EVALUATION OF THE 2008/9 AGRICULTURAL INPUT SUBSIDY PROGRAMME, MALAWI

Maize Production and Market Impacts

May 2010

Andrew Dorward and Ephraim Chirwa

1. Introduction

Impacts of the subsidy programme on maize yields and production are critical for programme benefits, and hence estimating these impacts is critical for economic cost benefit evaluation of the programme. Increases in production result from the yield response to incremental fertiliser use as a result of the programme, and lead to changes in average maize yields. These, together with any changes in crop areas, lead to changes in total maize supply from smallholder production. This in turn affects smallholder maize consumption, the balance between overall maize supply and demand in the country, and maize prices. This report presents information on these elements in the maize system in attempting to develop a consistent understanding of programme production and other impacts. We begin from an examination of historical changes in maize prices and supply to provide a context for examination of changes in maize yields and production, which in turn informs estimation of the yield response to and incremental production from the subsidy programme.

2. Maize prices and supply, 1993/94 to 2008/9

Figure 1 (overleaf) shows estimated domestic maize consumption (MoAFS crop estimates plus net imports less net official cross seasonal storage) and real (monthly) maximum and mean prices in 1990MK/kg and US$/kg[1]. Subsidy years (shown as triangles) are labelled by year.

The four graphs show broadly similar features:

- There is wide variation in estimated per capita consumption per year
- Inspection suggests that for data up to and including the 2005/6 harvest (2006/7 marketing year) there is some evidence of a negative relationship between per capita supply and prices in three of the graphs (with mean and maximum price in US$, and with maximum price in 1990 MK) and this is borne out by linear and logged regression estimates (these all have R squared values more than 0.25, with 0.36 for the US$ maximum prices data set). If the last three years data are included then the R squared values drop to below 0.12.
- Higher than expected mean prices relative to supply are observed in two subsidy years (2007/8 and 2008/9) and higher than expected maximum prices are also observed for those two years and for 2006/7.

Overall these graphs suggest some consistency in maize supply estimates up to the 2006/7 market season and if these are correct in absolute as well as relative terms then they suggest significant elasticity of demand within Malawi. The analysis is significant in raising questions about the accuracy of the 2007/8 and 2008/9 crop production estimates (and to a lesser extent about the 2006/7 estimates) and in suggesting limits on the volumes of production in the subsidy years, and hence on subsidy programme impacts on maize production.

---

[1] Estimates of estate production and livestock feed are excluded as they are relatively small and unlikely to change sufficiently to affect the broad pattern shown,

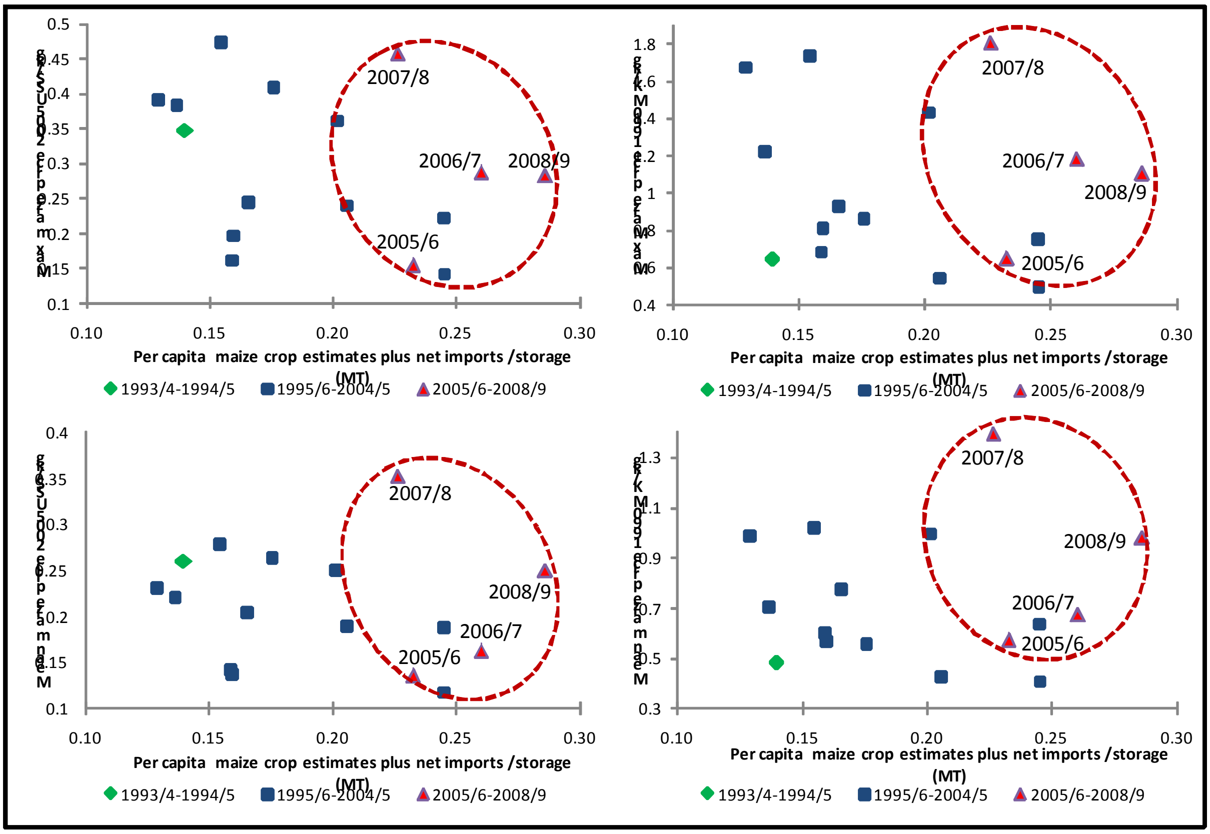

Figure 1. Maize prices and estimated per capita maize supplies, 1991/92 to 2008/9

Sources: MoAFS (2008), FEWSNet/ MoAFS price data, other sources as for table 1, based on NSO (2009) population data

3. Maize prices and supply, 1993/94 to 2008/9

We now take this analysis further with more specific analysis of alternative national supply and demand 'budgets' using different estimates of yield and associated demand.

Table 1 presents alternative low, medium and high maize production and consumption scenarios. For each scenario three different population estimates are introduced (a 'low' estimate from 2008 census, a 'medium' estimate and a 'high' estimate using 2008/9 MoAFS figures). For each production scenario a budget for total supply (including estates and net imports estimated from historical information) is built up, and a budget for total consumption (using low estimates of per calorie consumption and high importance of maize in accordance with low nutritional status of many in Malawi and relative cultivated areas under maize), with higher consumption under conditions of higher production and lower prices. Imports, and official exports are also included and vary with production. Smallholder yields that provide balanced national supply and demand consistent for each scenario are shown in italics the first row of the table.

The main points to note from this table are that yields under the low production scenario are estimated at around 650kg/ha, under the medium scenario at around 860kg/ha, and under high production scenario at around 1,150kg/ha. These represent, under constant hectarage under maize, increases in total smallholder production of around 550,000MT from the low to the medium scenario and 695,000MT from the medium to the high scenario. It should be noted that the high scenario allows for 200,000MT going into formal and informal inter-seasonal storage or export. If this is an over (under) estimate then yields and incremental smallholder production under this scenario would be lower (higher) than estimated here for the market is to clear with the same consumption levels.

Yields presented in table 1 are considerably lower than those estimated in more recent national crop estimates (from 2005/6 onwards) as shown in table 2. They are also considerably lower than yields of around 1450 kg ha and 1774 kg/ha estimated by Holden and Lunduka (2010) for smallholder local and hybrid maize over the 2006 to 2009 harvests. Smallholder maize areas in the national crop estimates are, however, also much lower. As table 2 shows, these lead to estimates of maize area per household which are much lower than the 0.89 ha/household estimated in the 2008/9 household survey, even with the 'low' population estimates used in table 2 (areas per household would be much lower with MoAFS estimates of household numbers).

These observations raise serious questions about the validity of these various figures: if the maize yield figures in table 1 are too low (as suggested by MoAFS crop estimates) then either the maize areas must be too high or the consumption estimates must be too low. If the consumption estimates are broadly correct, then it would also seem that from 2006/7 either the MoAFS yields or areas must be too high, particularly given the high prices from 2007/8.

Further examination of table 2 shows that over the four years shown, starting with the year before the introduction of the subsidy programme, maize yields have increased dramatically due to (a) higher yields for all maize varieties (with a more than doubling of composite yields and near doubling of hybrid yield) and (b) a declining proportion of local maize in the total maize area. The increases in yield are accompanied by a modest increase in total maize area.

Table 1 National Maize production and consumption budgets, 2008/9

Production Scenario	Low yield			Medium Yield			High yield		
Farm hh (million)	Low (NSO) 2.50	Medium 3.09	High (MoAFS) 3.67	Low (NSO) 2.50	Medium 3.09	High (MoAFS) 3.67	Low (NSO) 2.50	Medium 3.09	High (MoAFS) 3.67
PRODUCTION									
Yield (kg/ha)	*680*	*655*	*640*	*915*	*865*	*830*	1,215	1,130	1,060
area maize/household (ha)	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Total area (million ha)	2.22	2.74	3.26	2.22	2.74	3.26	2.22	2.74	3.26
Production/hh (kg)	604	582	568	813	768	737	1,079	1,004	941
Total Smallholder Production (million MT)	1.51	1.79	2.09	2.03	2.37	2.71	2.70	3.10	3.46
Estate production (million MT)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total production (million MT)	1.66	1.94	2.24	2.18	2.52	2.86	2.85	3.25	3.61
TRADE									
Informal imports (million MT)	0.15	0.15	0.15	0.10	0.10	0.10	0.04	0.04	0.04
Formal imports /out of store (million MT)	0.13	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Formal exports/ into store (million MT)	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20
Net imports / out of store (million MT)	0.28	0.28	0.28	0.10	0.10	0.10	-0.16	-0.16	-0.16
TOTAL SUPPLY after smallholder storage losses	1.71	1.96	2.20	1.92	2.21	2.48	2.15	2.47	2.76
TOTAL SUPPLY per capita (MT)	0.13	0.13	0.13	0.15	0.15	0.15	0.16	0.16	0.16
TOTAL SUPPLY before losses & estates	1.79	2.07	2.37	2.13	2.47	2.81	2.54	2.94	3.30
TOTAL SUPPLY per capita (MT) (see figure1)	0.14	0.14	0.14	0.16	0.16	0.17	0.19	0.20	0.20
CONSUMPTION									
Total population (million)	13.07	14.99	16.91	13.07	14.99	16.91	13.07	14.99	16.91
Human Consumption (million MT)	1.68	1.93	2.17	1.88	2.16	2.44	2.10	2.41	2.72
Add brewery / animals (million MT)	0	0	0	0	0	0	0	0	0
Total consumption (million MT)	1.71	1.96	2.20	1.92	2.20	2.48	2.15	2.46	2.77
Assumptions:									
smallholder storage losses	15.0%			17.5%			20.0%		
Kg maize/person /day:	0.35			0.40			0.44		
kcal/person/day:	1,800			1,950			2,100		
kcal/kg maize:	3,578			3,578			3,578		
% kcal from maize:	70.0%			72.5%			75.0%		

Sources: NSO (2009), Carr (pers comm.), (Jayne et al 2010), AISS2 survey estimates

Table 2 National Smallholder Maize Crop Estimates, 1991/92 to 2008/9

Source: MoAFS (2008)

		Total				Per household			
		2004/5	2005/6	2006/7	2007/8	4/5	5/6	6/7	7/8
Maize yield (kg/ha)	Local	518	877	3,638	866				
	composite	888	1,802	2,132	1,767				
	Hybrid	1,331	2,486	2,965	2,472				
	all	809	1,608	2,655	1,650				
Maize area (ha)	Local	768,605	654,176	164,731	559,912	0.34	0.28	0.07	0.23
	composite	372,703	545,553	585,486	587,041	0.17	0.24	0.25	0.24
	Hybrid	372,621	424,301	465,139	450,002	0.17	0.18	0.20	0.19
	all	1,513,929	1,624,030	1,215,356	1,596,955	0.68	0.71	0.51	0.66
	'% change	2%	7%	-25%	31%	-0.4%	4%	-27%	28%
Production (MT)	local	398,137	573,712	599,291	484,884	0.16	0.23	0.24	0.19
	composite	330,960	983,087	1,248,256	1,037,301	0.13	0.40	0.50	0.42
	hybrid	495,959	1,054,812	1,379,137	1,112,405	0.20	0.43	0.56	0.45
	all	1,225,056	2,611,611	3,226,685	2,634,590	0.50	1.06	1.30	1.06

4. Yield estimates, 2008/9

The 2006/7 evaluation failed to obtain yield information that was sufficiently reliable for the estimation of fertiliser and seed effects on yield and production, and attempts to estimate these effects from the IHS2 data were also unsuccessful. In the design of the field work for the current evaluation, two approaches were taken to attempt to obtain better quality information on maize yields: utilisation of the same method of yield estimation with attempts to improve the quality of enumeration through more stringent training and management, and the use of yield sup plots to gather an alternative source of yield information for a sub sample of farms.

Table 3 sets out the main features of these two approaches as regards methodologies and potential sources of estimation errors inherent in each approach.

Four different types of potential sources of estimation errors are considered in Table 3:

- random errors which are not likely to introduce bias,
- errors which may introduce bias in the results but the nature of that bias cannot be predicted,
- errors which are likely to introduce positive bias (that overestimates yield and yield effects of different crop management practices), and
- errors which are likely to introduce negative bias (that underestimates yield and yield effects of different crop management practices).

For each potential source of estimation errors, means of reducing this are listed. These involve specific attention in survey design, in enumerator training and supervision, and in analysis.

Table 3 Yield estimation approaches and their errors and bias

Approach	Farmer report on whole field harvest		Measurement of yield from 50m^2 yield sub plots	
Methods	Yield is calculated from farmer reports of estimated harvest from each plot (measured in units defined by the farmer) divided by farmer estimates of the area of the plot (measured in units defined by the farmer). Applied to all plots cultivated by all sample farmers. Total sample size of just under 2,000 maize plots with valid yield, fertiliser and other crop management data (the precise number varies with management variables considered).		Yield is harvested & weighed from a 50m^2 yield sub plot (the ysp). The ysp is marked out by enumerators in the middle of the season for one maize plot for each of a subsample of farmers. Yield is harvested either by the farmer or by the enumerator & recorded by the enumerator. Total sample size of 90 & 579 maize plots harvested by enumerators & farmers respectively, 78 & 520 respectively with valid data (on yield, fertiliser and other crop management data).	
Possible errors	*Description*	*Possible remedial action*	*Description*	*Possible remedial action*
Principal sources of random errors	• Enumeration quality, farmer estimates of area & harvest • Small plots may have high % errors.	Survey & questionnaire design. Enumerator training & supervision Remove small plots from analysis	• Enumeration quality • Small sample size • Within field variability • Farmer plot area estimates affect fertiliser rate estimates	Survey & questionnaire design. Enumerator training & supervision Can gather more information specific to YSP management
Principal sources of errors with possible but unknown bias	• Correlation between variables (eg seed type & fertiliser) may bias estimates of their impacts	Selection of variables & estimation methods	• Correlation between variables (eg seed type & fertiliser) may bias estimates of their impacts	Selection of variables & estimation methods
Principal sources of errors with possible positive bias (overestimate yield & yield effects)			• Enumerators may not site ysps randomly in parts of plot with low yield. • Farmers may include harvest from outside ysp • Fertiliser response may be overestimated with plot areas & fertiliser application rates over- and under-estimated respectively	Enumerator training & supervision Estimate separately for enumerator & farmer harvest Use alternative plot area estimation methods – eg GPS
Principal sources of errors with possible negative bias (underestimate yield & yield effects)	• Farmers may under report harvest due to harvesting of green maize, storing/ consuming &/or selling in small & non standard units, or very full bags. Likely bias (underestimate) in harvested units • Over estimate of plot areas	Enumerator training, supervision & interviewing Improve estimates of conversion coefficients for farmer units, estimate separately for different harvest units Use alternative plot area estimation methods – eg GPS		

4.1 Results : yield estimates

Table 4 provides estimates of yields and management variables from the different methods. It should be noted that the selection of plots for the siting of yield subplots was done purposively in order to provide a sample that had a mix of plots of different varieties and fertiliser application rates, and simple sample means can therefore be misleading. A number of features of table 3 are noteworthy: yields estimated from farmer whole plot reporting are very low, seed rates are a little low, but fertiliser rates are within the range one might expect, though much lower than the mean for 210kg/ha reported by Holden and Lunduka (2010) for six districts in Central and Southern Malawi in 2008/9. Estimates of fertiliser rates, yields and fertiliser response are all higher when enumerator measures of plot area are used, and are more consistent the maize budgets discussed earlier and with Holden and Lunduka (2010) who used GPS for measurement of plot areas. From the yield subplots, all yields are higher than might be expected from the earlier analysis s of table 1 (and in reports such as the Poverty Vulnerability Assessment) but are more consistent with MoAFS crop estimates . Farmer harvested yields are consistently above enumerator harvested yields (on the sample as a whole by 25%). Plant density measured by counting the plants within yield sub plots is also above what would be expected on smallholder fields, although more widespread adoption of the 'Sasakawa method' of single plants per hole is leading to increasing plant populations.

Table 4 Descriptives

		Farmer reported whole plot harvest[2]		Yield sub plot harvest		
		Farmer reported area	Enumerator measured area	Farmer harvest	Enumerator harvest	All
Yield (kg/ha)	Local	540	998	2,085	1,546	2,007
	Hybrid	860	1,502	3,049	2,518	2,978
	All	672	1,216	2,541	1,999	2,468
Seed rate (kg/ha)		17		N/A	N/A	N/A
Fertiliser rate (kg/ha)		96	191	N/A	N/A	N/A
Plant density (plants/ha)		N/A	N/A	N/A	N/A	33,930
Number of weedings		1.74	N/A	N/A	N/A	N/A
Total plots sampled		2,148	535	579	90	669

Source: AISS2 household survey

The existence of considerable bias in the low farmer reported yield estimates is supported by our earlier analysis of national maize budgets, where yields of 670 kg/has were only expected in a poor year, but in a good year (such as 2008/9) average yields of up to 1,125kg/ha might be expected, nearly 70% more than the estimate of 670kg/ha. As noted in table 3, possible reasons for such bias are unrecorded harvesting of green maize, unwillingness to fully report harvested amounts for social and other reasons, under estimates of grain in '50kg' bags (which were the dominant unit of measure for reporting harvests and the only units used in calculating yield estimates)[3], and farmers reporting harvests in shelled bags before they have shelled it, and where they do shell and store maize in bags then these bags may be overfilled. Yields might also be low as a result of farmers over-

[2] Weighted by plot area and household sampling weights. For plots with harvests recorded in 50kg bags. Enumerator measured area only for plots with yield sub plot.

[3] Standard NSO conversion rates were used, but it was noted that the median reported price of maize sales was 30% higher for sales in bags as compared with sales per kg

estimating plot areas. This is consistent with revised estimates using the admittedly rough plot area measurements by enumerators on plots where yield sub plots were sited, with the lower fertiliser rates reported (as compared with the study by Holden and Lunduka) and with low seed rates, but would have significant implications for statistics on farm sizes and cultivated areas.

Enumerator harvesting of yield sub plots should provide reliable information on yields, apart from the widely reported tendency for siting and harvesting of yield sub plots to avoid parts of fields with very low plant densities and yields, which is reported to lead to upward bias of 10 to 30% (Poate and Daplyn). This is consistent with the reported plant density, which is somewhat higher than expected. If there is a 10% (20%) yield increase due to sample bias, then adjusted estimates of yields from enumerator harvesting will be 1,405, 2,290 and 1,817 kg (1,288, 2,098 and 1,665 kg) for local maize, hybrid maize and all maize plots, respectively. The average of just over 1,800kg/ha (1,665) average yield is considerably higher (50 to 60%) than the yield of around 1,125 kg/ha estimated under the high production scenario in table 2. Applying the same adjustment to plant density gives an estimate of just over 30,845 (28,275) plants per ha. Similar issues apply to the farmer harvested yield subplot estimates, but further allowance is needed here to allow for errors in harvesting and recording the sub plot yield, and comparing the mean enumerator and farmer harvest yields suggests a reduction of 20% on the combined sample yield.

Comparing the two approaches, each has different advantages and disadvantages. The 'Farmer report on whole field harvest' approach allows a large sample size which provides more flexibility and more degrees of freedom in analysis, but there are inherent difficulties from reliance on farmer estimates of area and harvest, both likely to introduce negative bias (and underestimate yield and yield effects of crop management practices[4]). The 'measurement of yield from 50m^2 yield sub plots' approach is restricted to a much smaller sample size, due to the time demands on enumerators, but has more measurement under the control of enumerators with standard measures (of yield sub plot area, of weighed shelled grain harvest). However it is well documented that these often introduce some positive bias, though comparison with the earlier analysis of national maize budgets suggests a very high bias.

In addition to survey design and implementation and enumerator training and supervision that paid attention to these issues, these issues were also addressed in survey analysis as we now discuss.

4.2 Estimated yield responses to fertiliser and seed

Both the farmer reported whole plot harvest and the yield sub plot data sets were used to estimate yield responses to a variety of crop management and other variables: fertiliser rate (kg Nitrogen per ha), plant density or seed rate, number and time of weedings, rainfall measured in septades at different maize growth stages (determined by locality and planting date), use of organic fertiliser . Within each data set, different functional forms and a variety of regression equations were investigated. A Cobb Douglas function was tried but found not to give as good a fit to the data as linear regression with a quadratic function for fertiliser use and with interactions of fertiliser rates and plant population with each other and with other variables. Adjusted R squared values were generally low (up to 0.165 for regressions with yield sub plot data and up to 0.242 a larger sample of farmer harvest estimates)as is common with cross sectional data of this type.

Multicollinearity between variety and fertiliser use, and also between these and other management variables, makes it very difficult to isolate the separate effects of each variable. Tables A1, A2 and A3 in the appendix show different regression equations estimated for each data set. Unexpected results in table A1 (using data from farmer reported whole plot harvest and yields) should be noted,

[4] Negative bias is likely because of (a) likelihood of over filling bags and (b) difficulties in identifying total harvest when there is (1) sequential harvest with (2) different people involved and (3) storing, consuming or selling in small and non standard units. Together these may lead to under reporting (these are problems of non-registered and continuous data types – see Lipton M and Moore M, 1972) . Biased scales at sales may also lead to under recording.

as regards a negative interaction between hybrid seed and fertiliser (with a very high estimated response to hybrid seed in the absence of fertiliser), and a positive quadratic term for fertiliser use. Comparing the three models in table A1, the first includes a wide range of variables, many with very high p values, the latter two eliminate some of these variables. In all models there are problems in isolating the effects of particular variables due to multicollinearity between them.

Results in table A2 are more in line with expectations as regards a positive interaction between hybrid seed and fertiliser (with a lower estimated response to hybrid seed in the absence of fertiliser), and a negative quadratic term for fertiliser use. As in table A1, the first model includes a wide range of variables, many with very high p values, the latter two eliminate some of these variables, and there are again multicollinearity problems in isolating the effects of particular variables. It was not possible to estimate yields for OPV as very few farmers reported use of OPVs.

Table A3 presents the results of regressions carried out on plots where yield sub plots were laid and enumerators made rough measurements of plot areas by pacing and counting and measuring ridges. The sample size is restricted (similar to the sample size for models presented in table A2). The enumerator estimates of plot areas were used to revise the rate of fertiliser use across plots. Enumerator estimates of plot area were on average some 30% lower than farmers' estimates, with the result that estimated yields are on average some 60% higher and fertilisers rates some 50% higher. The use of the smaller plot areas leads to a considerable reduction in the fertiliser response rate in the YSP models but does not have a substantial effect on the famer reported whole plot harvest models (as both yield and fertiliser rate are adjusted upwards in the latter case, but only fertiliser rate, not yield, is adjusted upward in the former case).

Despite the multicollinearity difficulties, major points to note from these tables are

- All model estimations show yields and responses to fertiliser varying with crop management (in terms of planting date, number of weedings, time of fertiliser application). Programme effectiveness and efficiency can therefore be improved by measures that improve these aspects of crop management – for example by early delivery of subsidised inputs and by improved extension services.
- All models show that rainfall has important impacts on yields and on fertiliser response.

Responses to fertiliser and the effects of hybrid as opposed to local varieties can be estimated from these models under farmers' average management regimes. There are however difficulties in this as a result of (a) multicollinearity which may lead to under- or over-estimation of responses to particular variables, and (b) the overall yield biases discussed earlier which suggest that all model coefficients should have adjustment factors applied to address these biases.

Table 5 shows different estimates of average returns to fertiliser use from these models. For the models developed using farmers' estimates of plot areas, adjustment factors bring average yields in table 5 roughly in line with those in the high production scenario in table 1. For the models developed using enumerator estimates of plot area no attempt is made to make the yields match with the analysis in table 1, as if farmers' plot area estimates are consistently and significantly upwardly biased then this calls into question the results from IHS and other surveys which have estimated household cultivated areas based on farmer recall.

Table 5 Yield responses to fertiliser (kg grain/kg N) and to hybrid seed without fertiliser (base hybrid gain, kg/ha) estimated by different models and with different assumptions

Variety	Local	Hybrid	All	Base hybrid gain
Models with farmer area estimates				
Fertiliser rate	83	121	97	0
FSH models, * 1.7				
FSH6-1	17.6	15.5	16.8	1,140
FSH6-14	17.6	17.0	17.3	766
FSH6C-13	17.0	17.1	17.0	817
YSP models , * 0.55				
YSP2B1	10.7	15.0	12.4	182
YSP2B13	10.7	13.6	11.9	296
YSP2C13	11.3	14.4	12.6	298
Mean YSP2B13&C13	14.1	15.4	14.7	583
Models with enumerator area estimates, current management				
Fertiliser rate	208	229	218	0
FSH model – best fit (kg/kgN)	10.0	16.4	12.4	216
FSH model – full (kg/kgN)	5.5	12.2	8.4	278
YSP Model * 0.9	4.0	8.7	6.0	164
Models with enumerator area estimates, potential management				
Fertiliser rate	208	229	218	0
FSH model – best fit (kg/kgN)	14.9	20.8	17.1	216
FSH model – full (kg/kgN)	20.8	26.1	22.8	278
YSP Model * 0.9	10.3	14.6	12.0	164

All other variables are set at beneficiary averages for each variety.

Three important points emerge from the discussion above and the results presented in table 5:

1. Current widely used farmer survey data collection methods that rely on farmer reported yields and areas lead to over estimation of crop areas and under-estimation of yields.
2. Yield and yield response estimates in table 5 show, with the exception of models using farmer estimated harvest and areas, a substantially higher fertiliser response for hybrid maize as compared with local maize, (models using farmer reported harvests and areas show an insignificantly lower fertiliser response for hybrid maize together with a very large yield gain for hybrid maize in the absence of fertiliser). The former results suggest that yield response and hence programme effectiveness and efficiency can be substantially improved by increasing farmers access to hybrid seed – as implemented in 2009/10.
3. All models demonstrate the potential to raise yields and returns from improved crop management and increased cultivation of hybrid maize. Yields and programme benefits are thus amenable to significant increases from wider adoption of improved management practices such as greater complementary use of improved seed and inorganic and organic fertilisers, more timely and frequent weeding, higher plant populations, and earlier planting. A symmetrical point also needs to be recognised, that poor management can reduce yield responses.

4. There are very substantial differences in estimated yield responses to fertiliser depending upon the data used in model estimation and the variables included in the model. As discussed earlier, these differences arise from different biases in different estimates of yield and plot area, and from multicollinearity between management variables.

Since (a) responses to input use are highly variable and depend upon both crop varieties (hybrid maize showing a substantially greater yield response) and to the conditions and management affecting individual maize plots (for example time of planning and weeding, number of weedings, and rainfall distribution) and (b) there are substantial data, methodological and multicollinearity difficulties in estimating yield responses to fertilisers, it is not possible to come up with a single set of consistent unbiased estimates of national maize yields, areas, and production, or of precise impacts of the programme on these. Instead, as in the 2006/7 evaluation report, we therefore use information from a large number of secondary sources to provide an estimate of maize yield response to nitrogen, using 18kg grain per kg N for hybrid maize varieties and 12kg grain per kg N for local maize varieties.

We now consider estimates of incremental production, combining estimates of incremental inputs use as a result of the programme with the yield responses to fertilisers and hybrid seed as discussed above.

5. Estimates of incremental input use, 2008/9

Rickert Gilbert and Jayne (2010) estimate displacement of commercial purchases by subsidised purchases as 2%. These subsidised purchases include both fertilisers redeemed with coupons and fertilisers bought significantly more cheaply than unsubsidised The very high fertiliser prices in the 2008/9 season are a major contributor to this, compared with an equivalent estimate of 29% for 2006/7, along with improved targeting.

Displacement not only occurs as a result of smallholders ‘ receipt of subsidised fertilisers : where subsidised fertilisers are used by other farmers then these are more likely to displace unsubsidised purchases, although again the extent of this may be mitigated by the very high fertiliser prices in 2008/9. It was estimated by Dorward et al (2010) that, depending upon the number of rural households, leakage of subsidised fertiliser to use by others might have made up 20% of total subsidised fertiliser sales in 2008/9. A figure of 10% displacement as a result of this may be appropriate. Displacement will have been considerably higher in 2007/8 as a result of lower fertiliser prices (and hence higher displacement for smallholder subsidy purchases) and larger estimates of diverted fertilisers. Table 6 presents estimates of this information.

Table 6 Estimated incremental fertiliser and seed use by variety and displacement rate

Displa-cement	Maize variety Input source		Local	OPV		Hybrid		Total
				Unsubsidised	Subsidised	Unsubsidised	Subsidised	
10%	Fertiliser (MT)	Unsubsidised	56,108	262	2,956	18,676	16,084	94,086
		Subsidised	107,342	500	5,656	35,730	30,772	180,000
		Total	163,450	762	8,612	54,406	46,856	274,086
0%	Seed (MT)	Unsubsidised	NA	74	0	5,262	0	5,336
		Subsidised	NA	0	833	0	4,532	5,365
		Total	NA	74	833	5,262	4,532	10,701

Note: Total subsidised inputs from LU sales, total unsubsidised input purchases and the division of fertiliser across varieties estimated from survey data, division of subsidised and unsubsidised use by crop from proportional allocation of column and row totals.

6. **Incremental production estimates, 2008/9**

Combining the information from table 6 with an estimate of yield response of 12 and 18kg grain per kg N for local and hybrid maize respectively, with 200kg/ha gain from the use of hybrid seed without fertiliser, allows the estimation of incremental production from the programme as shown in table 7, with two different fertiliser displacement rates (5% and 15%) (low and high yield response scenarios allow fertiliser yield responses respectively of 80% and 120% of the medium scenario)

Table 7 Estimated incremental maize production by variety, fertiliser response and displacement rate (MT)

Displacement	5%			15%		
Yield response to fertiliser	Low	Medium	High	Low	Medium	High
Local	375	469	563	336	420	504
OPV	34	43	52	32	39	47
Hybrid	405	506	608	368	460	552
Total	815	1,018	1,222	736	920	1,104

Note: OPV yield responses are evaluated as a mean of hybrid and local responses.

It should be noted that incremental production figures in table 7 represent estimates with current crop management and crop areas, including intercropping of maize with other crops. While intercropping may be one explanation for low maize yields per ha, the estimates of incremental production do not allow for any impacts on yields of other crops growing with maize (impacts which may be positive where such crops benefit from fertiliser or negative where they suffer from increased maize vigour and competition). They also do not allow for any impacts either on residual effects on yields the following year or on crop areas (as, for example, higher maize yields may either make maize production more attractive, leading to increased maize area and reduced area of other crops, or the satisfaction of subsistence maize needs from a smaller area may allow the area of maize to be reduced and that of other crops increased). There are no clear trends in changes in maize or other crop areas over the 2004/5, 2006/7 and 2008/9 surveys.

Estimation of incremental production in table 7 of around 1 million MT in 2008/9 is higher than a the equivalent estimate for 2006/7 (a little over 650,000MT) as a result of the lower estimated displacement rate and higher subsidy sales in 2008/9.

Total incremental production estimates in table 7 can also be compared with the differences in production estimates in the low, medium and high production scenarios in table 1. This suggested increases in total smallholder production of around 550,000MT from the low to medium and 695,000 MT from the medium to high scenarios. With constant maize area in these scenarios, differences are likely to be due to weather and subsidised and unsubsidised input use. The estimate of incremental production of just over 1 million MT from the 2008/9 subsidy programme appears to be broadly consistent with this.

7. Conclusions

This report has presented information on different elements in the national maize production and consumption system in an attempt to develop a consistent understanding of programme impacts on production, and its determinants.

Examination of historical changes in maize prices and per capita net supply from 1993/4 suggests some consistency in maize supply estimates up to the 2006/7 market season and significant elasticity of demand within Malawi. It also suggests likely maximum per capita supply of around 200kg in good years with the subsidy and inter-seasonal grain storage, and hence upper limits on smallholder maize production of 2.7 to 3.5 million MT depending upon the number of households in Malawi. Estimates of yields that achieve this depend upon estimates of cultivated maize area per household.

Two different survey approaches were taken in estimating maize production, yield and yield responses to fertiliser: using farmer reported whole plot harvests, and harvesting of production from yield sub plots. Each faces different problems of bias, but both face estimation difficulties in regression model specification and multicollinearity, and estimates of production, yield and yield response are also affected by the reliability of farmer estimates of plot area, which may be upwardly biased.

There are therefore critical data difficulties that impede estimation of precise yield and production benefits from the programme. Given the importance of smallholder production in the economy and for food security and welfare, it is very important that critical investments are made to improve national statistics on yields and crop areas, and to resolve differences between NSO and MoAFS estimates of the number of farm families. Nevertheless, the analysis of maize yields and yield responses in this report demonstrate the importance of good crop husbandry (timely and complementary seed and fertiliser delivery and use coupled with good weeding) for improving programme implementation, and this suggests that there may be substantial returns to investment in extension services to complement investments in fertiliser and seed subsidies.

Estimation of incremental production in table 7 of around 1 million MT in 2008/9 is higher than a the equivalent estimate for 2006/7 (a little over 650,000MT) due to the larger volume of inputs disbursed and lower displacement of smallholder purchases of unsubsidised fertilisers.

References:

Dorward, A., E. Chirwa and R. Slater (2010). *Evaluation of the 2008/9 agricultural input subsidy Malawi: Report on Programme Implementation.* London, School of Oriental African Studies (SOAS).

Dorward, A. R. (1984). *Farm management methods and their role in agricultural extension to smallholder farmers: a case study from northern Malawi*. Department of Agriculture and Horticulture. Reading, University of Reading**:** 262.

Griffith, J. F. (1960). *Bioclimatology and the meteorological services*. Proc. Symposium World Meterological Organisation., Nairobi.

Hess, U. and and Syroka, J. (2005) *Weather-based Insurance in Southern Africa: The Case of Malawi.* Agriculture and Rural Development Discussion Paper 13.World Bank, Washington D.C.

Holden S. and Lunduka R. (2010) Too poor to be efficient? Impacts of targeted firetiliser subsidy programme in Malawi on farm plot level input use, crop choice and land productivity. Norwegian University of Life Science, As, Norway.

Jayne, T. S., J. Mangisoni, N. Sitko and J. Ricker-Gilbert (2010). *Malawi's Maize Marketing System*, Michigan State University.

Lipton M and Moore M (1972) *The methodology of village studies in less developed countries*, Institute of Development Studies, Discussion Paper No 10

Ministry of Agriculture and Food Security (MoAFS) (2008). *2007/8 Annual Agricultural Statistical Bulletin*. Lilongwe.

National Statistical Office (2009). *2008 Population and housing census: preliminary report*. Zomba, Malawi, National Statistical Office.

Poate C.D. and Daplyn P.F. (1993) *Data for agrarian development*. Cambridge, Cambridge University Press.

Rickert Gilbert J. and Jayne T. (2010) *The impact of fertilizer subsidies on displacement and total fertilizer use*. Presentation, Lilongwe, May 2010.

Syroka, J. (2007). *A guide to understanding the calculations in the "WRSI Station Name.xls" files.* unpublished.

ANNEX **Table A1 Examples of models estimated with farmer reported harvest data and plot areas**

	All variables included. (FSH6-1)				Drop variables. (FSH6-14)				Drop variables, No constant. (FSH6C-13)			
Adjusted Rsq, N	0.237, 1559				0.241, 1559				N.A. , 1559			
	B	SE	t ratio	Sig	B	SE	t ratio	Sig	B	SE	t ratio	Sig.
Constant	-435.5	734.9	-.593	.553	-42.9	369.1	-.116	.907				
seed rate kg/ha	4.15	5.449	.762	.446	6.39	2.71	2.36	.019	5.98	2.20	2.72	.007
Hybrid dummy	76.16	84.163	.905	.366								
number weedings	129.3	77.096	1.677	.094	150.5	63.1	2.38	.017	134.5	49.9	2.72	.007
weeks from planting to 1st weeding	9.31	21.808	.427	.669					13.4	10.0	1.33	.182
Fert. app weeks from planting	3.79	25.425	.149	.881								
North dummy	207.6	115.6	1.80	.073	169.0	93.6	1.805	.071	120.4	64.7	1.86	.063
South dummy	57.7	88.0	.655	.512					47.2	30.9	1.53	.126
Total septades	14.68	25.6	.574	.566					-9.31	6.37	-1.46	.144
G1 septades	23.11	78.0	.296	.767					80.9	47.7	1.70	.090
G2 septades	52.3	101.9	.513	.608	66.3	70.9	.936	.350				
G3 septades	-46.2	84.5	-.547	.584	-63.3	64.6	-.980	.327				
G4 septades	-7.73	28.59	-.270	.787								
Fertiliser kg / ha	2.53	4.59	.552	.581					3.73	1.43	2.60	.009
Fertiliser squared	.001	.002	.480	.631								
Fertiliser * seed rate	-.022	.016	-1.36	.174	-.016	.015	-1.08	.282	-.02	.012	-1.60	.111
Fertiliser * Hybrid Dummy	-.452	.454	-.995	.320								
Fertiliser * No. Weedings	-.555	.405	-1.37	.171	-.490	.383	-1.28	.201	-.43	.291	-1.46	.144
Fertiliser * week of weeding	-.019	.156	-.122	.903								
Fertiliser * fert app weeks from planting	.039	.155	.248	.804								
Fertiliser * North dummy	-2.17	.630	-3.44	.001	-1.98	.517	-3.82	.000	-1.69	.342	-4.93	.000
Fertiliser * South dummy	-.776	.506	-1.53	.125	-.477	.249	-1.92	.055				
Fertiliser * Total septades	.093	.152	.608	.544	.183	.073	2.50	.012	.169	.065	2.62	.009
Fertiliser * G1 septades	-.441	.450	-.981	.327	-.334	.220	-1.52	.129	-.65	.289	-2.24	.025
Fertiliser * G2 septades	-.418	.571	-.732	.464	-.487	.383	-1.27	.204	-.24	.210	-1.15	.250
Fertiliser * G3 septades	.674	.594	1.14	.257	.816	.439	1.86	.063				
Fertiliser * G4 septades	.182	.162	1.13	.260	.148	.078	1.90	.058	.095	.054	1.76	.079
Seed rate * Hybrid Dummy	9.26	3.61	2.57	.010	9.27	2.04	4.54	.000	9.89	1.49	6.62	.000
Seed rate * No Weedings	1.88	2.73	.688	.492								

Wet septades: calculated using nearest rainfall stations with daily rainfall records, the rainfall season was analysed in terms of consecutive seven day 'septades', with a septade defined as 'wet' if it and the previous septade had more than 25mm of rain between them, or if the septade by itself had more than 10mm of rain. The crop growth period was divided up into four periods from the week in which it was recorded as being planted, with the first growth period being 2 weeks, the second growth period 7 weeks, and the third and fourth growth periods being 6 weeks each. All these were introduced as variables, but there was significant correlation between them. This adapts methods reported in Syroka (2007), Grifiths (1960 and Dorward (1984). Daily rainfall data were supplied by the Malawi Meteorological Service.

ANNEX **Table A2 Examples of models estimated with YSP data and farmer estimated plot areas**

	All variables included. (YSP2B1)				Drop variables. (YSP2B13)				Drop variables, No constant. (YSP2C 13)			
Adjusted Rsq, N	0.142, 339				0.165, 339				N.A., 339			
	B	SE	t ratio	Sig	B	SE	t ratio	Sig	B	SE	t ratio	Sig.
Constant	16.8	37.6	.447	.655	13.8	33.2	.42	.678				
maize plants in the ysp	.039	.048	.815	.416	.030	.01	2.60	.010	.030	.012	2.60	.010
Hybrid Dummy	-3.59	4.33	-.828	.408								
Farmer harvested	4.67	5.89	.793	.428	2.11	1.38	1.53	.127	2.134	1.376	1.55	.122
Number weedings	1.29	3.87	.334	.739								
weeks from planting to 1st weeding	-.352	.99	-.357	.722	-.53	.39	-1.37	.173	-.535	.389	-1.37	.170
Fert. app weeks from planting	.391	.774	.505	.614								
Organic fertiliser (dummy)	5.24	2.86	1.833	.068	4.87	2.74	1.77	.077	4.826	2.738	1.76	.079
North (dummy)	-8.19	3.89	-2.107	.036	-8.92	3.60	-2.48	.014	-9.321	3.465	-2.69	.008
South (dummy)	2.38	2.79	.854	.394	2.89	2.47	1.17	.242	3.074	2.427	1.27	.206
Total_septades	1.76	.95	1.852	.065	2.06	.88	2.35	.019	2.243	.760	2.95	.003
G1 septades	1.99	2.52	.791	.430								
G2 septades	-8.67	4.69	-1.849	.065	-7.53	4.15	-1.81	.071	-6.092	2.293	-2.66	.008
G3 septades	.380	1.74	.219	.827								
G4 septades	-.188	.722	-.261	.794								
Fertiliser kg / ha	-.263	.239	-1.097	.274	-.25	.22	-1.15	.251	-.170	.094	-1.81	.072
Fertiliser squared	.000	.000	-2.570	.011	.000	.00	-2.66	.008	.000	.000	-2.73	.007
Fertiliser * plant population	.000	.000	-.304	.761								
Fertiliser * Hybrid Dummy	.025	.014	1.724	.086	.018	.01	1.474	.142	.018	.012	1.47	.143
Fertiliser * Farmer Harvest	-.018	.017	-1.067	.287								
Fertiliser * No. Weedings	.010	.013	.739	.460	.011	.006	1.808	.072	.011	.006	1.80	.072
Fertiliser * week of weeding	.005	.004	1.071	.285	.006	.004	1.446	.149	.006	.004	1.45	.149
Fertiliser * fert app weeks from planting	-.006	.005	-1.222	.223	-.004	.003	-1.61	.108	-.004	.003	-1.62	.106
Fertiliser * Organic dummy	-.025	.021	-1.20	.230	-.020	.020	-1.04	.300	-.020	.020	-1.02	.310
Fertiliser * North dummy	.029	.022	1.28	.202	.035	.020	1.705	.089	.037	.020	1.87	.062
Fertiliser * South dummy	-.016	.018	-.895	.372	-.019	.017	-1.145	.253	-.020	.016	-1.22	.224
Fertiliser * Total septades	-.008	.006	-1.28	.202	-.010	.006	-1.67	.095	-.011	.006	-1.98	.049
Fertiliser * G1 septades	-.009	.016	-.588	.557								
Fertiliser * G2 septades	.069	.033	2.11	.035	.064	.029	2.21	.028	.055	.020	2.84	.005
Fertiliser * G3 septades	.006	.010	.54	.589	.007	.006	1.21	.228	.008	.006	1.23	.219
Fertiliser * G4 septades	.003	.004	.80	.421	.002	.002	1.34	.181	.002	.002	1.36	.176
Plant pop. * Hybrid dummy	.031	.022	1.44	.150	.016	.011	1.48	.140	.016	.011	1.50	.136
Plant pop. * No. Weedings	-.005	.021	-.226	.821								
Plant pop. * week of weeding	.000	.005	-.070	.944								
Plant pop. * Farmer Harvest	-.001	.027	-.023	.981								
Years continuous maize	-.387	.249	-1.55	.122	-.394	.240	-1.64	.101	-.396	.239	-1.65	.100

Dependent variable = yield per ysp, kg/0.005ha, for model with dependent variable yield per ha, multiply all coefficients by 200.

ANNEX **Table A3 Examples of models estimated with YSP data and farmer estimated plot areas**

	YSP model, all variables included				Farmer harvest model, all variables included				Farmer harvest model, drop variables			
Adjusted Rsq, N	0.107, 295				0.389, 165				0.422, 165			
	B	SE	t ratio	Sig	B	SE	t ratio	Sig	B	SE	t ratio	Sig
Constant	-50.95	35.08	-1.452	0.148	2630	5840	0.450	0.653	4317	2824	1.528	0.129
maize plants in the ysp	.036	0.049	0.722	0.471	-4.593	7.584	-0.606	0.546				
Hybrid Dummy	-2.549	4.364	-0.584	0.560	-924	693	-1.33	0.185	-876	506	-1.733	0.085
Farmer harvested	26.78	21.97	1.219	0.224								
Number weedings	4.544	4.534	1.002	0.317	-538	662	-0.812	0.418				
weeks planting to 1^{st} weeding	-0.281	1.250	-0.225	0.822	26.74	52.4	0.510	0.611				
Fert. app weeks from planting	-0.077	0.598	-0.129	0.898	5.479	122	0.045	0.964				
Organic fertiliser (dummy)	1.233	3.640	0.339	0.735	-460.7	490	-0.941	0.349				
North (dummy)	-3.813	2.917	-1.307	0.192	-1482	625	-2.374	0.0191	-1609	490	-3.285	0.001
South (dummy)	2.248	2.260	0.995	0.321	232	376	0.617	0.539				
Total_septades	1.210	1.190	1.016	0.310	219	123	1.780	0.077	225	75.0	3.00	0.003
G1 septades	0.510	1.951	0.261	0.794	-370	391	-0.946	0.346	-510	337	-1.512	0.136
G2 septades	2.588	3.481	0.743	0.458	-738	889	-0.830	0.408	-960	468	-2.051	0.042
G3 septades	0.775	1.462	0.530	0.596	66.9	284	0.236	0.814				
G4 septades	0.468	0.606	0.772	0.441	-170	120	-1.426	0.156	-197	104	-1.900	0.060
Fertiliser kg / ha	0.019	0.098	0.192	0.848	12.87	28.8	0.446	0.656				
Fertiliser squared	0.000	0.000	-0.474	0.636	0.001	0.0034	0.353	0.725				
Fertiliser * plant population	0.000	0.000	0.540	0.590	-0.006	0.0125	-0.471	0.638				
Fertiliser * Hybrid Dummy	0.006	0.006	0.956	0.340	1.474	1.221	1.207	0.230	1.529	1.082	1.413	0.160
Fertiliser * Farmer Harvest	-0.005	0.009	-0.605	0.545								
Fertiliser * No. Weedings	0.001	0.007	0.148	0.882	-0.716	1.189	-0.602	0.548				
Fertiliser * week of weeding	0.001	0.002	0.617	0.538	0.024	0.142	0.171	0.864				
Fert * app weeks from planting	-0.002	0.002	-0.876	0.382	-0.769	0.572	-1.345	0.181	-0.616	0.325	-1.892	0.060
Fertiliser * Organic dummy	0.013	0.010	1.318	0.189	4.417	2.288	1.930	0.056	2.909	1.284	2.267	0.0249
Fertiliser * North dummy	0.006	0.011	0.572	0.568	2.579	2.260	1.141	0.260	3.523	1.451	2.428	0.0164
Fertiliser * South dummy	-0.013	0.009	-1.516	0.131	-1.279	1.427	-0.900	0.372				
Fertiliser * Total septades	0.001	0.003	0.245	0.806	-0.326	0.551	-0.592	0.555	-0.387	0.243	-1.592	0.114
Fertiliser * G1 septades	0.003	0.007	0.450	0.653	1.597	1.456	1.0971	0.275	2.005	1.254	1.599	0.112
Fertiliser * G2 septades	-0.006	0.011	-0.557	0.578	-1.181	4.145	-0.285	0.776				
Fertiliser * G3 septades	0.003	0.005	0.562	0.575	0.667	1.431	0.466	0.642	1.063	0.633	1.680	0.095
Fertiliser * G4 septades	-0.001	0.002	-0.626	0.532	0.500	0.418	1.195	0.234	0.583	0.364	1.599	0.112
Plant pop. * Hybrid dummy	0.023	0.020	1.106	0.270	7.974	3.562	2.239	0.027	7.15	2.482	2.880	0.005
Plant pop. * No. Weedings	-0.008	0.019	-0.411	0.681	4.550	3.308	1.375	0.171	0.411	0.664	0.619	0.537
Plant pop. squared	0.000	0.000	-0.413	0.680	-0.004	0.0220	-0.183	0.855				
Plant pop. * Farmer Harvest	-0.009	0.024	-0.360	0.719								
Farmer Harvest * Hyb dummy	1.686	2.067	0.816	0.415								
Farmer Harvest * No weedings	-2.556	2.516	-1.016	0.311								
Farmer Harvest * week weeded	0.014	1.104	0.012	0.990								
Farmer Harvest * Tot. septades	-0.895	1.007	-0.888	0.375								
Farmer Harvest * Org. dummy	-2.912	3.821	-0.762	0.447								
Years continuous maize	0.003	0.230	0.013	0.990	-2.396	39.52	-0.061	0.952				

Dependent variable = yield per ysp, kg/0.005ha, for model with dependent variable yield per ha, multiply all coefficients by 200.