Chapter 9

FARMING PRACTICES AND PRODUCTIVITY

Getu Hailu, Alfons Weersink, and Bart Minten

One of the challenges in Africa south of the Sahara is the struggle to develop sustainable agricultural production systems to cope with increasing population pressure and the associated growth in the demand for food. The Ethiopian government wants to double the production of teff to aid in the alleviation of food insecurity among the general population, which will in the process enhance the well-being of individual farm households that grow, consume, and sell teff. The increase in Ethiopian teff production over the past decade resulted primarily from an increase in the area cultivated (Demeke and Marcantonio 2013). However, since there are limits to the amount of arable land available, the desired increases in teff production will have to be met largely through increases in agricultural productivity.

Understanding the relationships between farming practices and yield increases will help in the design of programs to promote the continued and necessary increase in teff yield. For example, if the productivity difference between individual farmers is due to differences in practices employed, then one policy option is to promote the adoption of yield-enhancing technologies (Ali and Byerlee 1991). This promotion could be through modern input methods or even subsidies. This assumes that the farmers are aware of the benefits but do not use the technologies because of credit constraints or being unable to handle the uncertainty of switching practices. However, if the farmers are not using the current technology properly or are not aware of the yield-enhancing practices, there is a role for extension efforts to develop the skills and knowledge of the farmer. Either publicly funded programs or farm organizations could provide the extension education.

Information about yield-enhancing technologies, such as seed variety, is generally provided to farmers in developing countries through publicly funded agricultural extension programs (Townsend et al. 2013). Producer organizations operate as an alternative mechanism to provide technical information and may also serve to link farmers with markets for inputs and outputs.

For example, agricultural producer cooperatives provide farmers with access to inputs and output markets, whereas producer community groups provide opportunities to discuss best management practices.

In this chapter, teff production practices are described, along with their relationships with the level of land productivity of teff producers in Ethiopia. Data are used on plots of teff from a survey of 1,200 stratified randomly selected households conducted at the end of 2012. We selected this dataset as it provides high-quality data, relevant information on teff practices, and a large sample. The relationships between farming practices and teff yield are assessed through a descriptive analysis of the data and the estimation of a production function to determine teff productivity. Although input levels and characteristics of the plot and household are included as right-hand variables, the focus is on the technology employed and producer organizations used. The analysis sheds light on the relationships between farming practices and yield across plots as well as the implications for policies to improve land productivity for teff producers.

Methods and Data

Two approaches are used to examine the links between farming practices and productivity differences. First, descriptive statistics and nonparametric tests are used as a crude measure for the relationship between farming practices and the cross-sectional variations in the level and distribution of land productivity with a focus on the role of technology adoption and extension activities. Since teff yield data has a skewed distribution according to the results of the Shapiro-Francia W' test (Shapiro and Francia 1972; Royston 1983), nonparametric tests are used—that is, the Wilcoxon-Mann-Whitney and the Kruskal Wallis tests—to determine if differences in yield across factors is statistically significant in the absence of normality. To test for a possible first-degree conditional stochastic dominance in the distribution of yields between two groups (for example, cooperative members versus nonmembers), a Kolmogorov-Smirnov (KS) test is used.

Second, the following Cobb-Douglas production function is estimated by ordinary least squares (OLS),

$$y_{ijp} = \beta_0 + \beta_i + \beta x_{ijp} + \delta H_{ijp} + \gamma Plot_{ijp} + \alpha Tech_{ijp} + \tau Extension_{ijp} + \zeta Weather_{ijp} + \varepsilon_{ijp} \qquad (1)$$

where i indexes household, j indexes village/district/region, and p indexes plot; y_{ijp} is the logarithm of total output for plot p from household i located in region j; β_i is a zone or kebele or household fixed effect that captures possible heterogeneity at the specified spatial level; x_{ijp} is a vector of quantity of logarithm of variable inputs; H_{ijp} is a vector of household characteristics; $Plot_{ijp}$ is a vector of plot characteristics; $Tech_{ijp}$ is a vector of technological practices adopted; $Extension_{ijp}$ is a vector of extension activities; $Weather_{ijp}$ is a vector of weather shock factors; and ε_{ijp} is an error term that summarizes the effects of unobserved plot quality variation and plot-specific production shocks on yields. β, δ, α, τ, and ζ are parameters to be estimated. Five versions of (1) are estimated: a base model without any fixed effects ($\beta_i = 0$), plus fixed effects for zone, district (woreda), village (kebele), and households.[1]

The data for the study come from a survey of 1,200 households conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI) (see Chapter 11). The main purpose of the survey was to understand the teff value chains to make recommendations to policy makers to improve the performance of value chains for farmers, wholesalers, retailers, and consumers. The survey was conducted in 2012 in sixty villages (kebele), in twenty districts (woreda), in five major teff-producing zones (regions) of Ethiopia (East Gojjam, West Gojjam, East Shewa, West Shewa, and South West Shewa). The five zones represent 38 percent of national teff area and 42 percent of the commercial surplus (Ethiopia, CSA 2012). The average (and the coefficient of variation of) altitude in meters of the five zones are 2,323 (10 percent) for East Gojjam; 2,200 (5 percent) for West Gojjam; 1,784 (24 percent) for East Shewa; 2,099 (13 percent) for West Shewa; and 2,188 (5 percent) for South West Shewa.

The detailed cross-sectional data contain household- and plot-level information on teff production. The number of teff plots per household range from 1 to 6 in the dataset with an average of 1.2. In addition to teff production on each plot, the data include information on six sets of variables identified in equation (1): (1) inputs (for example, amount of seed, labor use, number of oxen, DAP and urea fertilizer applied, and amount of herbicide applied); (2) household characteristics (for example, age, gender, and the level of education of the household head, and distance from the nearest marketplace); (3) plot characteristics (for example, plot size, soil color, slope); (4) technological practices (for example, seed variety and color, crop rotation, mobile phone

1 The fixed effect regressions estimated in this study "[are] usually called the dummy variable regression[s]" (Wooldridge 2010, 485).

ownership); (5) extension activities (for example, cooperative membership, the number of community meetings attended, the number of extension agent visits, and being a model farmer); and (6) weather shocks (for example, rainfall [timing and extent], frost).[2]

Descriptive Analysis of Teff Production

Before examining the relationships between farming practices and productivity in this section, a descriptive overview is provided of (1) the production practices of Ethiopian teff farmers, and (2) teff output and inputs. First, the statistics are presented for several parts of the production process—that is, land preparation, seed use, modern input use and teff cultivation, and harvest and postharvest practices. Then the labor allocations patterns are explored. Second, summary statistics are provided for yield and the variety of explanatory variables used in the analysis to examine yield variations.

Teff Production Practices

Most of the farmers grow teff on fragmented lands and as part of a rotation. The average number of parcels managed in the sample used is approximately four, with an average lot size of 0.48 hectares for teff. Farmers do not often plant teff two years in a row on the same plots. For the plots in the survey, in only 34 percent of the cases was teff also planted in the year prior to the survey (Table 9.1).

Plowing is one of the important land preparation practices, as the soil needs to be loose to allow the very small teff seeds to germinate. The average plot in the study sample was tilled 4.4 times (Table 9.1). In 95 percent of the cases, plowing was done by animals. In 4 percent of the cases, it was done by hand. Mechanized plowing is almost nonexistent, as it was mentioned for only 0.4 percent of the plots.[3] When animals were used, these were usually owned by the farmer himself (84 percent of the cases). Renting-in animals for plowing of teff plots in these zones is rare (4 percent).

Nutrient requirements can be provided through either organic fertilizer (that is, manure) or inorganic fertilizer. Manure use on plots for teff production is limited. Farmers stated that 89 percent of the teff plots never received

2 In many cases, "model farmers" or leader farmers are farmers chosen by extension services with the aim of working together in implementation of extension programs (Franzel et al. 2013).

3 The repeated plowing using animal traction for the preparation of fields and of trampling of fields with livestock before planting might possibly result in damaging soil structure and lead to soil erosion. The authors are, however, not aware of recent research on this issue.

TABLE 9.1 Land preparation practices employed to grow teff

	Unit	Mean (or %)	Median
Crop Rotation			
Teff was planted in prior year on plot	%	34	
Plowing			
Number of times plowed	Number	4.4	4.0
Manner that soil was plowed:			
Hoe	%	4	
Animal	%	95	
Tractor	%	0.4	
Mixed	%	0.4	
If animals used, owner of animals:			
Own	%	84	
Rented	%	4	
Sharing	%	1	
Mix	%	11	
Manure application			
Frequency of manure use:			
Every year	%	6	
Most years	%	1	
Some years	%	2	
Rarely	%	2	
Never	%	89	
Farmer used manure on the plot this year	% yes	8	
Farmer used other organic inputs this year	% yes	5	

Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

manure, while only 6 percent of the plots received it every year and 8 percent in the year prior to the survey. Only 5 percent of the plots used another organic input instead of manure. These results overall indicate that the use of organic fertilizer in teff production is low.

A wide variety of teff seeds are used. The four main color-based grades of teff are magna (very white), nech (white), sergegna (mix between white and red), key (brown/red) (see Chapter 3). In terms of market values, magna ranks first with key the least valuable. White teff seeds were used on 52 percent of the plots (Table 9.2) compared to 17 percent of magna seeds (very white).

TABLE 9.2 Input use in the production of teff by respondents

	Unit	Mean (or %)	Median
Seeds			
Color of seeds:			
Magna	%	17	
White	%	52	
Mix	%	11	
Black or red	%	20	
Variety of seeds:			
Quncho	%	19	
Other improved seeds	%	11	
Traditional	%	70	
Source of seeds:			
From own harvest	%	78	
Purchased	%	17	
For free or in barter	%	5	
If not from own harvest, source of seeds:			
Cooperative	%	19	
Other farmers	%	66	
Private trader	%	9	
Bureau of agriculture	%	6	
Seeds planted through broadcasting	%	99.5	
Quantity of seed used	kilogram per hectare	44	40
Sowed at normal time this year:			
Early	%	7	
Normal	%	85	
Late	%	9	
Late due to late access of fertilizer	% yes	3	
Late due to flooding or late rains	% yes	3	
Fertilizer			
% of plots where DAP was used	%	89	
Number of times that DAP was applied:			
Once	%	93	
More than once	%	7	
% of plots where urea was used	%	79	

	Unit	Mean (or %)	Median
Number of times that urea was applied:			
Once	%	49	
Twice	%	43	
More than twice	%	8	
Weed Control			
Number of weedings	Number	1.2	
% of plots where herbicides were used	%	65	
% of plots where pesticides were used	%	16	

Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

Sergegna (mix) and red seeds made up 11 percent and 20 percent of the plots, respectively. The high prevalence of white and magna seeds indicate the importance of consumer preferences as more white seeds are disproportionately sold than red or mixed seeds. Red or mixed seeds are often retained for home consumption (Minten et al. 2013).

Teff seeds can broadly be classified into traditional and improved varieties. In most of the cases, farmers rely on traditional seeds—as stated by the sample farmers. Of the plots, 30 percent were reported to be planted with improved seeds; 19 percent were planted with the improved Quncho ("top most") variety. Officially released in 2006, Quncho was developed by the Debre Zeit Agricultural Research Center (DZARC) from two parent materials: one high-yielding but pale color (Dukem, DZ-01-974) and the other a lower yielding but possessing a popular very white seed color (Magna, DZ-01-196) (Tefera, Belay, and Sorrells 2001). Yield performance on experimental trials with Quncho was found to be significantly higher than national average yields for teff (Assefa, Chanyalew, and Metaferia 2013). For further details, see Chapter 3. This survey was done in the most productive areas of Ethiopia (representing approximately 40 percent of national production), possibly explaining the relatively high adoption of improved seeds in this dataset.

Farmers obtained seeds from a variety of different sources including their own harvest, other farmers, cooperatives, private traders, and the Bureau of Agriculture. A full 78 percent of the seeds were obtained from their own harvest, and only 17 percent were purchased (5 percent were received for free or bartered). If the seeds were not from their own harvest, other farmers supplied seed for approximately two-thirds of the cases. Formal outlets for distribution are therefore relatively less important (that is, cooperatives 19 percent, private traders 9 percent, and Bureau of Agriculture 6 percent of the approximately one-fifth of the seeds purchased).

The government has in recent years started a program aimed at encouraging farmers to use row planting rather than broadcast seed. According to the Agricultural Transformation Agency (ATA 2013), row planting at a reduced seed rate is believed to have important positive effects on teff productivity as compared to sowing with broadcasting (ATA 2013). However, at the time of the survey, the row-planting practice had not been promoted, so the majority of the farmers practiced broadcasting for sowing. The quantities of seeds used were therefore high—that is, on average 44 kilograms per hectare, as compared to 5 kilograms per hectare seeding rate used with row planting (ATA 2013).

In terms of timing, 85 percent of the plots were sown at the normal time (typically July), 7 percent early, and 9 percent late (mostly because of late access to fertilizer [3 percent] or because of flooding or late rains [3 percent]), indicating that the survey year experienced typical growing conditions (Table 9.2).

Fertilizers and herbicides were used on a large number of the plots in the survey. The application of inorganic fertilizer is particularly widespread and is the main source of additional nutrients given the low use of organic fertilizer noted earlier. In the year prior to the survey, 89 percent of the plots received DAP and 79 percent received urea. DAP was mostly used once (at the time of planting), while urea was applied once (49 percent), twice (43 percent), or even more (8 percent). Although herbicides are often used (65 percent) to help reduce weeding efforts, manual weeding is, on average, still done once per season. The use of pesticides or other sprays is less prevalent as these were only applied on 16 percent of the teff plots. The finding that inorganic fertilizers and herbicides are often used in teff production, whereas insecticides and fungicides are not commonly used, is consistent with the analysis of Gorfu and Ahmed (n.d.).

As with most agricultural products, teff is subject to disease and weather shocks. However, it is believed that teff is more resistant to diseases than a number of other crops, which might partly explain its success in Ethiopia (Assefa, Chanyalew, and Metaferia 2013). During the cultivation period, 84 percent of the plots did not suffer from any insects, animal damage, or pests. If there were such problems, they were mostly related to cutworm, root rot, and ball worm (Table 9.3). Questions were also asked about the type of disease that affected teff on a plot. Farmers reported that 85 percent of the plots had not suffered from any diseases. Leaf rust was the most common

TABLE 9.3 Growing stresses and harvest methods on teff plots by respondents

Stresses and harvest methods	Unit	Mean (or %)	Median
Shocks and diseases			
Most important insects/animals/pests issues:			
Locust or grasshopper	%	2	
Shootfly	%	1	
Cutworm/root rot/ball worm	%	13	
None	%	84	
Most important disease issues:			
Leaf rust	%	7	
Head smudge	%	4	
Damping off	%	3	
None	%	85	
Moisture stress this year:			
Drought	%	8	
Excess moisture	%	9	
Normal	%	83	
% of plots that suffered from lodging	%	10	
Harvest and postharvest			
Length of growing period	Weeks	17	17
Time between harvesting and threshing	Days	40	30
Type of threshing floor:			
Dried cow dung	%	99.7	
Other	%	0.3	
Type of threshing used:			
Animals	%	97.3	
Humans using sticks	%	2.5	
Thresher	%	0.2	
Threshing on own or joint threshing floor:			
Own	%	59	
Joint	%	39	
Others	%	2	
Main use of straw:			
Sales	%	3	
Fodder	%	93	
Other	%	4	

Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

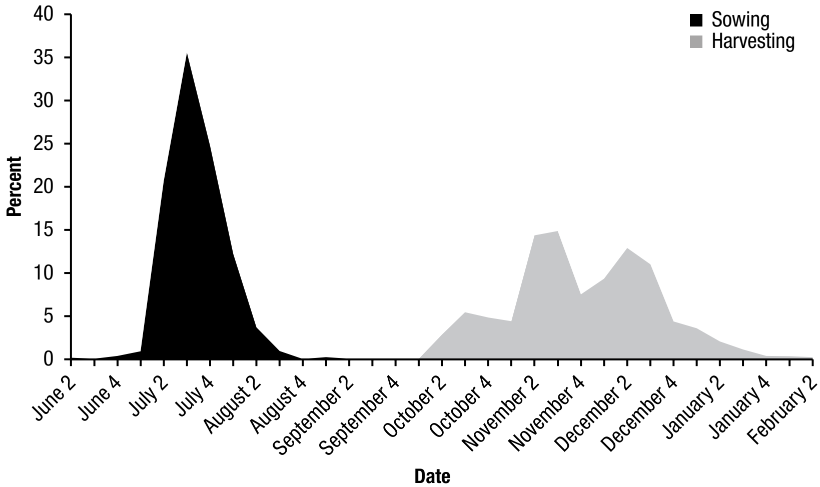
disease, with 7 percent of the plots reported to have been affected by this disease. Lodging is an important problem in teff cultivation and significant efforts are made in teff breeding to develop varieties with stronger stems (Assefa, Chanyalew, and Metaferia 2013). Farmers reported that 10 percent of the plots were affected by lodging during the survey year. Finally, the survey year was viewed as a "normal" cropping year in terms of the moisture content for 83 percent of the plots, with the other 8 percent of the plots suffering from drought and 9 percent from excess moisture. The lack of growing stresses in the survey year implies that the differences noted for yields in the subsequent analysis is due primarily to differences in production systems rather than the growing conditions unique to the year of the survey.

Figure 9.1 illustrates the week in which teff is planted and harvested in the five zones. Almost all of the sowing happens over a period of one month at the beginning of the rainy season (the meher), stretching from the second week of July to the first week of August. However, the harvest period is much more varied and lasts from the beginning of October to the end of January. The average length of the growing season for teff is 17 weeks (Table 9.3). However, significant variation is noted with the variation correlated with elevation (Figure 9.2). Teff that is grown in relatively lower altitudes (<2,100 meters) takes 15 weeks to mature on average as opposed to 18 weeks for teff grown at higher altitudes (>2,100 meters).

After teff is harvested, a threshing process is needed to separate teff grains from the straw. The average time between harvesting and threshing is about 40 days during which period the teff plants are left to dry. In almost all cases threshing is done on a dry threshing floor that is "polished with" cow dung and using animals (97 percent) (Table 9.3). However, some farmers thresh the teff themselves by using sticks, and a very small proportion of farmers use mechanized threshers (0.2 percent). Almost 60 percent of the farmers create their own threshing floor while 40 percent share a threshing floor with other farmers. The straw from teff is mainly used for livestock fodder, and few farmers sell the straw.

Currently little is known about the use of labor in teff production practices, but the survey provides some insights into the amount of labor used for different activities, the source of that labor, and the gender of the workers (Table 9.4). In total, about 141 person-days are spent on the production of 1 hectare of teff. The most labor-intensive activities are weeding (32 person-days), harvesting (28 person-days), and tilling (21 person-days). Postharvest activities (for example, gathering and piling), threshing and winnowing each count for about 22 person-days. Family labor makes up

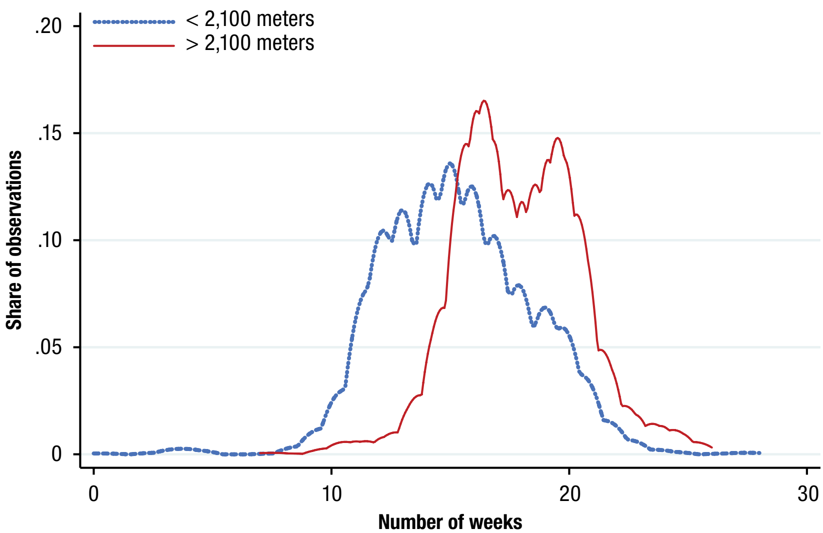
FIGURE 9.1 The sowing and harvesting times of teff on the plots of survey respondents



Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

Note: '2' and '4' refer to the second and fourth week of the month. 'June 2,' for example, refers to the second week in June, 'June 4,' to the fourth week in June.

FIGURE 9.2 Number of weeks between planting and harvesting by low elevation (<2,100 meters) and high elevation (>2,100 meters)



Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

TABLE 9.4 Labor use per hectare in teff production by task

	Number of person-days		Share family labor (%)			Gender (%)	
Practice	Mean	Median	Family	Hired	Exchange	Male	Female
Tilling	23.7	20.0	85	7	8	97	3
Manure and organic input use	2.3	0.0	93	4	3	71	29
Sowing and fertilizer use	7.5	4.0	86	6	7	88	12
Weeding	32.5	24.0	73	10	16	67	33
Herbicide and pesticide application	2.2	0.6	76	23	1	95	5
Harvesting	28.7	23.3	41	32	27	93	7
Postharvesting activities	21.9	16.0	69	7	24	71	29
Threshing and winnowing	21.9	16.0	57	11	32	87	13
Total	**140.6**	**112.5**	**63**	**14**	**22**	**82**	**18**

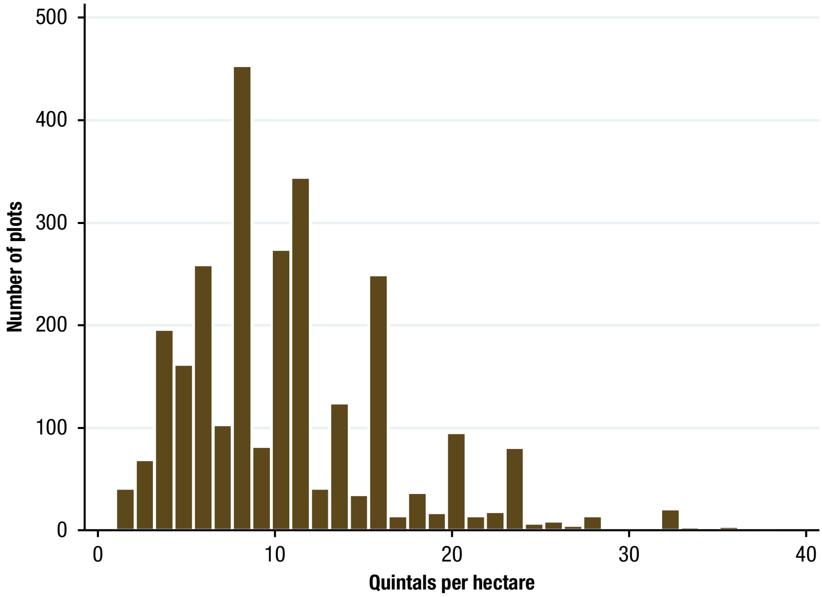
Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

63 percent of the total labor used, with hired labor accounting for 14 percent, and labor provided through a reciprocal exchange among farming families comprising the remaining 22 percent. The share of hired labor is especially high during the harvesting period, when it makes up 32 percent of total labor use. If labor supply is broken down by gender, male labor dominates teff production. Males perform 82 percent of the all the work during teff production, with tilling and harvesting almost exclusively undertaken by men. Women, however, are relatively more involved in weeding activities and make up 33 percent of all labor used for this activity.

Teff Yield and Inputs

Table 9.5 provides summary statistics for yield and the variety of explanatory variables used in the analysis to explain yield, with each given by zone. Average yield per hectare is approximately 11 quintals or 1,100 kilograms, which is lower than the 2010/2011 national average yield of 1,260 kilograms per hectare but higher than the 2004/2005 average national yield of 950 kilograms per hectare (Demeke and Marcantonio 2013). The distribution of yields across all plots is illustrated in Figure 9.3 and indicates that some plots had yields above 30 quintals per hectare. Figure 9.3 further illustrates that teff yield is lower than 1,000 kilograms per hectare for 50 percent of the sample plots, and only 10 percent of the plots have yields of 2,000 kilograms per hectare or higher. There are significant regional variations in plot productivity with

FIGURE 9.3 Distribution of teff yield per hectare across all plots for all zones



Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

average yield highest in East Gojjam (14.9 quintals per hectare) and lowest in the West Shewa and South West Shewa zones (8.9 and 8 quintals per hectare respectively) (see Table 9.5).

There are considerable differences in input use across the five zones (Table 9.5) and by yield category (Table 9.6). The average input tends to increase with yield category, particularly for yields above 14 quintals per hectare. For example, average labor use is similar at 124 person-days per hectare for the two lowest groupings with yields less than 10 quintals per hectare (that is, the first- and second-yield quartiles) and then increases to over 185 person-days per hectare used on plots with yields above 14 quintals per hectare (that is, the fourth quartile). The effect of labor on yield is similar to the effects from the other variable inputs on teff productivity.

Gender and age of the operator are similar across zones, with more than 70 percent of the plots operated by males, 28 percent by both males and females, and 2 percent by females. The average age of the operator is approximately 45 years. Education varies between regions *(text continued on page 220)*

TABLE 9.5 Descriptive statistics of variables used in the production of teff by zone

		Zones					
	Pooled Mean	East Gojjam	West Gojjam	East Shewa	West Shewa	South West Shewa	p value*
Yield (quintals per hectare)	**10.88**	**14.94**	**10.86**	**12.58**	**8.93**	**7.98**	**0.000**
Inputs							
Seed (kilograms per hectare)	45.01	33.43	45.49	59.93	49.50	38.22	0.000
Labor (person-day per hectare)	140.49	159.47	195.27	110.18	169.33	93.66	0.000
DAP (kilograms per hectare)	99.65	86.77	149.47	104.42	69.62	94.60	0.000
UREA (kilograms per hectare)	78.05	138.01	70.01	54.10	51.40	72.17	0.000
Herb (birr per hectare)	43.99	5.38	49.82	43.95	86.22	41.91	0.000
Oxen (number)	3.04	2.07	1.65	4.98	2.93	3.09	0.000
Household characteristics							
Formal education (0–14)	2.20	1.75	1.20	2.49	2.42	2.87	0.000
Adult education (0/1)	0.13	0.15	0.28	0.08	0.10	0.08	0.000
Church or mosque education (0/1)	0.02	0.06	0.07	0.00	0.00	0.00	n.a.
Household head age (in years)	45.46	43.43	45.31	46.50	45.82	46.26	0.000
Household size (number)	10.77	10.66	10.70	11.02	10.29	10.93	0.172
Plot characteristics							
Plot size (hectare)	0.48	0.31	0.27	0.64	0.52	0.59	0.000
Soil type:							
Red soil (0/1)	0.19	0.27	0.33	0.08	0.30	0.04	0.000
Brown soil (0/1)	0.20	0.14	0.22	0.30	0.17	0.16	0.000
Black soil (0/1)	0.47	0.50	0.33	0.34	0.51	0.64	0.000
Mix soil (0/1)	0.14	0.09	0.12	0.28	0.02	0.16	0.000
Plot slope:							
Meda/level (slope) (0/1)	0.82	0.85	0.81	0.84	0.64	0.93	0.000
Dagetama (nearly level) (0/1)	0.15	0.10	0.18	0.13	0.33	0.05	0.000
Gedel (0/1)	0.03	0.04	0.01	0.03	0.03	0.01	0.008
Ease of plowing (0/1)	0.81	0.79	0.75	0.85	0.79	0.84	0.000
Plowing frequency (number)	4.40	5.12	4.66	4.02	4.26	4.05	0.000
Manure (0/1)	0.08	0.09	0.08	0.02	0.16	0.04	0.000
Crop rotation (0/1)	0.63	0.66	0.57	0.57	0.92	0.52	0.000
Walking distance (minutes)	17.15	22.12	14.51	22.15	12.46	13.57	0.000
Distance to cooperative (hours)	0.99	0.86	1.29	0.82	1.19	0.89	0.000
Distance to market (hours)	1.37	1.31	1.12	1.37	1.87	1.23	0.000
Distance to all-weather road (hours)	0.90	1.23	1.16	0.51	0.91	0.77	0.000

		Zones					
	Pooled Mean	East Gojjam	West Gojjam	East Shewa	West Shewa	South West Shewa	p value*
Plot managed by:							
Male (0/1)	0.70	0.95	0.24	0.76	0.56	0.87	0.000
Female (0/1)	0.02	0.01	0.02	0.01	0.03	0.02	0.012
Female and male (0/1)	0.28	0.04	0.74	0.24	0.41	0.12	0.000
Technology							
Seed variety:							
Quncho (0/1)	0.19	0.18	0.30	0.30	0.06	0.14	0.000
Other improved (0/1)	0.11	0.10	0.00	0.08	0.05	0.25	n.a.
Traditional (0/1)	0.70	0.72	0.70	0.61	0.89	0.60	0.000
Seed color:							
Very white (magna) (0/1)	0.17	0.15	0.00	0.28	0.05	0.28	0.000
White (nech) (0/1)	0.53	0.58	0.58	0.50	0.48	0.49	0.000
Mix (sergegna) (0/1)	0.11	0.04	0.27	0.03	0.13	0.11	0.000
Red (key) (0/1)	0.20	0.23	0.15	0.19	0.34	0.11	0.000
Mobile phone ownership (0/1)	0.36	0.22	0.11	0.63	0.27	0.46	0.000
Extension and organization							
Cooperative membership (0/1)	0.64	0.77	0.67	0.50	0.53	0.74	0.000
Community meetings (0/1)	0.69	0.70	0.73	0.67	0.68	0.67	0.188
Extension with extension (0/1)	0.77	0.84	0.69	0.75	0.85	0.69	0.000
Extension by NGO (0/1)	0.04	0.02	0.03	0.02	0.05	0.06	0.000
Model farmer (0/1)	0.39	0.43	0.37	0.35	0.30	0.49	0.000
Weather shock							
Low rainfall (0/1)	0.19	0.16	0.08	0.18	0.20	0.29	0.000
High rainfall (0/1)	0.10	0.13	0.14	0.04	0.12	0.08	0.000
Less logging (0/1)	0.05	0.01	0.02	0.06	0.03	0.09	0.000
More logging (0/1)	0.10	0.09	0.10	0.11	0.13	0.07	0.003
Less frost (0/1)	0.08	0.02	0.02	0.07	0.05	0.18	0.000
More frost (0/1)	0.09	0.15	0.15	0.01	0.06	0.07	0.000
Late rain (0/1)	0.20	0.07	0.12	0.16	0.27	0.37	0.000
Early rain (0/1)	0.08	0.16	0.07	0.06	0.03	0.08	0.000
Early planting (0/1)	0.07	0.04	0.07	0.14	0.01	0.06	0.000
Late planting (0/1)	0.09	0.06	0.07	0.18	0.07	0.05	0.000
Number of plots		**569**	**451**	**600**	**494**	**646**	

Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

Note: n.a. = not applicable.

*Kruskal-Wallis equality of populations rank test p-values.

with average years of formal schooling higher in the Shewa zones. For plots with yields less than 6 quintals per hectare (that is, the first-yield quartile), the average formal level of education of the operator is 1.74 years (Table 9.6). Education level increases steadily with yield category. For operators managing plots with yields above 14 quintals per hectare, for example, the education level is 2.41 years.

The difference in yield appears to be inversely related to plot size (Table 9.6). For all plots in the sample, the average teff plot size allocated to teff production is 0.48 hectares (1.2 acres) and ranges between 0.03 and 5 hectares (12.35 acres). The average plot size tends to be larger in Shewa than in Gojjam (around 0.6 hectares versus 0.3 hectares), but yields are approximately 50 percent higher in the latter region. In general, small plots tend to have higher average land productivity, suggesting there is an inverse relationship in the average land productivity across plot size categories. This result is consistent with other studies that found an inverse relationship between plot size and productivity (for example, Assunção and Braido 2007; Barrett 1996). While smaller plots may have higher yields, there also appears to be higher variability in land productivity for smaller plots than larger ones (Figure 9.4).

The relationship between proportion of soil type (that is, color) and land productivity is statistically significant across zones (Table 9.5) and teff yield quartiles (Table 9.6). For example, plots with black soil are more prevalent in East Gojjam, West Shewa, and South West Shewa, whereas brown soil plots are more prevalent in West Gojjam and East Shewa, and the differences are statistically significant. In addition, the majority of teff plots are on flat field (meda); 88 percent of the plots in the fourth-yield quartile are on flat field, compared with 83 percent for the first quartile.

The distance of the plot to alternative site measures is generally inversely related to plot productivity. Plots closer to an all-weather road tend to have higher yields. For example, the distance from all-weather road for plots in the fourth-quartile yield category is approximately 0.78 hours (45 minutes), compared with 1.08 hours (65 minutes) for plots in the first-yield quartile. Similarly, average distance to market and to the cooperatives tends to be inversely associated with plot yield.

As noted in the previous section across the sample plots, approximately 20 percent are seeded with Quncho, 10 percent with other improved varieties, and 70 percent with traditional seed varieties. Table 9.6 shows the proportion of seed variety by yield quartile and reveals the presence of considerable differences in the proportion of seed variety by yield quartiles. For example, the proportion of Quncho seed variety is approximately *(text continued on page 223)*

TABLE 9.6 Mean values of variables used in production function by yield quartiles

		Teff yield quartiles (mean in quintals per hectare)				
	Pooled Mean	First quartile	Second quartile	Third quartile	Fourth quartile	p value*
Yield (quintals per hectare)	**10.88**	**4.65**	**8.43**	**12.23**	**20.57**	**0.000**
Inputs						
Seed (kilograms per hectare)	45.01	41.31	45.37	47.16	47.32	0.000
Labor (person-days per hectare)	140.49	123.98	123.84	136.87	186.23	0.000
DAP (kilograms per hectare)	99.65	83.42	89.46	100.07	130.60	0.000
Urea (kilograms per hectare)	78.05	50.09	69.94	70.89	124.57	0.000
Herbicides (birr per hectare)	43.99	40.17	46.22	47.41	42.39	0.000
Oxen (number)	3.04	2.67	3.26	3.39	2.79	0.003
Household characteristics						
Formal education (0–14)	2.20	1.74	2.39	2.32	2.41	0.000
Adult education (0/1)	0.13	0.13	0.12	0.12	0.15	0.246
Church or mosque education (0/1)	0.02	0.02	0.02	0.02	0.04	0.031
Household head age (years)	45.46	47.45	45.49	44.91	43.72	0.000
Household size (number)	10.77	10.27	10.90	10.58	11.23	0.017
Plot characteristics						
Plot size (hectare)	0.48	0.55	0.52	0.49	0.35	0.000
Soil type:						
Red soil (0/1)	0.19	0.18	0.16	0.24	0.21	0.002
Brown soil (0/1)	0.20	0.15	0.22	0.23	0.19	0.000
Black soil (0/1)	0.47	0.53	0.48	0.39	0.48	0.000
Mix soil (0/1)	0.14	0.14	0.14	0.14	0.13	0.747
Slope:						
Meda/level (slope) (0/1)	0.82	0.83	0.79	0.81	0.88	0.001
Dagetama (nearly level) (0/1)	0.15	0.15	0.18	0.16	0.10	0.000
Gedel (0/1)	0.03	0.03	0.03	0.03	0.02	0.752
Ease of plowing (0/1)	0.81	0.75	0.80	0.85	0.85	0.000
Plowing frequency (#)	4.40	4.18	4.39	4.53	4.55	0.000
Manure (0/1)	0.08	0.07	0.07	0.07	0.09	0.578
Crop rotation (0/1)	0.63	0.61	0.64	0.68	0.63	0.108
Walking distance (minutes)	17.15	16.09	16.45	17.82	18.65	0.000
Distance to cooperative (hours)	0.99	1.22	0.99	0.91	0.78	0.000
Distance to market (hours)	1.37	1.59	1.41	1.36	1.11	0.000
Distance to all-weather road (hours)	0.90	1.08	0.86	0.86	0.78	0.000

(continued)

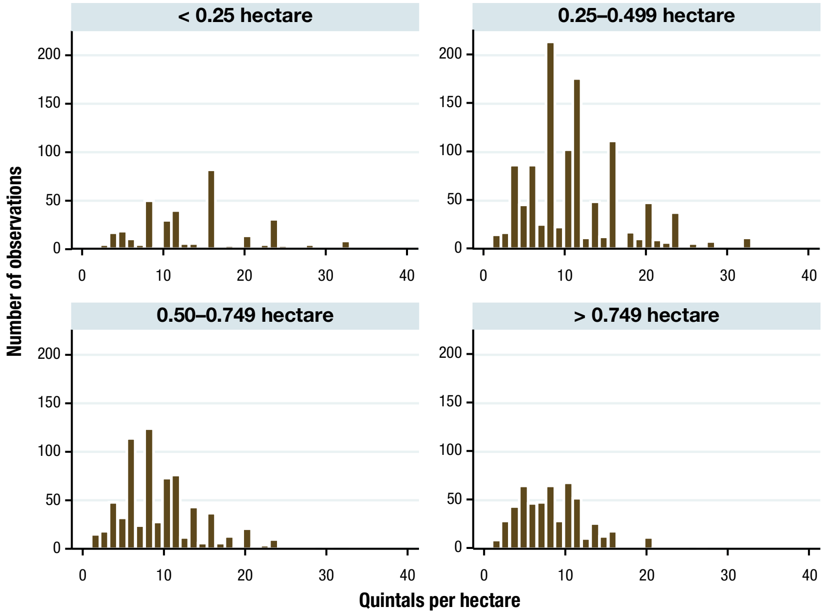
TABLE 9.6 Continued

		Teff yield quartiles (mean in quintals per hectare)				
	Pooled Mean	First quartile	Second quartile	Third quartile	Fourth quartile	p value*
Plot managed by:						
Male (0/1)	0.70	0.68	0.70	0.71	0.72	0.488
Female (0/1)	0.02	0.03	0.02	0.01	0.00	0.001
Female and male (0/1)	0.28	0.28	0.29	0.28	0.28	0.963
Technology						
Seed variety:						
Quncho (0/1)	0.19	0.10	0.12	0.26	0.34	0.000
Other improved (0/1)	0.11	0.09	0.15	0.10	0.08	0.000
Traditional (0/1)	0.70	0.81	0.73	0.65	0.57	0.000
Seed color:						
Very white (magna) (0/1)	0.17	0.13	0.15	0.19	0.22	0.000
White (nech) (0/1)	0.53	0.44	0.54	0.56	0.57	0.000
Mix (sergegna) (0/1)	0.11	0.17	0.12	0.08	0.05	0.000
Red (key) (0/1)	0.20	0.26	0.20	0.17	0.16	0.000
Mobile phone ownership (0/1)	0.36	0.30	0.36	0.39	0.39	0.001
Extension and organization						
Cooperative membership (0/1)	0.64	0.62	0.61	0.65	0.73	0.000
Community meetings (0/1)	0.69	0.64	0.67	0.71	0.76	0.000
Extension with extension personnel (0/1)	0.77	0.68	0.76	0.79	0.84	0.000
Extension by NGO (0/1)	0.04	0.04	0.04	0.03	0.04	0.730
Model farmer (0/1)	0.39	0.35	0.38	0.43	0.44	0.002
Weather shock						
Low rainfall (0/1)	0.19	0.23	0.21	0.18	0.12	0.000
High rainfall (0/1)	0.10	0.11	0.11	0.07	0.08	0.009
Less lodging (0/1)	0.05	0.04	0.04	0.07	0.02	0.001
More lodging (0/1)	0.10	0.11	0.10	0.10	0.08	0.485
Less frost (0/1)	0.08	0.09	0.10	0.06	0.03	0.000
More frost (0/1)	0.09	0.15	0.08	0.04	0.06	0.000
Late rain (0/1)	0.20	0.28	0.25	0.16	0.10	0.000
Early rain (0/1)	0.08	0.07	0.08	0.06	0.11	0.014
Early planting (0/1)	0.07	0.06	0.07	0.07	0.07	0.634
Late planting (0/1)	0.09	0.07	0.09	0.09	0.10	0.176
Number of plots		**698**	**859**	**565**	**638**	

Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

Note: *Kruskal-Wallis equality of populations rank test p-values; First Quartile: ≤ 6 quintals per hectare; Second Quartile: 6.1–10 quintals per hectare; Third Quartile: 10.1–14 quintals per hectare; and Fourth Quartile: >14 quintals per hectare.

FIGURE 9.4 Distribution of land productivity by plot size categories, quintals per hectare



Source: Authors' calculation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

34 percent for the fourth-yield quartile, compared with 10 percent for the first-yield quartile. The average yield from Quncho for all plots is 35 percent higher than with the traditional variety and the difference is statistically significant at the 1 percent significance level based on Somers' D nonparametric test. It is also found that the relative teff yield of Quncho varies across regions with the increase in yield compared with the yield from traditional seeds ranging from 46 percent for East Shewa to 8 percent for West Shewa. The Wilcoxon-Mann-Whitney nonparametric test suggests that in all zones, except for West Shewa, there is a statistically significant difference in the underlying distributions of teff yield between Quncho and traditional seed varieties. For the pooled sample, the Kolmogorov-Smirnov (KS) test suggests that the distribution of Quncho's productivity dominates the yield distribution of both the traditional and other improved seeds.

Assefa, Chanyalew, and Metaferia (2013) identify especially innovative approaches toward technology dissemination as a major reason for the success of Quncho in widespread adoption. The fundamental features of the extension approach involved the following: (1) use of technology as a package (not only was the seed variety extended but other management practices too); (2) use of large farm holders' fields for demonstration purposes; (3) coordinated multistakeholder partnership extension methods (including farmers, farmers' associations, private seed growers, governmental institutions, and NGOs); (4) revolving seed loans; and (5) regular training, follow-up, and supervision. Although these factors have contributed to widespread adoption, the success of Quncho seems also to be linked closely to the prior absence of improved teff cultivars. Quncho was, in some sense, the variety that could reinvigorate teff research. It is possible that adoption rates were so large because the market conditions were very strong and there was such a dearth of previous improved varieties.

Teff seed color and seed varieties are correlated. For example, all Quncho seed varieties are reported as very white (magna, 51 percent) or white (nech, 49 percent). Similarly, the majority of other improved seeds (94 percent) are very white (magna, 18 percent) or white (nech, 75 percent). For all varieties, very white and white color seeds tend to have higher productivity.

Cooperative members manage at least 60 percent of the plots across all zones with approximately three-quarters of the plots run by cooperative members in East Gojjam and South West Shewa (Table 9.5). While yields for cooperative members are 8 percent less than that generated by nonmembers in East Gojjam, yields are generally higher for members and up to 41 percent higher in West Gojjam (8.4 versus 11.9 quintal per hectare respectively). Cooperative membership is higher at 72 percent for plots in the fourth-yield quartile, compared with plots in the first quartile at 62 percent (Table 9.6). For the pooled sample, Somers' D nonparametric test indicates cooperative members outperform nonmembers by approximately 10 percent, and the Kolmogorov-Smirnov (KS) test suggests that the yield distribution from cooperative members dominates the yield distribution of nonmembers at a 1 percent significance level.

Extension efforts are also associated with higher yields as shown in Table 9.6. Farmers' participation in a community meeting to discuss teff-related issues results in a higher average teff yield. Further descriptive analysis indicates that relative to nonparticipants, teff productivity for participants was higher by approximately 6 percent in East Gojjam, 15 percent in West Gojjam, 17 percent in East Shewa, 7 percent in West Shewa, and 11 percent in South West Shewa. For the pooled sample, the yield on plots for those who attended a community meeting on teff was approximately 13 percent higher than for nonparticipants, indicating that the difference is statistically significant according to the Somers' D test. The Kolmogorov-Smirnov test also suggests that the yield distribution for participants dominates the distribution of productivity for nonparticipants. Average yield is also higher for plots run by farmers who had one or more extension agent visits, especially in West Gojjam. Perhaps related to extension efforts, the average productivity is found to be higher for mobile phone owners in all five zones and the differences are statistically significant for four of the five zones.

In summary, this descriptive analysis reveals (1) plots with Quncho seed variety are more productive than traditional and other improved seeds, and the magnitude varies by zone; (2) activities to enhance understanding and market access (for example, cooperative membership and participation in community meetings) increase yield; and (3) proximity to an all-weather road and the nearest agricultural cooperative has a positive effect on land productivity. However, attributing the cross-sectional differences in productivity across plots to a single factor may hide the effect of other observable and unobservable heterogeneities. For example, when examining the effect of the adoption of Quncho on plot productivity, it is important to control for differences in household- and plot-specific observable (for example, education) and unobserved factors (for example, soil quality) that may lead to higher productivity. In the next section, a teff production function is estimated that allows for the control of multiple household- and plot-specific differences simultaneously.

Associates of Teff Productivity

The estimated coefficients for five specifications of a Cobb-Douglas production function are listed in Table 9.7. The five estimations of equation (1) (described at the beginning of this chapter) represent the base model along with four fixed-effect versions: zone, woreda (district), kebele (village), and household. The vast majority of the estimated coefficients tend to be significant across the estimated models and tend to vary little in absolute terms, suggesting the estimation results are robust. Across all models, seed and labor have a statistically significant positive association with yield. The output elasticity averages approximately 0.2 for seed input across the five models. The amount of urea fertilizer applied and the number of oxen per household also tend to have a statistically significant association with yield. The output elasticity for these two inputs, however, is approximately one-tenth the elasticity for seed and labor. DAP is not shown to be significantly associated with yields. As a large number of farmers use significant amounts of DAP and urea, it is possible that estimates are done on those parts of the domain of the production function where marginal associations are relatively *(text continued on page 230)*

TABLE 9.7 Parameter estimates of teff production function

Parameter	Base		Zone fixed effect		Woreda fixed effect		Kebele fixed effect		Household fixed effect	
Inputs										
Seed	0.166***	(5.71)	0.191***	(6.46)	0.193***	(6.82)	0.183***	(6.38)	0.177***	(2.82)
Labor	0.157***	(4.27)	0.127***	(3.72)	0.116***	(3.93)	0.107***	(4.14)	0.266***	(5.42)
DAP	−0.00392	(−0.95)	0.000864	(0.21)	0.00430	(0.96)	0.00575	(1.30)	0.00158	(0.21)
Urea	0.0209***	(6.12)	0.0194***	(5.69)	0.0102***	(2.95)	0.00703**	(2.05)	−0.0000602	(−0.01)
Herb	−0.0152***	(−6.09)	0.00313	(1.09)	0.00166	(0.59)	0.00306	(1.04)	0.0107**	(2.18)
Oxen	0.0257***	(2.67)	0.0224**	(2.45)	0.0178**	(2.01)	0.0185**	(2.12)	0.132**	(2.52)
Household characteristics										
Formal education (0–14)	0.00992*	(1.88)	0.0140***	(2.75)	0.00783	(1.64)	0.00767	(1.59)		
Adult education (0/1)	−0.0354	(−0.86)	−0.0297	(−0.76)	−0.0176	(−0.51)	−0.0305	(−0.93)		
Church or mosque education (0/1)	−0.0127	(−0.14)	−0.0491	(−0.57)	−0.0848	(−1.08)	−0.0746	(−0.99)		
Household head age (years)	−0.00317***	(−3.08)	−0.00276***	(−2.76)	−0.00318***	(−3.43)	−0.00342***	(−3.65)		
Household size (number)	0.00555**	(2.42)	0.00536**	(2.49)	0.00508**	(2.57)	0.00485***	(2.68)		
Plot characteristics										
Plot size (hectares)	0.545***	(14.91)	0.549***	(15.31)	0.590***	(17.66)	0.611***	(18.66)	0.558***	(8.30)
Soil type:										
Brown soil	−0.00942	(−0.27)	0.0225	(0.63)	0.0166	(0.50)	0.0286	(0.88)	0.0156	(0.29)
Black soil	−0.0388	(−1.25)	0.00363	(0.12)	0.0473	(1.64)	0.0644**	(2.27)	0.0415	(0.90)
Mix soil	−0.0101	(−0.24)	−0.000869	(−0.02)	0.0497	(1.29)	0.0616*	(1.66)	0.0557	(0.98)

Plot slope:										
Dagetama	−0.0102	(−0.33)	−0.00939	(−0.31)	−0.0847***	(−3.07)	−0.0575**	(−2.17)	−0.0576	(−1.09)
Gedel	0.0182	(0.27)	−0.0146	(−0.23)	−0.0218	(−0.33)	0.0487	(0.74)	0.0551	(0.41)
Ease of plowing	0.104***	(3.24)	0.105***	(3.46)	0.0925***	(3.30)	0.0766***	(2.91)	0.0591	(1.28)
Frequency of plowing	0.0264***	(2.61)	0.00425	(0.40)	0.0419***	(3.77)	0.0372***	(3.37)	0.0256	(0.88)
Manure	0.0384	(1.01)	0.0393	(1.06)	0.0597*	(1.66)	0.0334	(0.90)	−0.0665	(−0.98)
Rotation	0.0631**	(2.50)	0.0532**	(2.19)	0.0517**	(2.19)	0.0503**	(2.19)	0.0326	(0.69)
Walking	−0.000278	(−0.47)	−0.00146**	(−2.58)	−0.00136***	(−2.58)	−0.00147***	(−2.72)	−0.000389	(−0.48)
Distance to cooperative (hours)	−0.0589***	(−3.09)	−0.0357*	(−1.88)	−0.0475**	(−2.53)	−0.0594***	(−3.09)		
Distance to market (hours)	−0.00672	(−0.50)	−0.0142	(−1.04)	0.0179	(1.28)	0.0441***	(2.97)		
Distance to all-weather road (hours)	−0.0106	(−0.58)	−0.0181	(−1.05)	0.00260	(0.16)	0.00633	(0.40)		
Plot managed by:										
Male	0.176**	(2.24)	0.114	(1.41)	0.102	(1.20)	0.121	(1.57)	0.382	(0.69)
Male and female	0.0584	(0.72)	0.0847	(1.02)	0.0578	(0.66)	0.0826	(1.02)	0.338	(0.59)
Technology										
Seed variety										
Quncho	0.122***	(3.51)	0.103***	(3.01)	0.127***	(3.36)	0.129***	(3.49)	0.109*	(1.89)
Other improved	0.0284	(0.69)	0.0708*	(1.76)	0.103**	(2.57)	0.100***	(2.62)	−0.00664	(−0.12)
Seed color:										
White seed	−0.0564	(−1.58)	−0.0562	(−1.61)	−0.0581*	(−1.65)	−0.0205	(−0.61)	−0.0288	(−0.56)
Mix seed	−0.227***	(−4.82)	−0.158***	(−3.32)	−0.107**	(−2.28)	−0.0822*	(−1.80)	−0.0376	(−0.52)
Red seed	−0.185***	(−4.27)	−0.174***	(−4.16)	−0.0883**	(−2.10)	−0.0568	(−1.38)	−0.0543	(−0.89)
Mobile phone	0.0232	(0.69)	0.0277	(0.86)	0.0520*	(1.80)	0.0360	(1.32)		

(continued)

TABLE 9.7 Continued

Parameter	Base		Zone fixed effect		Woreda fixed effect		Kebele fixed effect		Household fixed effect	
Extension and organization										
Cooperative	−0.0390	(−1.29)	−0.0222	(−0.73)	−0.0530*	(−1.82)	−0.0348	(−1.30)		
Community	0.0396	(1.39)	0.0453*	(1.69)	0.0438*	(1.74)	0.0345	(1.41)		
Extension	0.135***	(4.38)	0.0901***	(2.98)	0.0686**	(2.35)	0.0622**	(2.25)		
Extension–NGO	0.0241	(0.41)	0.0726	(1.27)	0.0940	(1.58)	0.0768	(1.45)		
Model farmer	0.0356	(1.18)	0.0305	(1.08)	0.0512**	(2.00)	0.0590**	(2.42)		
Weather shock										
Low rainfall	−0.0414	(−1.10)	−0.0524	(−1.47)	0.00971	(0.29)	−0.00664	(−0.21)	−0.0727	(−0.43)
High Rainfall	−0.0408	(−0.86)	−0.0386	(−0.85)	0.0284	(0.68)	0.0280	(0.75)	−0.0860	(−0.57)
Less Logging	0.0361	(0.61)	0.0743	(1.39)	0.0911*	(1.72)	0.0850*	(1.72)	0.139	(1.27)
More Logging	−0.00358	(−0.09)	0.00262	(0.07)	−0.00766	(−0.21)	0.0169	(0.51)	−0.0522	(−0.85)
Less frost	−0.192***	(−4.20)	−0.0904**	(−2.15)	−0.0676	(−1.53)	−0.0715*	(−1.70)	−0.0343	(−0.29)
More frost	−0.247***	(−4.93)	−0.232***	(−4.76)	−0.195***	(−4.35)	−0.171***	(−4.00)	−0.102	(−0.78)
Late rain	−0.123***	(−3.25)	−0.0435	(−1.22)	−0.0412	(−1.24)	−0.0534*	(−1.67)	−0.274	(−1.28)
Early rain	−0.0605	(−1.15)	−0.0819*	(−1.68)	−0.0759*	(−1.67)	−0.0719*	(−1.66)	−0.0271	(−0.14)
Early planting	0.0373	(0.83)	0.00137	(0.03)	−0.0180	(−0.42)	−0.0395	(−0.94)	−0.0294	(−0.23)
Late planting	0.0580	(1.40)	0.0264	(0.67)	0.0153	(0.39)	−0.0147	(−0.40)	−0.0265	(−0.29)

(continued)

Fixed effects										
Zone	No		Yes		No		No		No	
Woreda	No		No		Yes		No		No	
Kebele	No		No		No		Yes		No	
Household	No		No		No		No		Yes	
Constant	−0.296**	(−2.42)	0.256**	(1.99)	−0.350**	(−2.11)	−0.340**	(−2.02)	0.368	(0.62)
Observations	**2,760**		**2,760**		**2,760**		**2,760**		**2,773**	
Adjusted R^2	**0.615**		**0.651**		**0.688**		**0.712**		**0.828**	

Source: Authors' estimation using data from the 2012 teff value-chain survey conducted by the Economic Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI).

Note: t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of observations for the household fixed effect is higher than for the other model. This is because of missing values for some of the farmers' (for example, school) and farms' (for example, distance) characteristics.

small. The government has recently started to replace DAP with Nitrogen-phosphoric fertilizer containing sulphur (NPS), given the high deficiency of sulphur (S) in Ethiopian soils, possibly indicating its lower performance.

In addition, operator age and household size are the socioeconomic variables that have a statistically significant association with yield. While the summary statistics indicated little difference in operator age across regions (Table 9.5), younger farm managers produce higher yielding plots. In contrast, the regression analysis suggests operator's education is unrelated to teff productivity, although the summary statistics suggested otherwise. Any increases in household size are associated with a corresponding increase in teff output levels. This may be related to the labor available for production activities, which was shown to increase yield levels.

The log of plot size has a positive effect on teff output. However, increases in (logarithmic) plot size are associated with a decrease in teff yield per hectare. The average elasticity value of approximately 0.6 is statistically significant across models. This effect translates to an elasticity of −0.4 of plot size on yield per hectare, suggesting a 10 percent increase in farm size is associated with a reduction of teff yields by 4 percent.[4] A number of reasons for the inverse relationship between farm size and land productivity exist in the literature, which include labor market imperfections and opportunity costs of labor (Sen 1962), measurement errors and unobserved land quality, credit market imperfections (Assunção and Ghatak 2003), and land distribution policies and uneven off-farm work opportunities (Benjamin and Brandt 1997).

Other plot characteristics related to soil type and typography generally have no link with teff productivity. While the gentle-sloped (dagetama) and hilly (gedel) plots have lower yields than level plots, the results are generally not statistically significant, except for plots on gentle slopes. In contrast, the distance measures between the farm plot and various locations tend to have a mixed relationship with yield. For example, for the kebele fixed-effect regression, a 1-minute increase in the time it takes to a travel to the nearest marketplace is associated with 0.044 percent increases in teff yield on average. Plots owned by households that are farther away from the nearest agricultural cooperative are found to have lower productivity for the kebele fixed-effect model. The result on proximity to a marketplace contradicts the findings that relate

4 From the production function in (1), the relationship between productivity and plot size is given by $(\hat{b} - 1)$ and can be derived from the production function as follows: $ln(y) = a + bln(x)$. Subtracting $ln(x)$ from both sides and rearranging gives: $\ln(\frac{y}{x}) = \hat{a} + (\hat{b} - 1)ln(x)$. A nonlinear relationship for farm size is incorporated using quadratic logarithm of plot size. However, this effect is statistically insignificant.

to proximity to agricultural cooperatives, although the coefficient of access to market is significant for the kebele fixed-effect model only. The closer a plot is to the nearest marketplace, the lower the rate of productivity of the plot.

Proximity to a marketplace may allow farmers to participate in leisure and off-farm income-generating activities, which may provide incentive to spend less time and efforts on the farm. In this situation, distance from the marketplace may create incentives and fewer distractions from off-farm activities, thus allowing a farmer to spend more time on managing teff plots. Also, farm labor supply may be scarce for farms in close proximity to a marketplace as the labor force tends to migrate to urban areas to seek off-farm income opportunities. Furthermore, often proximity to a marketplace may not serve as a measure of remoteness, as "local markets often exist in the most remote communities, but they operate in isolation from the rest of the world" (Brooks 2012, 95). The local markets might be distant from urban centers where supplies of goods and services as well as opportunities for social interaction are concentrated.

Developments in technology result in the anticipated link with productivity. For example, from descriptive statistics, plots seeded with the Quncho seed variety produce approximately 13 percent more than plots planted with traditional varieties. Improved seed varieties, other than Quncho, yield 10 percent more than traditional seeds. The differences on the productivity benefits from new technology across the fixed-effects models highlight the importance of controlling for observed and unobserved heterogeneities across plots and households when conducting quantitative impact analysis.

Other practices considered included the use of a crop rotation. If teff was not grown on the plot in the previous year, the yield of teff is approximately 5 percent greater than on plots growing continuous teff. Owning a mobile phone leads to a 5 percent increase in teff yield for the owner, but it is only significant in one out of the four specifications used (that is, the woreda fixed-effect model). The positive yield impact from the adoption of these two practices is statistically significant and consistent with the results of previous studies such as Asfaw and Shiferaw (2010).

While the major technological practices tend to have a significant positive relationship with yield, the role of extension activities and organization on teff productivity depends on the variable considered. For example, cooperative membership generally has an unexpected negative yet statistically insignificant link with yield. In contrast, participation in a community meeting increases teff yield by 4 percent across the fixed effects and is statistically significant at the 10 percent level for zone and woreda regressions. Similarly, one or more visits by an extension agent is associated with an increase in yield by an average of 6 percent to 13 percent, depending on the model. The difference in the results for the alternative forms of extension participation may be explained by the reason that each is organized for. Cooperatives are mainly targeted at making the sector more commercial and at providing access to input and output markets, particularly fertilizer and other improved inputs. Often agricultural cooperatives do not provide technical training to their members. In contrast, the community meetings and extension visits are focused on how the operator can improve the plot's productivity for growing teff. The effect of producer cooperative membership may be reflected in the use of fertilizer and other modern inputs and distance from agricultural cooperatives. In addition, the existence of spillover effects from cooperative members to nonmembers may explain the insignificant effect of cooperative membership on productivity. Other factors that have links with plot productivity are weather shocks, such as water logging, frost, and rainfall. The only weather variables that have a consistently statistically significant relationship with yield are frost and hailstorms. As expected, a greater frequency of these events decreases plot yield.

Conclusion

There are significant variations in the productivity of plots growing teff across Ethiopia. This chapter has attempted to illustrate this variation as well as to examine the link between farming practices and these differences. The major associations for productivity differences appear to be the levels of input use, the management practices employed, the age of the operator, the ease of access to markets, and the level of engagement in extension efforts (see Chapter 7). While the links of these factors are consistent with prior expectations, the analysis does not, however, adequately consider the complexity of the system. For example, the adoption of high-yielding seed varieties (Quncho) may be the result of farmers participating in community meetings to discuss teff production and/or visits by extension agents. Conversely, the level of fertilizer use may instead be associated with the distance to travel in order to obtain this input. It is difficult to determine the direct and indirect effects of these factors, and therefore a structural equation model would be appropriate to allow for simultaneous estimation of the input factors and teff output.

While further analysis would help direct policy efforts to achieve the desired gains in teff output, the current analysis highlights that there are effective means to enhance the productivity of teff and provide encouragement to those involved with farmers who are reliant on the production and consumption of teff for their livelihoods. The findings lead therefore to a number of policy implications. First, input use, and especially improved seed varieties, is associated with improved productivity, and it appears that there are high rates to return to investments in the development of better seed varieties. The investments to Quncho development clearly illustrate this positive benefit through calculations of the rates of return. Flaherty, Kelemework, and Kelemu (2010) estimate that Ethiopia invested in 2008 US$70 million in agricultural R&D. Assuming, generously, that US$10 million would have been spent annually on teff research, and that the Quncho development was achieved after breeding investments for five years, this leads to a cumulative investment of US$50 million. The results in this chapter show that productivity of Quncho is at least 10 percent higher than other varieties. Assuming that half of the producers in Ethiopia would adopt Quncho and that prices remain unchanged, that would lead to a sustained yearly benefit of US$80 million. If these benefits were to be spread over a 20-year period, the rate of return for that investment would amount to 160 percent. Admittedly, no costs for extension efforts are included in this calculation. However, even if the investments were quadrupled to US$200 million to accommodate this, the rate of return would still be high at 40 percent.

Second, the Ethiopian government has invested heavily in the expansion of the agricultural extension system. At the end of 2010, the government had placed 45,000 extension agents in villages, compared with 2,500 and 15,000 extension agents in 1995 and 2002, respectively (Davis et al. 2010). With a target of three extension agents per kebele, Ethiopia has one of the largest extension agent–farmer ratios found in the world today (Davis et al. 2010). It seems that there is a payoff to some of these investments as shown in the higher productivity of teff that is being achieved by those farmers who have been able to participate in community meetings and had access to extension agents.

Third, remoteness is found to be an important determinant of productivity because of the lack of incentives due to lower output prices but also possibly because of the costs of getting access to modern inputs at reasonable prices (Minten et al. 2013). Reducing the costs of remoteness through the construction of rural roads, as well as increasing distribution outlets of modern inputs, is likely to have an important positive impact on teff productivity.

Fourth, teff is shown to be a labor-intensive crop with higher yields being achieved when farmers spend more time plowing and weeding. Given structural changes in the Ethiopian economy, which leads to increasing real rural wages, innovations that can initiate a reduction in these labor demands, might satisfy the increasing demands for teff at an affordable price. Further efforts to simulate greater use of mechanization for planting, threshing, and weeding might therefore be important for the sustainability of the teff sector.

References

Ali, M., and D. Byerlee. 1991. "Economic Efficiency of Small Farmers in a Changing World: A Survey of Recent Evidence." *Journal of International Development* 3 (1): 1–27.

Asfaw, S., and B. A. Shiferaw. 2010. "Agricultural Technology Adoption and Rural Poverty: Application of an Endogenous Switching Regression for Selected East African Countries." African Association of Agricultural Economists (AAAE) and Agricultural Economics Association of South Africa (AEASA).

Assefa, K., S. Chanyalew, and G. Metaferia. 2013. "Quncho: The Most Outstanding Tef Variety in Ethiopia." In *Achievements and Prospects of Tef Improvement*, edited by K. Assefa, S. Chanyalew, and Z. Tadele, 325–331. Addis Ababa: Ethiopian Institute of Agricultural Research (EIAR); Bern, Switzerland: Universitat Bern.

Assunção, J. J., and L. H. Braido. 2007. "Testing Household-Specific Explanations for the Inverse Productivity Relationship." *American Journal of Agricultural Economics* 89 (4): 980–990.

Assunção, J. J., and M. Ghatak. 2003. "Can Unobserved Heterogeneity in Farmer Ability Explain the Inverse Relationship between Farm Size and Productivity?" *Economics Letters* 80 (2): 189–194.

ATA (Agricultural Transformation Agency). 2013. "Results of 2012 New Tef Technologies Demonstration Trials Draft Report." Addis Ababa: ATA.

Barrett, C. B. 1996. "On Price Risk and the Inverse Farm Size-Productivity Relationship." *Journal of Development Economics* 51 (2): 193–215.

Benjamin, D., and L. Brandt. 1997. "Land, Factor Markets, and Inequality in Rural China: Historical Evidence." *Explorations in Economic History* 34 (4): 460–494.

Brooks, J., ed. 2012. *Agricultural Policies for Poverty Reduction*. Wallingford, UK: CABI.

Davis, K., B. Swanson, D. Amudavi, D. Mekonnen, A. Flohrs, J. Riese, C. Lamb, and E. Zerfu. 2010. *In-Depth Assessment of the Public Agricultural Extension System of Ethiopia and Recommendations for Impact*. International Food Policy Research Institute (IFPRI) Discussion Paper 1041. Washington, DC: IFPRI.

Demeke, M., and F. Di Marcantonio. 2013. *Analysis of Incentives and Disincentives for Teff in Ethiopia*. Technical notes series. Rome: Monitoring African Food and Agricultural Policies (MAFAP), Food and Agricultural Organization (FAO).

Ethiopia, CSA (Central Statistical Agency). 2012. *Agricultural Sample Survey 2011/2012: Report on Area and Production of Major Crops.* Addis Ababa, Ethiopia.

Flaherty, K., F. Kelemework, and K. Kelemu. 2010. *Ethiopia: Recent Developments in Agricultural Research*. Washington, DC: IFPRI; Addis Ababa: Ethiopian Institute of Agricultural Research (EIAR).

Franzel, S., C. Wambugu, T. Nanok, and R. Coe. 2013. *The "Model Farmer" Extension Approach Revisited: Are Expert Farmers Effective Innovators and Disseminators*? Proceedings of the International Conference on Innovations in Extension and Advisory Services: Linking Knowledge to Policy and Action, November 15–18, 2011, Nairobi, Kenya.

Gorfu, D., and E. Ahmed. n.d. *Crops and Agro-ecological Zones of Ethiopia*. Ethiopian Institute of Agricultural Research. Accessed June 11, 2014. www.prrp-ethiopia.org/index.php/component/phocadownload/category/1-public-documents?download=51:crops-and-agro-ecological-zones-total-dereje-gorfu.

Minten, B., S. Tamru, E. Engida Legesse, and K. Tadesse. 2013. *Ethiopia's Value Chains on the Move: The Case of Teff.* Ethiopia Strategy Support Program (ESSP) Working Paper 52. Addis Ababa: ESSP.

Royston, J. P. 1983. "Some Techniques for Assessing Multivarate Normality Based on the Shapiro-Wilk W." *Applied Statistics* 32 (2): 121–133.

Sen, A. K. 1962. "An Aspect of Indian Agriculture." *Economic Weekly* 14: 243–246.

Shapiro, S.S., and R. S. Francia. 1972. "An Approximate Analysis of Variance Test for Normality." *Journal of the American Statistical Association* 67 (337): 215–216.

Tefera, H., G. Belay, and M. Sorrells, eds. 2001. *Narrowing the Rift: Teff Research and Development.* Proceedings of the International Workshop on Teff Genetics and Improvement, Debre Zeit, Ethiopia, October 16–19, 2000. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Townsend, R. F., I. Ceccacci, S. Cooke, M. Constantine, and G. Moses. 2013. *Implementing Agriculture for Development: World Bank Group Agriculture Action Plan (2013–2015).* Washington, DC: World Bank.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA, US: MIT Press.