Hoe conservation farming of maize in Zambia

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Abstract – Hoe Conservation Farming practice in Zambia focuses on the retention of residues, restricting tillage of the land to the area where the seed is to be sown, completion of land preparation in the dry season, establishment of precise and permanent planting basins, precision use of inputs, early and continuous weeding, and rotations. The method is compared with conventional farm practice with the same inputs. The result from on-farm trials in agro-ecological regions IIa and III in Zambia among smallholder farmers with the same inputs shows an average increase in maize yield of 77 per cent after controlling for planting dates, rotations, residues and weeding effort, socio-economic factors and location, management and environment, at a lower risk. Lime and inoculum increased yields by 32 per cent. Planting dates, rotations, residues and weeding effort contributed 29 per cent, 11 per cent, 9 per cent and 17 per cent respectively to the yield increase attributed to conservation farming method. Socio-economic factors explained 17 per cent of yield, age and number of hoes contributing around nine per cent each and education 13 per cent. Household size and bicycles had 11 per cent and four per cent negative impacts respectively.

Key Words: Conservation farming, Hoe cultivation, Oxen cultivation, agro-ecological Region IIa and III, smallholder, maize, sunnhemp, planting date, lime, inoculum, yield risk, age, gender, education, socio-economic factors, sustainable food production, Zambia.

Introduction

Hoe conservation farming (CF) method in Zambia is an aggregate of best practice extended from Brian Oldrieve's work in Zimbabwe (Oldreive, 1993). The concepts are not new: they are the retention of residues, completion of land preparation in the dry season, establishment of precise and permanent planting basins, precision use of inputs, early and continuous weeding, and rotations (CFU, 2003).

Conventional farming method is any farming method practiced by smallholders, which often includes several seasons of maize or maize-cotton rotation followed by a period of fallow.

Studies have found conservation farming method increases yield by 50 per cent or more and doubles that of conventional oxen cultivation (Haggblade & Tembo, 2003; Langmead, 2002a). Timeliness of planting is found to be important, increasing yields by around 1.3 per cent in Zimbabwe and Zambia (Elwell, 1995; *ibid*), but it is not confined to conservation farming method. Conventional farmers tend to plant late because the hardness of the ground makes land preparation difficult, particularly for oxen cultivation. Gender, however, has not been an issue (Haggblade & Tembo, *ibid*).

This study focuses on regions IIa and III agro-ecological zones: the former receives 800 to 1,000mm of rain and has temperatures of 17 to 18°C during the growing season, which is 100 to 140 days; the latter has more than 1,000mm with a growing season of 120 to 150 days, and temperatures of 14 to 16°C.

A regression model examines relationships between yields from hoe, oxen and CF cultivation, and the yield effects of socio-economic factors after controlling for location and planting dates. The main intervention is basins versus conventional hoe and oxen culture, with lime, lime and inoculum, and inoculum; differences are measured by yield changes. The same interventions with maize intercropped with red sunnhemp *in situ* are expected to achieve yield equivalence with conventional sole-cropped maize. The standard conservation package is basins with lime and fertiliser.

If conservation farming culture increases yield, then its associated risk may also rise. If the risk-yield profile rises, there is little incentive for farmers to adopt the technology; but if the risk remains same or declines and yield rises, there are real benefits.

The findings show that conservation farming makes an appreciable difference to yields, and the yield risk is lower than that of conventional hoe culture. Timeliness of planting, rotations, crop residues and weeding effort contribute to yield, together with lime and inoculum. Farmers benefit from their age, education and the number of hoes, but gender was not important. Bicycles and the number of occupants in the household have negative influences. Yields from oxen farmers were no different to those of conventional hoe farmers after controlling for planting date. The results are consistent with findings in other countries, but the study is particularly important because it sheds light on the performance of smallholder conservation farming effort in Zambia, in terms of sources of yield gain, risks and benefits.

Data

Introduction

The data are recorded at the time of activity and collected quarterly. Farmers were closely supervised, as were the supervisors. All conservation farmers are hoe farmers and conventional farmers are either oxen cultivators or hoe cultivators.

Trials

The data are collected from five trials in Copperbelt, Northern, Western, Southern and Central regions during the 2002/3 agricultural season, which was characterised by early drought periods.

The first trial was a three-year rotation of maize, a legume and cotton in Western, Southern and Central regions in the region IIa agro-ecological zone. Associated with these were control plots farmed by conventional farmers. Conservation and conventional farmers received sufficient lime, basal dressing and top dressing to cultivate specified plots[1], and their farming activities recorded; but the latter did not receive extension advice. There were weaknesses: there was no follow up that confirmed the inputs were applied on the control plots; and those receiving free inputs were commonly observed to work harder on their crop than normal, apparently hoping for more free inputs next season (Kwashirai et al, 2003). The trial ages range from new to seven years.

The reasons for using other farmers for the control plots were that it had been observed on the second trial in the previous season that 1) if the same farmers are used, all activities are performed at the same time, so that timeliness of planting, application of inputs and continuous weeding spread to the control plots; 2) including a conventional plot within a trial constrains the method of cultivation to hoe culture, as opposed to oxen cultivation; 3) farms are small and a trial can compromise other activities on the farm in the face of scarce labour, which causes performance distortions.

The second trial was in the Northern and Copperbelt regions in the region III agro-ecological zone. The farming systems were (conservation farming) basins, conventional practice and (conservation farming) permanent ridges, and the cropping systems were sole-cropped maize rotated with groundnuts and maize intercropped *in situ* with red sunnhemp, which therefore has half the normal maize plant population. All treatments received fertiliser and lime except the conventional treatments that received fertiliser only. The control plot was part of the trial so that the agricultural activities happen at the same time; the yields are expected to be higher than those in the first trial. Some of the trials in Northern are in their second year.

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[1] Conservation farmers received enough for 0.177ha, 40 by 70 basins, and conventional farmers received enough for 0.127ha, equivalent to 40 by 50 basins.

Trial three was sole-cropped maize and maize intercropped *in situ* with red sunnhemp and trial four was sole-cropped maize and inoculum-treated sole-cropped maize. Both have two levels, lime and no lime, and are in Western, Southern and Central regions of the region IIa agro-ecological zone. The data are from all four treatments, which are basins with fertiliser. It is believed that maize intercropped *in situ* with sunnhemp can compete with serially sole-cropped maize, and inoculated maize is expected to perform better. Some of the trials are in the second season.

The last trial was sole-cropped maize rotated with sole-cropped soyabean at two levels, lime and no lime, in Western, Southern and Central regions of the region IIa agro-ecological zone. The data are from the maize treatments, with and without lime, and the data are from the first season.

Farming characteristics

The data are from table one. The farming systems are CF basins and permanent ridges, and conventional hoe and oxen cultures. The cropping systems are sole-cropped maize rotated on a legume, serial cropping of maize, and maize intercropped with red sunnhemp *in situ*. Lime and inoculum are factors. Sixty-four per cent of the treatments are basins, 13 per cent are permanent ridges, 31 per cent grow maize/sunnhemp, 67 per cent use lime, six per cent use inoculum and five per cent are oxen cultivators.

There are 967 observations: 186 from the Copperbelt region, 203 from Northern region, 222 from Western region, 220 from Southern region and 136 from Central region, see table two. Of these, 753 are CF cultivated, and 214 are conventionally cultivated: of the latter, 164 treatments are by hand hoes and 50 by oxen.

From the five trials there a seven levels of conservation farming for each region, see table two. The average yield of the 967 treatments is 3,683kg ha^{-1} with a standard deviation of 2,024kg. The average yield of conventional treatments was 2,721kg ha^{-1}, where conventional hoe treatments harvested 2,824kg ha^{-1} and conventional oxen treatments 2,381kg ha^{-1}. These yields are higher than normally expected in Zambia, because control sample farmers received the same inputs as CF cultivators. In comparison, the 753 CF treatments yielded 3,956kg ha^{-1}.

On average, conservation treatments were planted on 25 November, four days earlier than hoe treatments on 30 November and 15 days before plots by conventional oxen farmers on 15 December.

There was no oxen cultivation data from Copperbelt, Northern and Western regions: 44 treatments by oxen cultivators in Southern yielded an average of 2,240kg ha^{-1} and the six in Central 3,416kg ha^{-1}.

Basins have an average yield is 4,778kg ha^{-1}. This is 69 per cent more than conventional hoe cultivation, 101 per cent more than oxen cultivation, and nine per cent higher basins without lime. Permanent ridges are a development for the region III agro-ecological zone and are in use in Copperbelt and Northern regions. The average yield from permanent ridges with lime and fertiliser is 4,241kg ha^{-1}. The average yield for maize intercropped *in situ* with sunnhemp in basins is 2,370 kg ha^{-1}, which compares with 2,220kg ha^{-1} in permanent ridges in Copperbelt and Northern regions. When basins are used with fertiliser but without lime, the average yield is 4,389kg ha^{-1}. Inoculum is used in the region IIa agro-ecological zone: without lime the average yield is 5,239kg ha^{-1} and with lime it is 5,441kg ha^{-1}, which is 93 per cent more than the yield with conventional hoe cultivation.

If CF culture is an improved method, the yield risk should be the same as conventional hoe culture or lower. The coefficient of variation (CV) for conventional hoe is 53 per cent, which compares with 42 per cent for basins without lime, 44 per cent with lime and 39 per with lime and inoculum: the dispersion appears to decline with the use of basins and suggests the variance is lower. At the regional level, these figures are likely to represent not only yield risk but also management competence. For basins with lime, Central region has the highest CV, 55 per cent, followed by the Copperbelt region with 50 per cent. The lowest was 30 per cent in Northern region.

The planting date is the number of days after the first farmers planted. The earliest planting date was 31 October 2002, see table three. On average farmers planted 27 days later, on 27 November, with a standard deviation of 15 days. The last farmer planted on 16 January 2003, 77 days after the first farmer. Because the rains are so varied, planting dates differ substantially across Zambia.

Conservation farming characteristics

The mean age of the 753 CF treatments is 0.68 years with a median of zero, suggesting many of the trials are new. The oldest trial is in its seventh year. Since the trial age reflects rotation effects, the first year is zero.

Sixty-seven per cent of 753 treatments had residues of some level. In Western region, farmers commonly retained their residues, 84 per cent, as they did in Northern, 73%; but residues in Southern were poorest, where only 45 per cent of farmers had residues.

The length of time spent weeding maize in conservation treatments was 74.5 days per hectare with a standard deviation of 33.5 days; Central region took the longest, an average of 89 days, followed by the Copperbelt region with 82 days. Northern did least weeding, 62 days.

The average cultivated area associated with the 753 treatments was 4.8ha with a standard deviation of 9.6ha. The median was, however, 3ha, which may be a better view. The Copperbelt has the larger farms, 9.2ha, and Northern has the smallest, 3.1ha.

An average of 29.5 per cent of the CF maize crop was replanted with a standard deviation of 38 per cent. The median was zero, implying most farmers did not replant.

Farmer characteristics

The average age of the 368 participating farmers was 44.6 years with a standard deviation of 13.5 years; see Table three. The youngest participating household head was 17 years old and the oldest was 85. The 34 hoe cultivators were 43.6 years old on average and 284 CF cultivators were 46.3 years old, but the 50 oxen cultivators were much younger, only 35.8 years old; see table one.

In the sample, 74 per cent of the participants are male, which is not significantly different from the reported distribution of male-headed households of 76.18 per cent[2] (Central Statistical Office, 1999/2000). The distribution is not even across the regions and cultivator types however: 86 per cent of the hoe cultivators and 71 per cent of oxen cultivators were male, and 74 per cent of CF cultivators were.

The average educational grade level is 7.2 with a standard deviation of 3.6 grades. The education system is from grade level 1 to 12. College is assumed to be one more year, equivalent to grade level 13 and university is assumed to be grade level 16. In the sample, 47 farmers, 12.8 per cent, did not go to school, 11 went to college (three per cent) and 3 went to university (0.8 per cent). Hoe cultivators had an average grade level of 8.6, which compares with 7.4 for oxen cultivators and seven for CF cultivators.

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[2] TEST OF MU = 0.7618 VS MU N.E. 0.7618: t =–0.87; p = 0.39

The average household size is 7.8 people with a standard deviation of 3.9. CF cultivators have the largest households with 8.2 people and conventional hoe cultivators are the smallest with 6.4.

Cattle are an accepted indicator of wealth in Zambia. The average number of cattle per household is 2.8 with a standard deviation of 9.9 animals and a maximum of 121. Hoe cultivators have most cattle, an average of 4.7 animals; oxen cultivators have 2.2 and hoe cultivators have 2.7 animals.

Sending children to school incurs a real cost so the number of school children is an indicator of realisable wealth. On average there are 3.4 children at school in each household with a standard deviation of 2.5. Hoe cultivators have an average of 3.3 children in school; oxen cultivators have fewer, only 2.2, whilst CF cultivators have 3.7.

Buildings are essential assets. The largest compound has 15 buildings; the average is 3.79 with standard deviation of 2.3. Hoe cultivators have an average of 3.7 huts in their compounds, oxen cultivators 3.14 and CF cultivators 3.9.

A bicycle probably tops the list of desired durables. The average number of bicycles is 0.95 with a standard deviation of 0.80. Since the median is one, most farmers have bicycles. The most bicycles in a compound are five. Hoe cultivators have an average of 1.09 bicycles, whilst oxen cultivators and CF cultivators have 0.80 and 0.95 bicycles respectively.

Hoes are essential equipment. There are seven hoes in each household with a standard deviation of 4.6. Hoe cultivators tend to have around 7.5 hoes, oxen cultivators around 4.7 hoes and CF cultivators around 7.4 hoes.

'Birds' are any domestic fowl owned by the household. Farmers in the sample have 12.9 birds with a standard deviation of 17.6. Hoe cultivators have 14.4 birds, oxen cultivators have 6.2 birds, and CF cultivators have 13.8 birds.

Method

The dependent variable is $Yield_t$ for treatments $t = 1,...,T$. There are intervention, interaction, socio-economic and controlling variables. The intervention and interaction variables are management input decisions; the socio-economic variables are loosely capital; and the controlling variables represent the environment. The unrestricted model is

$$
\begin{aligned}
Yield_t &= \alpha_0 + \alpha_1 Basins_t + \alpha_2 PermanentRidges_t + \alpha_3 MaizeSunnhemp_t + \alpha_4 Lime_t \\
&+ \alpha_5 Inoculum_t + \alpha_6 Oxen_t + \alpha_7 Basins_t.PlantingDate_t + \alpha_8 Basins_t.TrialAge_t + \alpha_9 Basins_t.Residues_t \\
&+ \alpha_{10} Basins_t.WeedingLabour_t + \alpha_{11} Basins_t.CultivatedArea_t + \alpha_{12} Basins_t.\%replanted_t \\
&+ \alpha_{13} Age_t + \alpha_{14} Gender_t + \alpha_{15} Education_t + \alpha_{16} HHSize_t + \alpha_{17} Cattle_t + \alpha_{18} SchoolChildren_t \\
&+ \alpha_{19} Huts_t + \alpha_{20} Bicycles_t + \alpha_{21} Hoes_t + \alpha_{22} Birds_t + \alpha_{23} Control_t + \alpha_{24} Copperbelt_t \\
&+ \alpha_{25} Western_t + \alpha_{26} Southern_t + \alpha_{27} Central_t + \alpha_{28} PlantingDate_t + \alpha_{29} PlantingDate_t.Copperbelt_t \\
&+ \alpha_{30} PlantingDate_t.Western_t + \alpha_{31} PlantingDate_t.Southern_t + \alpha_{32} PlantingDate_t.Central_t + \varepsilon_i
\end{aligned}
$$

α_0 is the constant term, which implicitly represents conventional hoe culture by female farmers in Northern region. The units are kilograms per hectare. $\alpha_1,...,\alpha_6$ are the coefficients for the intervention variables; $\alpha_7,...,\alpha_{12}$ are the coefficients for the interaction variables; $\alpha_{13},...,\alpha_{22}$ are the coefficients for the socio-economic variables; and $\alpha_{23},...,\alpha_{32}$ are the coefficients for the controlling variables. For the dummy variables, the units are kilograms per hectare and for the stochastic variables they are kilograms per unit of the variable. ε_t is the independent and normally distributed error term, $\varepsilon_t \sim IN(0,\sigma^2)$.

Intervention variables

The intervention variables are *$Basins_t$*, *$PermanentRidges_t$*, *$MaizeSunnhemp_t$*, *$Lime_t$*, *$Inoculum_t$*, and *$Oxen_t$*,. They are all dummy variables. Basins are conservation farming method without lime across all the regions; permanent ridges are in Copperbelt and Northern regions only; and hoe culture is implicit in the constant term. The purpose is to find the yield contributions that basins, permanent ridges, maize/sunnhemp intercrop, lime and inoculum, individually and jointly, make to conventional hoe culture.

The hypotheses are that the interventions of basins, permanent ridges, lime and inoculum make significantly positive contributions to yield. Practitioners expect oxen cultivation to make a negative contribution because the oxen cannot plough or rip until the soil is soft enough, which results in late land preparation and late planting.

Anecdotal evidence suggests that basins and permanent ridges increase yields, but because of the presence of interaction variables, the coefficients of *$Basins_t$* and *$PermanentRidges_t$* are only constant terms and may be zero if the information is contained in the interaction coefficients. The null hypothesis is that there is no difference between yields from basins and from conventional hoe culture, against the alternative that basins increase yields. To test the hypothesis the model is restricted by omitting the interaction variables and testing $H_0 : \alpha_1 = 0; H_1 : \alpha_1 > 0$. For permanent ridges, the null hypothesis is the same but with the coefficient for permanent ridges, α_2.

There is no expected difference between the yields from basins and permanent ridges, but because the coefficients from $Basins_t$ and $PermanentRidges_t$ are not sufficient on their own, the hypothesis is tested by the F-statistic from the analysis of variance test for stability, by comparing the unexplained variance of the unrestricted model with the total variances from the model restricted by omitting the data for permanent ridges and from the regression for the permanent ridges only. Basins and permanent ridges are mutually exclusive, so the null hypothesis is that yields from basins and permanent ridges are the same against the alternative that they are different,

$$H_0: \left(\alpha_1 + \sum_{n=7}^{12} \alpha_n x_{nCF}\right) - \left(\alpha_2 + \sum_{n=7}^{12} \alpha_n x_{nPR}\right) = 0; H_1: \left(\alpha_1 + \sum_{n=7}^{12} \alpha_n x_{nCF}\right) - \left(\alpha_2 + \sum_{n=7}^{12} \alpha_n x_{nPR}\right) \neq 0$$

Individual t-tests test the significance of the remaining intervention variables. There are two interpretations: the coefficients can be a combination of interventions or they individually represent the yield difference from conventional hoe culture. The hypothesis for conventional maize intercropped with sunnhemp *in situ* is that its yield is the same as the yield from sole-cropped conventional maize, but because the plant population is half that of sole-cropped maize the alternative is that the yield is lower, $H_0{:}\alpha_3=0$; $H_1{:}\alpha_3<0$. Lime and inoculum are expected to increase yields for both conservation and conventional hoe cultures; the respective hypotheses are $H_0{:}\alpha_4=0$; $H_1{:}\alpha_4>0$ and $H_0{:}\alpha_5=0$; $H_1{:}\alpha_5>0$. $Oxen_t$ cultivation by anecdotal evidence is expected to have a negative effect, so $H_0{:}\alpha_6=0$; $H_1{:}\alpha_6<0$.

Interaction variables

The interaction variables contribute to the yields of CF cultivation. These are between CF cultivation and planting date, trial age, residues and weeding labour. The interaction between CF culture and planting date accrues to basins because of early land preparation. Yields increase with trial age because of rotations and farmer experience; including this variable offsets the overestimation of average yield increase. Because residues improve moisture retention and increase organic matter in the soil, they are expected increase yield.

The interaction terms are constructed by multiplying ($Basins_t$ + $PermanantRidges_t$), which are mutually exclusive dummy variables, with factors that influence yields from CF cultivation. In the presence of these variables, the individual coefficients of $Basins_t$ and $PermanentRidges_t$ are effectively constant terms for conservation farming, absorbing unexplained information. $Basins_t.PlantingDate_t$ is the interaction between ($Basins_t$ + $PermanentRidges_t$), which are mutually exclusive dummy variables, and planting date.

Basins$_t$.*TrialArea*$_t$ is zero to six for CF cultivation only and zero otherwise. *Basins*$_t$.*Residues*$_t$ is a dummy variable which is one for residues and zero for none; and *Basins*$_t$.*WeedingLabour*$_t$ is the number of days it takes to weed a hectare of treatment *t*.

Individual t-tests test the significance of this second group of variables. There are *a priori* expectations that the coefficients of the interactions between basins, and permanent ridges, and planting date, trial age, residues and weeding labour are significantly positive so the hypotheses are all of the form $H_0{:}\alpha_n{=}0$; $H_1{:}\alpha_n{>}0$. In the presence of these variables, together with controlling variables *Basins*$_t$.*CultivationArea*$_t$ and *Basins*$_t$.*%replanted*$_t$, the significance of the coefficients of *Basins*$_t$ and *PermanentRidges*$_t$ are jointly dependent upon the extent of the explanatory power of the interactions.

Testing whether all the interaction coefficients are in fact all zero, the unexplained variance from the unrestricted model is compared with that from the first restricted model (R1) that omits the interaction variables. The null hypothesis is that the interaction variables make no contribution to the model against the alternative that they do.

To test that there is no difference between the estimates of yields from basins and permanent ridges, the coefficients of *Basins*$_t$ and *PermanentRidges*$_t$, omitted in the second restricted model (R2), and the total value of the interactions, omitted in model R1, are compared using the F-statistic. Basins and permanent ridges are mutually exclusive, so the null hypothesis is that the yields from conservation farming or permanent ridges and the aggregate yields from the interactions are the same, against the alternative that they are different,

$$H_0 : \alpha_{1,2} - \sum_{n=7}^{12} \alpha_n x_n = 0; H_1 : \alpha_{1,2} - \sum_{n=7}^{12} \alpha_n x_n \neq 0.$$

The removal of either the interaction terms or the intervention terms should not hurt the explanatory power of the model, so there should be little difference between the error variances of the restricted and unrestricted models.

Socio-economic variables

Age is a general measure of experience and responsibility, gender a measure of social equality and education often explains increased incomes. Increasing household size may be associated with more children at school, larger pools of labour and economies of scale; on the other hand it may be associated with dysfunctionality, orphans, more funerals and more illness, for example HIV/AIDS.

Cattle roam freely over most of Zambia consuming valuable crop residues but depositing appreciated manure, but they may be a distraction to crop farming. Children of school age help when labour is scarce, for planting, weeding and harvesting, and therefore contribute to yield, but they also impose the cost of their schooling. Huts are assets that may facilitate credit. Bicycles can facilitate input supply and marketing, or encourage absenteeism that results in late planting and late and inadequate weeding, for which hoes are needed. Domestic fowl often eat recently planted seed, and the more birds, the more eaten.

Age_t is the age of the participating farmer. $Gender_t$ is unity for men. The $Education_t$ variable is grade levels zero to 12, 13 for college education and 16 for graduates. $HHSize_t$ is the number of occupants in a household. $Cattle_t$, $SchoolChildren_t$, $Huts_t$, $Bicycles_t$, $Hoes_t$ and $Birds_t$ are the number of each associated with the household. The coefficients of Age_t, and $Education_t$ are expected to be positive and significant, so H_0:α_n=0; H_1:α_n>0. A previous study on conservation farming in Zambia found that $Gender_t$ had no effect, so the hypothesis, H_0:α_n=0; H_1:$\alpha_n \neq 0$. The signs and significances of the coefficients for $HHSize_t$, $Cattle_t$, $SchoolChildren_t$, $Huts_t$, $Bicycles_t$, $Hoes_t$ and $Birds_t$ are less clear and speculative, so H_0:α_n=0; H_1:$\alpha_n \neq 0$.

There will be some bias in the coefficients of these variables, because there are 967 treatments and only 368 farmers: trial 2 in the Copperbelt and Northern regions has six treatments whereas trials one and five have two and the remaining trials have four.

Controlling variables

$Control_t$ is a dummy variable that is unity for conventional treatments in trial two. Its value represents the potential increase in yield performance of conventional hoe culture with good management. $Copperbelt_t$, $Western_t$, $Southern_t$ and $Central_t$ are the location dummy variables and Northern region is implicit in the constant term. $PlantingDate_t$ is the number of days treatment t is planted in Northern region after the first treatment was planted and $PlantingDate_t.Copperbelt_t$, $PlantingDate_t.Western_t$, $PlantingDate_t.Southern_t$, $PlantingDate_t.Central_t$ are the interactions of planting date with the location variables. The coefficients illustrate the critical nature of planting and are measures of relative management performance of both farmers and technicians. From the interaction group of variables, $Basins_t.CultivatedArea_t$ and $Basins_t.\%replanted_t$ are important as controlling variables; the former is in hectares for CF cultivation and the latter is the percentage of the field replanted for CF cultivation.

The coefficient of *Control$_t$*, is expected to be greater than zero, so H_0:α_n=0; H_1:α_n>0, whilst the coefficients of *Copperbelt$_t$*, *Western$_t$*, *Southern$_t$* and *Central$_t$* are likely to be different from zero but the sign is not clear, so H_0:α_n=0; H_1:$\alpha_n \neq 0$. The same is true for *PlantingDate$_t$.Copperbelt$_t$* , *PlantingDate$_t$.Western$_t$* , *PlantingDate$_t$.Southern$_t$* , *PlantingDate$_t$.Central$_t$*; they are also likely to be significant but their signs depend on the location of the *PlantingDate$_t$* term, again H_0:α_n=0; H_1:$\alpha_n \neq 0$. From the interaction variables, *Basins$_t$.CultivatedArea$_t$* is expected to be negative and significant, H_0:α_n=0; H_1:α_n<0, and *Basins$_t$.%replanted$_t$* is expected to be significant and positive, H_0:α_n=0; H_1:α_n>0.

The values of yields and their standard errors for maize and maize with sunnhemp are predicted from the model for conventional hoe culture, basins, basins with lime and basins with lime and inoculum. The percentage changes in yields are calculated. To find if there are differences in the risk-yield profiles of conservation farming and conventional hoe culture, simple F-tests are done with the predicted standard errors: the hypotheses are that the variance of yields from conventional hoe culture (CH) is the same or more than that of conservation farming (CF), $H_0 : \sigma^2_{CH} = \sigma^2_{CF} ; H_1 : \sigma^2_{CH} > \sigma^2_{CF}$, for basins without lime, basins with lime and basins with lime and inoculum. The trial with maize intercropped with sunnhemp *in situ* was observed to be more highly variable than expected, to the extent that the hypothesis is two-tailed, $H_0 : \sigma^2_{CH} = \sigma^2_{CF} ; H_1 : \sigma^2_{CH} \neq \sigma^2_{CF}$.

The yield changes between interventions and interactions estimated by the model are valued at the government maize price of K600 (US$0.1333) per kilogram, to find the percentage contribution to incremental yield for the standard package and for the standard package with inoculum. The incremental costs are calculated and deducted from the benefits to find the net benefit of the interventions and the interactions. The yield benefits from the interactions are their respective coefficients times the expected values at the government price. The contributions of socio-economic variables and the control variables are valued in the same way. The costs associated with the socio-economic variables are assumed sunk.

Results

Table four reports the results. In the unrestricted model, the constant, which represents hoe cultivation by female farmers in Northern region, is 1,156kg ha^{-1}, which is significant at the ten per cent level. The coefficients of basins and permanent ridges are not significant. Since these are constant terms to the interaction variables, the latter explain the variance in conservation farming yields. The first restricted model shows yields from basins and permanent ridges are significantly more than conventional hoe cultivation at the one per cent level, increasing yields by 1,987kg ha^{-1} and 1,895kg ha^{-1} respectively, and the F-statistic of 0.851 at 33 and 901 degrees of freedom, p = 0.71, shows the difference, so the yields from the two improved systems are the same.

The yield from conventional hoe-cultivated maize/sunnhemp intercrop is 2,001kg ha^{-1} less than the yield from conventional hoe-cultivated sole-cropped maize at the one per cent level. Adding lime to conventional hoe cultivation or to basins does not significantly increase yields. Using inoculum however produces an increase of 941kg ha^{-1} at the one per cent level. The results from the unrestricted and R2 models are similar for lime and inoculum, but in the R1 model lime is significant (419kg ha^{-1}) and inoculum is less (691kg ha^{-1}). The effect of lime is therefore captured in the interaction variables in the unrestricted and R2 models and part of the inoculums performance may also be explained by lime.

The yield from oxen cultivation is not significantly more than conventional hoe cultivation by female farmers in Northern, which suggests that the difference between conventional hoe and oxen cultivators is explained by other variables in the model, most likely planting dates.

The coefficient of the interaction of planting dates with basins is 33.4kg ha^{-1} per day and is significant at the one per cent level. This result suggests that CF farmers gained this amount per day until they planted. The $Basins_t.TrialAge_t$ coefficient is also significant at the one per cent level and suggests that CF cultivators gain 317kg ha^{-1} per year of practicing conservation farming. The residues coefficient is significant at the ten per cent level, which implies that residues increase yields by 259kg ha^{-1}, but is more marginal. The coefficient of $Basins_t.WeedingLabour_t$ is significant at the one per cent level and suggests that yield increases by 6.61kg ha^{-1} per day spent weeding.

The coefficient of $Basins_t.CultivationArea_t$ suggests CF cultivators lose 15.9kg ha^{-1} per incremental hectare they cultivate, and is significant at the five per cent level. Replanting reclaimed yields of 5.75kg ha^{-1} per percentage point of the field replanted; this is significant at the one per cent level.

The F-statistic that shows if these interaction variables jointly have no effect on the model is 11.902, which fails to accept the null hypothesis at 6 and 934 degrees of freedom. The more important analysis of variance test that compares the coefficients of the restricted models with the coefficients of the pooled data gives a F-statistic of 0.427, which as a onetailed test is not significantly different at 33 and 1,866 degrees of freedom, p = 0.998, so the null hypothesis that there is no difference between the yield benefit from basins and permanent ridges in the first restricted model and the yield benefit from the interaction variables in the second restricted model fails to be rejected. The implication is there is no difference between the 1,987kg ha^{-1} gross yield estimate from basins and the aggregate yield estimate from the interaction terms.

The socio-economic variables do contribute information to the model. Age makes a significant contribution to yield of 7.35kg per year of age, at the ten per cent level. The coefficient of education is positive, suggesting that farmers increase their yields by 66kg ha^{-1} per grade level, and significant at the one per cent level. Household size is negative but significant at the five per cent level, and suggests that farmers lose 48.4kg per hectare per family member.

Bicycles also have a negative effect, and are significant at the one per cent level, suggesting that farmers with bicycles lose 184kg ha^{-1} per bicycle. Hoes on the other hand result in farmers gaining 48.7kg ha^{-1} per hoe in the household and are significant at the one per cent level. Gender is not an issue, proposing a positive influence for male farmers but far from significant. The coefficients of cattle and huts have positive signs but are not significant. The coefficient of domestic fowl is not significant but negative.

The control coefficient is 1,250kg ha^{-1} and is significant at the one per cent level; it suggests that there is an important difference between the on-trial conventional yields from trial 2 and the off-trial conventional yields associated with trial 1, despite the farmers having the same inputs. It also shows that yields from conventional hoe culture can be increased by 50 per cent to 3,738kg ha^{-1} by timely planting and weeding. The yields of conventional hoe farmers from the Copperbelt and Western regions are significantly different from conventional hoe culture in Northern at the one per cent level, Central at the five per cent level, and Southern is not significant, with incremental yields of 2,418kg ha^{-1}, 1,885kg ha^{-1}, 692kg ha^{-1} and 1,525kg ha^{-1} respectively. The results suggest that the Copperbelt has the greatest agricultural potential followed by Western and Central. Northern has the lowest potential.

The coefficient of $PlantingDate_t$ is 19.6 but is not significant. This represents the coefficient of the planting date of Northern. Copperbelt and Western regions are significantly negative at the one per cent level and Southern and Central are significantly negative at the five per cent level, and show daily yield losses due to late planting by location. The signs are a function of the Northern region acting as the constant planting date. The results suggest that Northern has the best management given the environment, gaining 19.6kg ha^{-1} per day late planted. Southern in comparison lost 14kg ha^{-1} per day late planted. The Copperbelt lost the most, 85kg ha^{-1} per day late planted, which suggests that the planting date is highly critical in the Copperbelt region.

The predicted yields for the interventions are reported in table five. These results do not include the location and environmental effects but do include the socio-economic effects at their expected values. The expected yield from conventional hoe culture is 2,488kg ha^{-1}. If conventional hoe culture is practiced in a timely manner, the yield increases to 3,738 kg ha-1, 50 per cent more than traditionally practiced conventional hoe.

Basins without lime increase yield by 68 per cent, with a 95 per cent confidence interval of 49 per cent to 88 per cent, to 4,182kg ha^{-1}, which is 4.7 per cent less than the unadjusted estimate of 4,389kg ha^{-1}. Adding lime to basins increases the yield to 4,407kg ha^{-1}, an increase of 77 per cent over conventional hoe culture without lime, with an interval of 62 per cent to 92 per cent, and 7.8 per cent less than the unadjusted average of 4,778kg ha^{-1}.

If inoculum is added as well, the yield increases to 5,348kg ha^{-1}, giving a 115 per cent increase over conventional hoe culture. This is 1.7 per cent less than the 5,441kg ha^{-1} unadjusted average. The increase due to the inoculum over the standard package is 21.3 per cent with a confidence interval of eight per cent to 35 per cent.

The hypothesis is that the yield risk from conventional hoe culture is the same or higher than that from basins. Using the standard errors from the predicted estimates, the F-statistic that compares the variances of yields from timely conventional hoe culture with conventional hoe culture is 4.952, which is significant at 164 and 65 degrees of freedom, so there is substantial reduction in risk when conventional hoe culture is practiced in a timely manner. The F-statistic that compares basins without lime and conventional hoe culture is 2.792, which is significant at 164 and 108 degrees of freedom at the one per cent level and means that the null hypothesis fails to be accepted and yields from basins have a lower variance than yields from conventional hoe culture and so have lower risk. Adding lime to the basins gives an F-statistic of 4.531, also failing to accept its null hypothesis, so basins with lime are less risky than conventional hoe culture without lime. When lime and inoculum are used with basins, the F-statistic declines to 1.859 but remains significantly different at 164 and 30 degrees of freedom; so the yield risk of conservation farming is less than conventional hoe culture, but the yield is substantially higher.

The adjusted yield for maize intercropped with sunnhemp in basins is 2,325kg ha^{-1}, seven per cent less than sole-cropped maize; when lime is added to the basin, the yield increases to 2,550kg ha^{-1}, slightly above the yield from sole-cropped maize; but when inoculum is also used, the yield is predicted to be 3,491kg ha^{-1}, 40 per cent more than conventional sole-cropped maize. Anecdotal evidence suggests than variance in the maize/sunnhemp intercrops is high, and this is borne out with standard errors of around 500kg, more than the 393kg from conventional sole-cropped maize. With the two-tailed test at the five per cent level, the alternative hypothesis fails to be rejected so basins without lime and basins with lime and inoculum have more risk than conventional sole-cropped maize; the standard package, however, is not significantly different and fails to reject the null hypothesis that the risk levels are the same.

Using the expected values from table three and the coefficients from the unrestricted model in table four, the incremental yield due to CF is 2,964kg ha^{-1}; the results are in table six. Lime is not significant in the unrestricted model, so its contribution and benefit are already captured in the interaction variables; but it still incurs a cost of US$19. The incremental benefit of lime and inoculum is US$125; the costs, US$29; and the net benefit US$96. The contributions of the interactions in order of magnitude are planting date contributed 29 per cent, weeding 17 per cent, rotation 11 per cent, residues 8.7 per cent and replanting 5.7 per cent; farm size reduced the impact by 2.6 per cent. The incremental benefit was US$269 and the incremental cost was US$39, so the net benefit is US$231.

The contribution to all farm systems from socio-economic variables is 594kg ha^{-1}, a net benefit of US$79. For conservation farmers, this is 17 per cent of the gross yield of 3,559kg ha^{-1}: education provides most of the advantage, 13.4 per cent, followed by hoes at 9.7 per cent and age 9.2 per cent. The bigger the household the more debilitating, reducing benefit by 10.7 per cent (US$51); and bicycles reduced benefit by 4.9 per cent (US$23).

The control variables add insights: the on-trial control treatments in region III yielded 1,250kg ha^{-1} more than their off-trial counterparts in region IIa, valued at US$167. The yield potential arising from a combination of management and location is highest in Northern at US$224 ha^{-1}. This is followed by Western region with a net benefit of US$178 ha^{-1}. Central region has a net yield gain of 813kg ha^{-1} worth US$108. Southern had the lowest potential, of

692kg ha^{-1}, but still had a net gain of US$66. Copperbelt had the lowest management and location performance, making a net loss of US$66 ha^{-1}.

Conclusions

Using predictions from the unrestricted model for the average case and a baseline of conventional hoe cultivation, timely conventional hoe cultivation (activities are undertaken at the same time as CF activities) increased yields by 50 per cent, reduced risk substantially over conventional hoe and increased income by US$167. Basins without lime increased yields by 68 per cent, are also less risky and increased income by US$231. Although lime is not significant, it is in the model, resulting in a 77 per cent increase over conventional hoe at less risk and an increased income of US$242; see table five. Lime and inoculum increases yield by 115 per cent and the risk remains lower than conventional hoe, but the income increased by US$358. The conclusions are that yield risk is mostly reduced by timely farming; timeliness is an important component of conservation farming; and the risk-yield profile of conservation farming is much better than conventional farming – the risk is lower and the return is higher.

The model predicts that basins, lime and inoculum on maize intercropped with sunnhemp *in situ* produces 40 per cent more yield than conventional sole-cropped maize, however the yield-risk profile is higher than that of conventional hoe culture and therefore the system cannot be recommended.

The yield from conventional oxen cultivation is no different to conventional hoe cultivation, suggesting the failure of oxen cultivation to achieve comparable maize yields is due to late planting rather than oxen cultivation *per se*.

Planting date made the largest contribution, explaining 29 per cent of yield attributed to conservation farming method. Weeding contributed 17 per cent to the increased yield contribution. Rotations contributed 11 per cent and the contribution from residues was 8.7 per cent. Replanting increased yield by 5.7 per cent. The cultivated area reduced the yield by 2.6 per cent.

The socio-economic variables contribute to all farmers' yields. In the case of conservation farmers, 17 per cent of the yield was due to these variables. Education contributed 13 per cent; hoes, 9.7 per cent; and age 9.2 per cent. Household size detracted from this contribution as did bicycles, but gender was not an issue.

There was a large yield difference between on-trial and off-trial control plots. Where interventions include timeliness of activities, on-farm on-trial control treatments are not effective. The yield difference also shows that conventional hoe farmers can substantially increase their yields by 50 per cent simply by improving the timing of their activities.

Potential yields are highest in the Copperbelt region of Zambia but planting date and on-going management is critical, suggesting it is a risky area. Taking account of management and location effects, Northern has the highest potential, with Western following. Southern on the other hand had the lowest potential after Copperbelt. These results and their interpretation need more research.

The deficiencies in the design of the analysis are, firstly, the trial age coefficient absorbs a lot of information that is described over time, particularly, lime residue effects, the build-up of organic matter, the reduction of land preparation labour and the decline in weeds and weeding labour. Secondly, yield is more likely to have a second order polynomial relationship with yield than a linear one.

There are technical shortfalls: 1) the data are not as inclusive as they might have been because some data were not available for the control sample, resulting in the interaction approach. 2) The small numbers of oxen cultivators in Central and of conventional hoe cultivators in Southern and Central are disappointing and make interpretations less reliable in those regions. 3) Although safely into the realm of large sample theory and its assumptions of asymptotic distributions, yield data are measured with error, due to different moisture levels, field edge effects, samples from obscure anthills, *et cetera*, and there are probably measurement errors in the stochastic explanatory variables as well, leading to underestimation of the coefficients and therefore the results; however, underestimated results are more desirable. 4) The final shortfall is that although the benefits of fertiliser are fully recognised, it would be meaningful to find the proportion of yield gain attributable to the basin and to the fertiliser.

Because of the geographic spread of the trials and the large sample, the results are more reliable than the few previous studies on conservation farming in Zambia. Despite the contribution to knowledge on conservation farming culture in Zambia and the region, it is premature to make generalisations any more precise than H&T's 50 to 100 per cent yield increases based on one year's data, and it is clear that much work needs to be done to test the strength of these conclusions, particularly on the contributions of the characteristics of hoe conservation farming and the yield benefits from the socio-economic variables.

There are opportunities to study the performance of unassisted adopters of this hoe conservation farming model and, after some time of developing an appropriate method for oxen cultivation, there is a technique that is promising. There is also an opportunity to study training efficiency and linkages at smallholder level. These methods are for small-scale farmers but are best assessed for suitability and viability by on-farm trials with the farmers themselves.

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Table 1 is the distributions of the agricultural and farmer characteristics across the regions and by cultivation method.

Distributions									
	Regions					Cultivation			
	Copperbelt	Northern	Western	Southern	Central	Hoe	Oxen	CF	Total
n	186	203	222	220	136	164	50	753	967
%	19%	21%	23%	23%	14%		5%	78%	100%
Agricultural characteristics									
Yield	2,782.50	3,390.80	4,506.10	3,618.90	4,109.10	2,824.10	2,380.80	3,956.20	3,682.70
Basins	33%	33%	88%	77%	94%	0%	0%	83%	64%
PermanentRidges	33%	33%	0%	0%	0%	0%	0%	17%	13%
Maize/sunnhemp	50%	50%	18%	16%	22%	40%	0%	31%	31%
Lime	67%	67%	64%	75%	60%	21%	100%	75%	67%
Inoculum	0%	0%	9%	9%	15%	0%	0%	8%	6%
Oxen cultivation	0%	0%	0%	20%	4%	0%	100%	0%	5%
Planting date	26-Nov-02	4-Dec-02	16-Nov-02	28-Nov-02	4-Dec-02	30-Nov-02	15-Dec-02	25-Nov-02	27-Nov-02
CF characteristics									
Basins*PlantingDate	26-Nov-02	4-Dec-02	15-Nov-02	22-Nov-02	5-Dec-02	--	--	25-Nov-02	25-Nov-02
Basins*TrialAge	0.19	0.53	1.06	1.17	0.06	--	--	0.68	0.68
Basins*Residues	0.68	0.73	0.84	0.45	0.65	--	--	0.67	0.67
Basins*WeedingLabour	82.10	68.19	70.93	67.48	88.82	--	--	74.54	74.54
Basins*CultivatedArea	9.24	3.14	3.92	4.74	3.58	--	--	4.78	4.78
Basins*%replanted	10.65	2.37	43.90	60.91	12.64	--	--	29.51	29.51
Farmer characteristics									
n	31	34	112	136	55	34	50	284	368
%	8%	9%	30%	37%	15%	9%	14%	77%	100%
Age	49.68	43.94	43.74	44.80	43.75	43.56	35.82	46.34	44.65
Gender	81%	74%	79%	70%	71%	82%	86%	71%	74%
Grade	9.74	7.65	7.96	6.88	4.78	8.56	7.38	7.01	7.21
Household size	6.81	6.00	8.32	8.38	7.31	6.44	7.06	8.16	7.85
Cattle	1.55	1.44	2.91	4.10	0.82	4.71	2.16	2.67	2.79
Children at school	3.39	3.56	3.91	3.06	3.31	3.29	2.20	3.66	3.43
Huts	2.84	2.65	4.23	4.00	3.60	3.74	3.14	3.91	3.79
Bicycles	1.29	0.71	1.24	0.79	0.69	1.09	0.80	0.95	0.95
Hoes	8.23	5.71	8.05	6.69	6.16	7.50	4.68	7.43	7.07
Birds	19.00	12.65	15.08	11.47	8.40	14.41	6.24	13.83	12.85

Table 2 is the average yields of each of the farming systems in each of the regions.

Farming system		Regions Copperbelt	Northern	Western	Southern	Central	All	CV
All systems	n	186	203	222	220	136	967	
	E(x)	2,783	3,391	4,506	3,619	4,109	3,683	***55%***
	sd	(1,620)	(1,571)	(1,964)	(2,002)	(2,582)	(2,024)	
Conventional	n	62	68	26	50	8	214	
	E(x)	2,595	2,874	3,622	2,145	3,053	2,721	***53%***
	sd	(1,711)	(1,349)	(1,505)	(944)	(1,044)	(1,453)	
	CV	66%	47%	42%	44%	34%	53%	
Oxen cultivation	n				*44*	*6*	*50*	
	E(x)	--	--	--	*2,240*	*3,416*	*2,381*	***43%***
	sd	--	--	--	*(965)*	*(911)*	*(1,025)*	
Hoe cultivation	n	*62*	*68*	*26*	*6*	*2*	*164*	
	E(x)	*2,595*	*2,874*	*3,622*	*1,453*	*1,963*	*2,824*	***55%***
	sd	*(1,711)*	*(1,349)*	*(1,505)*	*(271)*	*(555)*	*(1,548)*	
CF cultivation, all	n	124	135	196	170	128	753	
	E(x)	2,876	3,651	4,623	4,052	4,175	3,956	***53%***
	sd	(1,572)	(1,615)	(1,991)	(2,026)	(2,637)	(2,080)	
Basins, standard CF	n	*31*	*34*	*86*	*86*	*48*	*285*	
	E(x)	*3,898*	*4,766*	*5,415*	*4,520*	*4,678*	*4,778*	***44%***
	sd	*(1,938)*	*(1,420)*	*(2,016)*	*(2,119)*	*(2,566)*	*(2,124)*	
	CV	***50%***	***30%***	***37%***	***47%***	***55%***	***44%***	
PermanentRidges	n	*31*	*34*				*65*	
	E(x)	*3,682*	*4,751*	--	--	--	*4,241*	***30%***
	sd	*(1,136)*	*(1,216)*	--	--	--	*(1,287)*	
Basins, Maize/sunnhemp	n	*31*	*33*	*40*	*36*	*30*	*170*	
	E(x)	*2,020*	*2,549*	*2,639*	*2,348*	*2,202*	*2,370*	***53%***
	sd	*(1,032)*	*(1,156)*	*(1,206)*	*(1,368)*	*(1,424)*	*(1,251)*	
PermanentRidges, maize/sunnhemp	n	*31*	*34*				*65*	
	E(x)	*1,906*	*2,507*	--	--	--	*2,220*	***38%***
	sd	*(733)*	*(839)*	--	--	--	*(840)*	
Basins, no lime	n			*50*	*28*	*30*	*108*	
	E(x)	--	--	*4,525*	*4,320*	*4,228*	*4,389*	***42%***
	sd	--	--	*(1,471)*	*(1,605)*	*(2,476)*	*(1,822)*	
Basins, inoculum, no lime	n			*10*	*10*	*10*	*30*	
	E(x)	--	--	*5,261*	*4,652*	*5,803*	*5,239*	***37%***
	sd	--	--	*(1,323)*	*(1,296)*	*(2,870)*	*(1,962)*	
Basins, inoculum	n			*10*	*10*	*10*	*30*	
	E(x)	--	--	*5,603*	*4,822*	*5,897*	*5,441*	***39%***
	sd	--	--	*(1,614)*	*(1,724)*	*(2,930)*	*(2,147)*	

Table 3 is the summary of dependent and independent variables.

Summary statistics

	n	Mean	Median	StDev	Minimum	Maximum
Yield	967	3,683	3,350	2,024.3	176	11,762
Planting date	967	27.559	27	15.3	31-Oct-02	16-Jan-03
Basins*PlantingDate	753	25.760	26	15.2	31-Oct-02	31-Dec-02
Basins*TrialAge	753	0.677	-	1.1		6
Basins*Residues	753	0.673	1.000	0.5		1
Basins*WeedingLabour	753	74.540	74.480	33.5	14.6	260
Basins*Cultivated area	753	4.782	3.000	9.6	0.1	100
Basins*%replanted	753	29.510	-	38.0		100
Age	368	44.652	43.000	13.5	17.0	85
Gender	368	74%				
Grade	368	7.207	7.000	3.6		16
Household size	368	7.848	8.000	3.9	1.0	35
Cattle	368	2.788	-	9.9		121
Children in school	368	3.429	3.000	2.5		21
Huts	368	3.788	3.000	2.3		15
Bicycles	368	0.946	1.000	0.8		5
Hoes	368	7.065	6.000	4.6	1.0	60
Birds	368	12.853	10.000	17.6		170

Table 4 is the results from the unrestricted and the restricted regression models.

	Unrestricted	Restriction 1	Restriction 2
Constant	1155.7*** (1.76)	-298.8 (-0.47)	984.3*** (1.82)
Interventions			
Basins	-143.7 (-0.32)	1987.1* (6.53)	
Permanent ridges	-258 (-0.53)	1895.1* (5.24)	
Maize/sunnhemp	-2000.9* (-17.16)	-2046.8* (-17.05)	-2003.4* (-17.23)
Lime	224.9 (1.54)	419.2* (2.84)	232.7 (1.61)
Inoculum	940.8* (4.13)	691* (3)	934.4* (4.12)
Oxen cultivation	230.9 (0.57)	-68.3 (-0.17)	261.5 (0.67)
Interactions			
*Basins*PlantingDate*	33.399* (3.35)		31.506* (3.96)
*Basins*TrialAge*	317.32* (5.41)		315.14* (5.41)
*Basins*Residues*	259.1*** (1.95)		251.7*** (1.93)
*Basins*WeedingLabour*	6.606* (3.54)		6.39* (3.6)
*Basins*CultivationArea*	-15.878** (-2.46)		-15.883** (-2.46)
Basins%replanting*	5.753* (2.91)		5.574* (2.93)
Socio-economic variables			
Age	7.349*** (1.69)	11.759* (2.65)	7.446*** (1.72)
Gender	-15.4 (-0.13)	-53.9 (-0.44)	-14.9 (-0.12)
Grade	66.06* (3.9)	66.36* (3.98)	66.09* (3.9)
Household size	-48.39** (-2.13)	-30.4 (-1.3)	-48.62** (-2.14)
Cattle	0.459 (0.07)	-1.084 (-0.16)	0.557 (0.09)
SchoolChildren	34.44 (1.35)	25.72 (0.97)	34.37 (1.34)
Huts	28.63 (0.82)	-13.28 (-0.38)	27.57 (0.79)
Bicycles	-183.77* (-2.81)	-200.32* (-2.98)	-183.69* (-2.81)
Hoes	48.73* (3.49)	51.32* (3.58)	49.04* (3.53)
Birds	-2.249 (-0.67)	-2.317 (-0.67)	-2.253 (-0.67)
Control variables			
RIIIControl	1249.9* (3.03)	1824.8* (4.44)	1377.2* (4.11)
Copperbelt	2417.9* (4.15)	2447* (4.12)	2415.1* (4.15)
Western	1885* (3.86)	2358.6* (4.83)	1946.5* (4.07)
Southern	692 (1.37)	1268.9** (2.58)	754 (1.52)
Central	1525.1** (2.59)	1424.1** (2.36)	1584* (2.72)
PlantingDate	19.58 (1.45)	44.99* (3.67)	20.93 (1.63)
*PlantingDate*Copperbelt*	-104.24* (-5.58)	-107.36* (-5.67)	-104.05* (-5.58)
*PlantingDate*Western*	-54.88* (-3.74)	-53.47* (-3.57)	-54.28* (-3.73)
*PlantingDate*Southern*	-33.33** (-2.49)	-38.88* (-2.86)	-33.14** (-2.48)
*PlantingDate*Central*	-39.9** (-2.51)	-30.15*** (-1.86)	-39.54** (-2.49)
n	967	967	967
Adj. R^2	43.60%	39.70%	43.70%
F-statistics		11.902	0.427
DF		6,934	33,1866

* Significant at one per cent level
** Significant at five per cent level
*** Significant at ten per cent level

Table 5 is the adjusted yields for conventional and conservation farming method predicted by the model and F-statistics comparing their variance.

Farming system	E(yield)	Incr. %	Cum. %	s	F-statistic	n	p
Sole cropped maize							
Conventional hoe, no lime	2,488kg			412kg		164	
Timely conventional hoe, no lime	3,738kg	50%	50%	185kg	4.952	65	0.000
Basins, no lime	4,182kg	12%	68%	247kg	2.792	108	0.000
Basins with lime, std. CFU	4,407kg	5%	77%	193kg	4.541	285	0.000
Basins with inoculum and lime	5,348kg	21%	115%	302kg	1.859	30	0.024
Maize with sunnhemp in situ v. sole cropped maize							
Conventional hoe, maize no lime	2,488kg			412kg		164	
Basins, maize/sunnhemp, no lime	2,325kg	-7%	-7%	535kg	0.593	57	0.994
Basins, maize/sunnhemp, lime, std. CFU	2,550kg	10%	2%	494kg	0.696	57	0.958
Basins, maize/sunnhemp, inoculum, lime	3,491kg	37%	40%	566kg	0.529	57	0.999

Table 6, panel (a) is the expected yield and economic values of the interventions of CF cultivation, panel (b) is the expected yield and economic values of the interactions of CF cultivation, panel (c) is the values of the socio-economic variables and panel (d) is the values of the control variables, as explained by the unrestricted model.

(a) Interventions

Variable, X_n	a_n	$E(X_n)$	$a_n.E(X_n)$ kg	%	CFU	Benefit	Cost	Net benefit
Lime						$ -	$ 18.63	$ (18.63)
Inoculum			941kg	31.74%		$ 125.43	$ 10.00	$ 115.43
E(yield of interventions)			941kg			$ 125.43	$ 28.63	$ 96.79

(b) Interactions with basins

Variable, X_n	a_n	$E(X_n)$	$a_n.E(X_n)$ kg	%	CFU	Benefit	Cost	Net benefit
*Basins*PlantingDate*	33.4kg	25.76	860kg	29.03%	25%	$ 114.71	$ 8.78	$ 105.94
*Basins*TrialAge*	317.3kg	1.00	317kg	10.71%	15%	$ 42.31	$ -	$ 42.31
*Basins*Residues*	259.1kg	1.00	259kg	8.74%	10%	$ 34.55	$ -	$ 34.55
*Basins*WeedingLabour*	6.6kg	74.54	492kg	16.61%	20%	$ 65.65	$ 24.62	$ 41.03
*Basins*CultivationArea*	-15.9kg	4.78	-76kg	-2.56%		$ (10.12)	$ -	$ (10.12)
Basins%replanted*	5.8kg	29.51	170kg	5.73%		$ 22.64	$ 5.18	$ 17.46
E(yield of interactions)			2,023kg			$ 269.74	$ 38.58	$ 231.16
E(conservation farming)			2,964kg			$ 395.16	$ 67.21	$ 327.95

(c) Socio-economic variables

Variable, X_n	a_n	$E(X_n)$	$a_n.E(X_n)$ kg	%	Benefit	Cost	Net benefit
Age	7.3kg	44.65	328kg	9.22%	$ 43.75	$ -	$ 43.75
Grade	66.1kg	7.21	476kg	13.38%	$ 63.48	$ -	$ 63.48
Household size	-48.4kg	7.85	-380kg	-10.67%	$ -	$ 50.64	$ (50.64)
Bicycles	-183.8kg	0.95	-174kg	-4.88%	$ -	$ 23.17	$ (23.17)
Hoes	48.7kg	7.07	344kg	9.67%	$ 45.90	$ -	$ 45.90
E(AllYield)			3,559kg	16.72%	$ 153.14	$ 73.81	$ 79.33

(d) Control variables

Variable, X_n	a_n	$E(X_n)$	$a_n.E(X_n)$ kg	%	Benefit	Cost	Net benefit
Constant, Northern	1,156kg	1	1,156kg	32.48%	$ 154.09	$ -	$ 154.09
Control	1,250kg	1	1,250kg	35.12%	$ 166.65	$ -	$ 166.65
Copperbelt	2,418kg	1	2,418kg	67.94%	$ 322.39	$ -	$ 322.39
Western	1,885kg	1	1,885kg	52.97%	$ 251.33	$ -	$ 251.33
Southern	692kg	1	692kg	19.45%	$ 92.27	$ -	$ 92.27
Central	1,525kg	1	1,525kg	42.86%	$ 203.35	$ -	$ 203.35
PlantingDate, Northern	20kg	1	20kg	0.55%	$ 2.61	$ -	$ 2.61
*PlantingDate*Copperbelt*	-104kg	1	-104kg	-2.93%	$ -	$ 13.90	$ (13.90)
*PlantingDate*Western*	-55kg	1	-55kg	-1.54%	$ -	$ 7.32	$ (7.32)
*PlantingDate*Southern*	-33kg	1	-33kg	-0.94%	$ -	$ 4.44	$ (4.44)
*PlantingDate*Central*	-40kg	1	-40kg	-1.12%	$ -	$ 5.32	$ (5.32)