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Abstract: The performance of cotton, groundnuts and soybean under hoe conservation farming culture in Zambia is examined with a GLS model weighted for groupwise error variance and controlled for location and planting dates, and the socio-economic factors of age, gender, education, household size and other wealth indicators. Basal dressing increases cotton yields by 26 per cent and lime and basal dressing increases yield by 46 per cent, both with net benefits. Adding lime to groundnuts already with basal dressing increases yield by 21 per cent in conservation farming basins and by 18 per cent on permanent ridges. Converting to permanent ridges, with lime, from conservation farming basins, without lime, increases yield by 35 per cent. Adding lime to cotton or to soybean already with basal dressing did not have significant responses.

Key Words: conservation, cash crops, smallholder, socio-economy, sustainability.

JEL: Q01

1. Introduction

The yield and economic effects of lime and basal dressing on cotton, and lime on basal dressed groundnuts and soybean are determined in conservation farming basins after controlling for planting dates, location effects and socio-economic factors. A comparison of groundnut yields is also made between conservation farming (CF) basins and conservation farming (CF) permanent ridges.

Conservation Farming Unit (CFU) of the Zambia National Farmers' Union developed the hoe conservation farming method of CF Basins in Zambia. The method focuses on retention of residues, limiting tillage to the area where the seed is to be sown, land preparation during the dry season, establishment of precise and permanent planting basins, precision use of inputs, early and continuous weeding, and rotations[2]. The method is appropriate in agro-ecological regions 1 and II in Zambia where rainfalls are from less than 800mm up to 1,000mm.

Permanent ridges are an extension of the CF method for use in region III agro-ecological zone. They are necessary because of torrential downpours, the rainfall is greater than 1,000mm a year, and fragile soils, and they encourage sedentary farming practice where migratory slash and burn is common (*chitemene*).

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[2] Aagaard, P. J. and Gibson, G.D.O. (2003a)

There are cotton trials in western, southern and central regions[3], agro-ecological region IIa, groundnut trials in the copperbelt and northern regions, agro-ecological region III, and soybean trials in western and central regions.

There is little contention that lime and fertiliser increase yields, so the purpose is to measure yield increases when applied to cotton, groundnuts and soybean in conservation farming (CF) basins. Here, cotton received lime and basal dressing incrementally, and groundnuts and soybean already receiving basal dressings additionally received lime. Cotton is a cash crop but anecdotal evidence suggests that 90 per cent of small-scale soybean and 50 per cent of small-scale groundnuts are grown for cash. There are also assertions that men grow cash crops and women grow groundnuts; so it seems likely that farmers can be characterised by crop type. If this is the case, then farmer characterisation will help explain variance between crops.

In 2001/02 season and without controlling for planting dates, regions and their interactions, Langmead (2002b) found lime increased cotton yield by 11 per cent, basal dressing by 59 per cent and lime and basal dressing by 68 per cent. The medians were lower, ten per cent, 44 per cent and 56 per cent respectively, the latter two suggesting some large outliers. In copperbelt and northern regions, at the ten per cent level of significance, there was a 16 per cent increase in groundnut yield attributed to CF permanent ridges over CF basins[4]. Lime was found to significantly increase soybean yield by 29 per cent, but the median was 17.3 per cent, and again, because of the clear presence of outliers, the latter may be a better estimate than the mean[5].

Langmead (2004) takes data from a spread of trials across Zambia and distinguishes between farming and farmer characteristics to examine maize yields from conservation farming basins. In the former he controls for planting dates, region and the interaction between planting dates and regions, and isolates the effects of basins and lime amongst others. Farmer age contributes to maize yields, which is explained by increasing experience. Women are found to be disadvantaged in many studies on developing and developed economies, but no evidence of yield differentials in maize cropping was found between male and female farmers in conservation farming, and Haggblade & Tembo (2003) concur. Education increases maize yields, possibly farmers can access written information. Increasing household size reduced maize yields, which may be due to dysfunctional behaviour in the family, and so

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[3] These are regions as distinct from provinces.

[4] Langmead, P. (2002a).

[5] Langmead, P. (2002b).

did bicycles, which may cause increased absenteeism. Because hoes are available, for weeding, the number of available hoes contributed to maize yield. The numbers of cattle and huts were not significant but had positive signs, while domestic fowl was not significant and had a negative sign.

The results here show that basal dressing, and lime and basal dressing, increases cotton yields in CF basins, and lime increases groundnut yield in CF basins and on CF permanent ridges. CF permanent ridges also increase groundnut yields over basins. Western region was the most productive and Southern appears to be least so. Surprisingly, education has a negative influence and bicycles and domestic fowl have positive influences, contrary to Langmead (2004).

Following this section, ‘Data’ describes the sources of data and summarises the characteristics of cotton, groundnut and soybean farming in copperbelt, northern, western, southern and central regions in terms of planting dates and location, and the socio-economic characteristics of the farmers. ‘Method’ describes the GLS regression model in which data are grouped by crop and weighted by their estimated unexplained variance, and a brief cost-benefit analysis. The ‘Conclusions’ are drawn, and also identify shortfalls in the study and proposed future research.

2. Data

The data are from 449 on-farm treatments from three CFU-operated trials worked by 143 participating farmers in copperbelt, northern, western, southern and central regions that span agro-ecological regions IIa and III. The 49 cotton trials are 2^2, with and without lime and with and without basal dressing; they are in western, southern and central regions, and all are in region IIa agro-ecological zone. There are 196 cotton treatments, 44 per cent of the sample, 60 in Western region, 80 in Southern region and 56 in Central region; see Table 1. The data from 65 groundnut trials are from three treatments from 3^3 trials in copperbelt and northern regions, and are in region III agro-ecological zone. There are therefore 195 groundnut treatments, 43 per cent of the sample, 93 in copperbelt and 102 in northern. The data from 29 soybean trials are from two treatments from 2^2 trials in western and central regions, in region IIa agro-ecological zone, so there are 58 soybean treatments, 13 per cent of the sample, 40 in western region and 18 in central region. The data are described as farming and farmer characteristics.

2.1 Farming characteristics

The average yield of cotton across the regions was 1,443 kg ha^{-1} with a standard deviation of 608 kg, of groundnuts 850 kg ha^{-1} with a standard deviation of 410 kg and of soybean 1,310 kg ha^{-1} with a standard deviation of 555kg. The average yield of cotton without lime was 1,186kg ha^{-1} with a standard deviation of 520 kg. This increased to 1,278 kg ha^{-1}, a rise of eight per cent, with a standard deviation of 562 kg with lime. If basal dressing was used instead, the yield increased to 1,596 kg ha^{-1}, a rise of 35 per cent, with a standard deviation of 588 kg. If both lime and basal dressing were applied, the average cotton yield increased to 1,711 kg ha^{-1}, a rise of 44 per cent over cotton without inputs, with a standard deviation of 616 kg. The coefficient of variation is 44 per cent for cotton without inputs and cotton with lime; with basal dressing, however, the proportion of standard deviation to mean declines to 37 per cent, and with lime as well to 36 per cent: so it appears that fertiliser reduces yield risk.

The average yield of groundnuts with basal dressing but without lime was 686 kg ha^{-1} with a standard deviation of 318 kg. If lime was added, the yield increased to 868 kg ha^{-1}, a rise of 26 per cent, and the standard deviation to 356 kg. The yield risk as measured by the coefficient of variation declines from 46 per cent to 41 per cent. The average yield from soybean with basal dressing but without lime was 1,283 kg ha^{-1} with a standard deviation of 556 kg. When lime was added, the yield increased to 1,337 kg ha^{-1}, a rise of four per cent, with a standard deviation of 563 kg, and the coefficient of variation declines from 43 per cent to 42 per cent. From the coefficients of variation, it appears that cotton is less risky than both groundnuts and soybean, and that risk diminishes with lime and basal dressing.

The simple average yield for cotton was highest in western region, 1,560 kg ha^{-1} with a standard deviation of 565 kg, and lowest in central with 1,344 kg ha^{-1} and a standard deviation of 561 kg. Southern had an average yield of 1,425 kg ha^{-1} with a standard deviation of 662 kg. The coefficient of variation in western is 36 per cent compared with 42 per cent in central and 46 per cent in southern, so yield risk in western appears to be lower. The groundnut yield in northern region was 969kg ha^{-1}, higher than the yield of 719 kg ha^{-1} in copperbelt. In northern, the coefficient of variation is 43 per cent compared with 51 per cent in copperbelt, suggesting yield risk is higher in copperbelt. The soybean yield in central was 1,387 kg ha^{-1}, higher than 1,275 kg ha^{-1} yield in western but the coefficient of variation of 42 per cent is lower than the 44 per cent found in the copperbelt, which is more risky.

On average farmers planted on 27 November 2002, see

Table 2; cotton and soybean farmers planted on 25 November and groundnut farmers planted on 30 November. The earliest planting was 5 November. In western region, cotton farmers planted on 18 November, in southern in 25 November and in central 2 December. Groundnut farmers planted on 26 November in copperbelt and on 4 December in northern. Soybean farmers in western planted on 18 November and in central on 11 December. The planting dates are very diverse and correlation between yield and planting date is only 0.036, not significantly different from zero, which suggests little association.

2.2 Farmer characteristics

Of the 143 participating farmers, their average age is 43.7 years with a standard deviation of 12 years, see Table 3. The median is 42 years. The youngest farmer was 20 years of age and the oldest, 80.

Eighty-two percent of the farmers were male. The expected proportion of male household heads is 76.18 per cent, which is not significantly different at the five per cent level, but it is at the ten per cent level,[6] so it is a marginal result. The distribution across crops was not even: 84 per cent of cotton farmers were male and so were 90 per cent of soybean farmers, which compares with 77 per cent of groundnut farmers.

Educational level is defined as grade level 1 to 12, 13 for college education and 16 for university education. The average educational level of the farmers is grade level 8.1 with a standard deviation of 2.9. The median is nine. Given that normal education is to grade level 12 and that the average age of maize farmers in Langmead (2004) is 7.2, these farmers were well educated. It is interesting to note that the correlation between educational level and gender is 0.184 and significant, suggesting that males tend to have better educations; and because most of the farmers were male the educational level is higher.

The average household size is 7.17 with a standard deviation of 2.8. The median is seven. The smallest household was one and the largest, 19 occupants. Households growing cotton were the largest with 7.7 occupants and those growing groundnuts were the smallest with 6.4 occupants. Soybean farmers had 7.6 occupants. The small household size of groundnut farmers appears to be associated with the copperbelt and northern regions, which have household sizes of 6.8 and 6 occupants respectively, both smaller than the other farmers' groups. Western cotton farmers had the largest households, 8.4 occupants; after the region III groundnuts farmers, southern cotton farmers had the smallest households, with seven occupants.

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[6] TEST OF MU = 0.7618 VS MU N.E. 0.7618: t = 1.74; p = 0.084

The average number of cattle owned by participating farmers is 2.7 with a standard deviation of 4.8. The largest herd owned by one farmer was 38 animals. The smallest average number of animals is 1.5, owned by groundnut farmers in copperbelt and northern regions. Cotton farmers had the most animals, an average of 3.7, which compares with soybean farmers who owned 1.9 animals. Southern cotton farmers had 5.5 animals whilst northern farmers have only 1.4.

The average number of school children is 3.6 per household with a standard deviation of 2.5. The median is three. There is little difference: cotton and soybean had 3.6 children at school and groundnut farmers had 3.5. Western cotton farmers had most children at school, 4.5, while southern cotton farmers had the fewest, three.

There is an average of 3.33 huts to a household with a standard deviation of 1.97; the median is 3. The largest compound had 11 huts. Soybean farmers had the largest compounds, 4.3 huts, followed by cotton farmers with 3.5. The smallest compounds were in the copperbelt and northern regions, and the largest were soybean farmers in Central.

The average number of bicycles is 0.97 bicycles with a standard deviation of 0.83; the median is one, which suggests most farmers have one. At least one compound had five bicycles. Both groundnut and soybean farmers had an average on one bicycle, whilst cotton farmers had unexpectedly fewer, 0.9 bicycles. The copperbelt had most bikes and northern and central soybean farmers had least.

There is an average of 6.8 hoes in the compounds with a standard deviation of 4.1; the median is six. Groundnut farmers had 6.9; cotton farmers, 6.8; and soybean farmers had 6.5. The copperbelt had the most, 8.2, and northern had the least, 5.7.

The average number of domestic fowl in the compounds is 15.3 with a standard deviation of 17.8 birds; the median is 12. Groundnut farmers had the most, 15.7; cotton farmers had the least, 13.9; and soybean farmers had 15.2 birds. Copperbelt farmers had most birds, 19; and western cotton farmers had the least, 10.8 birds.

These characteristics appear to describe the participating farmers quite well, multivariate discriminate analysis shows there is a better than average probability of correctly distinguishing between cotton, groundnut and soybean farmers, 61.5 per cent, but is less able to distinguish by region, 51.7 per cent.

The market price for cotton was ZMK 1,220 (US$ 0.27), for groundnuts, ZMK 1,000 (US$ 0.22) and for soybean ZMK 900 (US$ 0.20). The incremental costs of lime and basal dressing applications are in Table 4. The cost of four bags of lime was ZMK 18,000 (US$ 4.00) and two bags of Compound D basal dressing, ZMK 120,000 (US$ 26.67). Assuming the farmer is an average of 75 kilometres from the nearest supply centre, the cost of the return bus fare for the farmer was ZMK 18,000 (US$ 4.00) and one way for the lime and basal dressing US$ 0.89 and US$ 0.44 respectively. Town transport cost ZMK 3,000 plus US$ 0.44 and US$ 0.22 for the lime and basal dressing respectively. The farmer's opportunity cost is estimated to be ZMK 6,173 (US$ 1.37) for the one day trip at this time of year. It takes 7.9 standard man-days[7] to apply the full application of lime and basal dressing to a hectare. It is assumed that applying lime on its own, ⅔ of the physical application, takes 67 per cent of the full application time, and applying the basal dressing on its own, ⅓ of the physical application, takes 50 per cent of the full application time. The total expected cost for applying lime only is US$ 18.63, for applying basal dressing US$ 38.79 and for applying both lime and basal dressing US$ 50.21.

3. Methodology

The seemingly unrelated regression model increases the efficiency of the estimation but accommodates cross-equation error correlation and therefore needs the same number of observations in each equation. Here, cotton is 49 trials of four treatments, there are 65 groundnut trials of three treatments and soybean is 29 trials of two treatments. The yields of each crop and their variances are quantitatively different, and the farmer characteristics are described fairly well by MDA, so, if a system of equations is to be used, OLS will be relatively inefficient compared with GLS, because of inherent groupwise heteroscedasticity. The data in each equation are weighted with its associated estimated variance and iterated until the estimators converge. The GLS estimator is:

$$\hat{\boldsymbol{\beta}} = \left[\sum_g \frac{1}{\sigma_g^2}\mathbf{X}'_g\,\mathbf{X}_g\right]^{-1}\left[\sum_g \frac{1}{\sigma_g^2}\mathbf{X}'_g\,\mathbf{y}_g\right] \quad \textit{for} \quad g = 1,2,3$$

$$\textit{where} \qquad \hat{\sigma}_g^2 = \frac{\mathbf{e}'_g\,\mathbf{e}}{n_g}$$

$$\textit{for} \quad y_t = \boldsymbol{\beta}'\,\mathbf{x}_t + \varepsilon_t\,, \quad t = 1,\ldots,T$$

Yield per hectare is y_{gt} for group g and treatment t and is the dependent variable. There are three groups: y_{1t} is cotton yields, treatments $t = 1,...,196$; y_{2t} are groundnut yields, treatments $t = 197,...,391$; and y_{3t} are soybean yields, treatments $t = 392,...449$. The constant term is cotton without inputs and groundnuts and soybean with basal dressing before adjustments, so it should be positive and significant, H_0: $\alpha_0=0$;H_1: $\alpha_0>0$. There are two groups of x_t variables: the first are crops and interactions with lime and basal dressing, all dummy variables, unity and zero otherwise. Their units of measure are kilograms per hectare.

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[7] The figure is from the same data set. A standard man-day is assumed to be six hours.

$Lime_t.Cotton_t$ interaction is unity for cotton with lime and zero otherwise, and $Fertiliser_t.Cotton_t$ is unity for cotton with basal dressing and zero otherwise; the coefficients for both of these should be positive and significant. $Groundnuts_t$ and $Soybean_t$ are dummy variables that are one if they are and none if they are not, but the sign and significance of their coefficients are unclear so the hypotheses are H_0: α_n=0; H_1: $\alpha_n \neq 0$ for n=1,2. $Lime_t.Groundnuts_t$ and $Lime_t.Soybean_t$ are the interactions of the respective crops with lime[8], and the coefficients of both should be positive and significant. The hypotheses for the interactions are generally H_0: α_n=0;H_1: α_n>0 for n=3,...,6. Groundnuts are planted either in conservation farming basins or on CF permanent ridges in copperbelt and northern regions: $PermanentRidges_t$, which is in the first group of variables, is unity for and zero against: its coefficient is expected to be positive and significant because of the higher rainfalls in those regions and the hypothesis is H_0: α_7=0; H_1: $\alpha_7 \neq 0$.

Planting dates could be part of the crop groups, but rainfall is so varied across Zambia that regionalisation of the data is more appropriate. The second group of independent variables are planting dates, regions and socio-economic controls, and are independent variables for the groups of dependent variables. The planting date is the number of days after the first treatment is planted. $PlantingDate_t$ is generic for Central region and additive with $PlantingDate_t.Northern_t$, $PlantingDate_t.Copperbelt_t$, $PlantingDate_t.Western_t$ and $PlantingDate_t.Southern_t$, which are the planting dates multiplied by the dummy variables for the regions, $Northern_t$, $Copperbelt_t$, $Western_t$ and $Southern_t$, which are one for the region and zero otherwise. The units of measure for these interactions are kilograms per hectare per day; and for the regions, kilograms per hectare. The signs and significance of these variables are dependent upon their interrelationships rather than *a priori* expectations, the hypotheses are H_0: α_n=0; H_1: $\alpha_n \neq 0$ for n = 8,...,16, which are tested with the conventional t-statistic.

Also in the second group, the socio-economic variables are Age_t, $Gender_t$, $Education_t$, $HouseholdSize_t$, $Cattle_t$, $SchoolChildren_t$, $Huts_t$, $Bicycles_t$, $Hoes_t$ and $Birds_t$. The coefficients are in units of kilograms of crop per hectare per unit of the variable, but because these data are from 143 farmers and there are 449 treatments, and the number of treatments for each crop is different, the value of the coefficients will be biased and should be treated with caution. The coefficient of Age_t is in kilograms per hectare per year of age and may be positive because of experience. $Gender_t$ is a dummy variable, one for male farmers and zero otherwise and is in kilograms per hectare; the coefficient is commonly expected to show inequality favouring male farmers, but maize yield differentials have not been found in

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[8] There are no basal dressing interactions because all groundnut and soybean treatments receive basal dressing.

Zambia. The coefficient of $Education_t$ is often positive, because literate and numerate farmers can access and make use of printed extension information. $HouseholdSize_t$ may contribute to economies of scale but may also be dysfunctional with increasing size. $Cattle_t$ are commonly recognised as wealth but may be a distraction to crop farming. $SchoolChildren_t$ help to plant, weed and harvest, but they impose a cost of uniforms and school materials in Zambia, the sign and significance of the coefficient is uncertain. The number of $Huts_t$ is an indicator of wealth and is associated with age, household size and school children, its sign and significance is unclear. Although there are some *a priori* expectations, the hypotheses are H_0: $\alpha_n=0$; H_1: $\alpha_n\neq0$ for n = 17,...,26 and are tested with the conventional t-statistic.

4. Results

The constant term, which represents the average yield of cotton without inputs, and groundnuts and soybean with basal dressing before adjustments, is 1,137 kg ha^{-1} with a standard error of 185.9 kg, which is significant at the one per cent level and fails to accept its null hypothesis; see Table 5. Lime increases the average yield of cotton by 103.4 kg ha^{-1} with a standard error of 70.97 kg, which is not significant; and basal dressing increases its average yield by 421.5 kg ha^{-1} with a standard error of 70.97 kg ha^{-1}, which is, at the one per cent level: the latter fails to accept its null hypothesis. The yield of groundnuts with basal dressing is 263 kg ha^{-1} less than the estimate given by the constant term; but the difference is not significant with a standard error of 200.1 kg and so therefore fails to reject its null hypothesis. Soybean yield is 54.9 kg ha^{-1} less than average cotton yield per hectare, but is also not significant with a standard error of 129.3 kg, failing to reject its null hypothesis. Lime, however, significantly increases the yield of groundnuts by 181.5 kg ha^{-1} with a standard error of 62.8 kg ha^{-1}, which fails to accept its null hypothesis at the one per cent level. Soybean, on the other hand, does not respond significantly to lime, with an average increase 54.9 kg ha^{-1} and a standard error of 151.4 kg, failing to reject its null hypotheses. Groundnut yields rise by 127.1 kg ha^{-1} with a standard error of 62.8 kg, from using CF permanent ridges in copperbelt and northern regions rather than conservation farming basins; the result fails to accept the null hypothesis at the five per cent level.

The coefficient of $PlantingDate_t$ represents the latent effect from the planting date in central region: it is 6.75 kg ha^{-1} per day with a standard error of 4.62 kg, which is not significant and so fails to reject its null hypothesis. Copperbelt and western regions are not significantly different from central region, with coefficients of minus 1.65 with a standard error of 6.088 and minus 8.996 with a standard error of 5.975 respectively; northern yields 19.024 kg ha^{-1} per day less than central with a standard error of 6.66 kg, failing to accept its null hypothesis at the one per cent significance level; and southern yields 14.227 kg ha^{-1} more than central with a standard error of 5.638, significant at the five per cent level, so failing to accept its null hypothesis.

Northern region produced 163.7 kg ha^{-1} more than central region but the standard error is 168.4 kg and the difference is not significant, so the null hypothesis fails to be rejected. The copperbelt region dummy variable, which was highly correlated with its interaction with planting date, 0.943, was omitted from the estimation and so fails to reject its null hypothesis. Western region had average yields of 405 kg ha^{-1} more than central region with a standard error of 166.6 kg, failing to accept its null hypothesis at the five per cent level. Southern had average yields of 210.1 kg ha^{-1} less, with a standard error of 170.5 kg, which is not significant and fails to reject the null hypotheses. These results suggest, more generally, that western region has the highest cotton and soybean yields.

Of the socio-economic variables, the coefficients of education, bicycles and birds are significant. It appears that yield declines by 3.0 kg ha^{-1} per year of age with a standard deviation of 2.049 kg per, but this is not significant and fails to reject the null hypothesis. The coefficient of gender suggests the male farmers produce an average of 39.05 kg ha^{-1} more than female farmers, but the standard error of 55.02 kg means the result is not significantly different from zero, so the null hypothesis fails to be rejected. The coefficient of education is minus 20.51 kg ha^{-1} per grade level with a standard error of 8.061, which fails to accept the null hypothesis at the one per cent level. This is may be anomalous: either the high average grade level of 9.7 in copperbelt region is not reflected by reported yields and is biasing the coefficient, which seems unlikely given the sample size, or that less well-educated farmers have higher cash crop yields, which would be a subject that deserves more investigation. Since age and education are negatively correlated with yield and each other, it seems that younger less educated farmers achieve higher yields than older less educated farmers.

The coefficient of household size also fails to reject its null hypothesis with a coefficient value of minus 9.18 kg ha^{-1} per occupant and a standard error or 10.97 kg. Although not significant, the sign corresponds with Langmead (2004) and supports the idea that families may become increasingly dysfunctional with size. The cattle coefficient is minus 1.714 kg ha^{-1} per animal with a standard error of 4.708, which is not significant and fails to reject its null hypothesis; it implies that cattle may impose a cost on crop farmers, possibly from the consumption of residues. The coefficient of school children suggests that they contribute 1.79 kg ha^{-1} per child with a standard error of 12.53 kg: this is not significant, however, so the null hypothesis fails to be rejected. The number of huts appears to impose a cost of 10.1 kg ha^{-1} per hut, with a standard error of 16.38 kg, but this is not significant and the hull hypothesis fails to be rejected. With contrary sign to the finding by Langmead (2004) for maize farmers, bicycles contribute 51.6 kg ha^{-1} per bicycle with a standard deviation of

29.33 kg, which is significant at the five per cent level and fails to accept its null hypothesis. This may be because bicycles facilitate marketing of the product, which is a need less important to staple crop farmers. Another explanation is that cash crop farmers are less prone to absenteeism, which would impose a severe cost on cotton for example. Hoes appear to contribute 2.921 kg ha^{-1} with a standard error of 7.209 kg, but this is not significant and the null hypothesis fails to be rejected the sign is expected. The coefficient of birds, domestic fowl, significantly explains yields by 5.222 kg ha^{-1} per bird with a standard error of 1.173. Notwithstanding that this contradicts reports of bird damage at planting among maize farmers, it may be that cash crop farmers are more wealthy than staple crop farmers.

The expected yields from the interventions for each of the crops is in Table 6 together with the percentage and cumulated increases, benefits, costs and net benefits. Cotton without inputs yields 1,138 kg ha^{-1} with a standard error of 186 kg. Adding lime increases the yield to 1,241 kg ha^{-1} with a standard error of 199 kg, a rise of nine per cent, which, however, is not significant. Last season, 2001/02, the increase in yield due to lime on cotton in basins was ten per cent, so although this season's estimate is not significant, it appears to be in the right order of magnitude. The benefit of the increased yield is US$ 28.04 per hectare and the cost is US$ 18.63, giving a net benefit of US$ 9.40 per hectare.

Omitting the lime, but adding basal dressing instead, increases the yield to 1,559 kg ha^{-1} with a standard error of 199 kg, a rise of 26 per cent over cotton with lime and 37 per cent over cotton without inputs, which is a bit higher than last year's 44 per cent. The benefit is US$ 114.28 over cotton without inputs and the incremental cost is US$ 38.79, leaving a net benefit of US$ 75.49. If lime is added with the basal dressing, the yield increases to 1,662 kg ha^{-1} with a standard error of 211 kg, a rise of seven per cent over cotton with basal dressing and 46 per cent over cotton without inputs, which compares with 56 per cent last year. The incremental benefit is US$ 142.31 per hectare; the cost is US$ 50.21, which leaves a net benefit of US$ 92.10 per hectare.

Groundnuts were in northern and copperbelt regions and were planted either on permanent ridges or in basins. In basins, the expected yield is 875 kg ha^{-1} with a standard error of 273 kg; and, on ridges, it is 1,002 kg ha^{-1} with a standard error of 280 kg, an increase of 15 per cent that is worth US$ 28.24, assuming the land preparation cost is the same. This is close to the 16 per cent estimate of the previous season. If lime is added, the yield in basins is 1,056 kg ha^{-1} with a standard error of 280 kg, a rise of 21 per cent. The incremental benefit is US$ 40.33 with a cost of US$ 18.63, which leaves a net benefit of US$ 21.70. The yield on ridges is 1,183 kg ha^{-1} with a standard error of 280 kg, a rise of 18 per cent over ridges with basal dressing and a rise of 35 per cent over basins with basal dressing. If the farmer moves from basal dressing in basins to basal dressing and lime on ridges, the benefit is US$ 68.57, the cost remains US$ 18.63, and so the net benefit is US$ 49.94. These yield estimates appear high, higher than the average unadjusted yields: the losses are substantially due to late planting in northern region and, oddly, excessive education in the copperbelt.

Soybean with basal dressing yields 1,171 kg ha^{-1} with a standard error of 189 kg. If lime is added to this, the yield increases to 1,225 kg ha^{-1} with a standard error of 242 kg, a rise of five per cent, which is not significant and much lower than the previous season's 17 per cent. The incremental benefit is worth US$ 10.98 per hectare, the cost is US$ 18.63 and so the net loss is US$ 7.65.

5. Conclusions

Lime may increase cotton yield from basins by nine per cent and have a net benefit of US$9 per hectare but the result is ambiguous this season; however, it did produce a significant yield increase of ten per cent last year, which is in the same order.

Basal dressing increases cotton yield from basins by 26 per cent over cotton with lime and 37 per cent over cotton without inputs in the 2002/03 cropping season. Last season this was 44 per cent, so the order of the yield increase may be around 40 per cent. The net benefit this season is US$ 75 per hectare.

Basal dressing and lime increases cotton yield from basins by seven per cent over cotton with basal dressing only and 46 per cent over cotton without inputs. Last season, 2001/02, this was estimated to be 56 per cent, quite a lot more, so perhaps the order of yield benefit is around 50 per cent. The net financial benefit this season, 2002/03, is US $92 per hectare.

The yield of groundnuts with basal dressing is increased by applying lime in basins by 21 per cent and has a net benefit of US$ 22; and lime increases the yield on permanent ridges by 18 per cent and has the same net benefit.

Permanent ridges increase the yield of groundnuts with basal dressing by 15 per cent more than groundnuts with basal dressing in basins, which is similar in magnitude to the 16 per cent from the 2001/02 season, and have a net benefit of US$ 28 per hectare. Lime and permanent ridges together increase the yield of groundnuts to 35 per cent more than basins with basal dressing only. The net benefit is US$ 50.

The yield of soybean with basal dressing may increase yield in conservation farming basins by five per cent and the net loss would be around US$ 8, but the result is not conclusive in the 2002/03 season. Last season, however, there was a yield increase of 17 per cent.

The results are very strong for cotton with basal dressing and cotton with lime and basal dressing, and for lime with groundnuts, but the liming results for cotton and soybean are more ambiguous. The residual effects of lime can last for several years so they are not wholly captured in this study. It is premature to generalise conclusions about lime effects on cotton and soybean in basins.

Western region was the most productive, experiencing higher cotton and soybean yields than central, and southern region appears to be the least productive. The results from the socio-economic variables suggest that there is a difference between maize farmers and cash crop farmers. It seems that less well educated farmers achieve higher yields of cotton, groundnuts and soybean, which conflicts with Langmead (2004) who shows better educated farmers achieve higher yields of maize: it may be that less well educated farmers tend to grow cash crops in Zambia, which is an assertion that needs closer investigation. It is important to note that female farmers did not have lower yields than male farmers in conservation farming, which concurs with H&G (2003) for maize and cotton and Langmead (2004) for maize. There is increasing evidence that female farmers in Zambia do not under-perform their male counterparts. Again, in conflict with staple crop farmers, bicycles contribute to yield, perhaps by facilitating liaison with buyers and the marketing of the product; but the number of domestic fowl, also important, may reflect a more commercial nature of the farmers.

The study is important because it focuses on cash crops in conservation farming basins and on permanent ridges and not on staple crops. The performance of lime and basal dressing is generally accepted, but their use in conservation basins either in Zambia or the region has not been well examined. Also, the explanations of socio-economic variables are different to those of Langmead (2004) for maize the staple. It is reasonable to expect emergent cash crop farmers to have different characteristics from subsistence farmers, and there are hints in this study that this may be the case, but it is an area that needs more examination.

The numbers of treatments and farmers, and the study's geographic spread, make the results more reliable than the few past studies on cash crops, which contribute towards knowledge on conservation farming in Zambia and the region. It is premature to make generalisations based on only one year's data on cotton, groundnuts and soybean production and the few other studies that exist; but it is clear that there is much research to be done. The hoe conservation farming method is being promoted by a number of agencies but very little is understood about its performance either inside or outside Zambia. Most of the work that has been done has been on the cultivation of maize and, although there have been good results, poor implementation and dysfunctional behaviour have been harmful to the progress that has been made.

There are opportunities to study the performance of unassisted adopters of the hoe conservation farming model, a newly developed oxen conservation farming approach and the performance of training activities by implementing agencies at smallholder level. These methods are for the benefit of small-scale farmers, so perhaps they are best assessed by on-farm trials with the farmers themselves.

References

Aagaard, P. J. and G.D.O. Gibson (2003a): Conservation Farming in Zambia: Conservation Farming Handbook for Hoe Farmers in Agro Ecological 1 & II Flat Culture. Conservation Farming Unit, Zambia National Farmers' Union, Lusaka.

Aagaard, P. J. and G.D.O. Gibson (2003b): Conservation Farming in Zambia: Conservation Farming Handbook for Hoe Farmers in Agro Ecological Region III, the Basics. Conservation Farming Unit, Zambia National Farmers' Union, Lusaka.

Conservation Farming Unit (2002): Trials Handbook. Conservation Farming Unit, Zambia National Farmers' Union, Lusaka.

Elwell, H. (1995): An assessment of the performance of minimum tillage technologies in Zimbabwe in terms of drought risk alleviation, yields and cost-effectiveness. World Bank, Harare.

Elwell, H., D. Chiwele and S. Freudenthal (1999): An evaluation of SIDA and NORAD support to the Conservation Farming Unit of the Zambia National Farmers Union. SIDA, Lusaka.

GART (Golden Valley Agricultural Research Trust) (2001): Conservation farming general. GART Yearbook 2001, Lusaka: 50-65.

GART (Golden Valley Agricultural Research Trust) (2002): Accelerated transfer of conservation farming technologies: A concept note. Lusaka.

Haggblade, S. and G. Tembo (2003a): Conservation Farming in Zambia. In: InWEnt, IFPRI, NEPAD, CTA conference: Successes in African Agriculture. Pretoria.

Haggblade, S. and G. Tembo (2003b): Early evidence on Conservation Farming in Zambia. Submitted paper.

Langmead, P. (2000): A study on the yield and the financial and economic impacts of SCAFE and LM&CF intervations. LM&CF, Lusaka.

Langmead, P. (2001): Does conservation farming really benefit farmers?. GART Yearbook 2001, Lusaka: 58-64.

Langmead, P. (2002a): Conservation Farming technologies in Agro-ecological Region III: Results 2001/02002. Conservation Farming Unit, Zambia National Farmers Union, Lusaka.

Langmead, P. (2002b): Conservation Farming Trials' Analyses. Conservation Farming Unit, Zambia National Farmers Union, Lusaka.

Langmead, P. (2003): Conservation Farming 2002/03: preliminary results. Conservation Farming Unit, Zambia National Farmers Union, Lusaka.

Langmead, P. (2004): Hoe conservation farming of maize in agro-ecological regions IIa and III in Zambia. Submitted paper.

Oldreive. B (1993): Conservation farming for communal, small-scale, resettlement and cooperative farmers of Zimbabwe: a farm management handbook. Rio Tin Foundation, Organisation of Collective Cooperatives, Harare.

Table 1 are the sample sizes and distributions of yields by intervention, region and crop, and their coefficients of variation.

(a) Intervention

		Cotton	*Groundnuts*	*Soyabean*
No lime	n	49		
	E(x)	1,186		
	sd	*519.7*		
	CV	*44%*		
Lime	n	49		
	E(x)	1,278		
	sd	*561.7*		
	CV	*44%*		
Basal dressing	n	49	65	29
	E(x)	1,596	686	1,283
	sd	*588.4*	*318.1*	*556.3*
	CV	*37%*	*46%*	*43%*
Lime and basal dressing	n	49	65	29
	E(x)	1,711	868	1,337
	sd	*616.4*	*355.6*	*562.7*
	CV	*36%*	*41%*	*42%*
Lime and basal dressing, permanent ridges	n		65	
	E(x)		995	
	sd		*481.9*	
	CV		*48%*	

(b) Region

		Cotton	*Groundnuts*	*Soyabean*
Copperbelt	n		93	
	E(x)		719	
	sd		*365.2*	
	CV		*51%*	
Northern	n		102	
	E(x)		969	
	sd		*413.2*	
	CV		*43%*	
Western	n	60		40
	E(x)	1,560		1,275
	sd	*565.2*		*532.6*
	CV	*36%*		*42%*
Southern	n	80		
	E(x)	1,425		
	sd	*662.4*		
	CV	*46%*		
Central	n	56		18
	E(x)	1,344		1,387
	sd	*560.9*		*611.5*
	CV	*42%*		*44%*
Totals	n	196	195	58
	E(x)	1,443	850	1,310
	sd	*608.5*	*409.7*	*555.2*
	CV	*42%*	*48%*	*42%*

Table 2 is the distributions of yield, planting dates and socio-economic variables by region and crop

	Regional distributions							**Totals**		
	Copperbelt	**Northern**	**Western**		**Southern**	**Central**				
	Groundnuts	***Groundnuts***	***Cotton***	***Soyabean***	***Cotton***	***Cotton***	***Soyabean***	***Cotton***	***Groundnuts***	***Soyabean***
n	93	102	60	40	80	56	18	196	195	58
%	21%	23%	13%	9%	18%	12%	4%	44%	43%	13%
Yield	719	969	1,560	1,275	1,425	1,344	1,387	1,443	850	1,310
Planting date	26-Nov-02	4-Dec-02	18-Nov-02	18-Nov-02	25-Nov-02	2-Dec-02	11-Dec-02	25-Nov-02	30-Nov-02	25-Nov-02
Age	49.7	43.9	46.3	40.3	43.1	37.6	45.2	42.5	46.7	41.8
Gender	81%	74%	80%	95%	90%	79%	78%	84%	77%	90%
Grade	9.7	7.6	7.5	8.9	7.0	8.2	7.1	7.5	8.6	8.3
Household size	6.8	6.0	8.4	7.7	7.7	7.0	7.2	7.7	6.4	7.6
Cattle	1.5	1.4	2.2	2.0	5.5	2.9	1.8	3.7	1.5	1.9
School children	3.4	3.6	4.5	3.3	3.0	3.5	4.3	3.6	3.5	3.6
Huts	2.8	2.6	4.2	3.8	3.1	3.5	5.4	3.5	2.7	4.3
Bicycles	1.3	0.7	0.9	1.1	1.1	0.8	0.7	0.9	1.0	1.0
Hoes	8.2	5.7	7.7	6.2	5.9	7.1	7.2	6.8	6.9	6.5
Birds	19.0	12.6	10.8	14.0	14.4	16.7	18.1	13.9	15.7	15.2

Table 3 is the summary statistics of yield and planting dates, and the socio-economic factors.

	Summary statistics					
	n	**Mean**	**Median**	**StDev**	**Minimum**	**Maximum**
Yield	449	1,168	1,053	594	44	2,907
Planting date	449	27-Nov-02	29-Nov-02	14.07	19-Nov-02	5-Nov-02
Age	143	43.741	42	11.604	20	69
Gender	143	0.8182	1	0.3871	0	1
Grade	143	8.126	8	2.926	0	16
Household size	143	7.168	7	2.796	1	19
Cattle	143	2.692	0	4.85	0	38
School children	143	3.622	3	2.539	0	12
Huts	143	3.329	3	1.967	0	11
Bicycles	143	0.972	1	0.8303	0	5
Hoes	143	6.832	6	4.145	0	25
Birds	143	15.34	12	17.81	0	150

Table 4 is the cost of buying and applying lime, basal dressing, and lime and basal dressing.

Lime and fertiliser cost estimates		Price		Lime	Fertiliser	Both
US$1=ZMK4,500	No	ZMK	USD		USD	
Lime	4	4,500	1.00	4.00		4.00
Fertiliser	2	60,000	13.33		26.67	26.67
Farmer transport	2	9,000	2.00	4.00	4.00	4.00
Lime transport	4	1,000	0.22	0.89		0.89
Fertiliser transport	2	1,000	0.22		0.44	0.44
Farmer town transport	2	1,500	0.33	0.67	0.67	1.33
Lime town transport	4	500	0.11	0.44		0.44
Fertiliser town tranport	2	500	0.11		0.22	0.22
Farmer opportunity cost of town visit	1	6,173	1.37	1.37	1.37	1.37
Per cent of application cost				67%	50%	100%
Application cost	7.9	6,173	1.37	7.26	5.42	10.84
Totals				18.63	38.79	50.21

Table 5 is the results from the maximum likelihood estimation in four iterations.

Predictor	Coefficient	StErr
Constant	1137.5*	185.9
Groundnuts	-263	200.1
Soyabean	33	129.3
Lime*Cotton	103.41	70.97
Lime*Groundnuts	181.5*	62.8
Lime*Soyabean	54.9	151.4
Fertiliser*Cotton	421.54*	70.97
Permanent ridges	127.08**	62.8
Planting date	6.754	4.617
Planting date*Northern	-19.024*	6.66
Planting date*Copperbelt	-1.654	6.088
Planting date*Western	-8.996	5.975
Planting date*Southern	14.227**	5.638
Northern	163.7	168.4
Western	405**	166.6
Southern	-210.1	170.5
Age	-3	2.049
Gender	39.05	55.02
Grade	-20.51**	8.061
Household size	-9.18	10.97
Cattle	-1.714	4.708
School children	1.79	12.53
Huts	-10.1	16.38
Bikes	51.6***	29.33
Hoes	2.921	7.209
Birds	5.222*	1.173
n	449	

Table 6 is the estimated yields, the incremental percentage increase in yield, the cumulative percentage increase in yield, the incremental benefit and cost, and the net benefit.

Crop	*Intervention*	*E(yield)*	*StErr*	*Incr. %*	*Cum. %*	*Benefit*	*Cost*	*Net benefit*
Cotton	None	1,138 kg	186 kg					
	Lime	1,241 kg	199 kg	9%	9%	$ 28.04	$ 18.63	$ 9.40
	Fertiliser	1,559 kg	199 kg	26%	37%	$ 114.28	$ 38.79	$ 75.49
	Lime and fertiliser	1,662 kg	211 kg	7%	46%	$ 142.31	$ 50.21	$ 92.10
Groundnuts	Fertiliser in basins	875 kg	273 kg					
	Lime and fertiliser in basins	1,056 kg	280 kg	21%		$ 40.33	$ 18.63	$ 21.70
	Fertiliser on ridges	1,002 kg	280 kg		15%	$ 28.24	$ -	$ 28.24
	Lime and fertiliser on ridges	1,183 kg	280 kg	18%	35%	$ 68.57	$ 18.63	$ 49.94
Soyabean	Fertiliser	1,171 kg	189 kg					
	Lime and fertiliser	1,225 kg	242 kg	5%		$ 10.98	$ 18.63	$ (7.65)