CEREAL PRODUCTIVITY IN ETHIOPIA: AN ANALYSIS BASED ON *ERHS* DATA[1]

Getachew Ahmed Abegaz[2]

Abstract

This paper examines the recent phenomenon of cereal yield growth 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 of the Ethiopian Rural Household Surveys (ERHS). Results show that 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. The study further indicates that the source of this yield growth can be partly explained by modestly increasing use of modern inputs. It shows more intensification of modern agricultural inputs than that which the CSA data shows 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. However, using panel data analysis, the study also found an indication of some yield growth, unrelated to inputs such as seeds and fertilizer. This cannot be explained by weather changes and needs further research to capture its source in a time series setting.

Keywords: Cereal yield, yield growth, yield response to modern agricultural inputs

JEL Classification: O4, O13, O33, Q18

[1] *ERHS* is short for Ethiopian Rural Household Surveys. See section 2 for a full description of these datasets.

[2] Ethiopian Economics Association/Ethiopian Economic Policy Research Institute (EEA/EEPRI)

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 and Annex 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, and where crop specificity is an important feature (Gollin et. al., 2011).

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

Cereals	1999	2009	Annual AverageGrowth Rates
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. Although area expansion has been considerable, yield growth has accelerated more than area expansion particularly in the last few years (see Annex 2). However, the recent large yield increases do not seem to be explained by a sudden large increase in uses of modern inputs and improved farm management. Chemical fertilizer application is still low and only about 36.5 percent of total cereal acreage benefit from chemical fertilizer in 2009 (CSA, 2009; Gollin et. al., 2011). It also 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.

The share (in percent) of area under improved farm management for three time points is provided in Annex 3. 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.

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 both output and area cultivated grew, the growth rate in output outpaced area expansion. 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 or an unexpected shift.

Few studies were made on these recent phenomena. 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 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. al., 2011; Dercon and Hill, 2009).

A study on total factor productivity in agriculture by Fantu (2012) using a specification that used three primary inputs indicate that annual changes in total factor productivity averaged 4.5 percent during the five year period of 2004/05-2005/06 through 2008/9-2009/10. This figure declines to 1.4 percent for the same period with another specification accounting for factors that contribute to increased agriculture output. Pingali and Heisey (2009) documented studies on sources of total factor productivity in many developing countries. The majority of these studies found that modern farming technologies such as improved seeds (or high yielding varieties) and technology embodied in chemical fertilizer contribute to growth in total factor productivity. However, a study by Dercon and Hill (2009) 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.

There are many factors for this low-level use of high return technologies in Ethiopia and other sub-Saharan Africa. High transport costs, unfavorable climate, price risk, and illiteracy of household how to apply them, availability of fertilizer, price policies and credit availability, pricing environment and distribution costs, and infrastructural development are hurdles in the effective use of fertilizer markets (see for e.g. Daniel and Larson, 2010; Mwangi, 1996).

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 using other sources. This piece of work bases its analysis on the Ethiopian Rural Household Surveys (ERHS). The objective of the study is to examine recent cereal yield growth in Ethiopia and tries to see yield responses to modern inputs such as chemical fertilizer and improved seeds on major cereal crops.

Cereal crops constitute the largest share of farming household's production and consumption activities. Only five major cereals (barley, maize, sorghum, teff and wheat) account for about 70 percent of area cultivated and 65 percent of output produced (Alemayehu et. al, 2009). Moreover, according to Household Income, Consumption, and Expenditure Survey (HICE), these cereal crops account for 46 percent of household's total consumption. Therefore, a closer look at what is happening in cereal production has an important welfare and policy implication in Ethiopia.

The second section briefly describes the nature and source of data used. Furthermore, a production function is specified to see the impact of some important inputs on cereal yield. Discussion of results will be made in the third section. The fourth section concludes.

2. Data and Methods

This study uses data from the Ethiopian Rural Household Surveys (ERHS). ERHS is a longitudinal dataset and have 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). Production data were collected at plot level allowing analysis by plot and/or by crop and making sample size larger for consistent estimation.

Both descriptive and analytical methods are employed in this paper. 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. 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 recursive 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.

$$\boldsymbol{Y = Y(V, K, P, E)}$$

Where Y- 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 empirical model is specified to link yields with major inputs such as fertilizer

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

Where,

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

$\boldsymbol{f_{ic}}$= chemical fertilizer application (in kg) for crop c for household i

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

$\boldsymbol{x_{ic}'}$= other control variables including characteristics of the farm household (holder), characteristics of land, traditional fertilizer, dummy for villages, year etc.

Table 2: List of Some of the Questions/Variables in the Ethiopian Rural Household Survey (ERHS)

Variables (questions)	Variable Description/responses
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
Improved seed saved from last year/ bought/exchanged	Amount in kg
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
Education of household head	Highest grade obtained
Age of the household head	Number of years
Household size of the household	Number of household members
Gender of household head	Male=1, Female=0

A list of variables and their description is offered in Table 2. This model is 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.

$$\boldsymbol{y_{itc} = \beta_1 + \beta_2 f_{itc} + \beta_3 f_{itc}^2 + s_{itc} + \sum_{n=1}^{n=k} x'_{ic}\, \beta_n + \alpha_{ic} + \varepsilon_{itc}},$$

where α_{ic} is individual specific unobserved heterogeneity. This model is estimated using the levels and logs of yield. Fixed effects estimator was used.

3. Discussion of Results

3.1. Cereal yield and use of modern agricultural inputs in Ethiopia

After taking into account some adjustments on the data[3], Table 3 presents estimates of 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 they do not tell the stories in full. However, it is still useful for mean yield comparison between national figures. Moreover, even though the national trend seems robust to weather events (i.e. not just explained by 'good weather' in 2009–see Gollin et. al., 2011), in a smaller sample this may affect the findings. Furthermore, 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

[3] 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 nor 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. 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.

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) based on ERHS & CSA by Crop: 1999 and 2009

Crops	ERHS			CSA			Difference (%)	
	1999	2009	Period Growth (%)	1999	2009	Period Growth (%)	1999	2009
	A	B	(B/A-1)*100	C	D	(D/C-1)*100	(C/A-1)*100	(D/B-1)*100
Cereals	9.6	11.7	21.2	10.3	16.5	60.2	6.9	41.3
Teff	8.3	8.2	-0.4	7.9	12.2	54.4	-4.3	48.3
Barley	8.7	9.7	11.1	9.3	15.5	66.7	6.7	60
Wheat	10.1	16.3	61.6	11.3	17.5	54.9	12.3	7.6
Maize	12.1	14.5	19.4	18.5	22.2	20	52.7	53.4
Sorghum	13.1	8.2	-37.4	12.7	17.4	37	-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[4]? 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 Annex 3. Overall, the estimation based on the ERHS data shows more intensification of improved seeds.[5]

[4]In addition, 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.

[5]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 in the main text.

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.

Table 4: The Share of Areas (in percent) Cultivated with Modern Inputs: (1999-2009)[6]

Crops	Crop Area with Improved Seeds		Crop Area Applied with Fertilizer		Area Cultivated with Irrigation	
	1999	2009	1999	2009	1999	2009
Cereals	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

3.2. Responses of yield to modern inputs: Fertilizer and improved seeds

Regression results are reported based on the 2009 and1999 cross section and on panel datasets separately. 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 matched to inputs are included. Multi-collinearity test was made using variance inflating factor (VIF) and this data problem was not found. However, Breusch-Pagan/Cook-Weisberg test for heteroskedasticity was made and heteroskedasticity is present in both datasets as expected because we are dealing

[6]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.

with cross sectional datasets. We corrected this problem using robust standard errors.

Table 5 below presented estimations based on the 2009 cross section dataset. The model estimated below includes some interaction terms and all other variables. A descriptive statistics of the important variables was offered in Annex 4. 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.[7]

[7]This includes the impact of the concavity (the squared term on fertiliser is significant) reducing yield at 100 kg per hectare by 27 kg.

Table 5: 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	358.70		35.80	624.77	
	[135.9046]***	[319.2028]		[160.0459]	[358.1169]*	
Fertilizer application in kg per hectare	2.32	2.86	1.90	2.36	3.18	5.85
	[0.5456]***	[1.0259]***	[1.0395]*	[0.8566]***	[2.7600]	[8.4786]
Square of chemical fertilizer used in kg	-0.0004	-0.0005	0.0019	-0.0027	-0.0068	-0.0009
	[0.0002]**	[0.0003]	[0.0027]	[0.0011]**	[0.0080]	[0.0189]
Interaction term: Fertilizer & improved seeds	-0.33	-1.74		1.95	0.84	
	[0.7612]	[1.6658]		[1.1787]*	[2.2073]	
Use of traditional fertilizer	354.61	87.66	147.57	111.84	317.32	875.45
	[72.0241]***	[116.9787]	[65.8935]**	[134.4445]	[146.4417]**	[541.3394]
Irrigation: 1 if irrigated, 0 otherwise	16.93	20.30	-109.46	-501.10	287.82	-36.81
	[120.4961]	[127.1920]	[79.8081]	[579.7204]	[232.6713]	[266.8143]
Interaction term: fertilizer and Irrigation	2.10	-5.25	1.09	6.13	0.66	
	[1.2652]*	[5.5965]	[1.0566]	[4.1300]	[1.8808]	
Fertility of Soil (Lem=1, best quality)	222.45	193.87	170.14	189.22	223.12	300.70
	[56.1273]***	[84.7161]**	[81.4826]**	[145.4284]	[182.3776]	[161.7882]*
Fertility of Soil (Lemteuf=1, medium quality)	37.66	191.17	6.02	-168.49	101.28	167.82
	[52.0428]	[92.1537]**	[62.0759]	[153.3343]	[192.6097]	[140.8739]
Age of holder	1.59	25.22	10.58	16.68	-13.55	22.24
	[8.1870]	[19.5199]	[13.4008]	[21.5762]	[16.4296]	[18.1412]
The square of age of holder	-0.0214	-0.2135	-0.1336	-0.1543	0.1283	-0.2203
	[0.0723]	[0.1832]	[0.1199]	[0.1865]	[0.1271]	[0.1677]
Household size of holder	-1.20	-0.07	4.85	-23.76	9.54	-26.57

Dependent Variable=levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
	[9.8921]	[15.1795]	[13.8531]	[16.2527]	[32.4125]	[27.4108]
Gender of holder : 1 if Male, =0 if Female	73.96	68.84	109.05	-17.51	171.94	158.52
	[46.5607]	[65.9981]	[70.7740]	[108.2452]	[138.2774]	[242.4820]
Level of Education of holder						
Literate	33.046	148.571	-70.304	-9.779	134.426	-1.413
	[56.1197]	[75.5337]**	[80.4375]	[135.9657]	[173.6497]	[141.0628]
Primary (1-8)	28.31	109.97	-71.17	64.54	80.04	247.98
	[60.9615]	[75.2230]	[95.2352]	[114.9094]	[165.1064]	[171.8447]
Secondary (9-12)	151.91	715.98	262.79	158.11	-189.60	
	[109.4432]	[280.5677]**	[258.7840]	[150.3108]	[262.9586]	
Higher Education	-91.30	224.07		-87.67	1.22	
	[270.0945]	[295.4294]		[876.2344]	[549.0548]	
Constant	-289.42	-414.81	-33.85	-354.44	420.47	606.34
	[234.0535]	[528.8299]	[422.7629]	[585.5817]	[694.3032]	[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 6: 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)	16.2	1.3		0.1	3.0	
		Prob.	0.00	0.26		0.82	0.08	
	A-C	chi2 (1)	18.5	8.0		7.4	1.5	
		Prob.	0.00	0.00		0.01	0.23	
	A-D	chi2 (1)	24.7	3.4	6.5	2.2	4.8	0.8
		Prob.	0.00	0.07	0.01	0.14	0.03	0.38
	B-C	chi2 (1)	5.6	0.1		0.8	0.8	
		Prob.	0.02	0.81		0.36	0.38	
	B-D	chi2 (1)	18.5	8.0		7.4	1.5	
		Prob.	0.00	0.00		0.01	0.23	
	C-D	chi2 (1)	16.2	1.3		0.1	3.0	
		Prob.	0.00	0.26		0.82	0.08	

Source: Estimation from ERHS (2009)

In Table 6, the above analysis 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 7 provides the estimated results based on the 1999 cross section dataset. Similar analysis that we did for 2009 data was made. The same model is specified as in above and the same exercise is done in the choice of models.

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. However, these results show that there was no direct relationship found between chemical fertilizer and yield for all crops except sorghum in 1999. The fact that yield doesn't respond to chemical fertilizer in 1999 while this input has an impact in 2009 can be explained partly by a host of factors, that affect the effective utilization of chemical fertilizer (e.g. see Daniel and Larson, 2010; Mwangi, 1996), that can improve over time the application and utilization of the input.

Table 7: Estimates of the parameters of quadratic production functions (1999)

Dependent Variable = levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
Dummy for improved seeds	591.79	1148.57		514.12	716.36	
	[225.2956]***	[635.2339]*		[296.8951]*	[396.7304]*	
Fertilizer application in kg per hectare	-0.03	1.09	-0.45	-1.01	0.57	16.73
	[0.5116]	[1.1046]	[0.5869]	[1.1222]	[2.7280]	[5.0023]***
Square of chemical fertilizer used in kg	0.0028	0.0028	0.0029	0.0045	0.0035	-0.0428
	[0.0011]***	[0.0035]	[0.0013]**	[0.0024]*	[0.0037]	[0.0128]***
Interaction term: Fertilizer & improved seeds	-0.4668	-9.6388		-0.9758	0.0054	
	[1.1185]	[3.6333]***		[1.4356]	[2.1045]	
Use of traditional fertilizer	117.87	52.81	182.67	156.36	8.74	184.13
	[73.2864]	[71.0905]	[100.7599]*	[110.6515]	[242.2739]	[230.8071]
Irrigation: 1 if irrigated, 0 otherwise	-42.03	59.16	53.09	1293.51	71.29	-517.29
	[141.6628]	[131.8240]	[381.7819]	[1,248.8145]	[557.8339]	[271.3775]*
Interaction term: fertilizer and Irrigation	0.138	1.286	-0.759	-1.238	-1.194	
	[0.6556]	[1.4085]	[0.9632]	[2.1763]	[1.8578]	
Fertility of Soil (Lem=1, best quality)	153.51	119.39	58.73	111.09	910.37	-70.35
	[64.6390]**	[96.0072]	[77.6122]	[121.7844]	[376.3740]**	[368.6901]
Fertility of Soil (Lemteuf=1, medium quality)	-3.81	7.91	19.78	-57.66	821.58	-534.92
	[56.9943]	[81.0555]	[72.2738]	[112.8357]	[371.3108]**	[289.8176]*
Slope of land (flat=1)	311.07		242.93	344.95	-165.46	1407.18
	[109.8475]***		[109.1677]**	[256.9057]	[642.1618]	[482.9372]***
Slope of land (slopy)	265.13	11.19	189.54	407.00	713.91	918.53
	[106.2958]**	[69.8737]	[94.5266]**	[273.4644]	[519.5981]	[408.2295]**

Dependent Variable = levels of yield	Total	Teff	Barley	Wheat	Maize	Sorghum
Age of holder	0.86	12.08	-11.16	9.79	-8.21	4.91
	[8.2563]	[9.2227]	[12.1470]	[15.5737]	[33.3819]	[41.3445]
The square of age of holder	-0.0490	-0.1036	0.0541	-0.1140	-0.0903	-0.1850
	[0.0734]	[0.0823]	[0.1065]	[0.1387]	[0.3118]	[0.3721]
Gender of holder : 1 if Male, =0 if Female	87.63	33.70	9.55	-19.73	830.93	289.37
	[52.6170]*	[62.4834]	[63.5428]	[90.7456]	[269.7779]***	[300.3283]
Level of Education of holder						
Literate	47.10	69.97	23.86	101.65	-342.81	19.04
	[56.1226]	[74.1757]	[78.1125]	[120.3314]	[319.2460]	[222.0788]
Primary (1-8)	55.44	75.62	11.75	282.78	-292.17	-12.17
	[62.9413]	[76.2555]	[95.6923]	[137.4341]**	[221.0256]	[311.3857]
Higher Education	-72.27	195.71		-14.42	-535.25	
	[99.0007]	[94.6586]**		[224.3400]	[269.1230]**	
Constant	587.71	-74.91	1122.97	4.72	625.01	-789.55
	[254.0041]**	[380.9521]	[373.4130]***	[533.2163]	[903.3561]	[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

Bringing the 1999 and 2009 datasets together, fixed effects model was estimated and the result is reported in Table 8. 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 8: Estimates of the Parameters of Quadratic Production Functions- Panel (1999 and 2009)

Dependent Variable: Levels/logs of yield	levels of yield	logs of yield
	Model I	**Model II**
Dummy for improved seeds	317.48	0.00
	[183.6746]*	[0.1722]*
Fertilizer application per hectare	3.73	0.00
	[0.8665]***	[0.0008]***
Square of chemical fertilizer used in kg	0.003	0.000
	[0.0010]***	[0.0000]
Interaction term between Fertilizer and Improved seeds	-2.861	-0.001
	[0.8675]***	[0.0008]*
Irrigation: 1 if Part or all of plot irrigated, 0	223.6314	0.5181
	[102.1586]**	[0.2031]**
Interaction term between fertilizer and	0.228	-0.001
	[1.5910]	[0.0014]
Use of traditional fertilizer	152.67	0.16
	[74.7458]**	[0.0811]*
Year Dummy (2009=1)	28.50	0.13
	[39.2283]	[0.0474]***
Constant	571.41	6.22
	[59.1967]***	[0.0540]***
Observations	1006	942
Number of uid	507	506
R-squared	0.24	0.15
F Stat	F(8,506) = 43.40	F(8,505) = 26.06
Prob > F	0.0000	0.0000
sigma_u	518.8	0.5653
sigma_e	614.1	0.6896
rho (fraction of variance due to u_i)	0.4164	0.4019
corr(u_i, Xb)	-0.0311	0.0108

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 6 provides some descriptive statistics of the panel data. Table 8 presents two panel regression models. The first uses levels of yield while the second uses logarithms of yield. The log-linear regression model was run to have a rough estimate of the percentage change in the year dummy, a proxy for factors that change overtime but not considered in the model.

We find that yield responses to chemical fertilizer and improved seeds are statistically significant. The coefficient for year dummy seems to be significant. This can be translated into total factor productivity (TFP), and suggests a growth in TFP of 13 percent in this period. Although not comparable, similar results were also found by Fantu (2012). Possible candidates for the source of TFP in developing countries include institutional change, agricultural terms of trade, weather, infrastructure, and access to markets (see for e.g. Pingali and Heisey, 2009), none of which were included in this model. A rudimentary analysis is provided in Table 9 showing weather is unlikely to explain this difference: the relevant rainfall period for the 1999 and 2009 data are 1998 and 2008.

Table 9: 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

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.

4. Concluding Remarks

Although figures from official sources show that cereal yield growth has been high in the last few years, it remains to be explained in terms of the use of modern agricultural inputs, which are very low. The objective of this study is to examine cereal yield growth and the sources of this growth using another dataset. It was found that cereal yield grew between 1999 and 2009. However, this growth is much lower than that estimated using the CSA data. The levels of yield are also lower compared with the national figures, which is higher, by 7 percent in 1999 and 41 percent in 2009. The study also 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 the more recent cross section data 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 institutional change over the period, 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. Further research is needed to capture these variables in a time series setting.

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, the results can be first approximation.

References

Alemayehu S., Sinafikeh A. and Gerawork G. 2009. "Trends and Determinants of Cereal Productivity: Econometric Analysis of Nationally Representative Data." IFPRI, ESSP-II. Addis Ababa, Ethiopia

Cameroon, A. C., and Trivedi, P. K. 2005. *Microeconometrics: Methods and Applications*. Cambridge University Press.

CSA. 1998. Report on Farm Management Practices (Private Peasant Holdings, Meher Season), Ethiopian Agricultural Sample Survey (1997/98 (1990 E.C.)), Statistical Bulletin 193, Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

________. 1999. Report on Area and Production for Major Crops, Ethiopian Agricultural Sample Survey (1998/99 (1991 E.C.)), Statistical Bulletin 200, Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

________. 2000. Report on Area and Production for Major Crops, Ethiopian Agricultural Sample Survey (1999/2000 (1992 E.C.)), Statistical Bulletin 227, Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

________. 2001. Report on Area and Production for Major Crops, Ethiopian Agricultural Sample Survey (2000/2001) (1993 E.C.)), Statistical Bulletin 245, Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

________. 2005. Report on Farm Management Practices for Meher Season Crops, Ethiopian Agricultural Sample Survey (2004/05 (1997 E.C.)) – Volume III, Statistical Bulletin 331, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

________. 2006. Report on Area and Production of Crops, Ethiopian Agricultural Sample Survey (2005/06 (1998 E.C.)) – Volume I, Statistical Bulletin 361, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

________. 2007. Report on Area and Production for Major Crops, Ethiopian Agricultural Sample Survey (2006/2007) (1999 E.C.)), Statistical Bulletin 388, Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

________. 2008. Report on Area and Production Crops, Agricultural Sample Survey 2007/2008 (2000 E.C.): Volume I -, Statistical Bulletin 417, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

________. 2009. Agricultural Sample Survey 2008/2009 (2000 E.C.): Volume I - Report on Area and Production Crops, Statistical Bulletin 446, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

________. 2009. Report on Farm Management Practices for Meher Season Crops, Ethiopian Agricultural Sample Survey (2008/09 (2001 E.C.))–Volume III, Statistical Bulletin 446, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

Daniel Z. and Larson, D. F. 2010. "Incomplete Markets and Fertilizer Use: Evidence from Ethiopia." The World Bank Development Research Group Agriculture and Rural Development Team.

Dercon, S. and Hill V. 2009. Growth from Agriculture in Ethiopia: Indentifying Key Constraints. DfID, UK, 2009.

Ethiopian Economics Association. 2009. *Report on the Ethiopian Economy*. Volume VII. 2007/08, Ethiopian Economics Association. Addis Ababa, Ethiopia

Fantu N. Bachewe. 2012. "Growth in Total Factor Productivity in the Ethiopian Agriculture Sector: Growth Accounting and Econometric Assessments of Sources of Growth." ESSP-II Working Paper, 2012 IFPRI-ESSP-II, Addis Ababa, Ethiopia.

Food and Agriculture Organization. FAO. Faostat.org accessed at January 2011

Gollin, D., Lee F, R, Scher, I., Schlemme, C. 2011. "Crop Production in Ethiopia: Assessing the Evidence for a Green Revolution." Department of Economics, Williams College; IGC Growth Week.

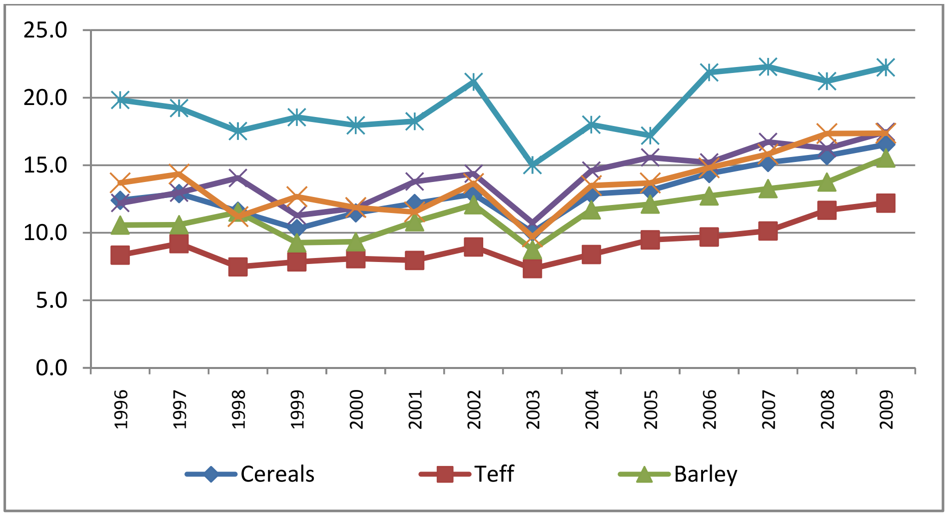
Mwangi, W. 1996. "Low Use of Fertilizers and Low Productivity in Sub-Saharan Africa." NRG Paper 96-05. Mexico, D.F.: CIMMYT.

Prabhu L. P. and Paul W. H. 1999. "Cereal Crop Productivity in Developing Countries: Past Trends and Future Prospects." CIMMYT, Working Paper 99-03.

Sing, I., Squire, L., Strauss, J. 1986. "A Survey of Agricultural Household Models: Recent Findings and Policy Implications." *The World Bank Economic Review*, Vol. 1 (Sept., 1986), pp. 149-179.

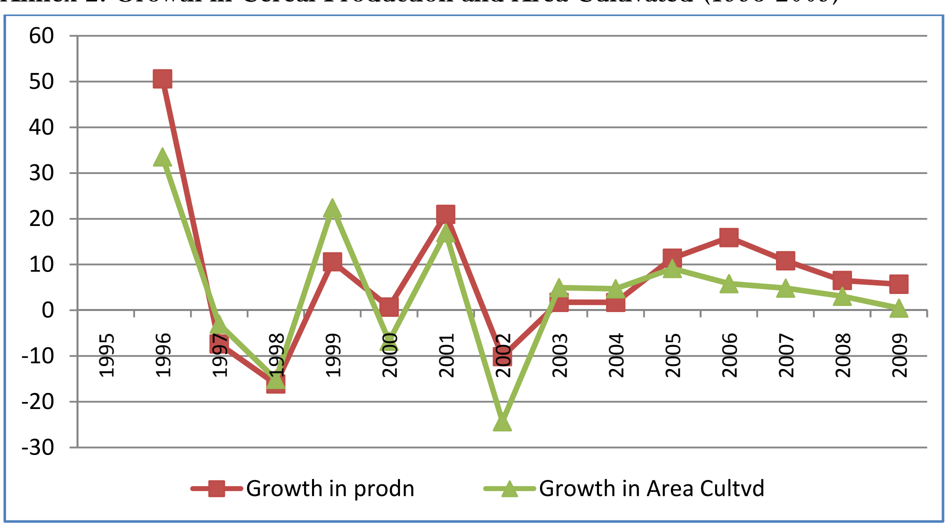
Annexes

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: 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 Chemical Fertilizer	2008/09	36.5	51.9	27.8	60.1	31.0	3.0
Share of Crop	2004/05	18.2	17.2	16.7	29.5	24.9	6.5
Area with Extension Package	2008/09	15.6	16.2	8.8	20.5	23.0	2.9

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

Annex 4: 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	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
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
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
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
Slop 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
Slop 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
Slop 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 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	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
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
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
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: 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

Variable		Mean	Std. Dev.	Min	Max	Observations
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 & 2009)