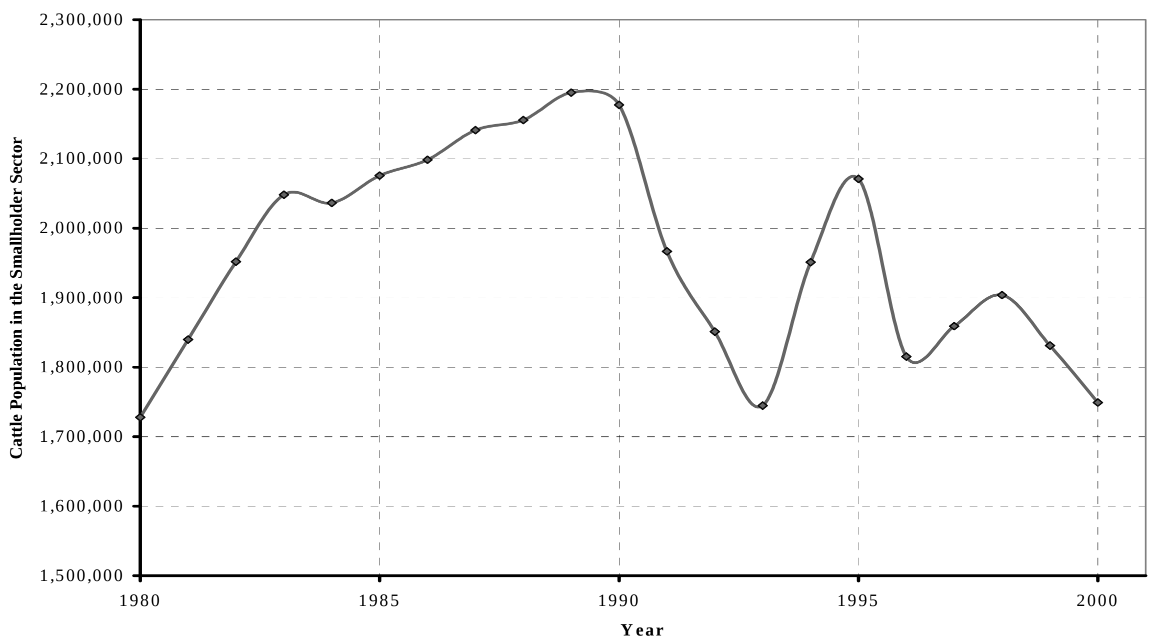
[7] Official figures, based on reporting by the Veterinary Services, suggest a modest 5% death rate. But reporting rates remain very low, and anecdotal evidence suggests far higher mortality rates, in the range of 20% to 50% in the affected regions.

Table 1. Trends in Zambian Agriculture, 1990-1999

Year	Maize			% of households with cattle	Average fertilizer use (kg/ha)	Rainfall (mm/year)
	Production index	Share of cultivated land area (%)	Yield (tons/ha)			
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 1. 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 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 Archdiocese 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 in Zimbabwe. 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 C.3).

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 2001/02 (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 International 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 C.4 and Figure C.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 MACO extension officers, actively promotes the Magoye Ripper.

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 vogelii* have proved 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, Food and Fisheries (MAFF, later renamed MACO), 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).[8]

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, 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), LMCF became 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.

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 Diocese of Monze, DAPP, World Vision and Africare, though their two longstanding partners have remained Dunavant Cotton Company and CLUSA.

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[8] 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.

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 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.[9] 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 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 – hand-hoe basins and rippers – developed for erratic rainfall zones of southern and central Zambia[10]. 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% 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 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.

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[9] 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).

[10] 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.

Table 2. Growth in the Number of Dunavant Cotton Farmers Using Conservation Tillage Practices, 2001/02 to 2002/03

	Basins			Rippers			Number of distributors interviewed
	Number of farmers		Change	Number of farmers		Change	
Province	2001/02	2002/03	(%)	2001/02	2002/03	(%)	
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 all 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 2,200 practiced ripping. See Table B.2 for details.

Source: Dunavant Distributor Survey, September/October 2002.

2.2. Adoption Rates

2.2.1. 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 C.2). 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.

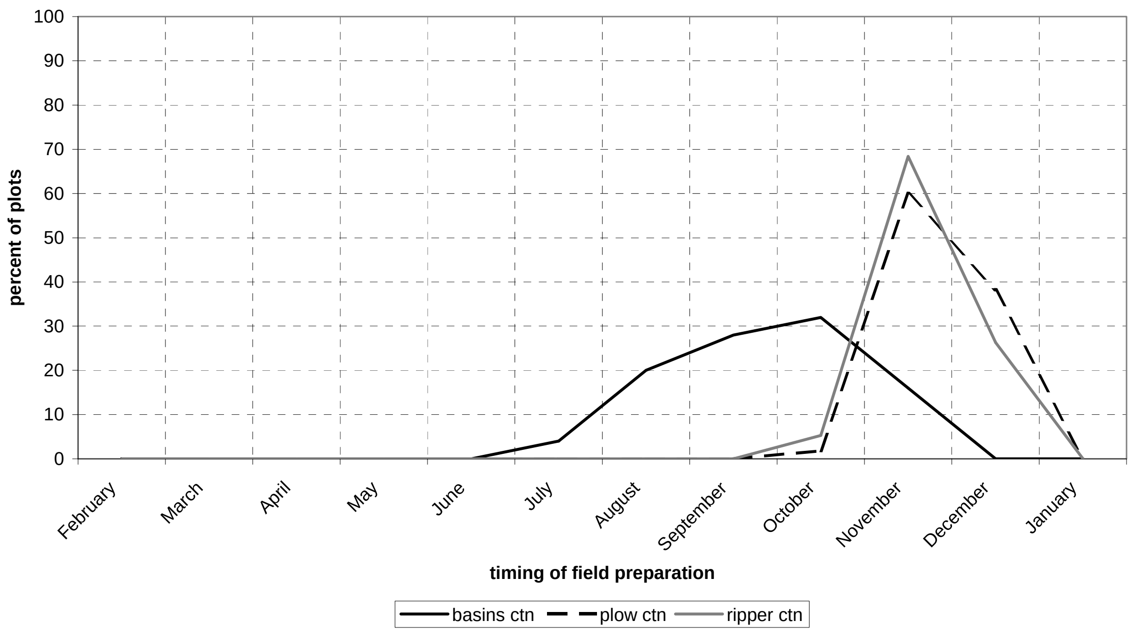
Individual farmers have responded by reducing input use, diversifying out of maize production, and seeking alternative tillage systems (Table 1). Collectively, farmer organizations, private companies, NGO's, specialized projects and MACO began to disseminate the CF technologies that emerged in response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

2.2.2. Overall Adoption Rates

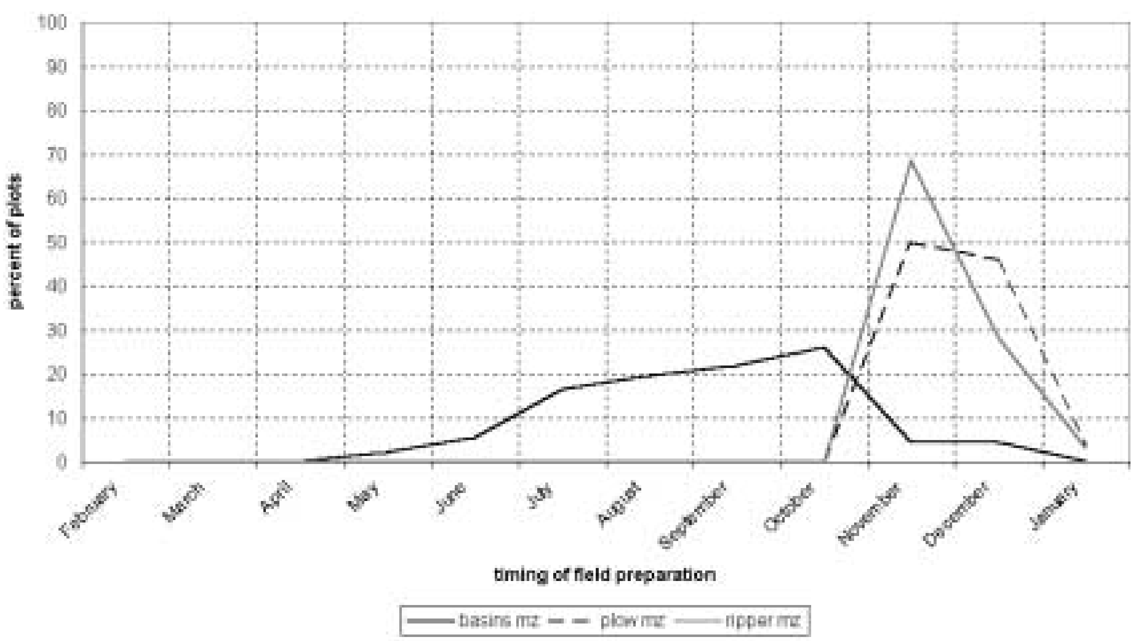
In response to these changes in their operating environment, how many farmers have adopted conservation farming practices in Zambia? The answer to this question requires considerable care, since many farmers adopt some of the recommended practices without adopting others (Arlusa, 1997; ECAZ, 1999; LMCF,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

Figure 2. Timing of Land Preparation, by Tillage Method

a. cotton plots



b. maize plots



Source: IFPRI/FSRP survey 2001/2.

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).[11] A further 20,000 who use both rippers and basins. 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 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 C.5), but rather use the ripper as a furrower or even as a plow after the rains have begun (Figure 2). Given the distribution of 2,000 more rippers in the 2002/03 season, adoption of ADP conservation farming probably more likely lies in the range of 4,000 to 6,000 farmers.

Table 3. Prevalence of Conservation Tillage Practices in Zambia, 1999/2000 Agricultural Season

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.

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 3). According to

[11] 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.

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. 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%, 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. 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.

2.2.3. 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% in Lusaka Province to 0% 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%) and Region I (at 3%), while none of the handful of cotton farmers interviewed in the higher-rainfall Region III applied CF basins in their cotton plots (Table 4).

Even within a given high-potential CF zone, adoption rates differ considerably. In Mumbwa District of Central Province, the heart of Zambia's cotton zone, adoption of CF basins ranges from 27% at the Nangoma Depot to only 8% at Shinuma (Table 4). As this disparity suggests, though agro-ecological region clearly affects the feasibility of CF adoption, other factors are also at play.

Table 4. 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 metho Plow	Ripper	Hoe	Basin	Total
Ranking by Agro-ecological Region								
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.

2.2.4. Partial and Incremental Adoption

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

Over time, proportions allotted to CF grow steadily. While first-year CF cotton farmers experiment with basins on only 1% of their cotton area (often placing a few lines of basins as a test run), those with four or more years of experience apply basins to over 40% of their cotton holdings. With maize holding, the 10% area allotted to CF basins rises to about 30% among farmers with four or more years of experience (Table 5). 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).

Table 5. 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 Farm Survey, 2001/02 Agricultural Season

However, adoption rates rarely reach 100%. 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).

2.2.5. Disadoption

Farmers continuously experiment with new technologies. One field survey suggests that among those farmers exposed to CF training, about 30% 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 disqualification of as much as 50%, 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.

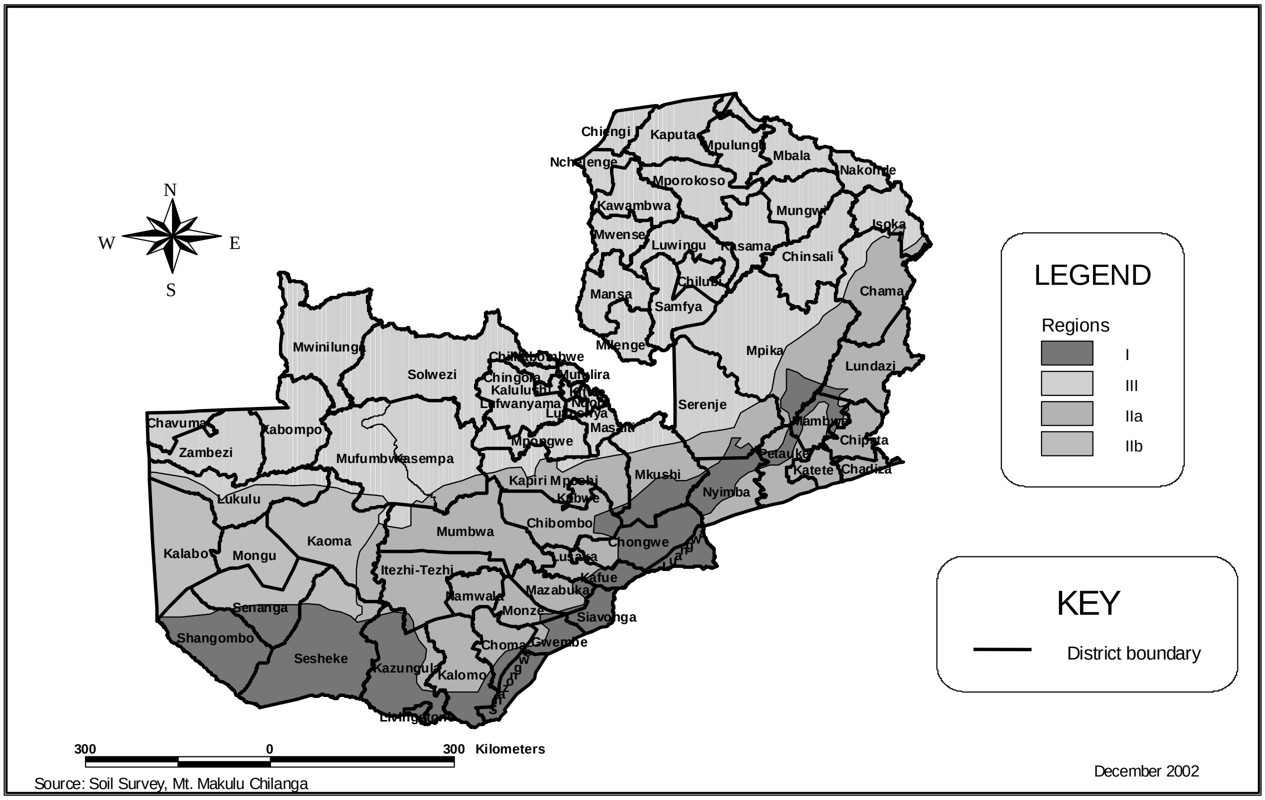
Spontaneous adoption of CF, of course, also occurs. Our census of cotton distributors offers tangible evidence of variable but potentially significant numbers of cotton farmers who have adopted CF basins in recent seasons. The acknowledged good performance of cotton farmers using CF basins during the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

2.2.6. 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% of cotton farmers in Agro-ecological Region IIa use CF basins, while none in the higher rainfall AER III do (Table 4). Geographically, the CF basins appeal most where rainfall proves erratic and unreliable, particularly in Agro-ecological Region I and, to a lesser extent, Agro-ecological Region IIa (Figure 3).

Figure 3. 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% at Dunavant Nangoma Depot to only 8% at Shinuma (Table 4). Access to extension support and ADP certainly influences farmer decisions. In Central districts, 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, despite heavy and longstanding extension support there. Even strong extension cannot easily overcome longstanding traditions of cattle culture and preference for animal draft power.

Table 6. Effect of Cotton Distributors on Group Member Tillage Methods

Distributor's tillage method	Number of groups	Average group size	Percentage of farmers using each tillage method: Plow	Ripper	Hand hoe	Planting basins	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.

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%, among groups whose distributor uses basins (Table 6).

Table 7 presents Tobit regression results, trying to explain variations in the proportion of the Distributor's farmer group members that use planting basins or rippers, as the case may be (see Equation 2). Given that 61 percent and 75 percent of the farmer groups had no farmers using planting basins and rippers, respectively, the Tobit estimator is most suited.

In general, the Tobit regression results bear out the importance of the role model provided by the Dunavant distributors (Table 7). Where distributors themselves farm with CF basins, we find 28 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 22 percent, even after holding location constant.

Table 7. Factors Affecting the Proportion of Dunavant Group Members Using Planting Basins or Rippers[a]

Variables	Proportion of farmers using **basins**	Proportion of farmers using **rippers**
Constant	-	-
Basins dummy variable, equal to one if distributor used basins in 2001/02	0.2764 ***	-0.0073
	(9.34)	(-0.28)
Rippers dummy variable, equal to one if distributor used basins in 2001/02	0.1242 ***	0.2161 ***
	(3.13)	(7.64)
Regional/District dummy variables (Petauke = 0)[b]		
Chibombo	0.5772 ***	0.1491 ***
	(5.03)	(3.44)
Kabwe	0.4440 ***	0.1282 **
	(3.58)	(2.34)
Kapiri Mposhi	0.4328 ***	0.1152 **
	(3.49)	(2.15)
Mumbwa	0.6318 ***	0.0963 **
	(5.63)	(2.44)
Mpongwe	0.1583	0.1663 *
	(0.74)	(1.85)
Chipata	0.5055 ***	-0.1683 ***
	(4.50)	(-3.44)
Katete	0.3608 ***	-0.0638
	(3.13)	(-1.34)
Lundazi	0.4211 ***	-0.1503 **
	(3.58)	(-2.29)
Chongwe	0.5739 ***	0.1243 **
	(4.76)	(2.36)
Choma	0.5212 ***	0.1624 ***
	(4.30)	(3.20)
Gwembe	0.3568 ***	0.0860
	(2.86)	(1.63)
Kalomo	0.4867 ***	0.1110 *
	(3.85)	(1.93)
Mazabuka	0.4327 ***	0.0718
	(3.57)	(1.39)
Monze	0.4002 ***	0.1636 ***
	(3.17)	(3.12)
Namwala	0.4697 ***	0.0156
	(3.82)	(0.27)
LR Chi-square	324.290 ***	265.760 ***
Pseudo R-squared[c]	0.264	0.327
Number of observations	1320	1319

*Significant at 90%; **Significant at 95%; ***Significant at 99%

[a] Marginal values, dy/dx, for the discrete change of dummy variables from 0 to 1. Figures in brackets are z statistics

[b] The District effect serves as a proxy for availability of cattle, soil and rainfall differences, and variations in extension support across locations

[c] Note that all the shortfalls of pseudo R^2 abide here.

Source: Data from the Dunavant Distributor survey by IFPRI and FSRP, 2002.

Distributor use of rippers is also associated with a 12 percent increase in probability of group members using CF basins (Table 7).[12] 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 8). 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 8. 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 post-harvest surveys (1997-2000) by the Central Statistical Office.

[12] However, the Distributor's use of planting basins does not seem to influence the proportion of group members using rippers in any significant way (Table 7)

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 school teachers, 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[13] 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 4) partition Zambia's smallholders along these two dimensions.

3.1. Agro-ecological Regions

Ministry of Agriculture staff have divided Zambia into three major agro-ecological regions using rainfall as the dominant climatic factor distinguishing the three regions (Figure 3). 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 that 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).

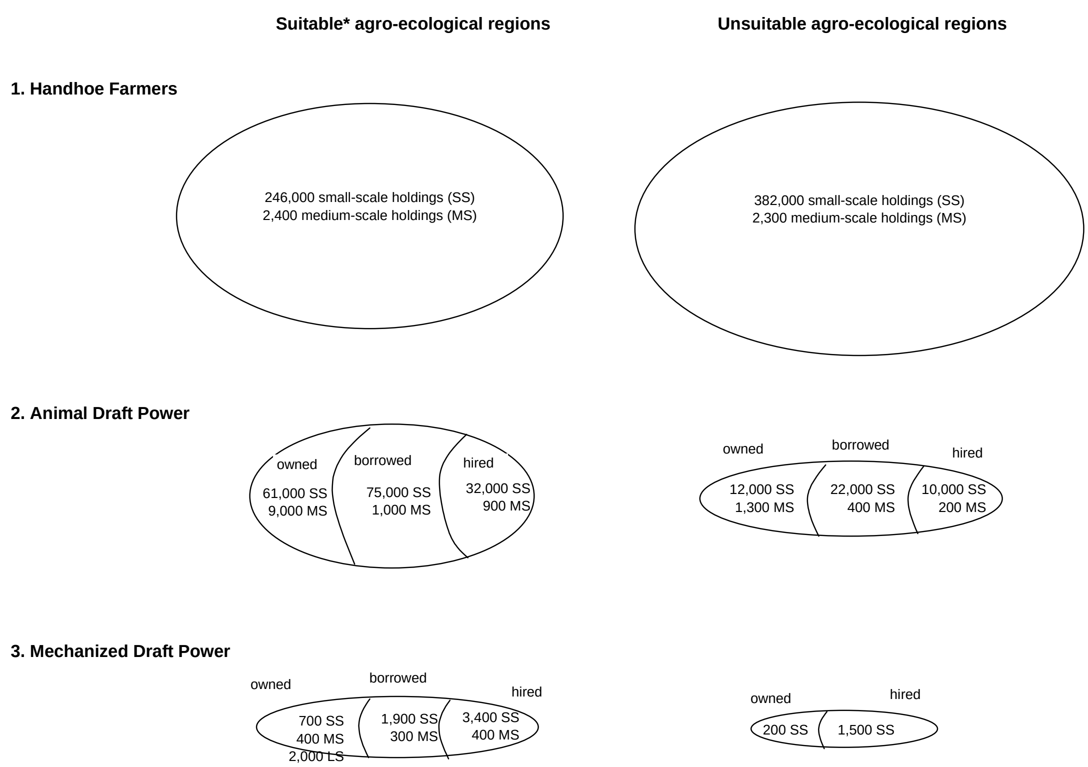
Region II covers the central belt of the country, comprising central, southern and eastern fertile plateau. It receives moderate rainfall, between 800 and 1000mm, a longer growing season of 100 to 140 days and relatively fertile soils. The region is further sub-divided into two sub-regions, IIa and IIb. 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% of the country, covers Copperbelt, Luapula, Northern and Northwestern provinces. This region is characterized by high rainfall with an

[13] 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.

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 4. Typology Of Farm Households By Agro-Ecological Region And Animal Draft Power For Determining Suitability Of 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

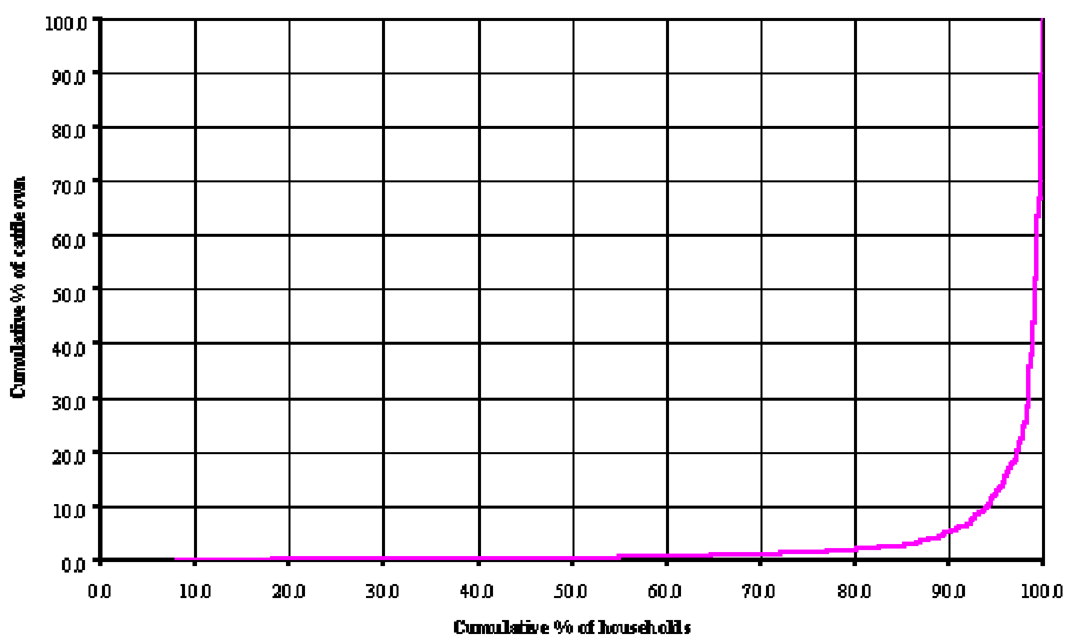
Figure 4 summarizes tillage recommendation domains according to agro-ecological conditions and farmer’s access to draught power. Overall, about 435,000 Zambian small and medium scale holders farm in regions favorable for water-conserving CF technologies while an almost equal number live in areas where other technologies will be required (Figure 4).

3.2. Animal Draft Power

3.2.1. Distribution of Ownership

Zambia's smallholder sector boasts about two million heads 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 5; Table 8). Under these circumstances, the vast majority of smallholders must either cultivate with hand hoes or obtain oxen from neighbors via rental or borrowing.

Figure 5. Concentration of Smallholder Cattle Ownership in Zambia, 1996/97 Agricultural Season



Source: Post Harvest Survey, 1996/97.

Nationally, 10% (or 83,000 farmers) of Zambia's small- and medium-scale holdings use their own ADP (Figure 4), which is almost exactly equal to the number of households with at least three cattle (Table 8). One of the major causes of low animal draft power (ADP) ownership is limited access to the necessary implements, although cattle numbers have also dwindled drastically in recent years. Our computations indicate that capital costs are very high at about USD800 (to be presented and discussed in Section 4.1.4). It is likely that such huge outlays play a major role in impeding ADP ownership. Access for ADP non-owners also seems to be limited as many smallholder farmers might not be able to meet the required rental costs. Figure 6 shows that access by borrowing is on the decline, while renting has gained in importance over the years. A comprehensive benefit-cost analysis of the ADP subsector seems essential to shed more light on the key processes regarding access to ADP. It is possible that draft cattle could be profitable aside from their value in crop production.

In the agro-ecological regions suitable for water-conserving CF technologies (AER I and IIa), only 15% (or 65,000 farmers) own three cattle or more and conceivably own enough cattle to plow with their own oxen (Table 8). The remaining 85% 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.[14] 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.

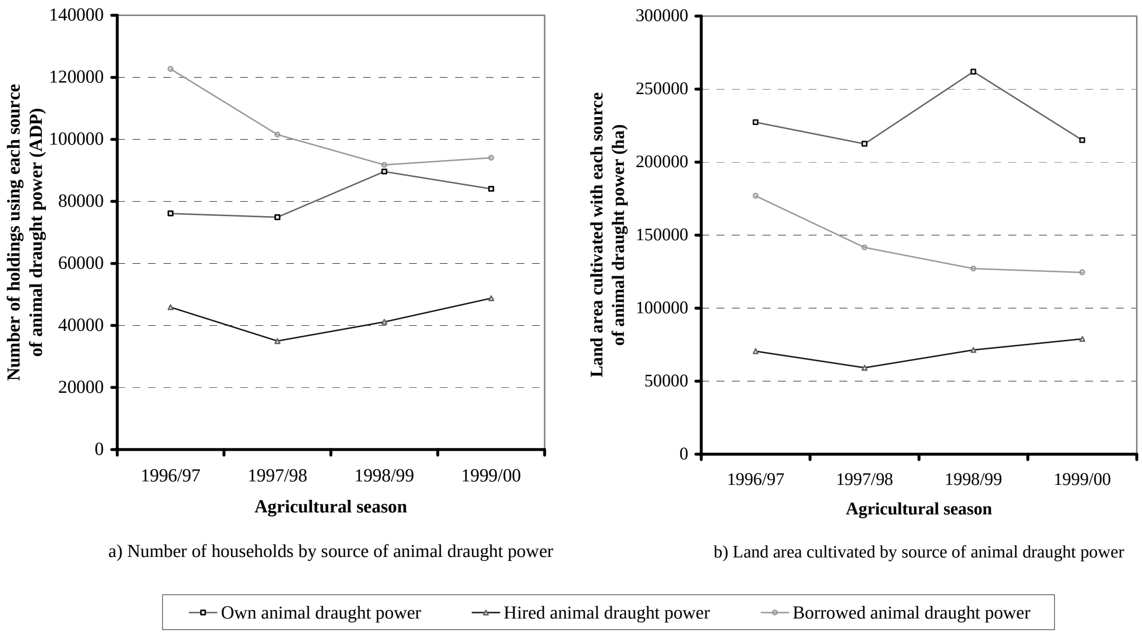
3.2.2. Rental Markets

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.[15] A four-season (1996/97-1999/00) average shows that the majority of 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 has steadily declined while hiring exhibits a striking and steadily upward trend (Figure 6). The upward trend in hiring as a method of accessing ADP shows that there is potential for the market to help foster ADP-dependent practices such as ripping.

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 6a and 6b). That is, although the number of holdings using own draught animals is less than the number of holdings using borrowed draught animals (Figure 6a), the total land area cultivated and planted by ADP owners is greater than that cultivated and planted with borrowed draught animals (Figure 6b). 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.[16] 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.

[14] 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 13.
[15] 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).
[16] 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.

Figure 6. Trends in Sources of Smallholder Draft Power, 1996/7 – 1999/2000



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

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.

3.3. 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-scale holders (about 435,000 households) farm in agro-ecological regions suitable for water-conserving CF technologies.[17] Among them, more than half – about 60% of smallholders and 15% of medium-scale holdings – do not have access to draft power. They must, therefore, farm with hand hoes (Figure 4). Another 25 percent of those living in suitable agro-ecological regions (AER I and

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

IIa) have access to ADP through hiring or borrowing of oxen. About 15% 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 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 4.

4. IMPACT

4.1. Economic Impact

4.1.1. Output Effects

Output differences between conservation 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 9). This result holds for both farmer-estimated output as well as physical crop cut measurements taken during the survey.

Table 9. Mean Yield and Yield Variability across Tillage Systems, 2001/02

Tillage method	Yield descriptive statistic	Cotton (farmer estimate)	Maize: Measured*	Maize: Farmer estimate	Maize: Aggregate**
Planting basins	Mean yield (kg/ha)	1,278	2,934	3,023	3,054
	Standard deviation	717	1,694	1,541	1,711
	Sample size	25	67	92	92
Hand hoe	Mean yield (kg/ha)	986	2,125	4,549	3,062
	Standard deviation	563	-	638	1,326
	Sample size	9	1	2	2
Ripper	Mean yield (kg/ha)	557	2,486	1,373	1,727
	Standard deviation	284	1,097	1,286	1,244
	Sample size	17	17	33	33
Plow	Mean yield (kg/ha)	818	1,468	1,559	1,339
	Standard deviation	372	997	1,164	920
	Sample size	47	43	77	77
All tillage methods	Mean yield (kg/ha)	903	2,375	2,213	2,189
	Standard deviation	541	1,555	1,567	1,592
	Sample size	99	128	205	205

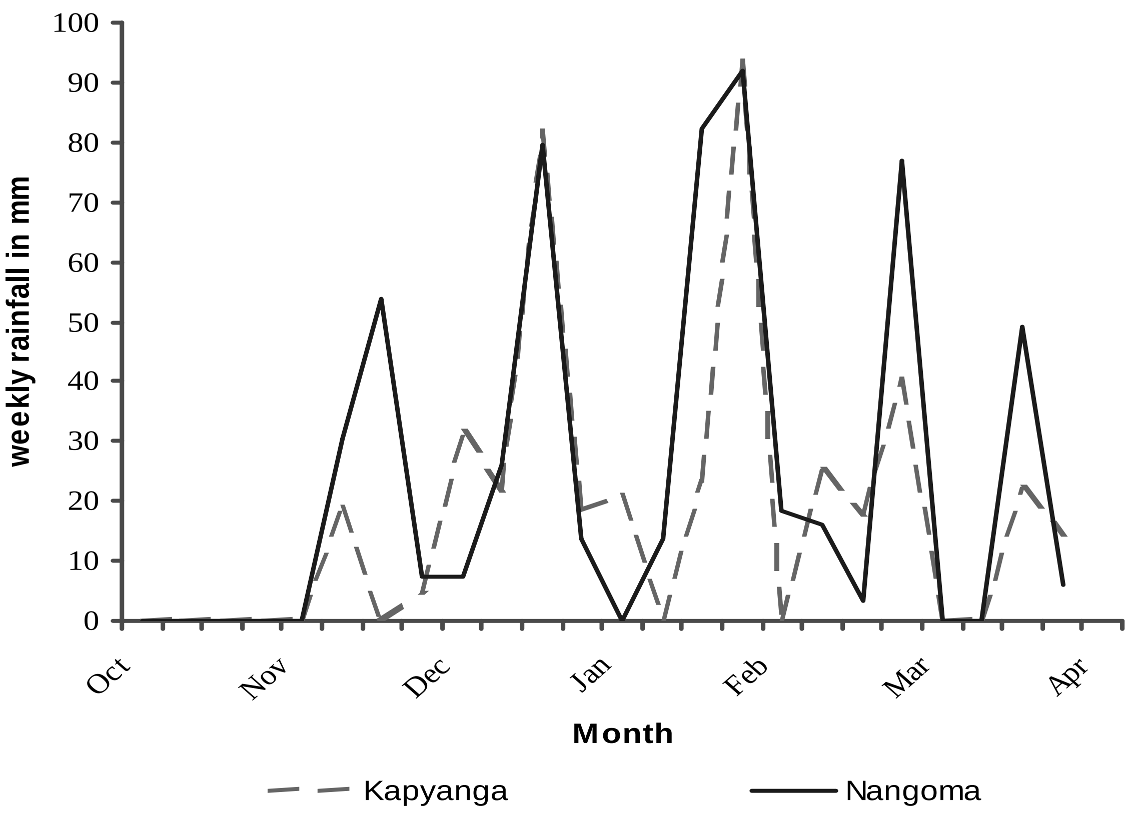
*By taking crop cuts
**Aggregate yield represents our "best" assessment. It takes plot samples as best estimates where available. Where plot samples are not available, we use farmer, interviewer or Dunavant distributor estimates.

Source: IFPRI/FSRP 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, farmer and distributor estimates of cotton yields suggests that cotton farmers using CF basins achieved yield gains of about 60% over farmers using conventional plows.

The very scattered rainfall experienced during the 2001/02 season showcased the important water harvesting benefits of CF basins, as many farmers noted. In particular, the basins helped farmers bridge the several-week gap in rainfall early in the season (Figure 7). 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 technologies 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 7. Scattered Rainfall during the 2001/2 Season



Source: Zambia Meteorological Department

Surprisingly, the CF farmers using ox-drawn rippers performed more poorly than farmers using hand-hoe CF basins (Table 9). 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 9-14, 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 from tillage system.

4.1.2. 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% for every day's delay in planting after the first planting rains (personal communication, Paul Gibson; Howard, 1996). Standard rules of thumb from Zimbabwe suggest that maize yield declines by a similar 1.3% 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).

Table 10. Average Planting Date under Different Tillage Systems

Tillage method	Planting date: Cotton	Planting date: Maize	How much earlier do farmers plant cotton? (days)*
Planting basins	13-Nov-01 (25)	18-Nov-01 (92)	6 (22)
Hand hoe	20-Nov-01 (9)	05-Nov-01 (2)	-
Ripper	23-Nov-01 (19)	27-Nov-01 (33)	3 (18)
Plow	28-Nov-01 (50)	02-Dec-01 (78)	4 (43)
All tillage methods	23-Nov-01	25-Nov-01	4
Standard deviation	15	16	
	(105)	(205)	83

( ) Figures in brackets are sample sizes
* Includes only households who plant both cotton and maize.

Source: IFPRI/FSRP survey.

In Zambia planting dates clearly differ among management systems (Table 10). 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 regression results suggest that this two-week advantage results in a gain of about 4 kg per hectare per day for cotton and about 27 kg per hectare per day for maize (Table 11).

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 completed 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.

Table 11. Sources of Yield Gains in Conservation Farming, Yield Measured as kg/ha

Variables	Cotton	Maize
Constant ('000)	139.517	1,010***
	(0.289)	(3.96)
Planting date, measured as number of days after November 1	-3.725	-27.114***
	(-1.06)	(-3.95)
Quantity of **chemical fertilizer** applied in kilogrammes per hectare	5.512***	-0.561
	(4.90)	(-0.68)
Quantity of **manure** applied in kilogrammes per hectare	0.330	-0.136
	(0.49)	(-0.41)
Seed variety dummy variable, equal to 1 if variety is high yielding[a]		817.311***
		(3.15)
Plot size in hectares	-192.184***	-106.854
	(-3.00)	(-1.55)
Residue dummy variable, equal to 1 if left in the field and not burnt	-81.376	240.986
	(-0.86)	(1.07)
Experience with conservation farming, in years	-51.434	101.926
	(-1.43)	(1.31)
Gender dummy variable, equal to 1 if person responsible for the plot is male	246.359**	-209.487
	(2.49)	(-0.88)
Tillage method effect[b]		
Planting basins, equal to 1 if tillage is basins	409.316**	744.715**
	(2.38)	(2.23)
Conventional hand-hoe, equal to 1 if tillage is hand hoe[c]	81.545	
	(0.53)	
Rippers, equal to 1 if tillage method is ripping	-87.532	-192.088
	(-0.54)	(-0.52)
Fertilizer/manure-tillage interaction terms (dropped due to insignificant joint *F* test)		
Joint *F* statistic	0.098	1.369
		(Significant only at 25%)
F-Statistic	8.620***	10.990***
Adjusted R-squared	0.448	0.334
Sample size	95	200

[a]For cotton, seed used by all the farmers in our sample is of the high-yielding type. Thus, the seed variety dummy variable was dropped from the cotton regression.
[b]Conventional plowing as the base
[c]Very few (3) of the maize plots in our sample were prepared by conventional hand hoe. Thus, the conventional hand hoe dummy variable is dropped from the maize regression

Source: Data from the IFPRI/FSRP Farm Survey, 2002

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% 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 22% more likely to do so as well (Table 7).

Fertilizer, manure and hybrid seeds

Differential input use clearly affects yield. With maize farmers, use of hybrid seeds and fertilizer go hand in hand. However, a preliminary examination of variance inflation factors did not detect any above critical levels of multicollinearity in any of the models reported here. Regression results indicate that hybrid seed strongly boosts maize output. On average, hybrid seed increases maize yield by over 800 kg per hectare and is significant at one percent.. There, however, does not seem to be a significant fertilizer or manure effect in the maize model.

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. A joint F test on fertilizer-tillage and manure-tillage interaction terms also proved that these terms are statistically inconsequential with F statistics of 0.098 and 1.369 in cotton and maize models, respectively (Table 11). The importance of these findings calls for further investigation in coming seasons.

The cotton farmers we interviewed all used Dunavant-supplied seeds, though only about 13% apply fertilizer to their cotton plots. Under these circumstances, it is difficult to effectively measure the effect of fertilizer. The cotton regression model shows that the few that use fertilizer generate output gains of about 5.512 kg for each kg of fertilizer they apply,making fertilizer a marginal economic investment for cotton farmers. Fertilizer trials by Dunavant and CFU will undoubtedly offer a more precise rendering of these fertilizer-induced output gains under differing field conditions.

Plot size, plot history 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.[18] A maize plot with a history of residue retention appears to produce unambiguously higher yields, though statistically insignificant. In cotton, residue retention has a negative but insignificant effect on yield.

Gender appears to make no difference for maize production, though it matters substantially for cotton where male farmers produce almost 250 kg per hectare more than females, all other things equal (Table 11). 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 harvesting, a particularly important contributor to output in years of sporadic rainfall, such as the cropping season in question. To obtain a feel of how farmers assess CF technologies, including planting basins, a set of carefully structured and sequenced questions were presented to each interviewee. Table 12 summarizes the farmers' responses. One of the prominent results is that over half of the CF farmers we interviewed specifically noted the importance of water harvesting in 2001/02 (Table 12). Other key observations by the farmers that, according to them, make CF a superior practice compared to conventional methods include CF's ability to foster early planting (mentioned by 62 percent of the respondents), and CF's ability to raise yields (mentioned by 70 percent of the respondents).

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% (Table C.2). But 25% estimate field sizes larger than they actually are. They waste purchased inputs by over applying them. The remaining 20% 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 close proximity to the seeds they are to assist. They also permit concentration of soil organic

[18] For maize larger plot size decreases yields by 107 kg for each hectare increase in size (Table 11). But this result is statistically significant only at the 13% rather than the normal 5% level.

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. However, , the "basins" dummy variable has an unambiguously positive and statistically robust (at 5 percent) effect on yield (Table 11). Likewise, the crop budgets reported in Tables 14 and 15 value these as additional costs. Thus, empirical evidence seems to prove the long-standing assertion that the accumulation of many advantages results in significant yield gains from the basins themselves. With cotton, the basins contributed an extra over 400 kg per hectare in output during the 2001/02 season.

Table 12. Farmer Assessment of Conservation Farming

	Responses	
Evaluation question	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.

With maize, gains were in excess of 700 kg per hectare (Table 11). Needless to say, the additional weeding that the basin-tilled plots received might also account for a sizable proportion of these yield gains.

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.

4.1.3. What Does it Cost?

Table 13 summarizes input information, based on farmer recall during the IFPRI/FSRP farm survey, and specifically compares input use across different tillage methods. In this section, we discuss in more detail the key observations as regards the differential purchased input use and labor use associated with different tillage systems.

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% of maize plots planted under CF basins received hybrid seeds compared to only 55% of conventionally plowed fields. About 85% of hand hoe CF farmers applied fertilizer compared to only 20% of conventionally plowed fields (Table 13).

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 person-days per hectare 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 person-days per hectare under conventional hand hoe to about 80 under CF basins.

Table 13. Differences in Input Use Across Tillage Systems*, 2001/02 Agricultural Season

	Cotton				Maize			
Input use	Basins	Hoe	Ripper	Plow	Basins	Hoe	Ripper	Plow
Number of sample plots	24	9	16	45	95	3	40	87
Seed								
% using HYV	100%	100%	100%	100%	93%	100%	85%	55%
kg/ha	30	23	20	26	20	18	18	24
Basal fertilizer								
% who use basal	33%	0%	0%	9%	85%	33%	55%	13%
kg/ha among users	80	0	0	76	131	205	163	126
Average use (kg/ha)	27	0	0	7	112	68	90	16
Top-dressing fertilizer								
% who use top dressing	0%	0%	0%	0%	87%	33%	45%	21%
Kg/ha among users	0	0	0	0	142	205	175	139
Average use (kg/ha)	0	0	0	0	124	68	79	29
Manure								
% who use manure	4%	0%	6%	0%	5%	0%	8%	5%
kg/ha among users	1125	0	5600	0	1294	0	758	764
Average use (kg/ha)	47	0	350	0	68	0	57	35
Lime (kg/ha)								
% who use lime	21%	0%	0%	0%	82%	33%	35%	8%
kg/ha among users	77	0	0	0	198	205	142	134
Average use (kg/ha)	16	0	0	0	162	68	50	11
Pesticides (ZK/ha)								
% who use pesticides	83%	78%	81%	91%	0%	0%	0%	0%
ZK/ha among users ('000)	254	239	192	166	0	0	0	0
Average use ('000 ZK/ha)	212	186	156	151	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
Subtotal labor	219	164	124	96	211	176	77	48

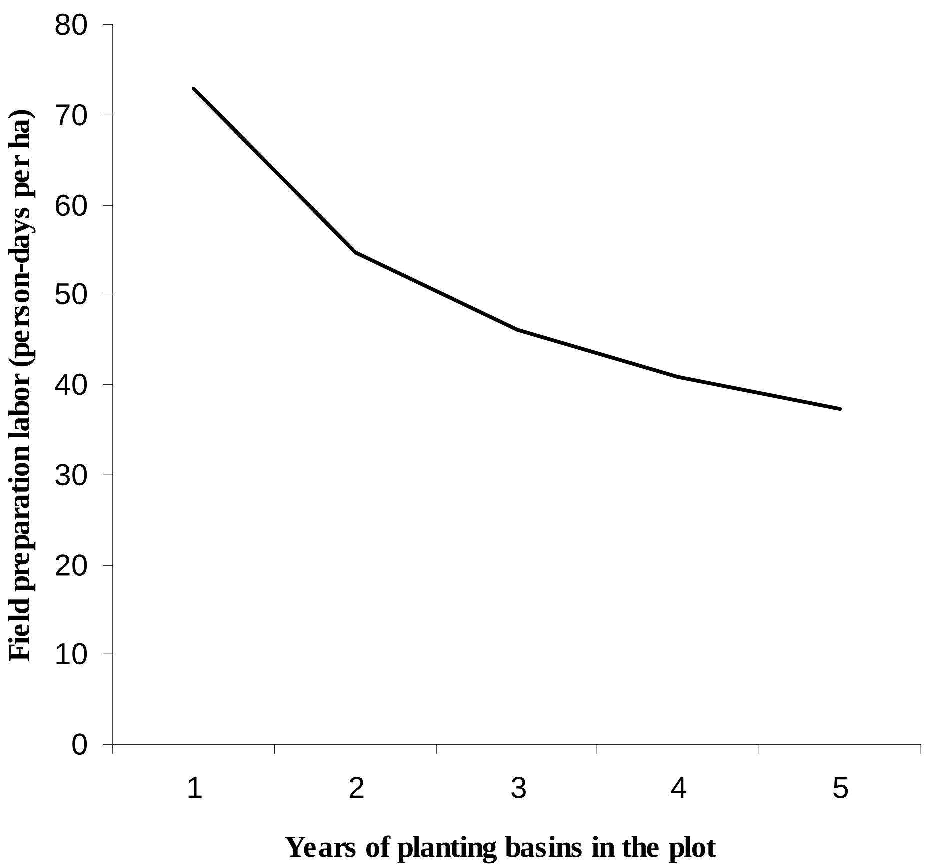
*For lack of information, this table does not include a quantification of the ADP input for ADP-dependent tillage methods. However, such information could definitely be helpful in understanding the costs of ADP.

Source: IFPRI/FSRP survey.

Similarly under ox-plowing, the full inversion of soil during plowing serves as a pre-season weeding tool. Consequently, plow farmers required only 45 person-days of weeding labor after planting per hectare. 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 12). 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 were, "very demanding laborwise *in the early years*."

Figure 8. Declining Labor Requirements over Time for Digging CF Basins



Source: IFPRI/FSRP Farm Survey, 2001/02

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 8). By maintaining permanent planting basins, farmers not only concentrate soil fertility but also reduce land preparation labor in subsequent years.

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 herbicides, 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 14 and 15).

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 14). But because CF redistributes heavy field preparation labor to the dry season (Figure 2), 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.

4.1.4. 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 households: 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-scale 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 more scarce 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 4). Even among users of ADP plows, only about 40% own sufficient draft animals to plow for themselves. The remainder must borrow or rent and are, thus, 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 11). 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 27 x 28 $\approx$ 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 7 x 27 $\approx$ 200 kg increase in output.

Tables 15 and 16 compare the economic returns to conservation farming with that of conventional tillage. Note that for conventional hand hoe tillage, we compute returns only for cotton, since our very small sample of hand hoe maize plots proved insufficient for making reliable projections. For all tillage systems, we assume male farmers and similar plot sizes across tillage systems. Then, using the observed basin yields from our sample farmers (Table 10), we compute yields of other tillage and input systems using the significant basic regression coefficients from Table 12 together with observed differences in these practices. For cotton, chemical fertilizer use and basin dummy differed significantly. For maize, planting date, HYV seed and basin dummies differed significantly. Tables C.5 through C.8 provide full details of these computations. 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. Input and output prices used to develop these budgets were obtained from Dunavant for cotton and from CLUSA for maize.

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% higher than conventional hand hoe cultivation and 150% higher than conventional plowing (Table 14). 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 44% higher returns to peak season labor than do ADP rippers (Table 14). 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%.

Cash costs prove lowest for hand-hoe cultivation, about $50 per hectare, but rise by about 50%, 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%, from 8,000 ($1.75) to 19,000 ($4.20) Kwacha/day. To achieve these gains, farmers' cash requirements rise by a further $19.25 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.

Table 14. Returns[a] to Farming in Households with Inadequate Draft Power[b]

	Hand Hoe Tillage				Animal Draft Power Tillage				
	Basins				Rent Ripper			Rent Plow	
	1st year		5th year			HYV seed			
Budget item	Hand weeding	weed wipe	weed wipe	Hand hoe (HYV)[c]	Local seed[d]	Late prep	Early prep	Local seed	HYV
Maize			(250,000 farmers)				(110,000 farmers)		
Output (kg/ha)[e]	3,000	3,000	3,000		682	1,499	2,255	682	1,499
Planting Date[f]	18 Nov	18 Nov	18 Nov		Dec 16	Dec 16	18 Nov	Dec 16	Dec 16
Labor inputs (person days)									
Peak season	124	58	58		53	53	44	53	53
Harvest	16	16	16		10	10	10	10	10
Dry season	70	70	35		0	0	9	0	0
Total	210	144	109		63	63	63	63	63
Gross margin (K/ha)									
Revenue	1,500,000	1,500,000	1,500,000		341,000	749,500	1,127,500	341,000	749,500
Input costs	413,805	494,655	494,655		67,000	462,325	462,325	67,000	462,325
Gross margin	1,086,195	1,005,345	1,005,345		274,000	287,175	665,175	274,000	287,175
Returns to labor (K/person day)									
Peak season labor	8,795	17,334	17,334		5,175	5,424	15,049	5,175	5,424
Total labor	5,182	6,977	9,215		4,370	4,580	10,609	4,370	4,580
Cash costs (K/ha)	413,805	494,655	494,655		67,000	462,325	462,325	67,000	462,325
Capital costs (K/ha)	20,000	95,600	95,600		20,000	20,000	20,000	20,000	20,000
Cotton			(50,000 farmers)				(70,000 farmers)		
Output (kg/ha)[e]	1,280	1,280	1,280	871		871	871		871
Planting Date[f]	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	731,640		731,640	731,640		731,640
Input costs	214,445	295,295	295,295	214,445		323,445	323,445		323,445
Gross margin	860,755	779,905	779,905	517,195		408,195	408,195		408,195
Returns to labor (K/person day)									
Peak season labor	8,151	18,884	18,884	3,645		5,167	5,662		5,167
Total labor	3,869	4,930	6,330	3,157		3,718	3,498		3,718
Cash costs (K/ha)	214,445	295,295	295,295	214,445		323,445	323,445		323,445
Capital costs (K/ha)	20,000	95,600	95,600	20,000		20,000	20,000		20,000

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Too few maize hand-hoe farmers (3) in the sample. HYV stands for high-yielding variety.
[d] None of the cotton plots in the sample used local seed.
[e] Estimated from the regression coefficients in Table 11.
[f] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

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

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 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. Preliminary indications are that CF basins generate higher returns to scarce resources than does conventional hand hoe cultivation. However, the number of hand hoe farmers in our sample was too low to reliably attach numbers to this assertion (Table 14). 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 14).

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-scale holders. Since owners of oxen plow their land 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 more subtle than under rental conditions. With cotton, returns to peak season labor are only 10% higher under ripping than under plowing.[19] Hand hoe CF, however, continues to dominate ox tillage, generating returns to peak season labor in excess of 24% higher and returns to land almost 70% higher than conventional plowing. Under maize cultivation, early planting with rippers produces a more decisive edge, with 16% higher returns to land and almost 40% higher returns to peak season labor (Table 15).

[19] In Table 15, the row "input costs" is the sum of the cost of purchased inputs and animal traction costs (see Table C.7.

Table 15. Returns[a] to Farming in Households with Adequate Draft Power[b]

	Hand Hoe Tillage				Animal Draft Power Tillage				
	Basins				Ripper			Plow	
	1st year		5th year			HYV seed			
Budget item	Hand weeding	Weed wipe	Weed wipe	Hand hoe (HYV)[c]	Local Seed[d]	Late prep	Early prep	Local seed	HYV
Maize			(250,000 farmers)				(110,000 farmers)		
Output (kg/ha)[e]	3,000	3,000	3,000		1,249	2,066	2,255	1,249	2,066
Planting Date[f]	18 Nov	18 Nov	18 Nov		25 Nov	25 Nov	18 Nov	25 Nov	25 Nov
Labor inputs (person days)									
Peak season	124	58	58		53	53	44	53	53
Harvest	16	16	16		10	10	10	10	10
Dry season	70	70	35		0	0	9	0	0
Total	210	144	109		63	63	63	63	63
Gross margin (K/ha)									
Revenue	1,500,000	1,500,000	1,500,000		624,500	1,033,000	1,127,500	624,500	1,033,000
Input costs	413,805	494,655	494,655		67,000	462,325	462,325	67,000	462,325
Gross margin	1,086,195	1,005,345	1,005,345		557,500	570,675	665,175	557,500	570,675
Returns to labor (K/person day)									
Peak season labor	8,795	17,334	17,334		10,529	10,778	15,049	10,529	10,778
Total labor	5,182	6,977	9,215		8,892	9,102	10,609	8,892	9,102
Cash costs (K/ha)	413,805	494,655	494,655		67,000	462,325	462,325	67,000	462,325
Capital costs (K/ha)	20,000	95,600	95,600		3,270,000	3,270,000	3,270,000	3,270,000	3,270,000
Cotton			(50,000 farmers)				(70,000 farmers)		
Output (kg/ha)[e]	1,280	1,280	1,280	871		871	871		871
Planting Date[f]	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	731,640		731,640	731,640		731,640
Input costs	214,445	295,295	295,295	214,445		323,445	323,445		323,445
Gross margin	860,755	779,905	779,905	517,195		517,195	517,195		517,195
Returns to labor (K/person day)									
Peak season labor	8,151	18,884	18,884	3,645		6,547	7,173		6,547
Total labor	3,869	4,930	6,330	3,157		4,710	4,432		4,710
Cash costs (K/ha)	214,445	295,295	295,295	214,445		323,445	323,445		323,445
Capital costs (K/ha)	20,000	95,600	95,600	20,000		3,270,000	3,270,000		3,270,000

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Too few maize hand-hoe farmers (3) in the sample. HYV stands for high-yielding variety.
[d] None of the cotton plots in the sample used local seed.
[e] Estimated from the regression coefficients in Table 11.
[f] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

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

4.2. 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 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.

4.3. Equity Impact

Over 75% of Zambia's 870,000 farmers operate holdings of less than 5 hectares (Figure 4). Available evidence suggests that the overwhelming majority of hand hoe CF farmers operate small farms. NGO-assisted smallholder farmers all lie in this range, and PHS data indicate that 95% of farmers digging basins are small-scale farmers (Table 3). The remaining 5% of hand hoe CF farmers operate on medium and even commercial farms. Field evidence assembled by CLUSA field staff suggests 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 have even experimented with CF basins because of the ease of managing farm labor on piecework.

Rippers, on the other hand, are more commonly used by medium-scale farmers who cultivate 5 to 20 hectares of land, own cattle and 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% per day for maize, the normal 4 week delay in plow rental implies a 30-60% yield reduction for small farmer renters that plow with rented oxen. So, the ripper opens up potentially important ADP prospects even for non-cattle-owning smallholders (Figure 4). In Agroecological Regions I and IIa, where water-conserving CF technology proves most appropriate, 60% of smallholders (246,000 households) currently farm with hand hoes while a further 25% (107,000 farms) till with borrowed or rented oxen and 15% (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 to 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. Thus, CF represents considerable potential to improve the capacity to deal with food insecurity and to foster the aggregate benefits from adequate food and lower prices to the people who are users and buyers of maize, inelasticity of maize demand notwithstanding.

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% 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.

Crop yields are also highly sensitive to planting delays. This result has been found to be more robust in maize, both statistically and in absolute terms. The practitioners and extension agents need to observe this and to encourage planting not too far after November 1. Our results also indicate that chemical fertilizer presents great potential to improve cotton yields but is virtually not of much consequence in maize. Our small sample presents no compelling evidence of the benefits of manure. However, these results need further investigation on a larger sample and with on-farm experimentation if they are to be of use in the development of informed extension messages.

Because of the need for close management and the laborious nature of cotton production, there is need to help the farmers to watch the size of their cotton plots. Evidence from this study suggests that there is an almost 200 kg loss in yield for every additional hectare. This result stands out and remains statistically robust even at one percent level of significance. Perhaps for the same reasons, male farmers are able to generate yield gains in excess of 250 kg, compared to their female counterparts. There is need to understand why this is so and to come up with an extension package based on this knowledge.

Our limited field research also 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 answer 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. A comprehensive study of adoption/disadoption would also help indicate how the constraints link to farmer knowledge and farmer assets and the need for research and extension that would focus on those aspects where there are alternatives or solutions.

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. Evidence from the census of Dunavant distributors seems to suggest and reaffirm the assertion that lead farmers can be an effective vehicle for diffusing CF technologies to smallholder farmers. For planting basins, both the lead farmer's use of planting basins and his/her use of rippers have a marked and statistically robust effect on the proportion of farmers using basins. However, only the distributor's use of rippers has a significant effect on the farmers' adoption of rippers.

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.

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ANNEX B. YIELD AND CF ADOPTION REGRESSION ANALYSES

Annex B.1 Yield Regression Analysis

The model used to explain the variation in and to determine the impact of conservation farming practices on crop yield was specified as (see also Table 11):

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

where *yield* is crop yield in kg per hectare, *plantdate* is the number of days after November 1 as a proxy for planting date, *fert* is the quantity of chemical fertilizer applied in kilograms per hectare, *manure* is the quantity of manure applied in kilograms per hectare, *HYV* is a high-yielding seed dummy variable equal to one if the seed used is a high-yielding variety and zero otherwise, *plotsize* is the size of the plot in hectares, *residue* is a residue retention dummy variable equal to one if the farmer retained and did not burn residues in that plot, *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. Plot history dummy variables (legume rotation, virgin land, etc) were included in preliminary runs of Equation (1) but were later dropped because they were grossly insignificant.

Of the four tillage methods encountered in the survey – planting basins, ripping, conventional hand-hoe cultivation and conventional plowing – conventional (ox-based) plowing proved most prevalent. Using this 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 manure and fertilizer, we initially included interaction terms to capture the combined effect of fertilizer/manure and CF tillage methods. However, a joint F test on the interaction terms between soil fertility enhancement (quantity of fertilizer and quantity of manure applied) and tillage method proved that these terms were statistically inconsequential in our sample, with joint F statistics of 0.098 and 1.369 in the maize and cotton models, respectively. The last term in the estimating equation is the error term assumed to be independently and identically distributed with mean zero and constant variance.[20]

In Equation (1), yield is expected to vary inversely with *plantdate* (planting delay leads to yield loss), *plotsize* (better management can be achieved better with smaller plots), and *gender* (female farmers more attentive to management details), and to vary directly with respect to all other regressors. Equation (1) was estimated with ordinary least squares (OLS) after establishing that there were no serious violations of the classical linear regression (CLR) model assumptions.

[20] Preliminary specification analysis showed that there is not enough evidence to dismiss this assumption.

Annex B.2 Factors Affecting Adoption Of Planting Basins And Rippers

This Annex presents the logic and modeling details used to decipher information concerning the factors that affect adoption of the two common conservation tillage practices in Zambia, among Dunavant Cotton farmers. Dunavant Cotton gets its cotton every season through contracts with a network of 75,000 smallholder farmers located mainly in regions that are suitable for conservation tillage (planting basins and ripping). To facilitate implementation and management of these cotton production contracts, the farmers are divided into 1,400 groups. Each group is headed and directly administered by a lead farmer, who is identified and collectively chosen by the community. Dunavant trains and provides inputs to these lead farmers at the beginning of each season and the lead farmers, in turn, pass on the knowledge and inputs to the farmers under them. Dunavant calls such lead farmers Distributors.

Being lead farmers and primary implementers of the Dunavant program at the lowest level, these Distributors are expected to exert some influence on their farmers, rendering them potentially effective technology diffusion agents. This may include not only mandatory practices received from Dunavant but also any other knowledge that they may have gained and are implementing from other sources. We choose to call farmer adoption of non-mandatory practices as ‘spontaneous adoption’. As far as the Dunavant program is concerned, conservation tillage practices, such as basins and rippers, fall in this category.

In the analysis presented here, we sought to determine the impact of the Distributor’s use of conservation tillage on the proportion of his/her group members adopting the same methods. For each of the conservation tillage methods considered – basins and rippers – this proportion is used to proxy adoption (in a rather loose sense) and as a dependent variable.

Preliminary diagnosis of the dependent variable showed that 61 percent and 75 percent of the entries were zeros for planting basins and rippers, respectively. Such huge probability mass at zero renders ordinary least squares (OLS) inappropriate. To circumvent this problem, we use a censored regression framework, also known as a Tobit model (after Tobin, 1958). Specifically, the two Tobit regression models (one for the basins and one for the ripper technology) were specified as:

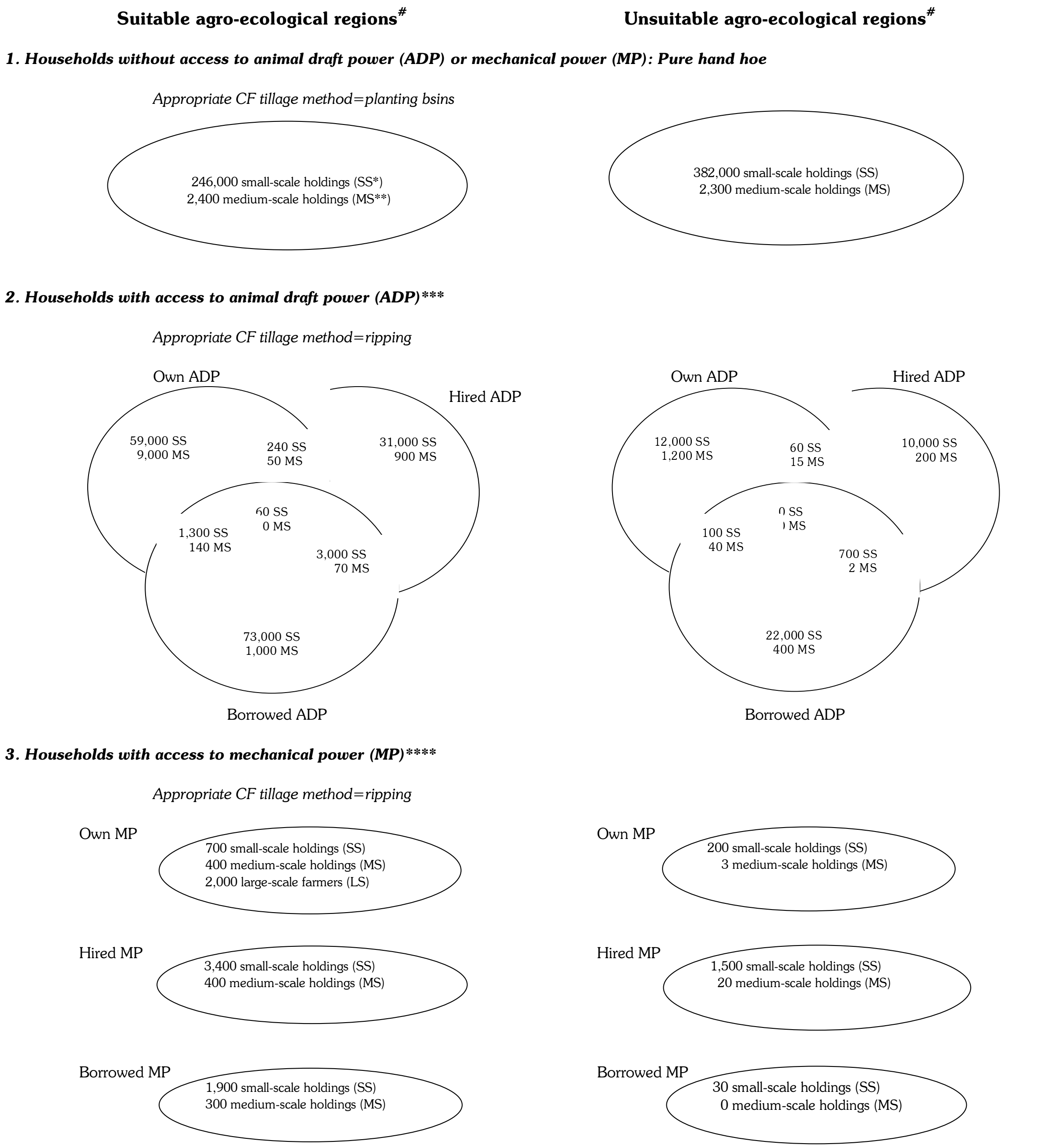
$$y_i = \begin{cases} \alpha_0 + \alpha_1 x_i + \alpha_2 z_i + \boldsymbol{\delta}_i' \mathbf{D}_i + \varepsilon_i, & \text{if } \varepsilon_i < \alpha_0 + \alpha_1 x_i + \alpha_2 z_i + \boldsymbol{\delta}_i' \mathbf{D}_i \\ 0, & \text{Otherwise} \end{cases} \qquad (2)$$

where y_i is the observed proportion of farmers using basins (or rippers as the case may be) under distributor i, $i = 1, 2, \ldots n$, x_i is basins dummy variables equal to one if the distributor uses planting basins and zero otherwise, z_i is the ripper dummy variable equal to one if the distributor uses rippers and zero otherwise. **D** is a vector of district dummy variables with dimension m-1, where the m^{th} district dummy is dropped and used as the base. Parameters α_0, α_1 and α_2 are the intercept and coefficients for x and z, respectively, and δ is an m-1 dimensional vector of the coefficients for the district dummies. The symbol ε represents the random error term, assumed to be normally, independently and identically distributed.

The key hypothesis is that y would be higher if the distributor used the CF tillage method than otherwise, considering that the distributor is a lead farmer through which (Dunavant's) extension messages are passed on to the farmer group members. Thus, α_1 and α_2 are expected to have positive signs. The district dummies are a proxy for differences in the effectiveness of Dunavant's district extension staff and spatial differences in availability and accessibility of CF technology and support services. The corner solution problem in Equation (2) was estimated with the **tobit** procedure in Stata (results in Table 7).

ANNEX C. SUPPLEMENTARY 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		
		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%
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-2. Measurement Errors in Farmer Recall of Plot Sizes

Percentile of plots measured	Farmer Estimate/Physical Measurement	
	plot size	yield
5%	0.67	0.22
10%	0.78	0.36
15%	0.85	0.47
20%	0.93	0.51
25%	0.94	0.60
30%	0.96	0.66
35%	0.96	0.80
40%	0.99	0.91
45%	1.00	1.03
50%	1.00	1.11
55%	1.00	1.23
60%	1.02	1.31
65%	1.04	1.49
70%	1.11	1.63
75%	1.19	1.75
80%	1.25	1.91
85%	1.47	2.11
90%	2.00	2.42
95%	2.27	2.88
Percentage within 10%	55%	15%
Averages		
farmer estimate	0.93	2,468
physical measurements	0.83	2,375
farmer/physical	1.12	1.04
Average farmer/physical measurement ratio	1.18	1.30
Number of plots measured	87.00	128.00

Brackets in the table mark the plot size values from 20% to 70% and the yield values from 40% to 50% as being within +- 10%.

Source: IFPRI/FSRP survey.

Table C-3. Cotton Budgets for Survey Farmers[a]

	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[b]	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)	20,000	20,000	3,000,000	3,000,000	
Sample size	24	9	16	45	

[a] Exchange rate at the time of the survey was K4,200/USD.
[b] Imputed at rental cost

Source: IFPRI/FSRP Farm Survey, 2001/02

Table C-4. Maize Budgets for Survey Farmers[a]

	Input usage under alternative tillate systems (per hectare)						
				Plow			
	Basins	Hand hoe	Ripper	All	Local seed	HYV seed	Price
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[b]	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)	20,000	20,000	3,270,000	3,270,000	3,270,000	3,270,000	
Sample size	95	3	40	87	33	54	

[a] Exchange rate at the time of the survey was K4,200/USD.
[b] Imputed at rental cost

Source: IFPRI/FSRP Farm Survey, 2001/02

Table C-5. Returns[a] for Smallholder Cotton Farmers Without Draft Power[b] Living in Regions Suitable for Water-Conserving Conservation Farming[c]

	Hand Hoe Tillage (50,000 farmers)				Animal Draft Power (70,000 farmers)			
	Basins				Rent Ripper			
	1st year		5th year					
Budget item	hand weeding	Weed wipe	Weed wipe	Hand hoe	Late prep	Early prep	Rent plow	Price (Kwacha)
Output (kg/ha)[d]	1,280	1,280	1,280	871	871	871	871	840
Planting Date[e]	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	
Gross margin (K/ha)								
Revenue	1,075,200	1,075,200	1,075,200	731,640	731,640	731,640	731,640	
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	517,195	408,195	408,195	408,195	
Returns to labor (K/person day)								
Peak season labor (Nov-Feb)	8,151	18,884	18,884	3,645	5,167	5,662	5,167	
Harvest labor (March-June)	18,353	16,629	16,629	23,616	13,253	13,253	13,253	
Dry season labor (July-Oct)	12,297	11,142	22,283			29,579		
Total labor	3,869	4,930	6,330	3,157	3,718	3,498	3,718	
Cash costs (K/ha)	214,445	295,295	295,295	214,445	323,445	323,445	323,445	
Capital costs (K/ha)	20,000	95,600	95,600	20,000	20,000	20,000	20,000	

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Agroecological regions I and IIa.
[d] Estimated from the regression coefficients in Table 11 using the observed 1,280 kg/ha in CF basins as a base, then deducting yield for late planting, no hyv and no basins.
[e] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey, 2001/02.

Table C-6. Returns[a] for Smallholder Maize Farmers Without Draft Power[b] Living in Regions Suitable for Water-Conserving Conservation Farming[c]

	Hand Hoe Tillage (250,000 farmers)					Animal Draft Power Tillage (110,000 farmers)					
	Basins			Hand Hoe		Rent Ripper			Rent Plow		
	1st year		5th year				hyv seed				
Item	hand weeding	Weed wipe	weed wipe	Local seed	HYV	Local seed	Late prep	Early prep	Local seed	HYV	Price (Kwacha)
Output (kg/ha)[d]	3,000	3,000	3,000	1,249	2,066	682	1,499	2,255	682	1,499	500
Planting Date[e]	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	624,500	1,033,000	341,000	749,500	1,127,500	341,000	749,500	
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	624,500	637,675	274,000	287,175	665,175	274,000	287,175	
Returns to labor (K/person day)											
Peak season labor (Nov-Feb)	8,795	17,334	17,334	5,044	4,494	5,175	5,424	15,049	5,175	5,424	
Harvest labor (March-June)	67,466	62,444	62,444	38,789	39,607	28,103	29,454	68,223	28,103	29,454	
Dry season labor (July-Oct)	15,517	14,362	28,724					76,020			
Total labor	5,182	6,977	9,215	4,464	4,036	4,370	4,580	10,609	4,370	4,580	
Cash costs (K/ha)	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325	
Capital costs (K/ha)	20,000	95,600	95,600	20,000	20,000	20,000	20,000	20,000	20,000	20,000	

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Agroecological regions I and IIa.
[d] Estimated from the regression coefficients in Table 11 using the observed 3,000 kg/ha in CF basins as a base, then deducting yield for late planting, no hyv and no basins.
[e] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey, 2001/02.

Table C-7. Returns[a] for Smallholder Cotton Farmers With Adequate Draft Power[b] Living in Regions Suitable for Water-Conserving Conservation Farming[c]

	Hand Hoe Tillage (few farmers)				Animal Draft Power (70,000 farmers)			
	Basins				Ripper			
	1st year		5th year					
Item	Hand weeding	Weed wipe	weed wipe	Hand hoe	Late prep	Early prep	Plow	Price (Kwacha)
Output (kg/ha)[d]	1,280	1,280	1,280	871	871	871	871	840
Planting Date[e]	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	731,640	731,640	731,640	731,640	
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	517,195	517,195	517,195	517,195	
Returns to labor (K/person day)								
Peak season labor (Nov-Feb)	8,151	18,884	18,884	3,645	6,547	7,173	6,547	
Harvest labor (March-June)	18,353	16,629	16,629	23,616	16,792	16,792	16,792	
Dry season labor (July-Oct)	12,297	11,142	22,283			37,478		
Total labor	3,869	4,930	6,330	3,157	4,710	4,432	4,710	
Cash costs (K/ha)	214,445	295,295	295,295	214,445	323,445	323,445	323,445	
Capital costs (K/ha)	20,000	95,600	95,600	20,000	3,270,000	3,270,000	3,270,000	

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Agroecological regions I and IIa.
[d] Estimated from the regression coefficients in Table 11 using the observed 1,280 kg/ha in CF basins as a base, then deducting yield for late planting, no hyv and no basins.
[e] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey, 2001/02.

Table C-8. Returns[a] for Smallholder Maize Farmers With Adequate Draft Power[b] Living in Regions Suitable for Water-Conserving Conservation Farming[c]

Item	Hand Hoe Tillage (few farmers)					Animal Draft Power Tillage (70,000 farmers)					Price (Kwacha)
	Basins			Hand Hoe		Ripper			Plow		
	1st year						hyv seed				
	Hand weeding	Weed wipe	5th year weedwipe	Local seed	HYV	Local seed	Late prep	Early prep	Local seed	HYV	
Output (kg/ha)[d]	3,000	3,000	3,000	1,249	2,066	1,249	2,066	2,255	1,249	2,066	500
Planting Date[e]	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	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)						1	1	1	1	1	67,000
land preparation						0	0	0	0	0	42,000
weeding											
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	624,500	1,033,000	624,500	1,033,000	1,127,500	624,500	1,033,000	
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	624,500	637,675	557,500	570,675	665,175	557,500	570,675	
Returns to labor (K/person day)											
peak season labor (Nov-Feb)	8,795	17,334	17,334	5,044	4,494	10,529	10,778	15,049	10,529	10,778	
harvest labor (March-June)	67,466	62,444	62,444	38,789	39,607	57,179	58,531	68,223	57,179	58,531	
dry season labor (July-Oct)	15,517	14,362	28,724					76,020			
total labor	5,182	6,977	9,215	4,464	4,036	8,892	9,102	10,609	8,892	9,102	
Cash costs (K/ha)	413,805	494,655	494,655	0	395,325	67,000	462,325	462,325	67,000	462,325	
Capital costs (K/ha)	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	

[a] Exchange rate at the time of the survey was ZK4200/USD.
[b] Inadequate draft power refers to all households with two or fewer cattle.
[c] Agroecological regions I and IIa.
[d] Estimated from the regression coefficients in Table 11 using the observed 3,000 kg/ha in CF basins as a base, then deducting yield for late planting, no hyv and no basins.
[e] Hand hoe farmers plant 1 week later and plow rentals 4 weeks later than basin farmers.

Source: IFPRI/FSRP survey, 2001/02.