

# CEREAL PRODUCTIVITY IN ETHIOPIA: AN ANALYSIS BASED ON ERHS DATA<sup>1</sup>

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## **Abstract**

*This paper examines recent trends of cereal yield in Ethiopia and tries to see yield responses to modern inputs such as chemical fertilizer and improved seeds on major cereal crops. It bases its analysis on two rounds (1999 & 2009) of the Ethiopian Rural Household Survey (ERHS). Cereal yield grew by 21 percent during the period 1999 and 2009, much lower than the national figure, which is 60 percent, for the same period. This growth was contributed by wheat, maize and barley, which grew by 62, 19 and 11 percent respectively for the same period. Evidence on modern input use is; however, higher in ERHS than the national average. Unlike the CSA data, the ERHS data show more intensification of modern agricultural inputs during the period. Overall, regression results in the two periods show that yield response to fertilizer and improved seeds was found to be statistically significant. Using panel data analysis, we also find an indication of some yield growth, unrelated to inputs such as seeds and fertilizer and which cannot be explained by weather changes.*

**Keywords:** Cereal yield, yield growth, cereal yield response to modern inputs

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<sup>1</sup> ERHS, short for Ethiopian Rural Household Survey, is longitudinal dataset and has been supervised by the Economics Department of Addis Ababa University, the Centre for the Study of African Economies (CSAE), University of Oxford and the International Food Policy Research Institute (IFPRI)

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## 1. Introduction

Official sources revealed that cereal yield recorded a significant growth in Ethiopia for the last 10 years. Across the main cereals, production increased from a level of 10.3 quintals per hectare in 1999 to 16.5 quintals per hectare in 2009; growth has been steady, with a temporary decrease due to drought in 2003 (see Table 1). Production of all the major cereal crops seems to have been increasing in unison especially in recent years (see Annex 1). There is no significant difference in yield growth of these crops unlike the experiences of other countries, which showed high yield growth during the green revolution, where crop specificity is an important feature (for more discussion of this see Gollin et. al., 2011).

**Table 1: Yield (quintal per hectare) for Major Cereal Crops: 1999 and 2009**

Cereals	1999	2009	Annual Average Growth Rates <sup>3</sup>
Cereals	10.3	16.5	2.9
Teff	7.9	12.2	3.5
Barley	9.3	15.5	4.1
Wheat	11.3	17.5	3.9
Maize	18.5	22.2	1.8
Sorghum	12.7	17.4	3.2

Source: Data from Central Statistical Agency (CSA), Different Agricultural Sample Surveys

Cereal crop production has been lifted well above long-term levels, and while area expansion has been considerable, yield growth has accelerated particularly in the last few years (see Annex 2). In recent years, estimates by the EEA (2009) based on the CSA data show that the improvements in yield surpassed area expansion except for maize and wheat. A more important observation from these official sources is the recent large yield increase that do as not seem to be explained by a sudden large increase in uses of modern inputs and improved farm management. More specifically, application of improved seeds, chemical fertilizers, pesticides, irrigation and extension package do not explain this large increase in yield.

Chemical fertilizer application is still low and only about 36.5 percent of total cereal acreage benefit from chemical fertilizer in 2009 (see also Gollin et. al., 2011). It also

<sup>3</sup> Estimated using OLS regression of logarithms of yield over time trend and take the coefficient of time.

shows that little change was registered by these shares over the period 2005 and 2009. Similar stories can be told of other modern inputs: use of improved inputs did not expand in such an overwhelming rate, as the yield growth did. Table 2 shows the share (in percent) of area under improved farm management for three time points. In addition to the low-level use of these improved farm management practices, little progress is shown for the last ten years. The maximum share of area cultivated with improved seeds is 20 percent for maize in 2009. On the other hand, the figure for wheat has even declined from 6 percent in 1998 to 4 percent in 2009. It is important to note that improved seeds are largely limited to only two crops, namely wheat and maize. More success is shown for wheat in terms of area where pesticide is applied, which is 41 percent in 2009 from 31 percent in 1998.

**Table 2: The Share of Area (in percent) under Improved Farm Management by Crop (1997/98-2008/09)**

Improved Farm Management	Year	Cereals	Teff	Barley	Wheat	Maize	Sorghum
Share of Crop	1997/98	2.4	1.7	0.1	5.6	5.2	0.2
Area with	2004/05	4.0	0.7	0.5	3.8	15.9	0.5
Improved Seeds	2008/09	4.9	0.7	0.6	3.9	19.8	0.1
Share of Crop	1997/98	12.0	17.7	9.6	31.3	1.3	3.1
Area with	2004/05	16.7	24.5	11.7	38.0	2.1	2.4
Pesticide Application	2008/09	20.4	29.7	19.9	41.1	3.5	8.7
Share of Crop	1997/98	0.6	0.7	0.6	0.3	1.1	0.4
Area with	2004/05	0.8	0.4	0.7	0.3	2.1	0.8
Irrigation	2008/09	1.1	0.5	0.9	0.5	2.8	1.1
Share of Crop	2004/05	36.0	48.7	27.9	58.5	29.4	3.0
Area with	2008/09	36.5	51.9	27.8	60.1	31.0	3.0
Chemical Fertilizer							
Share of Crop	2004/05	18.2	17.2	16.7	29.5	24.9	6.5
Area with	2008/09	15.6	16.2	8.8	20.5	23.0	2.9
Extension Package							

Source: Authors' calculations based on the 1997/98, 2004/05 and 2008/09, Agricultural Sample Surveys, CSA.

The foregoing analysis provides us with at least four salient features of the recent growth of cereal yield in Ethiopia. First, cereal yield recorded a significant growth in recent few years and this productivity is not crop specific. Second, although output and area cultivated grew, the growth rate in output outpaced area expansion in most of the major cereal crops in most recent years. Third, the use of modern inputs such as fertilizer, improved seeds and other modern farm management practices is low and has not been expanding for the same period under consideration. With these points in mind, and the fact that this increase in production cannot easily be justified given the massive increase in local food prices for an agriculture-dominated economy, where the rise and fall of food price is crucially dependent on agricultural production, it is imperative to see whether these changes are structural breaks (i.e. an unexpected shift).

Minot (2008) cited in Dercon and Hill (2009) shows that this could be an overestimation of yields in CSA estimations in recent years. Some of the cereal yield growth rates appear to outpace other East African countries and even Green Revolution India, especially taking into account the low growth in input intensity (Gollin et. a., 2011, Dercon and Hill, 2009). A paper by Dercon and Hill (2009) also shows that despite some rhetoric, to the contrary, the availability of appropriate and high return technologies on the ground is limited at present in the Ethiopian case. An impressive growth in cereal production with no evidence on intensification of agriculture such as increase in the use of modern inputs at the same time need a way of validating or invalidating the data on cereal production.

This piece of work bases its analysis on the Ethiopian Rural Household Surveys (ERHS). It offers complementary analysis using the ERHS to the work by Alemayehu et al. (2009) on the national data from the CSA. The paper examines recent trends of cereal yield in Ethiopia and tries to see yield responses to modern inputs such as chemical fertilizer and improved seeds on major cereal crops (teff, barley, wheat, maize and sorghum). The choice of these five crops emanates from their place in production and consumption of the Ethiopian farming household. (See Alemayehu et. al., 2009 for more on this).

The second section briefly describes the trends of cereal yield and use of modern inputs by smallholder farmers. A production function is specified and estimated in the third section to see the impact of some important inputs on cereal yield. Mean difference tests will also be made to see their isolated or combined impact of improved seeds and fertilizer on yield. The third section is divided into 3 sub-sections. The first two sub-

sections are devoted for the 2009 and 1999 cross-sectional data analysis and the third one for panel data analysis. The fourth section concludes.

## **2. Trends in Cereal Yield and Use of Modern Agricultural Inputs in Ethiopia**

This paper uses the Ethiopian Rural Household Survey (ERHS) data. Production data were collected at plot level allowing analysis by plot and/or by crop and making sample size larger for consistent estimation. An overview of important variables in this dataset can be seen from Table 3 below.

A brief note on the data is in order. Data on output and inputs per crop and plot were collected. However, due to a matching problem with the 2009 data, it has proven impossible to link all the input data to the output data. We had to restrict the matching to plots that did not intercrop or had multiple crops on, and only those used in one season (either Belg or Meher). Arguably, that is not fundamentally problematic as long as in both years (1999 and 2009) the same restrictions on plots are applied, and our interest is not in studying and comparing the *levels* of yields in 1999 and 2009, but to study growth rates. As we have access to the fully matched data set for 1999, we offer some comparison between the ‘adjusted’ 1999 and the ‘raw’ 1999 data. Furthermore, yield data are based on self-reported output, and outliers appear to affect the results, especially in 2009 data – and the most unlikely values accounting for 1.3% of observations were dropped<sup>4</sup>.

Taking into account these adjustments, Table 3 presents data on yield for the five major cereal crops (teff, barley, wheat, maize and sorghum) in the two rounds of ERHS (1999 and 2009). The CSA estimation of the same variable is presented for comparison. We have to be careful interpreting these results – these are just two years, and even though the national trend seems robust to weather events (i.e. not just explained by ‘good

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<sup>4</sup>It involves observations with reported harvests of more than 100 quintals per hectare. To decide the cut-off point for unlikely yields, we used as a benchmark yields from a series of high yielding countries. The assumption is that with all the available technology, natural fertility of the land and good weather prevailing in the country, a yield bigger than this benchmark yield must be an outlying case. Then, observations with bigger yield than these high yielding countries were dropped. This is done by crop. In the case of teff (local cereal crop), a benchmark of 3Xmedian better treats outliers and bigger than this benchmark were dropped. As a result, in total 37 observations (barley=6, wheat=4, maize= 18, sorghum=2 and teff=7), much less than 2 percent of total sample, were dropped.

weather’ in 2009—see Gollin et. al., 2011), in a smaller sample this may affect the findings. Also, these are not necessarily representative areas for actual growth – nevertheless, as the national data suggest broad and widespread growth, as a first approximation for a comparison, this is still worth exploring.

We present growth rates for all cereals and for specific crops, and compare growth rates between ERHS and CSA sources. The general observation is cereal yields in the CSA data are much higher than that in ERHS: overall, the difference is 7 percent in 1999 and 41 percent in 2009. This difference is highest for maize in 1999 and sorghum in 2009. Maize and wheat *growth* rates are nevertheless comparable: for maize, yields in CSA increased by 20 percent and in the ERHS by 19, wheat yields increased 55 percent in the CSA data and by 62 percent in the ERHS in this period. For teff, barley and sorghum, the gaps are huge. For example, stagnation of teff yields in the ERHS translates into a 54 percent growth in the CSA data. The overall result is that the national yield data grew three times as fast as in the ERHS.

**Table 3: Cereal Productivity (yield in quintal per hectare) Growth (ERHS & CSA) by Crop: 1999 and 2009**

Crops	ERHS			Period growth mean yield (%)		CSA		Difference (%)		
	1999	2009		1999	2009	Period Growth (%)	1999	2009		
	Mean yield all plots	Mean yield adjusted plots	Mean yield adjusted plots							
	A	B	C	(C/A-1)*100	(C/B-1)*100	D	E	(E/D-1)*100	(D/B-1)*100	(E/C-1)*100
<b>Cereals</b>	10.5	9.6	11.7	11.0	21.2	10.3	16.5	60.2	6.9	41.3
Teff	7.4	8.3	8.2	10.5	-0.4	7.9	12.2	54.4	-4.3	48.3
Barley	8.8	8.7	9.7	10.6	11.1	9.3	15.5	66.7	6.7	60.0
Wheat	10.9	10.1	16.3	49.9	61.6	11.3	17.5	54.9	12.3	7.6
Maize	14.1	12.1	14.5	2.9	19.4	18.5	22.2	20.0	52.7	53.4
Sorghum	15.5	13.1	8.2	-47.1	-37.4	12.7	17.4	37.0	-3.3	111.7

Source: ERHS with author's calculations, and CSA Agricultural Sample Survey

Do increased yields in the ERHS data for some cross match with input use data<sup>5</sup>? Looking into input use, there seems to be a modest increase in the use of modern inputs such as improved seeds and chemical fertilizers. Table 4 shows the share of area cultivated with modern inputs (improved seeds, fertilizer and irrigation). In the case of improved seeds, while the share is still low (i.e. only 14 percent of the cereal crop area cultivated with improved seeds), there is a big jump in the application of these seeds over the ten years period. Wheat and maize have the largest share of cultivated area with improved seeds in both periods with 25 and 33 percent in 2009 compared to 10 and 16 percent in 1999 respectively. A comparison can be made between the estimation of ERHS and CSA data using Table 4 and Table 2. Overall, the estimation based on the ERHS data shows that the sample is using improved seeds more intensively.<sup>6</sup>

Another important input expected to have an impact on cereal production is fertilizer. We find that the area cultivated using fertilizer is 64 percent, for all cereals, in 2009, which has increased from its level of 55 percent in 1999. This is bigger than the estimations using CSA data, which is still close to 36.5 percent (see section 1). The crop with the highest application of fertilizer in both periods is wheat (90 percent in 2009 from 71 percent in 1999). Cereal crop area cultivated with irrigation is also a bit higher, with 4 percent of the total area irrigated, than the national average (CSA data). Overall, we note higher intensification in the ERHS sample than the national data, although only for wheat and maize, they kept up with national yield growth. In the next section, we explore this further and study how the yields respond to inputs in the ERHS data for 1999 and 2009.

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<sup>5</sup>Also the input data were characterized by outliers. A few negative values were dropped. There were also other unlikely observations in terms of inputs per hectare. However, as the data in the table are reported in area under modern inputs, this does not affect the data here.

<sup>6</sup>One may worry about the data on improved seeds in surveys like this. With limited certification, farmers may believe certain seeds to be 'improved' even if they are not, or continue to recycle seeds e.g. for maize, even though they would gradually lose their extent of improvement. In self-reported data, this problem is not easily overcome. One example is the reported improved seeds for teff. In general, they are rarely used in Ethiopia – although this does not mean that farmers and research stations have used selection to get better yielding seeds in various places. The data has, however, substantial observations with improved seeds for teff as shown in the tables. Moreover, sorghum has no improved seeds applied, barley has only three observations with improved seeds, and this variable is left out of the regression model below.

**Table 4: The Share of Areas (in percent) Cultivated with Modern Inputs :( 1999-2009)<sup>7</sup>**

Crops	Crop Area with Improved Seeds		Crop Area Applied with Fertilizer		Area Cultivated with Irrigation	
	1999	2009	1999	2009	1999	2009
<b>Cereals</b>	4.1	14.2	55.4	64.4	3.3	3.9
Teff	1.3	7.2	66.6	71.7	2.3	4.0
Barley	0.5	0.9	51.5	65.5	0.9	3.3
Wheat	10.0	25.0	70.7	89.7	0.5	3.2
Maize	15.8	32.7	39.4	49.6	14.5	4.9
Sorghum	0.0	0.0	9.4	5.2	4.2	4.1

Source: Estimations using ERHS data

### 3. Responses of Yield to Modern Inputs: Fertilizer and Improved Seeds

A determinant of crop productivity analysis was made to see the response of cereal yield to modern inputs such as chemical fertilizer and improved seeds. The yield response functions can easily be derived from Agricultural Household Models (AHMs). In this model (more on this is a classic work by Singh, Squire and Strausss (1986)), production and consumption decision making is thought to be a joint one. Production decisions are made first through maximizing profits; consumption decisions are then made through utility maximization subject to those profits. However, this happens if markets (both input and output markets) exist and function perfectly. In this ideal case, these decisions are separable, household preferences and endowments do not affect production, and the models can be solved recursively.

This raises a question of whether these output and input markets exist and function perfectly. Markets are either thin or absent in Ethiopia. Hence, it is impossible to separate the production and consumption decisions. As a result, the following production function is used.

<sup>7</sup>In this table, we only report the 'adjusted' data – i.e. the data that can be compared between 1999 and 2009 for growth rates. Note that the only significant difference appears to be that for maize, once we include the intercropping rates, the data for 1999 show higher crop areas with improved seeds (23%) and with fertiliser (49%). This is consistent with the yields on the maize plots in 1999 higher when the full sample is used and not just the plots that can be compared over time. As there is no obvious reason why the growth in input use on these plots outpaces the other plots, it is unlikely to affect the overall results comparing 1999 and 2009.



Where  $Y_c$  = Level of output of crop produced by a household;  $V$  = Variable input level;  $K$ = Fixed input levels;  $P$ = Household preferences;  $E$ = Household endowments. The following model is specified to link yields with major inputs such as fertilizer

$$y_{ic} = \beta_1 + \beta_2 f_{ic} + \beta_3 f_{ic}^2 + s_{ic} + \sum_{n=1}^{n=k} x_{ic} \beta_n + \varepsilon_{ic}$$

Where,

$y_{ic}$  = production of crop c per hectare of land (yield) for household i

$f_{ic}$ = chemical fertilizer application (in kg) for crop c for household i<sup>8</sup>

$s_{ic}$ = amount of improved seeds used for crop c by household i

$x_{ic}$  = other control variables including characteristics of the household farmer (holder), characteristics of land, dummy for villages, year etc.

**Table 5: List of Some of the Questions /Variables in the Ethiopian Rural Household Survey (ERHS)**

Variables (Questions)	Variable Description/possible response
Total output by crop/plot (in quintals)	Teff, Barley, Wheat, Maize & Sorghum
Plot Area	Plot size in hectares
How much DAP/Urea/DAP+Urea did you apply to this plot?	Amount in kg
Amount of improved seed saved from last year/ bought/exchanged	Amount in kg (only for wheat and maize)
Did you apply manure/compost to this plot?	Yes=1, No=0
Extension coverage	Yes=1, No=0
Is the land Lem, Lem-teuf or teuf land?	Leum, Teuf, Leum-teuf
Slope of land	Medda, dagathama, geddel
How much of this plot is irrigated?	Percentage of irrigated land
Holder's Characteristics	
Education	Highest grade obtained
Age of the holder	Number of years
Household size of the holder	Number of household members
Gender of holder	Male=1, Female=0

<sup>8</sup> Squares of some variables are added as explanatory variables to capture the non-linear (in variables) relationship between those variables and the dependent variable (for more on this, see Wooldridge, 2009).

Variations of the above estimable general model include linear and log-linear models on each cross section estimated by OLS. This is done for the total sample and for each of the cereal crops under study. A fixed effects model of the following type was specified to allow time-constant unobserved heterogeneity correlate with explanatory variables. Fixed effects estimator was used.

$$y_{itc} = \beta_1 + \beta_2 f_{itc} + \beta_3 f_{itc}^2 + s_{itc} + \sum_{n=1}^k x_{itc} \beta_n + \alpha_{itc} + s_{itc}$$

where  $\alpha_{itc}$  is individual specific unobserved heterogeneity. This model too is estimated using the levels and logs of yield.

### 3.1 Analysis based on the 2009 ERHS Data

The data used are the ‘adjusted’ data as referred to in the descriptive analysis – correcting for outliers and ensuring that only plots that can be convincingly matched to inputs are included. Table 6 below presented estimations based on these adjusted yield data as described above. The production function specified above was estimated using OLS. The model estimated below includes some interaction terms and all other variables. Two models were specified; one with levels of yield (Table 6) and another with logarithms of yield (see Annex 4). In taking the logarithm of yield, zeros were first dropped. First, a descriptive analysis was offered in annex 3 which includes some of the other explanatory variables which were not discussed above.

Overall, we can see that, the estimated coefficients for chemical fertilizer, traditional fertilizer and improved seeds were found to be significant at 5 percent. Yield seems to respond to fertilizer application for teff, barley and wheat: for example, for the latter, using about 100 kg per hectare (the usual recommended quantity) would add about 200 kg yield – or about 14 percent relative to the mean yield observed.<sup>9</sup>

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<sup>9</sup>This includes the impact of the concavity (the squared term on fertilizer is significant) reducing yield at 100 kg per hectare by 27 kg.

**Table 6: Estimates of the Parameters of Quadratic Production Functions in Levels of Yield (2009)**

Dependent Variable=levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
Dummy for improved seeds	546.77 [135.9046]***	358.70 [319.2028]		35.80 [160.0459]	624.77 [358.1169]*	
Fertilizer application in kg per hectare	2.32 [0.5456]***	2.86 [1.0259]***	1.90 [1.0395]*	2.36 [0.8566]***	3.18 [2.7600]	5.85 [8.4786]
Square of chemical fertilizer used in kg	-0.0004 [0.0002]**	-0.0005 [0.0003]	0.0019 [0.0027]	-0.0027 [0.0011]**	-0.0068 [0.0080]	-0.0009 [0.0189]
Interaction term: Fertilizer & improved seeds	-0.33 [0.7612]	-1.74 [1.6658]		1.95 [1.1787]*	0.84 [2.2073]	
Use of traditional fertilizer	354.61 [72.0241]***	87.66 [116.9787]	147.57 [65.8935]**	111.84 [134.4445]	317.32 [146.4417]**	875.45 [541.3394]
Irrigation: 1 if irrigated, 0 otherwise	16.93 [120.4961]	20.30 [127.1920]	-109.46 [79.8081]	-501.10 [579.7204]	287.82 [232.6713]	-36.81 [266.8143]
Interaction term: fertilizer and Irrigation	2.10 [1.2652]*	-5.25 [5.5965]	1.09 [1.0566]	6.13 [4.1300]	0.66 [1.8808]	
Fertility of Soil (Lem=1, best quality)	222.45 [56.1273]***	193.87 [84.7161]**	170.14 [81.4826]**	189.22 [145.4284]	223.12 [182.3776]	300.70 [161.7882]*
Fertility of Soil (Lemteuf=1, medium quality)	37.66 [52.0428]	191.17 [92.1537]**	6.02 [62.0759]	-168.49 [153.3343]	101.28 [192.6097]	167.82 [140.8739]
Age of holder	1.59 [8.1870]	25.22 [19.5199]	10.58 [13.4008]	16.68 [21.5762]	-13.55 [16.4296]	22.24 [18.1412]
The square of age of holder	-0.0214 [0.0723]	-0.2135 [0.1832]	-0.1336 [0.1199]	-0.1543 [0.1865]	0.1283 [0.1271]	-0.2203 [0.1677]
Household size of holder	-1.20 [9.8921]	-0.07 [15.1795]	4.85 [13.8531]	-23.76 [16.2527]	9.54 [32.4125]	-26.57 [27.4108]
Gender of holder : 1 if Male, =0 if Female	73.96 [46.5607]	68.84 [65.9981]	109.05 [70.7740]	-17.51 [108.2452]	171.94 [138.2774]	158.52 [242.4820]

Table 6 cont'd...

Dependent Variable=levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
Level of Education of holder						
Literate	33.046 [56.1197]	148.571 [75.5337]**	-70.304 [80.4375]	-9.779 [135.9657]	134.426 [173.6497]	-1.413 [141.0628]
Primary (1-8)	28.31 [60.9615]	109.97 [75.2230]	-71.17 [95.2352]	64.54 [114.9094]	80.04 [165.1064]	247.98 [171.8447]
Secondary (9-12)	151.91 [109.4432]	715.98 [280.5677]**	262.79 [258.7840]	158.11 [150.3108]	-189.60 [262.9586]	
Higher Education	-91.30 [270.0945]	224.07 [295.4294]		-87.67 [876.2344]	1.22 [549.0548]	
Constant	-289.42 [234.0535]	-414.81 [528.8299]	-33.85 [422.7629]	-354.44 [585.5817]	420.47 [694.3032]	606.34 [770.2023]
Observations	1721	484	427	372	408	119
R-squared	0.39	0.38	0.62	0.52	0.25	0.36
F Stat	F(37,1683)=66.1	F(30,453)=11.2	F(25,401)=52.8	F(30,341)=32.0	F(30,377)=23.8	F(17,101)=5.8
Prob F>0	0.00	0.00	0.00	0.00	0.00	0.00
Root MSE	813.8	608.5	564.7	714.9	1114.6	693.2

Source: ERHS with author's estimations

Notes: Robust standard errors in brackets

\*Significant at 10 percent, \*\* significant at 5 percent, \*\*\* significant at 1 percent.

OSS Estimations were implemented with dummies for villages whose coefficients were not reported to save space

For maize, no direct fertilizer response is significant in the data; improved seeds matter strongly for this crop, adding 625 kg per hectare of output, *ceteris paribus*, or more than 40 percent relative to the mean. Interaction terms between fertilizer and improved seeds were significant for wheat – adding another 190 kg yield if both improved seeds and 100 kg per hectare fertilizer were used. A few other results emerge from the controls. First, that land quality matters significantly for teff and barley (with the lowest quality land as the base group), and traditional fertilizer (manure) adds substantially too. A strong effect from secondary education for teff cultivation also emerges, but this is based on very few households –virtually no-one has this grade in the data.

**Table 7: Predicted Mean Difference Tests (2009)**

Inputs		Sample	Total	Teff	Barley	Wheat	Maize	Sorghum
Predicted mean yield	Using Both (Seeds=1; fertilizer =100kg/ha)	A	1698.6	1189.8		1718.2	2047.4	
	Fertilizer Only (Fertilizer=100kg/ha; Seeds=0)	B	1151.8	831.1	1006.7	1682.4	1422.6	1345.6
	Seeds Only (Fertilizer=0; Seeds=1)	C	1470.6	908.6		1509.3	1796.9	
	Nether (No Fertilizer; Seeds=0)	D	923.8	549.9	798.0	1473.5	1172.2	770.1
Difference	A-B	chi2 (1) Prob.	16.2 0.00	1.3 0.26		0.1 0.82	3.0 0.08	
	A-C	chi2 (1) Prob.	18.5 0.00	8.0 0.00		7.4 0.01	1.5 0.23	
	A-D	chi2 (1) Prob.	24.7 0.00	3.4 0.07	6.5 0.01	2.2 0.14	4.8 0.03	0.8 0.38
	B-C	chi2 (1) Prob.	5.6 0.02	0.1 0.81		0.8 0.36	0.8 0.38	
	B-D	chi2 (1) Prob.	18.5 0.00	8.0 0.00		7.4 0.01	1.5 0.23	
	C-D	chi2 (1) Prob.	16.2 0.00	1.3 0.26		0.1 0.82	3.0 0.08	

Source: Estimation from ERHS (2009)

In Table 7, this was explored further by comparing mean yield predicted on the model using the levels of yield. It shows the predicted yield values when using both fertilizer (at recommended amount which is 100kg/ha) and seeds (i.e. seeds=1); fertilizer only (recommended, 100kg) with no seeds (seeds=0); seeds only (seed=1) with no fertilizer; and no fertilizer and no seeds. All other characteristics are at the mean values in the sample. A chi squared-test is offered to test the differences using one of the inputs and both. Overall, the data suggests using both fertilizer and seeds adds significantly to yields compared to using only either or to using neither, while for teff and wheat, using both adds to yield compared only to using seeds alone.

**Table 8: Estimates of the parameters of quadratic production functions (1999)**

<b>Dependent Variable=levels of yield</b>	<b>Total</b>	<b>Teff</b>	<b>Barley</b>	<b>Wheat</b>	<b>Maize</b>	<b>Sorghum</b>
Dummy for improved seeds	591.79 [225.2956]***	1148.57 [635.2339]*		514.12 [296.8951]*	716.36 [396.7304]*	
Fertilizer application in kg per hectare	-0.03 [0.5116]	1.09 [1.1046]	-0.45 [0.5869]	-1.01 [1.1222]	0.57 [2.7280]	16.73 [5.0023]***
Square of chemical fertilizer used in kg	0.0028 [0.0011]***	0.0028 [0.0035]	0.0029 [0.0013]**	0.0045 [0.0024]*	0.0035 [0.0037]	-0.0428 [0.0128]***
Interaction term: Fertilizer & improved seeds	-0.4668 [1.1185]	-9.6388 [3.6333]***		-0.9758 [1.4356]	0.0054 [2.1045]	
Use of traditional fertilizer	117.87 [73.2864]	52.81 [71.0905]	182.67 [100.7599]*	156.36 [110.6515]	8.74 [242.2739]	184.13 [230.8071]
Irrigation: 1 if irrigated, 0 otherwise	-42.03 [141.6628]	59.16 [131.8240]	53.09 [381.7819]	1293.51 [1,248.8145]	71.29 [557.8339]	-517.29 [271.3775]*
Interaction term: fertilizer and Irrigation	0.138 [0.6556]	1.286 [1.4085]	-0.759 [0.9632]	-1.238 [2.1763]	-1.194 [1.8578]	
Fertility of Soil (Lem=1, best quality)	153.51 [64.6390]**	119.39 [96.0072]	58.73 [77.6122]	111.09 [121.7844]	910.37 [376.3740]**	-70.35 [368.6901]
Fertility of Soil (Lemteuf=1, medium quality)	-3.81 [56.9943]	7.91 [81.0555]	19.78 [72.2738]	-57.66 [112.8357]	821.58 [371.3108]**	-534.92 [289.8176]*
Slope of land (flat=1)	311.07 [109.8475]***		242.93 [109.1677]**	344.95 [256.9057]	-165.46 [642.1618]	1407.18 [482.9372]***
Slope of land (slopy)	265.13 [106.2958]**	11.19 [69.8737]	189.54 [94.5266]**	407.00 [273.4644]	713.91 [519.5981]	918.53 [408.2295]**
Age of holder	0.86 [8.2563]	12.08 [9.2227]	-11.16 [12.1470]	9.79 [15.5737]	-8.21 [33.3819]	4.91 [41.3445]
The square of age of holder	-0.0490 [0.0734]	-0.1036 [0.0823]	0.0541 [0.1065]	-0.1140 [0.1387]	-0.0903 [0.3118]	-0.1850 [0.3721]
Gender of holder : 1 if Male, =0 if Female	87.63 [52.6170]*	33.70 [62.4834]	9.55 [63.5428]	-19.73 [90.7456]	830.93 [269.7779]***	289.37 [300.3283]

Table 8 cont'd...

Dependent Variable=levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
Level of Education of holder						
Literate	47.10 [56.1226]	69.97 [74.1757]	23.86 [78.1125]	101.65 [120.3314]	-342.81 [319.2460]	19.04 [222.0788]
Primary (1-8)	55.44 [62.9413]	75.62 [76.2555]	11.75 [95.6923]	282.78 [137.4341]**	-292.17 [221.0256]	-12.17 [311.3857]
Higher Education	-72.27 [99.0007]	195.71 [94.6586]**		-14.42 [224.3400]	-535.25 [269.1230]**	
Constant	587.71 [254.0041]**	-74.91 [380.9521]	1122.97 [373.4130]***	4.72 [533.2163]	625.01 [903.3561]	-789.55 [1,085.7112]
Observations	1480	435	467	257	194	127
R-squared	0.31	0.41	0.15	0.33	0.50	0.49
F Stat	F( 30,1449) =28.99	F( 25, 409) =21.80	F( 20, 446) = 10.12	F( 23,233) = 6.08	F( 26,167) =39.29	F( 16,110) =7.27
Prob F>0	0.00	0.00	0.00	0.00	0.00	0.00
Root MSE	704.17	453.69	601.63	588.26	1049.00	938.53

Source: ERHS with author's estimations.

Notes: Robust standard errors in brackets. \*Significant at 10 percent, \*\* significant at 5 percent, \*\*\* significant at 1 percent. OSS Estimations were implemented with dummies for villages whose coefficients were not reported to save space

### 3.2 Analysis based on the 1999 ERHS Data

The Tables 8 and 9 provide the same analysis that we did for 2009 ERHS data above. The same model is specified as in above. The same exercise is done also in the choice of models. The basic model is presented in Table 8. As in section 3.1, two models were specified; one with levels of yield (Table 8) and another with logarithms of yield (Annex 6).

Results show that no direct relationship was found between chemical fertilizer and yield for all crops except sorghum. However, yield response for improved seeds was significant. Overall, a mean difference of 592 kg per hectare was found between plots where high yielding variety seeds are applied and those cultivated with indigenous seeds.

**Table 9: Predicted Mean Difference Tests (1999)**

Inputs		Sample	Total	Teff	Barley	Wheat	Maize	Sorghum
Predicted mean yield	Using Both (Seeds=1; fertilizer =100kg/ha)	A	1515.1	1977.1		1424.1	1858.8	
	Fertilizer Only (Fertilizer=100kg/ha; Seeds=0)	B	923.3	828.5	840.9	910.0	1142.5	2312.2
	Seeds Only (Fertilizer=0; Seeds=1)	C	1490.8	1840.8		1480.4	1766.8	
	Nether (No Fertilizer; Seeds=0)	D	899.0	692.3	856.4	966.2	1050.5	1066.8
Difference	A-B	chi2 (1) Prob.	6.90 0.01	3.3 0.07		3.0 0.08	3.3 0.07	
	A-C	chi2 (1) Prob.	0.32 0.57	2.8 0.10		0.4 0.54	0.2 0.70	
	A-D	chi2 (1) Prob.	7.53 0.01	4.0 0.05		2.3 0.13	3.2 0.07	
	B-C	chi2 (1) Prob.	5.89 0.02	2.5 2.52		3.2 0.07	1.7 0.19	
	B-D	chi2 (1) Prob.	0.32 0.57	2.8 0.10	0.1 0.74	0.4 0.54	0.2 0.70	11.04 0.00
	C-D	chi2 (1) Prob.	6.90 0.01	3.3 0.07		3.0 0.08	3.3 0.07	

Source: Estimated from ERHS (1999)

### 3.3 Analysis based on the 1999 & 2009 panel data

We brought together the 1999 and 2009 data to make them panel. First, the sample size after joining the data was not as expected (in the sense that it is much lower than 2 times the usually used ERHS datasets). This was because only part of the households was considered for analysis in both periods. On the 2009 dataset, we started with 2055 plots before data cleaning. After data cleaning, we are remained with only 2,009 observations.



These are only 820 households. On the 1999 dataset, we started with 3166 plots. After cleaning 2,166 plots remained. These are 848 households. When we merge them, only 507 households matched.

**Table 10: Estimates of the Parameters of Quadratic Production Functions Panel (1999 and 2009)**

Dependent Variable: Levels/logs of yield	Dependent Variable: levels of yield		Dependent Variable: logs of yield	
	Model I	Model II	Model III	Model IV
Dummy for Improved Seeds (dummy for Model I and amount in kg in Model II)	317.48 [183.6746]*	3.67 [0.9584]***	0.00 [0.1722]	0.00 [0.0014]
Fertilizer application per hectare	3.73 [0.8665]***	3.40 [0.8729]***	0.00 [0.0008]***	0.00 [0.0008]***
Square of chemical fertilizer used in kg	0.003 [0.0010]***	0.004 [0.0011]***	0.000 [0.0000]	0.000 [0.0000]
Interaction term between Fertilizer and Improved seeds (dummy)	-2.861 [0.8675]***	-0.008 [0.0014]***	-0.001 [0.0008]*	0.000 [0.0000]**
Irrigation: 1 if Part or all of plot irrigated, 0 otherwise	223.6314 [102.1586]**	212.6591 [99.7713]**	0.5181 [0.2031]**	0.5071 [0.2042]**
Interaction term between fertilizer and Irrigation	0.228 [1.5910]	0.438 [1.5607]	-0.001 [0.0014]	-0.001 [0.0014]
Use of traditional fertilizer	152.67 [74.7458]**	153.48 [74.0962]**	0.16 [0.0811]*	0.17 [0.0807]**
Year Dummy (2009=1)	28.50 [39.2283]	33.19 [39.4784]	0.13 [0.0474]***	0.13 [0.0475]***
Constant	571.41 [59.1967]***	577.74 [57.6375]***	6.22 [0.0540]***	6.21 [0.0529]***
Observations	1006	1006	942	942
Number of unid	507	507	506	506
R-squared	0.24	0.24	0.15	0.15
F Stat	F(8,506) = 43.40	F(8,506) = 0.59	F(8,505) = 26.06	F(8,505) = 32.55
Prob > F	0.0000	0.0000	0.0000	0.0000
sigma_u	518.8	519.1	0.5653	0.5589
sigma_e	614.1	612.8	0.6896	0.6900
rho (fraction of variance due to u_i)	0.4164	0.4177	0.4019	0.3962
corr(u_i, Xb)	-0.0311	-0.0258	0.0108	0.0291

Source: ERHS with author's estimations

Notes: Robust standard errors in brackets. \*Significant at 10 percent, \*\* significant at 5 percent, \*\*\* significant at 1 percent.

OSS Estimations were implemented with dummies for villages whose coefficients were not reported to save space

Annex 7 provides some descriptive statistics of the panel data. Table 10 presented four panel regression models. The first two models simply use the levels of yield while the last two use logarithms of yield. The first and third models use dummy for improved seeds while the second and the fourth use simply the amount of improved seeds in kg per hectare. We find that yield response to chemical fertilizer is statistically significant.

The coefficient for year dummy seems to be significant in the logs regression. This can be translated into total factor productivity (TFP), and suggests a growth in TFP of 13 percent in this period. Possible candidates for the source of TFP in this model are weather, infrastructure, and access to markets and other services etc., all of which were not included in the model. Table 11 shows that weather is unlikely to explain this difference: the relevant rainfall period for the 1999 and 2009 data are 1998 and 2008. We can see that 2008 was a good year relative to the long-term mean (3.5% better than usual) but 1998 was ever relatively better, so this is unlikely to be responsible for the TFP growth in 2009 relative to 1999.

**Table 11: Mean Annual Rainfall**

Rainfall/Year	1998	1999	2008	2009
Mean Annual Rainfall in mm	1326.9	1292.7	1176.6	981.1
Average mean annual rainfall in mm	1136.9			
Difference (%)	16.7	13.7	3.5	-13.7

Source: Own computations using CSA annual abstract for different years

#### 4. Concluding Remarks

Using the ERHS data, it was found that cereal yields grew between 2009 and 1999, except for sorghum and teff. However, this growth is much lower than that estimated using the CSA data. The levels of yield are also lower compared with the national average (CSA data), which is higher, by 7 percent in 1999 and 41 percent in 2009. This difference is highest for maize in 1999 and barley in 2009. The ERHS showed that there seems to be a modest increase in the use of modern inputs such as improved seeds and chemical fertilizer. Overall, as far as modern input use is concerned, the estimation based on the ERHS data is somewhat higher.

Results on cross section regression show that use of improved seeds significantly affects yield in both years. They lose their economic importance in the panel data analysis

however. In both cross section and panel data analysis, use of fertilizer was found to be significant, but the contribution to yield is economically rather insignificant, in comparison to seeds. An important point to note is the coefficient of the year dummy using the panel data analysis; it can be interpreted as offering TFP-style growth in yields over the decade, and it showed about 13% growth, at least in the log-specification. Important sources include the weather, infrastructure, access to markets and services not included in the model. Some simple correlates suggest that weather is not responsible for this growth.

Important caution must be taken in interpreting the above results however. First, since this study uses only data from two periods, it may not properly show the trend in cereal yield over the decade, but at best a snapshot. Second, it may not represent the national cereal yield status as the sample considers only 18 villages. However, this latter caveat might not be a serious one. These villages are located spread all over the country and the national trend is broad and widespread; hence this can be first approximation.

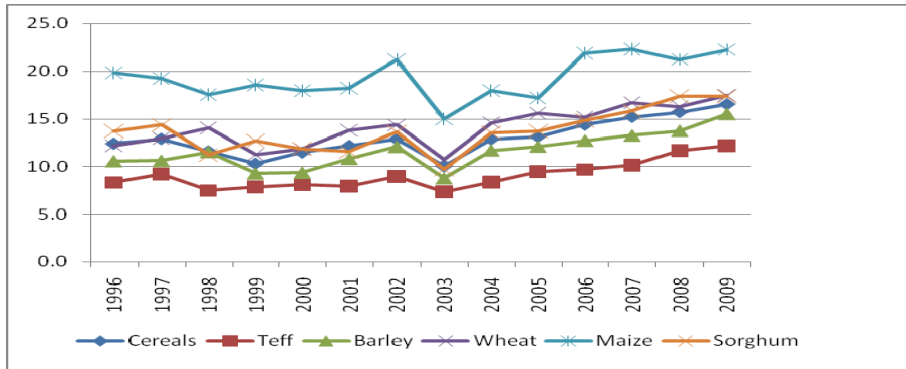
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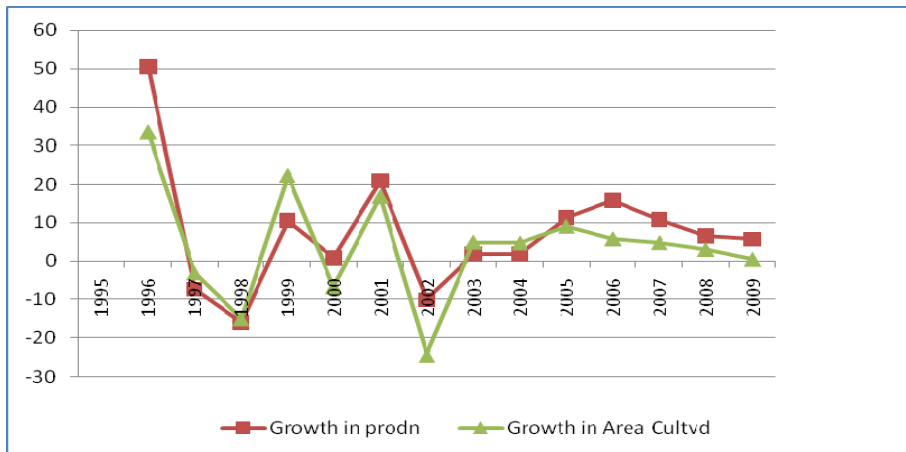
**Annexes**

**Annex 1: Trends in Yields of Major Cereal Crops (1996-2009)**



Source: Data from Central Statistical Agency (CSA), Different Agricultural Sample Surveys

**Annex 2: Growth in Cereal Production and Area Cultivated (1995-2009)**



Source: Data from Central Statistical Agency (CSA), Different Agricultural Sample Surveys

**Annex 3: Descriptive Statistics of Major Variables (2009)**

Variables	Total Sample		Teff		Barley		Wheat		Maize		Sorghum	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Yield (output in kg per hectare)	1167.7	1038.9	822.6	747.7	968.8	885.4	1626.1	980.4	1447.5	1326.3	822.0	792.4
Improved Seeds in kg per hectare	12.7	52.7	3.4	16.6	1.9	24.1	45.8	101.5	6.3	18.7	0.0	0.0
Chemical Fertilizer in kg per hectare	79.8	150.3	97.7	215.4	80.7	102.2	103.5	103.7	56.3	145.9	7.7	50.7
Use of Traditional Fertilizer (Man/Comp=1)	0.2	0.4	0.0	0.2	0.2	0.4	0.1	0.3	0.4	0.5	0.1	0.3
Use of Irrigation (Yes=1)	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.0	0.2
Natural Fertility of Land (Lem=1)	0.5	0.5	0.6	0.5	0.3	0.4	0.6	0.5	0.7	0.5	0.5	0.5
Natural Fertility of Land (Lemteuf=1)	0.3	0.5	0.2	0.4	0.4	0.5	0.3	0.5	0.2	0.4	0.3	0.5
Natural Fertility of Land (Teuf=1)	0.1	0.4	0.1	0.3	0.3	0.5	0.1	0.2	0.1	0.3	0.2	0.4
Slope of land (Medda=1)	0.8	0.4	0.8	0.4	0.8	0.4	0.8	0.4	0.8	0.4	0.8	0.4
Slope of land (Dagathama=1)	0.2	0.4	0.1	0.3	0.2	0.4	0.2	0.4	0.2	0.4	0.2	0.4
Slope of land (Geddel=1)	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.1
Age of holder (years)	52.4	14.0	52.2	13.1	55.5	14.1	51.5	13.5	50.8	14.7	49.7	13.7
Level of Education of holder												
Illiterate	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5
Literate (church -mosque)	0.3	0.4	0.3	0.5	0.4	0.5	0.2	0.4	0.2	0.4	0.2	0.4
Primary (1-8)	0.3	0.5	0.3	0.5	0.2	0.4	0.3	0.5	0.3	0.5	0.3	0.5
Secondary (9-12)	0.0	0.2	0.0	0.2	0.0	0.1	0.1	0.3	0.0	0.2	0.0	0.1
Higher Education	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1
Household size of holder	6.4	2.5	6.7	2.3	5.9	2.2	6.8	2.7	6.4	2.6	6.4	2.8
Gender of holder	0.7	0.4	0.8	0.4	0.6	0.5	0.7	0.4	0.8	0.4	0.8	0.4

Source: Estimated from ERHS (2009)

**Annex 4: Estimates of the parameters of quadratic production functions using log of yield (2009)**

<b>Dependent Variable= log of yield</b>	<b>Total</b>	<b>Teff</b>	<b>Barley</b>	<b>Wheat</b>	<b>Maize</b>	<b>Sorghum</b>
Dummy for improved seeds	0.42 [0.0935]***	0.13 [0.2659]		0.09 [0.1153]	0.33 [0.2114]	
Fertilizer application in kg per hectare	0.00 [0.0003]***	0.00 [0.0004]***	0.00 [0.0011]	0.00 [0.0006]***	0.00 [0.0016]*	0.01 [0.0070]
Square of chemical fertilizer used in kg	0.00 [0.0000]***	0.00 [0.0000]***	0.00 [0.0000]	0.00 [0.0000]**	0.00 [0.0000]	0.00 [0.0000]
Interaction term: Fertilizer & improved seeds	-0.0001 [0.0006]	-0.0002 [0.0013]		0.0010 [0.0008]	0.0007 [0.0013]	
Use of traditional fertilizer	0.3261 [0.0580]***	0.1184 [0.1498]	0.3060 [0.1487]**	-0.0985 [0.1191]	0.2400 [0.1051]**	0.5195 [0.3244]
Irrigation: 1 if irrigated, 0 otherwise	-0.0508 [0.1363]	0.1286 [0.1758]	-0.4260 [0.3297]	-0.1437 [0.3618]	0.1180 [0.2274]	-0.3276 [0.3176]
Interaction term: fertilizer and Irrigation	0.0020 [0.0009]**	-0.0049 [0.0075]	0.0035 [0.0020]*	0.0028 [0.0022]	0.0009 [0.0014]	
Fertility of Soil (Lem=1, best quality)	0.1347 [0.0666]**	0.1371 [0.1115]	0.1310 [0.1043]	-0.0049 [0.1448]	0.1280 [0.1832]	0.2582 [0.1820]
Fertility of Soil (Lemteuf=1, medium quality)	0.0438 [0.0689]	0.2115 [0.1165]*	0.0076 [0.1131]	-0.3076 [0.1689]*	0.1695 [0.1887]	0.1186 [0.2059]
Age of holder	-0.0097 [0.0073]	0.0038 [0.0165]	0.0066 [0.0144]	-0.0044 [0.0186]	-0.0192 [0.0112]*	-0.0001 [0.0323]
The square of age of holder	0.0001 [0.0001]	0.0000 [0.0001]	-0.0001 [0.0001]	0.0000 [0.0002]	0.0001 [0.0001]*	0.0000 [0.0003]
Household size of holder	0.0071 [0.0080]	0.0143 [0.0167]	0.0296 [0.0209]	-0.0083 [0.0123]	0.0149 [0.0182]	-0.0270 [0.0308]



**Annex 4 cont'd...**

Gender of holder : 1 if Male, =0 if Female	0.0235 [0.0468]	-0.0160 [0.0747]	0.0376 [0.1012]	-0.0110 [0.0876]	0.0854 [0.1031]	-0.0852 [0.2847]
Level of Education of holder						
Literate	-0.0900 [0.0557]	0.0502 [0.0821]	-0.2349 [0.1147]**	-0.1494 [0.1493]	-0.0144 [0.1180]	0.2370 [0.2659]
Primary (1-8)	-0.0210 [0.0538]	0.1270 [0.0928]	-0.1243 [0.1067]	-0.0579 [0.1130]	-0.0452 [0.1210]	0.4175 [0.2070]**
Secondary (9-12)	0.0583 [0.0764]	0.5140 [0.1757]***	0.0696 [0.1811]	0.0007 [0.1167]	-0.1503 [0.1753]	
Higher Education	-0.0736 [0.2062]	0.1271 [0.2297]		-0.2184 [0.5406]	0.1066 [0.2800]	
Constant	4.70 [0.3681]***	6.07 [0.5058]***	5.56 [0.5959]***	5.12 [0.8009]***	6.78 [0.4762]***	6.80 [1.0285]***
Observations	1567	476	327	353	381	118
R-squared	0.38	0.37	0.54	0.52	0.28	0.23
F Stat	F( 37, 1529) = 33.8	F( 29, 446) = 20.8	F( 25, 301) = 11.1	F( 30, 322) = 13.3	F( 29, 351) = 7.3	F( 17, 100) = 4.6
Prob F>0	0.00	0.00	0.00	0.00	0.00	0.00
Root MSE	0.74	0.64	0.74	0.59	0.78	0.85

Source: ERHS with author's estimations

Notes: Robust standard errors in brackets

\*Significant at 10 percent, \*\* significant at 5 percent, \*\*\* significant at 1 percent.

OSS Estimations were implemented with dummies for villages whose coefficients were not reported to save space

**Annex 5: Descriptive Statistics of Major Variables (1999)**

Variable	Total Sample		Teff		Barley		Wheat		Maize		Sorghum	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Yield (output in kg per hectare)	963.5	860.0	825.7	579.5	871.8	618.5	1006.3	697.8	1211.9	1373.3	1314.0	1399.5
Improved Seeds in kg per hectare	5.6	47.0	3.7	55.6	2.2	29.4	17.0	72.6	7.0	25.6	0.0	0.0
Chemical Fertilizer in kg per hectare	69.5	100.8	82.7	78.0	58.0	95.4	99.2	117.0	52.8	109.2	32.1	116.7
Traditional Fertilizer (Man/Comp=1)	0.2	0.4	0.0	0.2	0.2	0.4	0.1	0.3	0.4	0.5	0.4	0.5
Use of Irrigation (Yes=1)	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.2	0.4	0.0	0.2
Extension Coverage (Yes=1)	1.9	0.2	2.0	0.2	2.0	0.2	1.9	0.3	1.8	0.4	2.0	0.2
Natural Fertility of Land (Lem=1)	0.5	0.5	0.6	0.5	0.4	0.5	0.5	0.5	0.7	0.5	0.4	0.5
Natural Fertility of Land (Lemteuf=1)	0.3	0.5	0.3	0.4	0.3	0.5	0.3	0.5	0.3	0.4	0.4	0.5
Natural Fertility of Land (Teuf=1)	0.2	0.4	0.1	0.3	0.3	0.5	0.1	0.3	0.1	0.2	0.2	0.4
Slop of land (Medda=1)	0.8	0.4	0.9	0.2	0.8	0.4	0.8	0.4	0.8	0.4	0.7	0.5
Slop of land (Dagathama=1)	0.1	0.3	0.1	0.2	0.2	0.4	0.1	0.4	0.2	0.4	0.3	0.4
Slop of land (Geddel=1)	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.1
Age of holder (years)	49.4	14.9	47.5	14.4	51.8	15.1	50.0	15.6	47.6	13.9	47.8	14.2
Gender of holder	1.2	0.4	1.1	0.3	1.2	0.4	1.2	0.4	1.2	0.4	1.1	0.3
Level of Education												
Illiterate	0.4	0.5	0.3	0.5	0.5	0.5	0.4	0.5	0.3	0.4	0.5	0.5
Literate (church-mosque)	0.2	0.4	0.1	0.3	0.2	0.4	0.1	0.3	0.1	0.3	0.3	0.4
Primary (1-8)	0.1	0.3	0.2	0.4	0.1	0.3	0.2	0.4	0.2	0.4	0.1	0.3
Secondary (9-12)	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.1
Higher Education	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0

Source: Estimated from ERHS (1999)

**Annex 6: Estimates of the parameters of quadratic production functions (1999)**

<b>Dependent Variable =log of yield</b>	<b>Total</b>	<b>Teff</b>	<b>Barley</b>	<b>Wheat</b>	<b>Maize</b>	<b>Sorghum</b>
Dummy for improved seeds	0.34 [0.1429]**			0.39 [0.2621]	0.23 [0.2088]	0.00 0
Fertilizer application in kg per hectare	0.00 [0.0004]*	0.00 [0.0019]	0.00 [0.0006]	0.00 [0.0011]	0.57 [2.7280]	0.01 [0.0024]***
Square of chemical fertilizer used in kg	0.00 [0.0000]	0.0000 [0.0000]	0.0000 [0.0000]	0.0000 [0.0000]	0.0035 [0.0037]	0.0000 [0.0000]***
Interaction term: Fertilizer & improved seeds	0.00 [0.0007]	-0.0090 [0.0025]***		-0.0005 [0.0013]	0.0054 [2.1045]	
Use of traditional fertilizer	0.13 [0.0593]**	-0.01 [0.1336]	0.21 [0.0984]**	0.26 [0.1250]**	8.74 [242.2739]	0.18 [0.1770]
Irrigation: 1 if irrigated, 0 otherwise	-0.05 [0.1606]	0.10 [0.2328]	-0.14 [0.3987]	1.16 [0.7662]	71.29 [557.8339]	-0.39 [0.3267]
Interaction term: fertilizer and Irrigation	0.00 [0.0004]	0.002 [0.0034]	0.000 [0.0009]	-0.001 [0.0014]	-1.194 [1.8578]	
Fertility of Soil (Lem=1, best quality)	0.22 [0.0626]***	0.29 [0.1477]**	0.14 [0.0931]	0.00 [0.1477]	910.37 [376.3740]**	0.23 [0.2152]
Fertility of Soil (Lemteuf=1, medium quality)	0.02 [0.0603]	0.12 [0.1456]	0.05 [0.0860]	-0.12 [0.1322]	821.58 [371.3108]**	-0.20 [0.1976]
Slope of land (flat=1)	0.37 [0.1134]***		0.43 [0.1502]***	0.28 [0.2719]	-165.46 [642.1618]	0.92 [0.2983]***
Slope of land (slopy)	0.33 [0.1137]***	0.02 [0.1359]	0.38 [0.1399]***	0.36 [0.2879]	713.91 [519.5981]	0.68 [0.2964]**
Age of holder	0.01 [0.0080]	0.03 [0.0128]**	-0.01 [0.0149]	0.01 [0.0159]	-8.21 [33.3819]	0.01 [0.0298]
The square of age of holder	0.00	-0.0002	0.0001	-0.0001	-0.0903	-0.0001

**Annex 6 cont'd...**

	[0.0001]	[0.0001]**	[0.0001]	[0.0001]	[0.3118]	[0.0003]
Gender of holder : 1 if Male, =0 if Female	0.09	0.05	0.04	-0.01	830.93	0.08
	[0.0516]*	[0.0999]	[0.0783]	[0.0997]	[269.7779]***	[0.1857]
Level of Education of holder						
Literate	0.01	0.09	0.00	0.05	-342.81	0.04
	[0.0540]	[0.1025]	[0.0865]	[0.1419]	[319.2460]	[0.1734]
Primary (1-8)	0.09	0.19	0.11	0.19	-292.17	0.09
	[0.0610]	[0.1080]*	[0.1154]	[0.1196]	[221.0256]	[0.2614]
Higher Education	0.00	0.29		-0.08	-535.25	
	[0.0999]	[0.1391]**		[0.2293]	[269.1230]**	
Constant	5.96	4.54	6.49	5.79	625.01	4.54
	[0.2598]***	[0.7552]***	[0.4578]***	[0.5673]***	[903.3561]	[0.9000]***
Observations	1480	435	467	257	194	127
R-squared	0.34	0.43	0.18	0.34	0.50	0.46
F Stat	F(30,1449) =31.66	F(25, 409) = 17.78	F(20, 446) =8.81	F(23, 233) = 7.50	F(26, 167) = 39.29	F(16,110) =12.60
Prob F>0	0.00	0.00	0.00	0.00	0.00	0.00
Root MSE	0.68	0.67	0.67	0.58	1049.00	0.71

Source: ERHS with author's estimations

Notes: Robust standard errors in brackets

\*Significant at 10 percent, \*\* significant at 5 percent, \*\*\* significant at 1 percent.

OSS Estimations were implemented with dummies for villages whose coefficients were not reported to save space

**Annex 7: Descriptive Statistics of Major Variables (1999 & 2009)-Panel**

Variable		Mean	Std. Dev.	Min	Max	Observations
Yield	overall	1031.4	914.8	0.0	8333.3	N = 1655
	between		911.4	0.0	8333.3	n = 1156
	within		382.8	-1669.8	3732.6	T-bar = 1.431
Dummy for improved seeds	overall	0.12	0.33	0.00	1.00	N = 1668
	between		0.32	0.00	1.00	n = 1161
	within		0.14	-0.38	0.62	T-bar = 1.4366
Improved seeds used in kg per hectare	overall	7.6	40.7	0.0	1000.0	N = 1665
	between		42.2	0.0	1000.0	n = 1160
	within		16.6	-292.4	307.6	T-bar = 1.4353
Fertilizer application per hectare	overall	67.0	148.4	0.0	3400.0	N = 1665
	between		166.3	0.0	3400.0	n = 1160
	within		35.8	-308.0	442.0	T-bar = 1.4353
Square of chemical fertilizer used in kg	overall	26506.2	360610.3	0.0	11600000.0	N = 1665
	between		430843.3	0.0	11600000.0	n = 1160
	within		20212.2	-366018.0	419030.4	T-bar = 1.4353
Interaction term: Fertilizer & Improved seeds (dummy)	overall	13.3	54.7	0.0	1250.0	N = 1665
	between		55.8	0.0	1250.0	n = 1160
	within		23.2	-386.7	413.3	T-bar = 1.4353
Interaction term: Fertilizer & Improved seeds (continuous var)	overall	1702.2	32958.1	0.0	1250000.0	N = 1665
	between		37516.0	0.0	1250000.0	n = 1160
	within		8395.7	-238298	241702.2	T-bar = 1.4353
Irrigation: 1 if Part or all of plot irrigated, 0 otherwise	overall	0.06	0.24	0.00	1.00	N = 1668
	between		0.22	0.00	1.00	n = 1161
	within		0.12	-0.44	0.56	T-bar = 1.4366
Use of traditional fertilizer	overall	0.32	0.47	0.00	1.00	N = 1668
	between		0.42	0.00	1.00	n = 1161
	within		0.24	-0.18	0.82	T-bar = 1.4366
Interaction term between fertilizer and Irrigation	overall	3.20	22.63	0.00	400.00	N = 1665
	between		18.99	0.00	214.86	n = 1160
	within		13.26	-196.80	203.20	T-bar = 1.4353
Period dummy2009	overall	0.50	0.50	0.00	1.00	N = 2322
	between		0.00	0.50	0.50	n = 1161
	within		0.50	0.00	1.00	T = 2

Source: Estimated from ERHS (1999 &amp; 2009)

