The impact of conservation farming basins on maize yields and soil pH over time in a three-year rotation

Introduction

The objective is to establish whether the observed increases in maize yields over time are real, in plots demonstrating conservation farming basins and a three-year rotation including maize, cotton and a legume, and if so, whether they can be explained by farmer experience or to increasing pH individually or jointly.

Data

The average maize yield on 110 demonstration plots in Southern, Western and Central regions in the 2002/32 season was 4,659kg ha^{-1} with a standard deviation of 2,310kg. The median is 4,427kg ha^{-1}, a little lower, suggesting a positive skew to the distribution, which indicates some farmers had higher yields than normally expected. The lowest yield was 536kg ha^{-1} and the highest 11,186kg ha^{-1}. The average pH from 191 samples taken in the fields and on the edge of the fields was 5.01 with a standard deviation of 0.73. The median is a little lower, 4.98, suggesting a fairly normal distribution. The lowest pH in the data is 3.8 and the highest 7.24.

Table 1 shows the summary yield and pH statistics for demonstration plots held in Central, Western and Southern regions.

	Demonstration plots					
	n	**Mean**	**Median**	**StDev**	**Minimum**	**Maximum**
Yield	110	4,659kg	4,427kg	2,310kg	536kg	11,186kg
pH	191	5.0131	4.98	0.7279	3.8	7.24

Table 2 shows the distributions of maize yields from the demonstration plots in each region. The mean yield in Western region was 6,752kg ha^{-1} with a standard deviation of 2,059kg, in Southern region 3,559kg ha^{-1} with a standard deviation of 1,824kg, and in Central region, 4,214kg ha^{-1} with a standard deviation of 1,370kg. There is significant difference between the yields, and it can be clearly seen that the yields in Western region are much higher than the other regions, but it is less clear whether the yield of Southern region is in fact significantly lower than that in Central province, although with the larger sample size it seems likely.

Table 2 shows the distributions of maize yields from the demonstration plots in each region.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
Region      2 221675360 110837680    32.94    0.000
ERROR     107 360048224   3364937
TOTAL     109 581723584
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -----+---------+---------+---------+-
Western    34      6752      2059                            (----*----)
Southern   57      3559      1824   (---*---)
Central    19      4214      1370     (------*------)
                                   -----+---------+---------+---------+-
POOLED STDEV =     1834              3600      4800      6000      7200
```

Table 3 shows the distributions of maize yields at difference trial ages. In the first year, 41 new farmers had an average yield of 3,490kg ha^{-1} with a standard deviation of 1,451kg. The 12 second-year farmers had a higher average yield of 4,590kg ha^{-1} with a standard deviation of 1,602kg. The 13 third-year farmers however, had a lower average yield of 3,872kg ha^{-1} than the previous year with a standard deviation of 2,989kg. The 11 fourth-year farmers had a mean yield of 6,286kg with a standard deviation of 2,735kg. The average yield of 15 fifth-year farmers was lower, 5,522kg ha^{-1} with a standard deviation of 2,418kg. The nine sixth-year farmers had an average yield of 6,577kg ha^{-1} with a standard deviation of 2,155kg; and the nine seventh-year farmers had average yield of 5,872kg ha^{-1} with a standard deviation of 1,479kg. The yields appear to be increasing over time and a simple test fails to accept the null hypothesis that the means are all the same.

Table 3 shows the distributions of maize yields at difference trial ages.

```
ANALYSIS OF VARIANCE ON Yield
SOURCE     DF        SS        MS        F        p
TrialAge    6 150781920  25130320     6.01    0.000
ERROR     103 430941664   4183900
TOTAL     109 581723584
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
     1     41      3490      1451   (---*---)
     2     12      4590      1602       (-------*------)
     3     13      3872      2989  (-------*------)
     4     11      6286      2735                 (-------*-------)
     5     15      5522      2418             (------*------)
     6      9      6577      2155                  (--------*--------)
     7      9      5872      1479             (--------*--------)
                                   --+---------+---------+---------+----
POOLED STDEV =     2045            3000      4500      6000      7500
```

Table 4 shows the distributions of pH levels from the maize plots of the demonstrations and from the edge of the field. The average pH on the edge of the field is 4.93 with a standard deviation of 0.68; but in the maize part of the demonstration plot, the average pH is 5.10 with a standard deviation of 0.77: which is seemingly higher but not quite significantly, according to the simple F-test.

Table 4 shows the distributions of pH levels from the maize plots of the demonstrations and from the edge of the field.

```
ANALYSIS OF VARIANCE ON pH
SOURCE     DF        SS        MS        F        p
pH          1     1.430     1.430     2.72    0.101
ERROR     189    99.239     0.525
TOTAL     190   100.669
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
Edge       95    4.9261    0.6793   (--------*---------)
Maize      96    5.0992    0.7669             (---------*---------)
                                   --+---------+---------+---------+----
POOLED STDEV =   0.7246            4.80      4.95      5.10      5.25
```

Table 5 shows the distributions of pH by trial age. First year farmers have an average pH of 4.94 with a standard deviation of 0.93. Second year farmers have an average pH of 5.45 with a standard deviation of 0.81. Third year farmers have an average pH of 4.96 with a standard deviation of 0.63. Fourth year farmers have an average pH of 5.08 with a standard deviation of 0.85. Fifth year farmers have an average pH of 4.97 with a standard deviation of 0.64. Sixth year farmers have an average pH of 5.38 with a standard deviation of 0.41. And seventh year farmers have an average pH of 5.42 with a standard deviation of 0.90. Apart from second year farmers who seem to have better soil than the average, there may be an upward trend in the pH levels of the soils, but the analysis of variance fails to reject the null hypothesis that the mean yields from the different trial ages are the same.

Table 5 shows the distributions of pH by trial age.

```
ANALYSIS OF VARIANCE ON pH
SOURCE     DF        SS        MS        F        p
TrialAge    6     3.914     0.652     1.05    0.402
ERROR      80    49.888     0.624
TOTAL      86    53.802
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --------+---------+---------+--------
     1     24    4.9400    0.9305     (-------*--------)
     2     11    5.4482    0.8099              (-----------*-----------)
     3     12    4.9633    0.6283   (----------*----------)
     4     10    5.0770    0.8494    (------------*-----------)
     5     13    4.9654    0.6420   (----------*----------)
     6      8    5.3775    0.4084           (------------*-------------)
     7      9    5.4178    0.8990            (------------*-------------)
                                   --------+---------+---------+--------
POOLED STDEV =   0.7897                  4.80      5.20      5.60
```

Table 6 shows the results from a general linear model. The regional differences remain significant, and a little bit stronger, from an F-statistic of 32.94 to 56.59. The trial age also remains significant after taking account of the regional and pH impacts, but increases slightly from an F-statistic of 6.01 against 6,103 degrees of freedom (p=0.000) to 6.08 against 6,137 degrees of freedom (p=0.000). The slopes of yield against pH are not jointly or individually significantly different from zero, which means that yields are not a function of farmer management ability on a day to day basis. This means that yields differ with trial age after taking account of the effects of pH. The result suggests that the more experienced farmers have with conservation farming basins, the higher the yields.

Table 6 shows the results from a general linear model.

F-test with denominator: Error
Denominator MS = 3659214 with 137 degrees of freedom

Numerator	DF	Seq MS	F	P
Region	2	1.11E+08	56.59	0.000
TrialAge	6	11890684	6.08	0.000
pH(1)(TrialAge)	7	2245422	1.15	0.344

Figure 1 shows plots of maize yields at different trial ages. The ages sequence is black, red, green, blue, cyan, magenta and yellow. The adjusted average maize yield for the first year farmers is 4,631kg ha^{-1} with a standard deviation of 351kg. The second year farmers yield 4,403kg ha^{-1} with a standard deviation of 585kg, which is significantly different from first year farmers at a ten per cent level[1]. The third year farmers yield 4,181kg ha^{-1} with a standard deviation of 524kg, which is also not significantly different from the first year farmers[2]. The yield of the fourth year farmers is 5,968kg ha^{-1} with a standard deviation of 550kg, which is significantly different from the first year farmers[3]. The fifth year farmers yield 6,604kg ha^{-1} with a standard deviation of 511kg, also different from first year farmers at a ten per cent level of significance[4]. The sixth year farmers yield 6,881kg ha^{-1} with a standard deviation of 708kg, which continues to be different from first year farmers[5]. The seventh year farmers' yield is 6,700kg ha^{-1} with a standard deviation of 567kg, which also continues to be significantly different from first year farmers[6]. The increased yield from 4,631kg ha^{-1} to 6,700kg ha^{-1} is an annualised yield growth rate of 6.16 per cent.

[1] F=2.4534, p=0.0747

[2] F=0.0544, p=1.6583

[3] F=17.7413, p=0.0000

[4] F=18.0016, p=0.0000

[5] F=12.1082, p=0.0004

[6] F=10.1125, p=0.0010

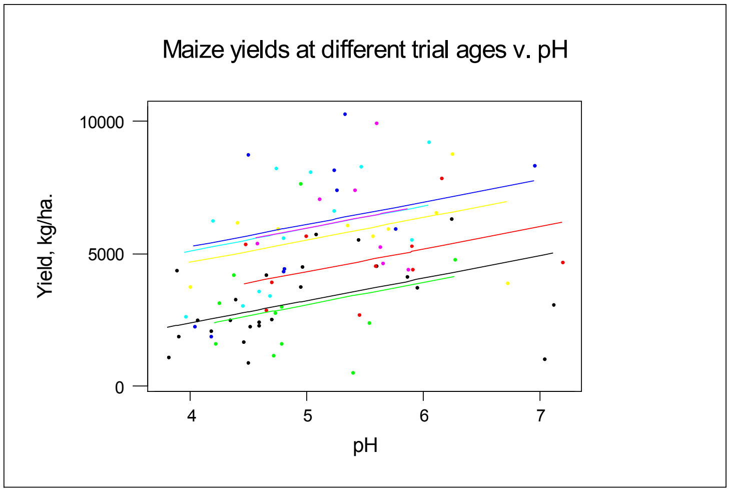

Figure 1 shows plots of maize yields at different trial ages. The ages sequence is black, red, green, blue, cyan, magenta and yellow.

Table 7 shows the regression results from the yield on pH and trial age. The constant is not significant. The pH coefficient is significant with a t-statistic of 3.27 and suggests that the average maize yield is 869kg ha^{-1} for every pH unit of the soil. The trial age coefficient is also significant, with a t-statistic of 4.87 and suggests that for each year the farmer has practiced conservation farming basins, he increases his yield by 499kg ha^{-1}. Since the pH level is taken account of, the increased yield with time is explicitly due to farmer experience and rather than improved pH levels. The model predicts that a farmer with a pH of five who has been practicing conservation farming for three years will have a yield of around k5,837kg ha^{-1}.

Table 7 shows the regression results from the yield on pH and trial age.

```
The regression equation is
Yield = - 974 + 868 pH(1) + 499 TrialAge

Predictor        Coef       Stdev    t-ratio        p
Constant         -974        1364      -0.71    0.477
pH(1)           868.0       265.5       3.27    0.002
TrialAge        498.8       102.4       4.87    0.000

s = 1923         R-sq = 32.7%     R-sq(adj) = 31.0%
```

Table 8 shows the regression results from pH on trial age. The constant is significant at a pH of 4.99 with a t-statistic of 37.00. The age of the trial does not appear to have any impact on the pH level, which means that conservation farming basins have not yet demonstrated an ability to improve the quality of the soil. There are several caveats about this finding: first, there was a change of scale of demonstration plots in the 2001/2, which means that many of the demonstrations may not have had the same number of years under conservation farming cultivation that the farmers have practiced. This is consistent with the finding above that farmers gain experience. Second, although the coefficient is not significant, there may have been sufficient information in the data for the quantity to be in the right order, suggesting that pH may be increasing by around 0.046 per year. If this is the case, then it will take 43.5 years to bring a pH of five to neutrality.

Table 8 shows the regression results from pH on trial age.

```
The regression equation is
pH(1) = 4.99 + 0.0463 TrialAge

Predictor       Coef       Stdev    t-ratio        p
Constant      4.9930      0.1349      37.00    0.000
TrialAge     0.04634     0.04254       1.09    0.279

s = 0.8048      R-sq = 1.4%      R-sq(adj) = 0.2%
```

Conclusions

1) There is an annualised maize yield growth rate of 6.16 per cent.

2) The annual increase in yield is due to increasing farmer experience.

3) There is little evidence to support the belief that pH levels are rising over time either due to the usage of lime or conservation farming cultivation.