Chapter 9

Policies and Programs Affecting Land Management Practices, Input Use, and Productivity in the Highlands of Amhara Region, Ethiopia

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Increasing agricultural productivity is an important challenge in Sub-Saharan Africa (SSA). Since the 1960s, agricultural production in SSA has failed to keep up with population growth. The situation is severe in Ethiopia, particularly in the highland areas, where agriculture is primarily rain fed (about 95 percent); soil loss rates average 21 to 42 tons per hectare per year on cultivated lands (Hurni 1988; Kebede 1996); many soils show large negative nutrient balances (Stoorvogel, Smaling, and Janssen 1993; Elias, Morse, and Belshaw 1998); cereal yields are less than 1 ton per hectare in many places; and up to 2 percent of total crop production is lost annually from soil erosion alone (Kappel 1996).

Since 1991, the federal and regional governments of Ethiopia, within the framework of the Agriculture Development Led Industrialization (ADLI) strategy, have undertaken a massive program of natural resource conservation and huge investment in infrastructure (e.g., roads, irrigation), agricultural extension and credit, education, and other services to reduce environmental degradation, increase agricultural productivity, reduce poverty, and increase food security. Fundamental empirical evidence based on sound scientific methodology on the contribution of these public investments and programs to agricultural production is lacking. Also important is the relative contribution of the public investments and programs to agricultural productivity in low- versus high-agricultural-potential areas. Filling these knowledge gaps is the main objective of this chapter.

Data from household- and plot-level surveys conducted between 2000 and 2001 in the highlands of Amhara region are utilized in this chapter to examine the contributions (and implications) of land redistribution and tenure, infrastructure (irrigation, roads, markets), education, and agricultural extension to land management practices, input use, and land productivity (crop yield) in low- versus high-agricultural-potential areas. In contrast to many studies, several other factors including land investments, household structure and endowments, plot quality, population pressure, and natural factors that may affect land management practices, inputs, and land productivity are controlled for. The analysis is similar to that presented in Chapters 5 and 7 but focused on a different region.

The next section of this chapter presents the conceptual framework and hypotheses for examining the effects of policies and programs on adoption of land management practices, amount of inputs used, and land productivity. The study area and data are presented in the third section. The econometric approach, results, and discussion are presented in the fourth section, and conclusions and implications in the last section.

Conceptual Framework and Hypotheses

The underlying conceptual framework for the econometric analysis is similar to that presented in Chapter 5, though we present the framework here because of some important differences. It draws from the literature on agricultural household models (Singh, Squire, and Strauss 1986; de Janvry, Fafchamps, and Sadoulet 1991). In addition, the hypotheses about how land redistribution and tenure contracts may influence land management, inputs, and productivity draw from the literature on property rights and investment incentives (Barrows and Roth 1990; Feder and Feeny 1993; Place and Hazell 1993; Besley 1995; Gavian and Fafchamps 1996; Pender and Kerr 1999; Place and Swallow 2000; Otsuka and Place 2001a) and land rental markets and agricultural efficiency (Cheung 1969; Otsuka and Hayami 1988; Otsuka, Chuma, and Hayami 1992; Ahmed et al. 2002; Pender and Fafchamps 2006, forthcoming). The effects of other policies derive from theories of induced technical and institutional innovation in agriculture (Boserup 1965; Hayami and Ruttan 1985; Pender 1998; Fan and Hazell 2000).

Crop output is given by equation (9.1):

$$\begin{aligned}\text{CROP OUTPUT}_{h,p,t} = f(&\text{LAND INVESTMENTS}_{h,p,t}, \text{INPUTS}_{h,p,t},\\ &\text{LAND MANAGEMENT PRACTICES}_{h,p,t},\\ &\text{EXTENSION}_{h,t}, \text{CROP}_{h,p,t}, \text{LAND}\\ &\text{QUALITY}_{h,p,t}, \text{TECHNICAL KNOWHOW}_{h,t},\\ &\text{NATURAL FACTORS}_{v,t})\end{aligned} \tag{9.1}$$

In equation (9.1), crop output of household *h* on plot *p* in year *t* is expressed as a function of the stock of land investments (or indicators of long-term investments) on the plot, especially soil and water conservation structures (e.g., stone terraces, soil bunds) and irrigation, amount of inputs used on the plot (e.g., labor, animal draft power, seeds, chemical fertilizers), land management practices used on the plot, especially soil-fertility practices (e.g., crop rotation, crop residues, manure), extension, type of crops planted, and the operator's technical knowledge, which is enhanced through education and farm experience.[1] Other factors affecting crop output include characteristics and quality of the land (e.g., size, slope, soil depth) and natural factors (e.g., rainfall, elevation). Amount of inputs used, land management practices, extension, and type of crops planted are in turn given by equation (9.2), where *X* represents the vector of the above endogenous variables.

$$\begin{aligned} X_{h,p,t} = f(&\text{LAND INVESTMENTS}_{h,p,t}, \text{LAND QUALITY}_{h,p,t}, \\ &\text{TECHNICAL KNOWHOW}_{h,t}, \text{NATURAL FACTORS}_{v,t}, \\ &\text{LAND POLICY}_{v,t}, \text{LAND TENURE}_{h,p,t}, \\ &\text{ACCESS TO INFRASTRUCTURE AND CREDIT}_{h,t}, \\ &\text{ENDOWMENT OF ASSETS}_{h,t}, \text{SOCIAL CAPITAL}_{v,t}, \\ &\text{POPULATION DENSITY}_{v,t}) \end{aligned} \tag{9.2}$$

Here, the assumption is that inputs, land management practices, extension, and type of crops planted depend on the factors determining profitability of crop production. They depend also on the land policy and land tenure status (which affect the future returns from current practices); household access to roads, markets, and credit (which affect the ability to purchase or hire inputs); household endowments of land, labor, oxen, and other assets, and social capital (which are important for labor, draft power, manure, credit, etc., where markets for such inputs do not function properly or do not exist); and population density and other village-level factors (which affect the value of land relative to labor).

Note that equation (9.1) is a production function and so excludes those factors that do not have a hypothesized direct effect on crop production. Inputs, land management practices, extension, and type of crops planted, on the other hand, depend on additional factors that influence the awareness, availability, costs, benefits, and risks associated with them. Once the equations are estimated, the estimated coefficients can be used to predict the effect of the policy and program variables on crop output, for example, directly as specified in equation (9.1) or indirectly via the effects of land management practices, inputs, extension, and crop choice. For example, irrigation can affect crop output directly as well as indirectly via its influence on land management, inputs, or crop choice decisions, whereas the effect of market access on crop productivity can be measured indirectly via its influence on land management, inputs, and crop choice decisions.

Research Hypotheses

There are potentially a large number of testable hypotheses that can be considered concerning the relationships between the dependent and explanatory variables, as specified in the conceptual framework in equations (9.1) and (9.2). Many of these hypotheses have already been discussed in Chapters 2, 5, and 7. In this section, we focus on the effects of land redistribution and tenure, providing more local context than was possible in Chapter 2.

The nature of tenure on a plot of land can affect land management and productivity on that plot for several reasons. If land tenure is insecure, then the household operating the plot may have less incentive to invest in land improvement (Feder and Feeny 1993). However, the household may increase investment if the investment can in turn increase security of tenure (Besley 1995). Thus, there may be more investment in land improvement on plots with insecure tenure.

In Ethiopia, and particularly the Amhara region, one source of tenure insecurity derives from land redistribution, which has been frequent and ongoing since 1975 (instituted by the military government) to reduce landlessness and equalize landholding size and quality across households. Although land redistribution was stopped in many regions of Ethiopia in 1991 (with the current government coming to power), it continued in many parts of the Amhara region. A major recent redistribution exercise in the region took place in 1996–97, raising the proportion of farmers who owned land to about 72 percent (547,087 out of the total 756,809) (GEA 1997). However, actual implementation, type and amount of land affected, and population affected were not uniform across the region, as the exercise was left to local officials for needs assessment and implementation. In general, newly married couples (and the youth), widows, single women, and the poor were the main beneficiaries, and those classified as bureaucrats (associated with the feudal system or the previous military government and religious leaders), who were believed to hold excessive amounts of land, were the losers. See Ege (1997), Yigremew (1997), Gelaye (1999), and Ege and Aspen (2003), for example, for accounts of the implementation in specific parts of the region. Generally, the redistribution exercise drew a massive reaction, both against and in support of it, which was expressed through rallies and demonstrations (UNDP 1997) as well as songs and poetry (Gelaye 1999). Very few studies, however, have examined the effects of land redistribution on land management and productivity in Ethiopia. Although land redistribution may cause tenure insecurity (Holden and Yohannes 2002), it may have mixed influences on farmers' land management and productivity through short- and long-term effects

(Benin and Pender 2001). On one hand, by improving access to land of households that have relative surpluses of other important factors of production, such as labor, oxen, or cash to purchase inputs, particularly in the context of prohibited land sales and restricted lease markets as exist in Ethiopia, land redistribution may increase intensity of land management and use of purchased inputs, which may in turn increase productivity. On the other hand, land redistribution could also lead to inefficient factor ratios by forcing households with greater access to those other important factors of production to have the same landholding size as their poorer counterparts. Furthermore, expectations of future land redistribution may undermine farmers' incentive to invest in land improvements and soil fertility because farmers' ability to reap the benefits of such investments is undermined, adding to the ambiguity of the effect of land redistribution. Although the notion that a farmer may increase investment if the investment can in turn increase security of tenure or prevent one's land from being redistributed is not as evident in Ethiopia as it is in West Africa (for example, Besley 1995; Quisumbing et al. 2002), it can contribute to the ambiguity because farmers are entitled to compensation for any investments made on their redistributed lands, even if certain long-term investments such as planting trees on farmland are discouraged from the start.

Also responding to the problem of unequal landholding is the practice of transferring land through temporary leases in the form of sharecropping, fixed-fee rentals, or borrowing. The ability to temporarily transfer land can help households who own little or no land to overcome land constraints and also help those with little or no inputs (especially oxen and labor) to lease out the land and obtain capital to engage in other income-generating activity. However, the efficiency of alternative land tenure contracts has generated a lot of discussion in the past (Johnson 1950; Cheung 1969; Otsuka and Hayami 1988) and is still very much debated (Otsuka, Chuma, and Hayami 1992; Otsuka and Place 2001a; Ahmed et al. 2002; Pender and Fafchamps 2006, forthcoming). Underlying the debate about the inefficiency of alternative land contracts is the incentive that the contracts provide to the tenant. With perfect markets and no risk, fixed-fee or cash rental should result in an efficient resource allocation, as in the case of owner cultivation, because the fixed-fee rental would induce the tenant to produce the optimal level of output, where the marginal product of the tenant's extra effort equals the marginal cost of putting that effort. However, cash constraints (inability to pay the rent up front) or risk considerations may hinder the ability or preference of tenants in using fixed-fee rental. In this case, potential tenants may prefer sharecropping. However, because the share tenant receives as marginal revenue only a fraction of the value of his or her marginal product of labor, sharecropping limits the tenant's incentive to supply labor or other inputs at the optimum level, resulting in lower yields. If effort, however, can be easily monitored (or is costlessly enforceable), then a sharecropping arrangement can be as efficient as owner-cultivated or fixed-fee tenancy (Johnson 1950; Cheung 1969). The same result holds if there is mutual trust between the landowner and the tenant, as often exists in small communities where farmers know each other and lease markets are not restricted (Otsuka and Hayami 1988; Pender and Fafchamps 2006, forthcoming). To the extent that perfect markets for other factors of production exist, achieving allocative and productive efficiency may not require land rental markets to function (Pender and Fafchamps 2006, forthcoming).[2] However, imperfections in credit and input markets are important in developing countries' agriculture (Holden, Shiferaw, and Pender 2001), and they may be the main motive for the choice of sharecropping and the inefficiency surrounding alternative land tenure systems (Ahmed et al. 2002).

Given imperfections in factor markets, then whether or not the cost of monitoring and enforcement are low enough to result in efficient sharecropping remains an empirical question. The results can provide useful information, especially for the development by the regional government of the modalities of land leasing in the administration and use of land that has been ongoing in the region since 2000 (ANRSC 2000b).

Study Area and Data

Survey

The study is based on analysis of household and plot level surveys that were conducted in the highland areas (above 1,500 meters above sea level) of the Amhara region of Ethiopia in 2000 and 2001. These follow community surveys in 98 villages (*gots*) conducted in 1999 and 2000. At the community level, a stratified random sample of 49 peasant associations (PAs, usually consisting of three to five villages)[3] and two villages randomly selected from each PA were selected from highland areas of the region. Using district (*woreda*)-level secondary data, the stratification was based on indicators of agricultural potential (low or high),[4] market access (access or no access to an all-weather road), and population density (1994 rural population density greater than or less than 100 persons per square kilometer) (see Figure 9.1 in the color insert).[5] Two additional strata were defined for PAs where an irrigation project exists (in low- versus high-potential areas), resulting in a total of 10 strata. Five PAs were then randomly selected from each stratum (except the irrigated drought-prone stratum, in which there were only four PAs), for a total of 49 PAs and 98 villages. From each village, initially five households, and later four to speed up the data collection, were randomly selected to give a total of 434 households. In addition, all plots (1,422 in total) operated by the household were surveyed.

Information collected through structured surveys includes presence of programs and population in the community, household structure and endowments, household access to infrastructure and services, plot characteristics (mode of acquisition, size, slope, quality, crops cultivated, etc.), land investments, land management practices, inputs, and agricultural production in 1999. Recall methods were also used to obtain information before 1999, specifically 1991. Data on altitude were collected using a global positioning system (GPS). The primary data were supplemented by secondary information on amount of rainfall in 1999, obtained from the Meteorological Services Agency for weather stations located in the districts where the surveys were carried out.[6]

Data

Plot acquisition, tenure contracts, and land rights. In 1975, land was nationalized, and households were given use rights only, with occasional redistribution of farmland to accommodate landless households. Since 1991, households have been given the right to use the land indefinitely, lease it out temporarily to other farmers, and transfer it only to their children. However, they cannot sell or mortgage the land. In the Amhara region, land redistribution to address the increasing problem of landlessness and equalize landholding and quality of farmland has been common. There has been at least one land redistribution in about 73 percent of the villages since 1991, with the average number being three.[7] One of the villages interviewed had experienced as many as 14 land redistributions since 1975.

About 89 percent of the plots surveyed were cultivated by their owners, that is, by those receiving the land directly from the government or through gift, inheritance, or permanent exchange. These plots are referred to as owner-cultivated plots. The remaining 11 percent of the plots were mainly obtained through temporary farmer-to-farmer exchanges in the form of rental, mostly sharecropping. Renting in and out of plots of land is also common in other parts of the country, about 14 percent in Tigray region (Pender, Gebremedhin, and Haile 2002) and 11 percent in Oromiya region (Jabbar and Ayele 2002). Contracts for rented plots were very short (one season or year on average), and *equal* sharecropping (one-half of crop output to landowner) was the common practice. For fixed leases, rents were about 250–550 birr per hectare, depending on the quality of the land.[8]

Land rights associated with exchange, transfer, and making long-term investments were exclusive to owner-cultivated plots. There seems, however, to be a high level of restriction on rented plots even for simple activities such as crop choice and grazing animals. Tenants could not choose what type of crops to plant on 50 percent of the rented plots, and they could not graze their animals on 28 percent of the rented plots. Expectations to operate the plot over the next 5 or 10 years or to bequeath the plot were almost 100 percent on owner-cultivated plots but were between 20 and 28 percent on rented plots.[9] The main reason for expecting not to operate the plot in the future was fear of land redistribution on owner-cultivated plots and termination of rental contract or uncertainty of renewal of contract on rented plots.

Land investments and adoption of management practices and modern inputs. The presence of long-term land investments on plots was generally low. The most common types of investment were drainage ditches, occurring on 39 percent of all plots (Table 9.1). Stone terraces, fences, and live fences were next, ranging from 12 to 22 percent of all plots. Check dams, soil bunds, grass strips, and tree planting accounted for between 1 and 5 percent of all plots. There were some statistically significant differences in investments by land tenure. The incidence of stone terraces, live fences, trees, and check dams was significantly higher on owner-cultivated plots compared to rented plots, whereas the incidence of drainage ditches was higher on rented plots. In fact, there were no trees or check dams on rented plots. Possibly, owners of rented plots identify those as less productive or too far away and so did not invest in them before renting out, whereas those renting them have little or no incentive to invest in them. Note that it is not possible in the data to link

Table 9.1 Percentage of plots with investment by land tenure and redistribution in the highlands of Amhara region, Ethiopia

		Land tenure		Land redistribution in village since 1991	
Type of investment	All plots	Owner-cultivated	Rented	No	Yes
Stone terrace	21.9	23.5*	9.3*	26.4	19.9
Soil bund	3.2	3.2	3.6	1.2*	3.8*
Check dam	1.4	1.6*	0.0*	1.5	1.4
Drainage ditch	39.2	37.5*	52.6*	18.6*	47.4*
Irrigation canal	3.3	3.5	1.6	5.1	2.7
Grass strip	4.9	5.2	2.7	2.1*	5.8*
Planting trees	2.8	3.1*	0.0*	1.1*	3.3*
Fence	16.2	15.3	23.0	9.1*	18.8*
Live fence	12.5	13.7*	2.8*	11.4	13.0
Number of plots	1,187.0	1,057.0	130.0	346.0	841.0

Note: Rented plots include sharecropped and fixed-fee rented plots. Sample means are adjusted for stratification, weighting, and clustering of sample.

*Sample means in the relevant category are different at the 10 percent level of significance.

Table 9.2 Percentage of plots using land management practice by land tenure and redistribution in the highlands of Amhara region, Ethiopia

		Land tenure		Land redistribution in village since 1991	
Type of investment	All plots	Owner-cultivated	Rented	No	Yes
Reduced tillage	25.2	25.7	21.1	22.5	25.1
Contour plowing	69.3	69.6	67.4	82.8*	64.9*
Crop rotation	62.4	63.7*	53.6*	64.4	60.8
Crop residues	64.0	64.0	59.6	73.9*	59.2*
Household refuse	17.4	19.4*	3.7*	17.6	17.5
Manure	9.0	9.8*	2.7*	10.6	8.4
Chemical fertilizers	34.5	32.1*	53.3*	10.6*	44.3*
Improved seeds	13.0	11.7*	22.7*	2.4*	17.0*
Number of plots	1,187.0	1,057.0	130.0	346.0	841.0

Note: Rented plots include sharecropped and fixed-fee rented plots. Sample means are adjusted for stratification, weighting, and clustering of sample.

*Sample means in the relevant category are different at the 10 percent level of significance.

rented plots to their respective owners in order to verify this. Where there were statistical differences by land redistribution, the incidence of investments on plots was higher in villages that have experienced at least one land redistribution since 1991. Villages experiencing land redistribution tended to be located more in the high-potential areas where such investments are more profitable.

Table 9.2 shows the most common land management practices used on the plots, including contour plowing (occurring on 66 percent of all plots), plowing in crop residues (64 percent), and crop rotation (62 percent). Reduced tillage was used on 25 percent of all plots, and chemical fertilizer, household refuse, and improved seed and manure were used on 35, 17, 13, and 9 percent of all plots, respectively. The low incidence of manure use on plots is likely because it is also used as fuel. However, increased use of chemical fertilizers under implementation of the massive agricultural package program, which led to a substantial increase in the cultivated area under chemical fertilizers, may have also reduced the need for manure. Here too, there were some differences by land tenure and land redistribution. Applying household refuse and use of manure were more common on owner-cultivated than rented plots. On the other hand, using fertilizers was more common on rented plots. This may reflect the relative long-term versus short-term return on investment in different inputs, where those with immediate (one season) benefits are preferred on rented plots. It is likely that renters have more resources including access to credit to finance the purchase and use of chemical fertilizers. However, most of the rented plots are sharecropped, where sharing of chemical fertilizer cost is a common feature. Thus, the cost (and risk) of applying chemical fertilizer is reduced for each party, which increases the likelihood of using chemical fertilizers on rented plots. Moreover, several of the rented plots were planted to maize on which chemical fertilizers are commonly applied. Looking at the differences by land redistribution shows that use of chemical fertilizers and improved seeds was greater in villages that have experienced land redistribution, whereas use of contour plowing and crop residues was less. As mentioned earlier, villages experiencing land redistribution were located more in the high-potential areas, where use of chemical fertilizers and improved seeds is more profitable.

Land use, inputs, and crop production. A majority of the plots (76 percent) were located in the fields, as opposed to those cultivated on the compound of the household (homestead, 24 percent). With very little irrigation (about 4 percent of all plots) and unreliable small rains (*belg*), crop production was restricted to the main rainy season, which is normally from June to October. Cereals dominated the crops cultivated. *Teff,* barley, wheat, and maize were the dominant monocropped cereals, taking up 50 percent of all plots. Other cereals (sorghum, millet, and oat), either monocropped or mixed with other cereals, made up 14 percent of the plots, and cereals mixed with other noncereal crops made up 16 percent. Legumes cultivated as monocrops made up 11 percent of all plots. The remaining 9 percent of the plots were cultivated with other crops or combinations of crops, excluding cereals.

The amounts of inputs used are shown in Table 9.3. For all plots, 287 man-days, 54 animal-days, and 256 birr of labor, draft power, and seed were used per hectare of land, respectively. With the exception of labor, the use of which was statistically significantly higher on owner-cultivated than on rented plots, use of other inputs was not statistically different by land tenure or land redistribution. It is puzzling why labor was much lower (about 50 percent) on rented plots than on owner-cultivated plots. Possibly, renters underestimated or did not report the contribution of landowners. Recall that most of the rented plots were sharecropped where landowners often contributed labor. The average value of crop yield for all plots was 2,829 birr per hectare (Table 9.3).[10] Consistent with the higher use of inputs on owner-cultivated plots or in villages that have had at least one land redistribution since 1991, average yield was also higher, although the difference is not statistically significant.

Production and sociocultural environment. The highlands of Ethiopia are typically very densely populated. The highlands account for about 45 percent of the total area of the country, but they are home to about 80 percent of the total human

Table 9.3 Amounts of inputs used and value of output by land tenure and redistribution in the highlands of Amhara region, Ethiopia

		Land tenure		Land redistribution in village since 1991	
Type of investment	All plots	Owner-cultivated	Rented	No	Yes
Labor (man-days/hectare)	286.8	304.3*	157.6*	257.3	297.5
Draft animal (animal-days/hectare)	54.3	54.7	51.6	50.3	55.8
Seed (birr/hectare)	255.8	258.8	233.7	273.7	249.4
Value of crop yield (birr/hectare)	2,829.1	2,887.6	2,407.1	2,703.4	2,874.4
Number of plots	1,187.0	1,057.0	130.0	346.0	841.0

Note: Rented plots include sharecropped and fixed-fee rented plots. Sample means are adjusted for stratification, weighting, and clustering of sample.

At the time of the survey, US$1 ≈ 8.50 Ethiopian birr.

*Sample means in the relevant category are different at the 10 percent level of significance.

population and 75–80 percent of the cattle and sheep (Degefe and Nega 2000). The survey data show an average of about 45 households per square kilometer in each village. Rapid population growth has increased the demand for farmland and contributed to farming on fragile lands, especially on hillsides with steep slopes, which are traditional grazing areas. Compared to Tigray region and others, the region has relatively good rainfall, with an average annual rainfall of 1,408 millimeters.[11] The average elevation was 2,172 meters above sea level, and the average distance to the district town was 34 km. When these characteristics were examined by agricultural potential, population densities and rainfall amounts were higher in high-potential areas. Villages in high-potential areas also had better access to their respective district towns (less than one-half of the average distance in low-potential areas) and were also located at relatively lower altitudes.

The sociocultural environment is shaped by the evolution and historical distributions of population settlement norms and, particularly in this context, those that affect attitudes and behavior toward organization of agricultural production. The administrative zones (North and South Gondar, Awi, East and West Gojjam, Wag Hamra, Oromia, North and South Wollo, and North Shewa) best capture the major sociocultural differences in the population across the region.[12] The North and South Gondar (representing about 30 percent of the sample) and North Shewa (14 percent) zones are evenly distributed as low and high agricultural potential. The Awi (3 percent) and East and West Gojjam (33 percent) zones are mostly of high potential, whereas North and South Wollo (20 percent) zones are mostly of low potential.

Econometric Approach and Results

Econometric Approach

Econometric techniques were used to estimate equations (9.1) and (9.2) presented in the conceptual framework. Specifically, we estimate and present regression results for (1) whether various land management practices, including use of reduced tillage, contour plowing, crop rotation, crop residues, household refuse, manure, chemical fertilizers, and improved seeds, were used by farmers on their farm plots in 1999;[13] (2) amount of labor and draft animal power and value of seed used by farmers per hectare in 1999; and (3) value of crop yield (total output per hectare) in 1999.

Table 9.4 shows detailed description and summary statistics of the dependent and endogenous variables. The econometric models used to estimate them depend on how they are measured. For land management practices, probit models were used to explain the probability of the management practice being used on the plot. Least-squares models were used to explain the amount of labor, draft animal, and seed used per hectare and value of crop yield obtained. Although not reported, the determinants of extension visits and crop choice were also estimated, and the results used to enrich the discussion of the chapter. Ordered probit and multinomial logit models were used to estimate the probability of receiving extension and planting a particular crop or mix of crops, respectively.[14]

The explanatory variables used in the regressions are operational measurements of the factors discussed in the conceptual framework. Detailed description and summary statistics of the explanatory variables are also shown in Table 9.4, grouped first by those used in estimating both equations (9.1) and (9.2) and those excluded from the value of crop yield equation. How the variables were partitioned will be explained shortly under estimation procedure. Then, within the two categories, they are grouped by plot-, household-, village/district-, and subregional-level factors. Among the plot-level factors, the variables include whether the plot is owner-cultivated or not and whether the farmer expects to operate the plot in the next five years or not. Others include size, slope, perception of soil depth, soil color, and waterlogging problems, presence of gullies, irrigation, stone terraces, and soil bunds or fences, location of plot (homestead versus field), and walking time from plot to residence. Household factors include endowments of human capital (gender and age structure, size, and education), physical capital (size of farm operated, number of oxen, and total stock of livestock measured in tropical livestock units),[15] financial capital (exogenous income and access to credit), and access to infrastructure and services. The village/district-level factors include whether there was a land redistribution since 1991 or not, population density, altitude, rainfall, distance to the district town, availability of inputs, and social capital (presence of various local associations). For ease of estimation, the region is divided into four subregions: the northern part (North and South Gondar zones), the western part (Awi and East and West Gojjam zones), the eastern part (North and South Wollo zones), and the southern part (North Shewa zone).

Estimation Procedure

As the conceptual framework specified in equations (9.1) and (9.2) shows, land management practices, inputs, extension, and crop choice are endogenous in the crop production function. This endogeneity problem can be addressed by estimating the value of the crop yield equation by a two-stage procedure in which land management practices, inputs, extension, and crop choice are predicted from the first stage and used in the second-stage estimation of the value of crop yield regression. Some of the explanatory variables used in the first-stage estimation are excluded from the second-stage estimation. This procedure is similar to estimating the value of the crop yield equation by instrumental variables (IV), where the excluded explanatory variables in the second stage are the instruments. Finding appropriate instruments can be challenging because one needs to find variables (at least one for each explanatory endogenous variable) that are correlated with the endogenous explanatory variables being instrumented (i.e., land management practices, inputs, extension, and crop choice) but not correlated with the dependent variable (i.e., value of crop yield after controlling for the explanatory variables in equation [9.1]).

First, potential exogenous variables that were hypothesized to have an influence on land management practices, inputs, extension, and crop choice but no hypothesized direct effect on value of crop yield, in addition to the exogenous and endogenous explanatory variables specified in equation (9.1), were used directly in the value of crop yield model. The variables finally selected for exclusion from the value of crop yield regression model were those exogenous variables that had a zero effect (separately and jointly) on value of crop yield.

Ordinary least squares (OLS) and IV were used to estimate value of crop yield. Then endogeneity bias, potentially resulting from using the actual values of the endogenous explanatory variables (OLS method) rather than their predicted values (IV method), was tested for using a Hausman test (Hausman 1978; Greene 1993).[16] Exogeneity of land management practices, inputs, extension, and crop choice in the cereal yield regression was not rejected, suggesting that the OLS gives consistent and efficient estimates. Thus, only the OLS results are reported and discussed.

Recall that several of the factors specified in equation (9.2) with important potential policy implications (e.g., access to infrastructure and services) for increasing cropland productivity may in theory have only indirect effects on value of crop yield via their effect on land management practices, inputs, extension, and crop

Table 9.4 Detailed description and summary statistics of variables, by agricultural potential

Variable name	Variable description	Total sample		Low-potential areas		High-potential areas		
		Mean	S.E.	Mean	S.E.	Mean	S.E.	*t*-test
Endogenous variables								
Value of crop yield	Value of total crop output per hectare (Ethiopian birr/ha)	2,829.110	285.285	3,252.907	322.046	2,576.460	412.893	
Crops (cf. other crops)	Proportion of plot allocated to crops (compared to noncereals)							
Barley only	Barley only	0.135	0.013	0.197	0.026	0.097	0.015	*
Maize only	Maize only	0.079	0.010	0.039	0.011	0.105	0.016	*
Wheat only	Wheat only	0.086	0.010	0.120	0.017	0.064	0.012	*
Teff only	*Teff* only	0.197	0.015	0.164	0.021	0.218	0.022	*
Other cereals	Other cereal crops or combination of cereal crops	0.142	0.016	0.116	0.016	0.159	0.023	
Cereal and other crops	Cereals mixed with other crops	0.158	0.015	0.143	0.020	0.167	0.020	
Legumes only	Leguminous crops only	0.114	0.013	0.157	0.019	0.088	0.018	*
Extension (cf. 0 visits)	Number of visits by an extension agent (compared to no visit)							
1–5 visits	1–5 visits	0.305	0.038	0.362	0.048	0.269	0.055	
6–10 visits	6–10 visits	0.193	0.035	0.140	0.033	0.227	0.053	
More than 10 visits	More than 10 visits	0.163	0.031	0.137	0.032	0.179	0.047	
Use of reduced tillage	Dummy variable equal to 1 if reduced tillage is used, 0 otherwise	0.244	0.029	0.389	0.043	0.154	0.040	*
Use of contour plowing	Dummy variable equal to 1 if contour plowing is used, 0 otherwise	0.697	0.029	0.757	0.033	0.659	0.042	*
Use of crop rotation	Dummy variable equal to 1 if crop rotation is used, 0 otherwise	0.618	0.028	0.490	0.041	0.698	0.038	*
Use of crop residues	Dummy variable equal to 1 if crop residue is plowed in, 0 otherwise	0.631	0.035	0.640	0.048	0.625	0.050	
Use of household refuse	Dummy variable equal to 1 if household refuse is used, 0 otherwise	0.175	0.010	0.155	0.017	0.188	0.014	
Use of manure	Dummy variable equal to 1 if manure is used, 0 otherwise	0.090	0.010	0.102	0.018	0.082	0.012	
Use of chemical fertilizers	Dummy variable equal to 1 if chemical fertilizer is used, 0 otherwise	0.353	0.029	0.107	0.017	0.507	0.042	*
Use of improved seeds	Dummy variable equal to 1 if improved seed is used, 0 otherwise	0.131	0.022	0.040	0.010	0.188	0.034	*
Amount of labor	Amount of total labor used (excluding harvest and postharvest) (man-days/hectare)	286.854	32.592	297.530	38.237	280.177	47.252	
Amount of draft power	Amount of total draft animal used (excluding threshing) (animal-days/hectare)	54.379	4.378	49.385	4.745	57.502	6.485	
Value of seed	Value of total seed used (Ethiopian birr/hectare)	255.880	31.663	233.012	17.820	270.184	50.174	

Exogenous variables (for all endogenous variables)								
Plot-level factors								
Owner-cultivated	Dummy variable equal to 1 if plot is cultivated by the owner, 0 otherwise	0.880	0.020	0.956	0.014	0.833	0.030	*
Expectation to operate	Dummy variable equal to 1 if plot is expected to be operated within the next 5 years, 0 otherwise	0.885	0.021	0.964	0.013	0.836	0.032	*
Size	Size of plot (x10 m^2)	0.335	0.017	0.295	0.021	0.359	0.025	*
Slope	Average slope of the plot (degrees)	5.735	0.347	7.032	0.550	4.923	0.425	*
Soil depth (cf. deep)	Farmers' perception of depth of the soil on plot (proportion, compared to "deep" soil)							
Medium	Medium	0.595	0.025	0.564	0.032	0.615	0.035	
Shallow	Shallow	0.228	0.019	0.301	0.027	0.183	0.025	*
Soil color (cf. black)	Farmers' perception of color of the soil on plot (proportion, compared to "black" soil)							
Brown	Brown	0.297	0.027	0.337	0.035	0.272	0.038	
Gray	Gray	0.076	0.013	0.093	0.023	0.066	0.017	
Red	Red	0.342	0.031	0.180	0.026	0.442	0.046	*
Presence of gullies	Dummy variable equal to 1 if there are gullies on the plot, 0 otherwise	0.042	0.008	0.066	0.014	0.028	0.010	*
Waterlogging problem	Dummy variable equal to 1 if water logging is a problem on the plot, 0 otherwise	0.078	0.012	0.095	0.020	0.068	0.016	
Investments on plot								
Irrigation	Dummy variable equal to 1 if plot is irrigated, 0 otherwise	0.039	0.008	0.025	0.008	0.048	0.012	
Stone terraces	Dummy variable equal to 1 if there are stone terraces on plot, 0 otherwise	0.216	0.019	0.365	0.029	0.124	0.025	*
Drainage ditch	Dummy variable equal to 1 if there are drainage ditches on plot, 0 otherwise	0.397	0.034	0.160	0.030	0.546	0.052	*
Live fence	Dummy variable equal to 1 if there are live fences (e.g., living trees) on plot, 0 otherwise	0.126	0.013	0.094	0.020	0.146	0.019	*
Fence	Dummy variable equal to 1 if there are non-live fences on plot, 0 otherwise	0.162	0.023	0.106	0.020	0.197	0.034	*
Household-level factors								
Gender of head	Dummy variable equal to 1 if household head is male, 0 otherwise	0.964	0.012	0.976	0.016	0.956	0.018	
Average education	Average education of household members (years)	42.911	0.887	44.562	1.008	41.878	1.300	
Age of head	Age of household head (years)	1.887	0.187	1.756	0.174	1.969	0.283	
Size of farmland	Size of the total landholding of the household (x10 m^2)	1.278	0.062	0.935	0.061	1.492	0.088	*
Number of oxen	Number of oxen owned by the household	1.616	0.083	1.336	0.087	1.792	0.120	*
Tropical livestock units	Number of tropical livestock units owned by the household	3.918	0.216	3.547	0.281	4.151	0.301	

(*continued*)

Table 9.4 (continued)

Variable name	Variable description	Total sample		Low-potential areas		High-potential areas		
		Mean	S.E.	Mean	S.E.	Mean	S.E.	*t*-test
Village/district-level factors								
Land redistribution	Dummy variable equal to 1 if land redistribution occurred in village after 1991, 0 otherwise	0.734	0.031	0.627	0.044	0.802	0.043	
Household density	Number of households in the village per square kilometer	44.757	1.529	38.470	1.514	49.035	2.289	*
Altitude	Average altitude in the village (meters above sea level)	2,171.955	33.532	2,296.283	47.795	2,087.357	43.946	
Rainfall	Annual rainfall (millimeters)	1,407.815	33.931	1,049.204	15.281	1,632.131	47.761	*
Subregional location								
Location (cf. Southern)	Subregional location of household (compared to North Shewa Zone)							
Northern	Dummy variable equal to 1 if North/South Gondar Zones, 0 otherwise	0.297	0.033	0.331	0.028	0.276	0.052	
Western	Dummy variable equal to 1 if Awi/East/West Gojjam Zones, 0 otherwise	0.357	0.027	0.016	0.002	0.571	0.047	*
Eastern	Dummy variable equal to 1 if North/South Wollo Zones, 0 otherwise	0.197	0.016	0.509	0.032	0.002	0.000	*
Variables excluded from the value of crop yield equation								
Plot level								
Homestead plot	Dummy variable equal to 1 if plot is located in the homestead, 0 otherwise	0.240	0.012	0.238	0.018	0.241	0.015	
Plot to residence	Walking time in minutes from the plot to the household's residence	15.850	1.008	18.026	1.360	14.488	1.414	*
Household level								
Household size	Number of household members	6.855	0.206	6.553	0.204	7.043	0.306	
Proportion male	Proportion of household members that are male	0.542	0.012	0.507	0.016	0.563	0.016	*
Dependency ratio	Proportion of household members less than 15 years old or more than 59 years old	0.540	0.013	0.519	0.017	0.553	0.019	
Exogenous income	Sum of remittances, food aid, gifts, and pension (Ethiopian Birr)[2]	76.815	10.910	156.171	24.704	27.177	7.766	*
Access to markets or services	Walking time in minutes from the household's residence to the nearest market/service							
Drinking water	Drinking water source in the main cropping season	10.770	0.711	13.146	1.214	9.284	0.859	*
Grain mill	Grain mill	56.062	3.877	88.117	7.748	36.011	3.325	*
All-weather road	All-weather road	180.372	10.694	274.296	23.310	121.622	8.062	*

Development agent	Development agent's office	38.791	2.478	53.790	4.690	29.430	2.396	*
Bus service station	Bus service station	205.270	11.342	304.282	25.152	143.336	7.935	*
Fuelwood	Fuelwood source in main cropping season	54.212	4.516	68.714	6.909	44.996	5.866	*
Input supply shop	Input supply shop	145.704	8.347	211.117	13.708	104.768	8.768	*
Village/district-level factors								
Distance to district town	Average distance from the peasant association to the district town (kilometers)	33.536	1.936	51.058	3.851	20.926	1.115	*
Access to fertilizers	Dummy variable equal to 1 if chemical fertilizers are available in the village, 0 otherwise	0.972	0.008	0.929	0.022	1.000	0.000	*
Access to improved seeds	Dummy variable equal to 1 if improved seeds are available in the village, 0 otherwise	0.876	0.027	0.927	0.020	0.844	0.041	*
Access to purchased feed	Dummy variable equal to 1 if livestock feed can be purchased in the village, 0 otherwise	0.499	0.040	0.702	0.045	0.373	0.056	*
Access to credit	Dummy variable equal to 1 if credit from Amhara Credit and Savings Institution is available in the village, 0 otherwise	0.216	0.034	0.097	0.027	0.290	0.053*	
Presence of local association	Dummy variable equal to 1 if local association or organization or cooperative is present in the village, 0 otherwise							
Input cooperative	Input cooperative	0.397	0.039	0.151	0.028	0.550	0.055	*
Marketing cooperative	Marketing cooperative	0.044	0.011	0.114	0.028	0.000	0.000	*
Women's/youth	Women's/youth	0.955	0.012	1.000	0.000	0.927	0.020	*
Church	Church	0.944	0.009	0.858	0.025	0.998	0.000	*
Water users	Water users	0.536	0.040	0.452	0.048	0.589	0.056	*

Note: Agricultural potential is an adaptation of the classification used by the Ethiopian Disaster Prevention and Preparedness Commission, referring to non-drought-prone districts as high-agricultural-potential areas (located to the west and southern tip of the region) and drought-prone districts as low-agricultural-potential areas (located to the east) (see Fig. 9.1).

Sample means and standard errors are adjusted for stratification, weighting, and clustering of sample.

At the time of the survey, US$1 ≈ 8.50 Ethiopian birr.

***Sample means are different by agricultural potential at the 10 percent (or less) level of significance.**

choice. In order to examine the direct and indirect effects, a reduced-form model that excludes the endogenous variables as explanatory variables but includes the instruments (discussed earlier) is also estimated. The reduced-form specification allows estimation of the total effects of the exogenous explanatory variables on crop production. Furthermore, it eliminates the potential for endogeneity bias altogether.

In estimating the inputs (labor, draft animal power, and seed) and value of crop yield models, a logarithmic Cobb-Douglas specification was used.[17] This specification was chosen on empirical merit. For example, the translog specification, which is a more flexible form, was also attempted but not utilized because of severe multicollinearity problems introduced by the interaction and other terms. The logarithmic transformation also reduces problems resulting from outliers and nonnormality of the error term when an ordinary linear specification is used.

An attempt was made to examine the effect of interactions between some key variables on value of crop yield model, for example, the complementary effects of moisture-enhancing technologies and modern inputs. Various interactions among use of chemical fertilizers, improved seeds, irrigation, and stone terraces were tried. However, the interaction variables were dropped from the final regressions because there were too few observations (less than 2 percent in many cases) to warrant a reliable estimation, the results being very sensitive to a few positive observations. Finally, the models were estimated for the total sample and then separately for low- and high-agricultural-potential areas to provide information on the relative contribution of the policies and programs to technology adoption, land management, and productivity in the two production environments. Statistical test results show, except for use of reduced tillage, household refuse, and manure, significant differences in the effects of the explanatory variables between low- and high-agricultural-potential areas, suggesting that the observations should not be pooled in the regressions.[18] Thus, only results from estimation of the restricted models for use of reduced tillage, household refuse, and manure and the unrestricted models for the others are reported and discussed.

Generally, the different regression models were estimated and presented in order to provide as much information as possible as well as to generate a greater degree of confidence in the robustness of the econometric results. STATA software (StataCorp 2005) was used for the regression analysis, and the results are corrected for sample stratification, weighting, and clustering.

Regression Results

Detailed results of the econometric estimations are shown in Tables 9.5–9.7. Because of the large amount of output, which in turn is related to the large number of explanatory variables used,[19] discussion of the results is limited to those variables that are of interest in this chapter in order to conserve space. Thus, although all the estimated coefficients associated with the explanatory variables are reported for all the regression models, the discussion of results focuses on the effects of land redistribution and tenure, plot and farm size, household endowments (gender, education, oxen, and livestock ownership), population density, and access to infrastructure and services. The effects of irrigation, stone terraces, extension, land management practices, and use of conventional inputs (labor, draft animal, and seeds) and modern inputs (improved seeds and chemical fertilizers) on value of crop yield are also discussed.

Adoption of land management practices. Table 9.5 shows regression results for use of reduced tillage, household refuse, and manure on household farm plots for the total sample and for use of contour plowing, crop rotation, crop residues, chemical fertilizers, and improved seeds on household farm plots by agricultural potential.

With other factors controlled, owner-cultivated plots compared to rented plots were associated with a greater likelihood of using crop rotation and plowing in crop residues in high-potential areas only. Although it is meant to replenish soil fertility, Benin, Ehui, and Pender (2003b) argue that the concept of crop rotation as used in the Ethiopian highlands can be misleading because the rotation cycles practiced by farmers to incorporate legumes or fallow may not be long enough to be effective. In high-potential areas too, rented plots compared to owner-cultivated plots were associated with greater likelihood of using improved seeds, which is consistent with other observations that rented plots were planted more to maize for which improved seeds were used more. In general (i.e., in both low- and high-potential areas), incidence of manure use was lower on owner-cultivated plots than on rented plots, whereas in low-potential areas, incidence of use of chemical fertilizers and improved seeds was greater on owner-cultivated plots. Plots located in villages where there had been land redistribution were associated with lower likelihood of using several of the land management practices, especially in low-potential areas.

Larger plots were associated with greater likelihood of use of crop rotation in general and plowing in crop residues or using chemical fertilizers and improved seeds in high-potential areas in particular. Larger farms in low-potential areas were associated with greater likelihood of using contour plowing and improved seeds but lower likelihood of plowing in crop residues. In high potential areas, larger farms were associated with greater likelihood of using chemical fertilizers.

Irrigated plots were associated with greater likelihood of using household refuse but, surprisingly, lower likelihood of using chemical fertilizers in both low- and high-potential areas and lower likelihood of using improved seeds in low potential

Table 9.5 Probit regression results of use of land management practice by agricultural potential in the highlands of Amhara region, Ethiopia, 1999

	Reduced tillage	Contour plowing		Crop rotation	
	Total sample	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
Plot-level factors					
Owner-cultivated	–0.396	–1.802***	0.189	–0.412	0.679*
Expectation to operate	0.445	1.534*	–0.314	–0.374	0.407
Ln Size	0.010	–0.058	0.018	0.220**	0.279***
Ln Slope	0.026**	0.126***	0.083***	–0.035**	0.031*
Soil depth (cf. deep)					
Medium	0.848***	0.380	–0.271	–0.361	–0.010
Shallow	0.783***	0.324	–0.168	–0.362	0.232
Soil color (cf. black)					
Brown	–0.415**	0.389	0.557	0.130	–0.120
Gray	0.033	0.193	0.625	0.016	–0.377
Red	0.134	0.367	0.245	0.356	0.366
Presence of gullies	0.274	1.041***	–0.579	–0.001	–0.087
Water logging problem	–0.165	0.261	0.970**	–0.508*	0.162
Investments on plot					
Irrigation	–0.100	–0.736	–0.159	0.170	0.870
Stone terraces	0.043	0.834***	1.525***	–0.072	0.203
Drainage ditch	0.015	0.289	0.644***	–0.408	–0.021
Live fence	–0.909***	0.011	0.039	–0.206	–0.039
Fence	–0.193	0.915***	0.634**	0.339	0.133
Household-level factors					
Gender of head	–1.065***	–0.793	0.314	–0.100	0.248
Ln Age of head	–1.276***	–0.686	0.045	–0.216	–0.358
Average education	–0.142***	–0.063	0.079	0.031	–0.140***
Ln Size of farmland	0.025	0.447**	0.034	0.025	–0.203
Number of oxen	0.332***	0.046	–0.123	–0.459***	–0.374*
Tropical livestock units	–0.128***	–0.022	0.026	0.159***	0.157*
Village/district-level factors					
Land redistribution	–0.004	–0.762**	–0.485	–0.625**	0.358
Ln Household density	–1.397***	–1.855***	0.091	–0.235	–0.037
Ln Altitude	1.108**	–1.259	1.438	0.415	–1.544
Ln Rainfall	1.991***	6.197***	2.159***	0.710	1.279
Subregional location					
Location (cf. Southern)					
Northern	–0.804***	0.767*	0.034	–0.091	–1.611**
Western	–5.156***	0.278	1.647	0.869	–1.624**
Eastern	1.457***	2.164***	2.312***	–0.754*	1.409
Variables excluded from the value of crop yield equation					
Plot level					
Homestead plot	0.070	0.480*	0.271	0.128	–0.613***
Ln Plot to residence	0.002	0.010*	0.000	–0.007	–0.011***

Crop residues		Household refuse	Manure	Use of chemical fertilizers		Use of improved seeds	
Low-potential areas	High-potential areas	Total sample	Total sample	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
–0.156	0.874*	–0.103	–0.811**	0.692*	0.881	1.686*	–1.514***
1.079	–1.273***	–0.754*	0.935**	–0.552	–1.176**	–0.375	0.897
0.143	0.244*	–0.115	–0.070	0.111	0.674***	–0.127	0.440**
–0.002	–0.011	–0.068***	–0.031	–0.115***	–0.048***	–0.333***	0.023
0.457*	–0.372	0.367	0.052	0.228	0.035	0.730	–0.649
1.326***	–0.434	–0.532	–0.624*	0.408	0.610	0.318	–0.466
–0.303	0.956***	0.379	0.652***	0.110	–0.132	1.089***	–0.125
–0.453	1.210***	0.729*	0.731**	0.589	–1.013*	1.398***	–1.915**
0.329	0.934***	0.486	0.567*	–0.215	0.262	–0.934*	1.339***
–1.369***	–0.724	–1.656***	–0.438	–0.353	–0.226	2.405***	1.068**
0.783***	0.394	0.369	–0.311	–0.008	0.383	1.010***	–0.861
–0.228	–0.233	1.194***	0.479	–1.035***	–1.859***	–1.709**	0.892
0.463*	–0.081	–0.914***	0.069	0.827***	0.720*	0.405	0.315
0.267	0.819***	0.402	0.490***	0.112	0.763***	1.187***	0.159
–1.075***	–0.393	0.669***	0.821***	–0.778*	0.114	–0.033	–0.208
0.213	0.120	0.223	0.602***	–0.174	0.092	0.656	0.173
1.902***	1.572***	0.362	0.688	0.950	0.586	n.e.	–0.992
–0.643	–2.646***	0.862	–0.403	–1.147**	–3.281***	–1.222	–2.565***
0.049	–0.120**	0.015	0.036	–0.038	0.130*	0.098	0.246***
–0.357*	–0.351	0.276	–0.137	–0.350	0.803***	1.142***	0.155
0.463***	–0.219	–0.467***	–0.097	0.218	1.396***	0.451	0.466
–0.173***	0.079	0.204***	0.146**	0.019	–0.453***	–0.230*	–0.047
–0.965***	1.793***	–0.396	–0.535*	0.318	–2.728***	0.515	–0.476
1.859***	3.543***	–0.090	–0.184	–0.988**	0.148	2.718***	0.043
3.441***	–10.821***	0.203	0.529	2.160**	1.741	0.669	7.524*
2.143*	0.121	1.642***	1.829***	0.346	–1.399	1.585	0.779
–3.755***	–0.056	0.353	–1.445***	1.617**	4.838***	6.290***	7.766
–2.955***	–1.140	0.061	–1.094**	5.527***	5.453***	8.224	4.557
–3.734***	0.986	1.168	–0.134	2.884***	2.495*	2.639*	5.265
–0.014	–0.106	2.301***	0.825***	0.043	–0.198	–0.326	0.800**
0.014***	–0.011**	–0.168***	–0.081***	–0.005	–0.016**	–0.024	–0.021*

(*continued*)

Table 9.5 (continued)

	Reduced tillage	Contour plowing		Crop rotation	
	Total sample	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
Household level					
Ln Household size	0.749***	0.612	–0.610	–0.015	1.067***
Proportion male	0.401	0.722	–1.596*	–1.611***	0.590
Dependency ratio	–0.736	–0.909	–2.582***	–0.037	–2.483***
Exogenous income	0.000	0.000	–0.001*	–0.001*	0.001*
Access to markets or services					
Ln Drinking water	–0.521***	0.019	–0.093	0.346***	0.405***
Ln Grain mill	0.144	–0.172	0.021	–0.114	0.053
Ln All-weather road	0.556***	0.312***	0.710***	–0.177	–0.380**
Ln Development agent	–0.067	–0.010	–0.599***	0.028	–0.102
Ln Bus service station	–0.606***	0.236	–0.416*	0.625***	–0.001
Ln Fuelwood	–0.002	0.007***	–0.002	–0.001	–0.007***
Ln Input supply shop	0.235**	0.247	0.220	–0.441***	0.415**
Village/district-level factors					
Ln Distance to district town	–0.432***	–1.208***	–0.685	–0.202	1.205***
Access to fertilizers	–1.123***	0.412	n.e.	n.e.	n.e.
Access to improved seeds	1.074***	–1.037	1.235**	0.837*	0.891*
Access to purchased feed	–0.841***	0.462	–0.448	–0.531*	–0.056
Access to credit	0.719***	–0.908*	0.489	–0.124	0.243
Presence of local association					
Input cooperative	1.631***	–1.387	–1.639*	–1.351***	0.796
Marketing cooperative	–1.221***	1.595*	n.e.	2.875***	n.e.
Women's/youth	–1.829***	n.e.	0.844	n.e.	n.e.
Church	–0.363	–2.521***	n.e.	–0.341	–1.665***
Water users	0.787***	1.167***	0.357	0.272	0.845**
Constant	–10.591*	–26.017***	–24.402*	–4.769	–0.775
Wald chi-square	258.470***	173.970***	183.860***	142.620***	159.310***
Pseudo-R^2	0.497	0.408	0.448	0.306	0.340
Likelihood ratio test[a]	48.304	149.92***		120.26***	

Note: See Table 9.4 for detailed description of variables. Coefficients and standard errors are adjusted for stratification, weighting, and clustering of sample.

***, **, and *** mean coefficient is statistically significant at the 10 percent, 5 percent, and 1 percent level, respectively.**

Ln means variable is transformed by natural logarithm. n.e. means coefficient was not estimated because the associated variable was dropped to avoid dummy variable trap or because it perfectly predicted the outcome.

Crop residues		Household refuse	Manure	Use of chemical fertilizers		Use of improved seeds	
Low-potential areas	High-potential areas	Total sample	Total sample	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
1.713***	1.439***	–0.740***	–0.685**	0.378	0.887	–0.324	1.537**
–0.947	1.015	–0.980	–0.447	–1.517*	0.069	–3.939***	0.439
0.205	–1.467	0.116	0.811	–1.753*	–2.494***	1.226	–2.487*
0.000	0.000	–0.001	0.000	0.001	–0.001	0.005***	–0.002
0.204	0.212	0.151	0.354***	–0.123	–0.080	–0.227	–0.519**
0.689***	0.313*	–0.411***	–0.048	0.079	–0.170	0.528*	–0.422*
0.205	–1.369***	–0.250	0.090	0.269	0.033	0.497**	0.392
–0.813***	0.102	0.099	0.082	–0.491***	–0.690***	–0.344*	–0.410
–0.653***	0.435**	0.481**	0.156	0.101	–0.236	–0.650*	0.258
0.005**	0.012***	0.002	0.000	0.000	0.010***	0.004	0.002
1.050***	0.270	–0.007	0.331***	–0.112	0.286	–0.014	–0.185
0.333	2.486***	0.191	–0.517***	–0.299	–0.686*	0.423	–1.047
1.911***	n.e.	–0.110	–0.216	n.e.	n.e.	n.e.	n.e.
–1.037	–2.211***	–0.204	0.679*	–0.265	1.769***	n.e.	n.e.
–1.343***	0.014	–0.820***	–0.140	–0.056	1.535***	–0.124	1.520
–0.085	1.446***	–0.340	–0.032	–1.086*	1.094***	–2.174***	–0.242
1.288*	–0.481	–1.615***	–1.052***	–0.404	1.001*	n.e.	3.496***
0.821	n.e.	0.364	0.769	1.017	n.e.	0.204	n.e.
n.e.	–4.058***	0.464	–0.898*	n.e.	0.530	n.e.	–1.770
–1.524***	n.e.	0.297	–0.177	–0.179	n.e.	–2.644***	n.e.
–0.974***	–0.877*	–0.244	–0.049	0.464	1.535***	0.440	0.429
49.015***	73.876***	–17.730*	–15.739*	–12.239	–5.293	–35.157**	–63.165
365.02***	323.790***	257.500***	165.580***	189.810***	165.950***	124.990***	95.730***
0.699	0.648	0.691	0.502	0.324	0.545	0.569	0.485
356.67***		38.349	57.197	156.36***		128.80***	

[a]The likelihood ratio (LR) test, similar to a Chow test in a least-squares regression, is a test of equality of the coefficients in low- and high-potential areas, where LR = –2 [ln L_{LPA} + ln L_{HPA} – ln L_{pooled}] $\chi^2(k)$; ln L_i is the log likelihood in regression for low-potential areas only, high-potential areas only, and the pooled data, respectively, and *k* is the number of coefficients.

areas. Probably, manure is seen as a substitute for chemical fertilizers. As expected, the presence of stone terraces was associated with greater likelihood of using chemical fertilizers as well as contour plowing, although it was also associated with lower likelihood of using household refuse in low-potential areas.

Female-headed households in low-potential areas were more likely to use reduced tillage on their farm plots, which is expected given the customary prohibition of women using oxen to plow in many places in the highlands of Ethiopia. Better-educated households in high-potential areas were less likely to use crop rotation or to plow in crop residues, but they were more likely to use chemical fertilizers and improved seeds on their farm plots because education enhances the ability of individuals to utilize technical information associated with such modern inputs. Ownership of livestock in general, and of oxen in particular, had the opposite effects. For example, in high-potential areas, although greater ownership of oxen was associated with greater likelihood of using chemical fertilizers, greater ownership of livestock in general was associated with lower likelihood of using chemical fertilizers. However, the magnitudes (in absolute value terms) of the effects associated with ox ownership are larger, indicative of the relative importance of oxen within the household.

More densely populated villages were associated with a lower likelihood of using reduced tillage and greater likelihood of plowing in crop residues in general but greater likelihood of using improved seeds and lower likelihood of using chemical fertilizers in low-potential areas. These findings are mixed regarding the Boserupian (Boserup 1965) perspective about the responses of households to population pressure. However, some of the findings may be caused by the negative effect of population pressure on ownership of oxen and livestock (Benin, Ehui, and Pender 2003a; Chapter 6), thereby reducing the capability of households to plow while easing the demand on crop residues for livestock feed and increasing the likelihood of recycling them in the soil.

Amount of labor, draft animal power, and seed used. Regression results with respect to the amount of labor, draft animal power, and seed used on farm plots by agricultural potential are shown in Table 9.6. Owner-cultivated farms were associated with greater amounts of labor per hectare in high-potential areas and lower amounts of animal draft power and seed per hectare in low-potential areas. Villages in which land redistribution had taken place were associated with lower amounts of labor and animal draft power in low-potential areas. It seems that in an attempt to equalize the quality of landholding among households, especially in the low-potential areas, land redistribution may have made farms more fragmented, and, consequently, more resources (especially time spent to and from the different plots) are required per unit of area to manage the farm efficiently, reducing the actual amount of time spent on a particular plot.

As expected, larger plots were associated with lower amounts of labor, draft animal power, and seed per hectare. Irrigated plots were associated with greater use of labor and seed in high-potential areas and greater use of animal draft power in low-potential areas. Plots with stone terraces were associated with greater amounts of labor in low-potential areas only, reflecting additional labor input necessary for their maintenance. The other investments also were positively associated with some of the inputs, although the effects were different in low- versus high-potential areas.

Female-headed households were associated with smaller amounts of labor and animal draft power on their farm plots, which is consistent with the earlier result that they use more reduced tillage. However, they were associated with greater amounts of seed used in low-potential areas. Households with more educated members were associated with smaller amounts of labor and seed in high-potential areas and low-potential areas, respectively. Households with more oxen were associated with using less labor on their farm plots in high-potential areas, suggesting replacement of labor with animal draft power. Greater exogenous (nonfarm) income was associated with greater use of labor and animal draft power in both low- and high-potential areas, showing the positive influence of the nonfarm sector in promoting on-farm investment.

Access to infrastructure and services had mixed and varying effects on the amounts of the three inputs used in low- versus high-potential areas. For example, households that were closer to the district town or to an all-weather road were associated with lower amounts of labor and animal draft power in high-potential areas. This likely reflects higher opportunity costs of labor and capital assets among households with better access to towns where nonfarm employment opportunities are higher. Availability of formal credit in a village, on the other hand, had opposite effects and was associated with greater use of labor in low-potential areas but less use of labor in high-potential areas, which suggest use of credit for different purposes in the two areas.

Value of crop yield. Table 9.7 shows regression results with respect to value of crop yield (value of total output per hectare) in low- and high-agricultural-potential areas. The first two sets of results show the direct effects of the explanatory variables estimated by OLS. The other two show results of the reduced-form model (i.e., excluding extension, crop choice, land management practices, and inputs), which measures the total (direct and indirect) influence of the explanatory variables included. The discussion is based on the OLS model, the preferred model,

Table 9.6 Regression results of amounts of inputs used by agricultural potential in the highlands of Amhara region, Ethiopia, 1999

Explanatory variable	Amount of labor (Ln [man-days/hectare])		Amount of draft power (Ln [animal-days/hectare])		Value of seed (Ln [birr/hectare])	
	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
Plot-level factors						
Owner-cultivated	–0.200	0.426***	–0.561***	0.245	–0.472**	0.052
Expectation to operate	0.277	–0.193	0.687***	–0.188	0.805*	–0.126
Ln Size	–0.723***	–0.684***	–0.771***	–0.542***	–0.522***	–0.572***
Ln Slope	–0.009	0.008	0.000	–0.004	0.024***	–0.017
Soil depth (cf. deep)						
Medium	–0.142	0.020	0.001	0.000	–0.304**	–0.265
Shallow	–0.182	0.038	–0.065	0.116	–0.374**	–0.041
Soil color (cf. black)						
Brown	0.024	0.019	–0.025	0.194	–0.382***	–0.048
Gray	0.191	–0.055	–0.078	–0.036	–0.129	0.284
Red	0.111	0.139	0.026	0.092	–0.030	–0.009
Presence of gullies	0.211	0.298	0.011	0.075	–0.176	–0.001
Waterlogging problem	–0.347***	0.073	0.092	–0.320**	–0.066	–0.128
Investments on plot						
Irrigation	0.426	1.168***	0.581***	0.258	0.609	1.974***
Stone terraces	0.581***	0.218	0.035	0.212	0.201	–0.340
Drainage ditch	0.289***	–0.004	0.422***	0.206*	0.387***	0.090
Live fence	0.192	0.319***	–0.122	0.081	0.183	0.242
Fence	0.459***	0.249***	0.081	0.278**	0.443***	–0.064
Household-level factors						
Gender of head	1.077***	0.333	0.322*	0.299*	–0.670*	–0.210
Ln Age of head	–0.034	–0.272	–0.266*	–0.449**	–0.435	–0.301
Average education	–0.048	–0.048*	–0.025	–0.003	–0.063*	–0.020
Ln Size of farmland	–0.154*	0.179*	0.131*	–0.111	–0.051	–0.078
Number of oxen	0.073	–0.217***	0.067	–0.141	0.125	0.277
Tropical livestock units	0.022	0.054	0.008	0.054	–0.008	0.009

Village/district-level factors						
Land redistribution	−0.237*	0.363	−0.316***	0.016	0.097	0.286
Ln Household density	0.336*	−0.087	−0.053	0.119	0.055	−0.531**
Ln Altitude	−0.597*	0.580	−0.516*	0.518	0.995***	1.691**
Ln Rainfall	−0.633	−0.316	−0.119	0.246	1.124*	−1.064*
Subregional location						
Location (cf. Southern)						
Northern	0.566***	−0.543	0.159	−0.810***	−0.338	1.143***
Western	0.568	−0.688*	0.207	−0.137	−0.961*	0.930**
Eastern	0.359	0.196	0.314*	−0.061	−0.153	0.764
Variables excluded from the value of crop yield equation						
Plot level						
Homestead plot	0.106	0.200**	0.079	−0.190	−0.332*	−0.375**
Ln Plot to residence	0.000	0.000	0.003*	−0.001	0.002	0.004
Household level						
Ln Household size	−0.142	0.034	−0.095	0.136	0.469	−0.095
Proportion of males	0.029	0.609**	0.216	0.872***	0.327	0.729
Dependency ratio	0.180	−0.822***	0.038	−0.325	0.023	0.468
Exogenous income	0.001***	0.001***	0.001***	0.001***	0.000	0.000
Access to markets or services						
Ln Drinking water	−0.023	0.015	0.026	0.026	−0.127	−0.071
Ln Grain mill	0.009	−0.001	0.001	−0.012	0.050	−0.089
Ln All-weather road	−0.083	0.101	0.007	0.162*	0.049	0.060
Ln Development agent	0.012	−0.014	0.015	0.117*	0.030	0.145
Ln Bus service station	0.015	−0.235***	−0.063	−0.158	0.053	−0.160
Ln Fuelwood	0.001	−0.002**	0.000	0.002*	0.001	−0.001
Ln Input supply shop	0.050	0.075	0.041	0.009	−0.275***	−0.021

(*continued*)

Table 9.6 (continued)

Explanatory variable	Amount of labor (Ln [man-days/hectare]) Low-potential areas	Amount of labor (Ln [man-days/hectare]) High-potential areas	Amount of draft power (Ln [animal-days/hectare]) Low-potential areas	Amount of draft power (Ln [animal-days/hectare]) High-potential areas	Value of seed (Ln [birr/hectare]) Low-potential areas	Value of seed (Ln [birr/hectare]) High-potential areas
Village/district-level factors						
Ln Distance to district town	0.113	0.323**	–0.019	0.080	0.105	0.139
Access to fertilizers	0.161	n.e.	–0.140	n.e.	–0.338	n.e.
Access to improved seeds	0.070	–0.482***	–0.125	–0.152	0.136	0.296
Access to purchased feed	–0.108	–0.107	–0.013	0.344***	–0.549***	–0.231
Access to credit	0.528***	–0.362**	0.141	0.165	–0.108	0.222
Presence of local association						
Input cooperative	0.053	0.844***	0.267	0.485**	–0.193	–0.266
Marketing cooperative	–0.647***	n.e.	–0.408	n.e.	–0.103	n.e.
Women's/youth	n.e.	–0.512*	n.e.	–0.384	n.e.	1.564***
Church	0.168	n.e.	–0.001	n.e.	0.352*	n.e.
Water users	–0.011	–0.292**	0.117	0.358**	0.410**	0.157
Constant	15.592***	6.473	12.127***	1.167	–6.041	3.259
F	11.680***	13.420***	26.320***	9.840***	7.300***	6.930***
R^2	0.636	0.696	0.710	0.554	0.454	0.460
Chow test[a]	2.169***		2.775***		2.391***	

Note: See Table 9.4 for detailed description of variables. Coefficients and standard errors are adjusted for stratification, weighting, and clustering of sample.

***, **, and *** mean coefficient is statistically significant at the 10 percent, 5 percent, and 1 percent level, respectively.**

Ln means variable is transformed by natural logarithm. n.e. means coefficient was not estimated as the associated variable was dropped to avoid dummy variable trap or because it perfectly predicted the outcome.

At the time of the survey, US$1 ≈ 8.50 Ethiopian birr.

[a]The Chow test is a test of equality of the coefficients in low- and high-potential areas.

Table 9.7 Least-squares regression results of value of crop yield by agricultural potential in the highlands of Amhara region, Ethiopia, 1999

	Ordinary least squares		Reduced form	
Factor	Low-potential areas	High-potential areas	Low-potential areas	High-potential areas
Exogenous variables				
Plot-level factors				
Owner-cultivated	–0.067	–0.318*	–0.508**	–0.237
Expectation to operate	0.155	0.468***	0.873***	0.288
Ln Size	–0.111	–0.283***	–0.572***	–0.424***
Ln Slope	0.014**	0.008	0.018**	0.011
Soil depth (cf. deep)				
Medium	–0.132	0.107	–0.230	0.054
Shallow	–0.342***	–0.044	–0.468***	–0.202
Soil color (cf. black)				
Brown	0.124	0.080	–0.054	0.137
Gray	–0.257*	0.309*	–0.359	0.004
Red	–0.134	–0.072	–0.267*	–0.084
Presence of gullies	–0.039	–0.062	–0.053	0.213
Waterlogging problem	–0.051	–0.492***	–0.124	–0.740***
Investments on plot				
Irrigation	0.172	0.128	0.789***	0.352
Stone terraces	0.110	0.069	0.351***	0.197
Drainage ditch	–0.380***	0.134*	0.042	0.232**
Live fence	0.138	0.089	—0.085	0.303**
Fence	–0.050	–0.163	0.149	0.044
Household-level factors				
Gender of head	0.529	0.339*	0.771	0.475**
Ln Age of head	–0.020	–0.419***	0.276	–0.634***
Average education	0.027	0.000	0.020	0.033
Ln Size of farmland	–0.279***	–0.072	–0.314***	–0.020
Number of oxen	0.047	0.154**	0.146	0.188*
Tropical livestock units	–0.008	–0.053*	–0.008	–0.026
Village/district-level factors				
Land redistribution	0.278***	0.558***	0.184	0.467*
Ln Household density	–0.281***	–0.294***	0.031	–0.037
Ln Altitude	0.128	0.693*	0.198	1.291**
Ln Rainfall	0.323	0.158	–0.274	0.019
Subregional location				
Location (cf. Southern)				
Northern	0.521***	0.056	0.443*	–0.322
Western	0.567*	–0.152	1.256***	–0.517
Eastern	0.408***	0.857***	0.635**	1.122**

(*continued*)

Table 9.7 (continued)

Factor	Ordinary least squares: Low-potential areas	Ordinary least squares: High-potential areas	Reduced form: Low-potential areas	Reduced form: High-potential areas
Endogenous variables				
Crops (cf. other crops)				
Barley only	0.196	0.108		
Maize only	0.152	0.254		
Wheat only	0.106	0.198		
Teff only	0.529	0.465***		
Other cereals	0.417	0.492***		
Cereal and other crops	1.038***	0.632***		
Legumes only	1.111***	0.302		
Extension (cf. 0 visits)				
1–5 visits	0.153	0.269***		
6–10 visits	0.108	0.305***		
More than 10 visits	–0.186	0.214*		
Use of reduced tillage	0.003	–0.236		
Use of contour plowing	–0.095	–0.029		
Use of crop rotation	0.025	–0.035		
Use of crop residues	–0.279***	–0.114		
Use of household refuse	–0.245*	–0.212*		
Use of manure	–0.101	0.148		
Use of chemical fertilizers	–0.010	0.442***		
Use of improved seeds	0.199	0.387***		
Ln Amount of labor	0.146***	0.163***		
Ln Amount of draft power	0.309***	0.011		
Ln Value of seed	0.279***	0.189***		
Instruments				
Plot level				
Homestead plot			–0.081	–0.248*
Ln Plot to residence			0.003	–0.002
Household level				
Ln Household size			–0.156	–0.079
Proportion male			–0.191	0.266
Dependency ratio			–0.132	–0.668*
Exogenous income			0.000	0.000
Access to markets or services				
Ln Drinking water			–0.033	–0.087
Ln Grain mill			0.122*	–0.077
Ln All-weather road			0.020	0.221**
Ln Development agent			0.066	–0.095
Ln Bus service station			0.054	–0.192*
Ln Fuelwood			–0.001	–0.001
Ln Input supply shop			–0.151*	0.001

Table 9.7 (continued)

	Ordinary least squares		Reduced form	
Factor	**Low-potential areas**	**High-potential areas**	**Low-potential areas**	**High-potential areas**
Village/district-level factors				
Ln Distance to district town			0.042	–0.045
Access to fertilizers			0.158	n.e.
Access to improved seeds			0.018	–0.165
Access to purchased feed			–0.390***	0.135
Access to credit			0.535**	–0.285
Presence of local association				
Input cooperative			–0.724***	0.581**
Marketing cooperative			–0.175	n.e.
Women's/youth			n.e.	–0.303
Church			0.436***	0.708**
Water users			0.303	–0.254
Constant	3.181	2.226	9.739***	2.157
F	17.580***	12.540***	7.600***	5.040***
R^2	0.661	0.604	0.479	0.474
Hausman test[a]	4.400	0.010		
Chow test[b]	3.174***		2.093***	

Note: Values are Ln (birr/hectare). See Table 9.4 for detailed description of explanatory variables. Coefficients and standard errors are adjusted for stratification, weighting, and clustering of sample.

***, **, and *** means coefficient is statistically significant at the 10 percent, 5 percent, and 1 percent level, respectively.**

Ln means variable is transformed by natural logarithm.

At the time of the survey, US$1 ≈ 8.50 Ethiopian birr.

[a]Hausman test of endogeneity when the instruments are used to predict the endogenous variables in an instrumental variables (IV) regression.

[b]The Chow test is a test of equality of the coefficients in low- and high-potential areas.

although the reduced-form estimates are occasionally discussed to distinguish indirect effects.

Consistent with the finding of Benin and Pender (2001), land redistribution was directly associated with higher value of crop yield, although the effect was about twice as large in the high-potential areas, where the incidence of land redistribution was also higher. This result is surprising, however, because land redistribution, although associated with greater plowing in of crop residues in high-potential areas, was associated with lower incidence of use of several of the land management practices as well as use of labor and animal draft power (see Tables 9.5 and 9.6).

Owner-cultivated plots, compared to rented plots, were weakly associated with lower value of crop yield by 27 percent in high-potential areas.[20] This result is also puzzling because it contradicts the tendency of yields to be lower on rented plots

(Otsuka and Hayami 1988). It also contradicts results from other parts of Ethiopia in the Oromiya region (Ahmed et al. 2002; Pender and Fafchamps 2006, forthcoming) and the Tigray region (Pender, Gebremedhin, and Haile 2002). Pender and Fafchamps found no difference in yields between owner-cultivated and sharecropped plots, and Ahmed et al. (2002) and Pender, Gebremedhin, and Haile (2002) found that crop yields were lower on sharecropped plots than on owner-cultivated plots. The result is puzzling also because the econometric results do not show many statistically significant differences in land management practices and inputs between owner-cultivated and rented plots in high-potential areas, except the case where likelihood of using manure or improved seeds was lower on owner-cultivated plots, whereas likelihood of using crop rotation, crop residues, and labor was higher (see Tables 9.5 and 9.6). Although the result is consistent with some of the findings of Holden, Shiferaw, and Pender (2001), who found that barley yield was about 51 percent higher on rented plots, the puzzle was addressed by reestimating the value of crop yield regression in high-potential areas using a household fixed-effects model and also by restricting the sample to households with both owner-cultivated and rented plots only.[21] In the household fixed-effects model, all variables that do not vary across plots (within the household) are dropped. The results of these estimations, presented in the appendix, show that the weak negative effect associated with owner-cultivated plots was not robust, suggesting that the land rental market may actually be operating efficiently. Note, however, that there is substantial loss of information (i.e., dropping several variables in the fixed-effects model and observations in the restricted sample) associated with these models. Thus, although their estimates compare fairly well with those in Table 9.7, they are not preferred for further discussion.

For the same total farm size, larger plots were associated with lower value of crop yield in high-potential areas only (value of crop yield elasticity with respect to plot size is –0.28), which is consistent with the lower use of inputs, especially labor, animal draft power, and seed. Larger farms also were associated with lower value of crop yield, but significantly so in low-potential areas only (yield elasticity of –0.28). This inverse farm size–productivity relationship is consistent with the findings of many studies, including Hayes, Roth, and Zepeda (1997) and Holden, Shiferaw, and Pender (2001). However, these findings should not be misinterpreted to mean that plots and farm sizes in the region should be reduced in order to increase farmland productivity, as farm holdings are already small: they average 1.3 hectares per household, and more than one-half of the households own less than 1 hectare.

Irrigation contributed to a higher value of crop yield in low-potential areas only via choice of high-value crops and greater use of some inputs. That is, irrigation by itself had no direct effect on value of crop yield, controlling for crop choice, input use, and other factors. This finding is consistent with results from the Tigray region (Chapter 5), where irrigation was also found to have no direct effect on crop yield, although it contributed significantly to increased use of inputs. Similarly, plots with stone terraces had no direct effect on value of crop yield. The indirect effect, however, was significant in low-potential areas (associated with 42 percent more value of crop yield). This result is consistent with other findings from Tigray region, which is typical of low moisture and generally of low agricultural potential (Gebremedhin, Swinton, and Tilahun 1999; Pender, Gebremedhin, and Haile 2002).

Male-headed households were weakly associated with higher value of crop yield (about 40 percent more) than their female-headed counterparts in high-potential areas. Because we control for factors that may be biased against female-headed households and contribute to lower value of crop yield (e.g., household size, composition, and education, access to credit, extension, and inputs), it is not clear why this is the case. Perhaps, as most women take over the management of the farm only when their husbands are not in a position to manage the farm, they may be less experienced in managing the farm than their male counterparts. This result suggests that poverty and food insecurity may be more problematic in female-headed households in high-potential areas. Ownership of an additional ox was associated with greater value of crop yield (about 15 percent) in high-potential areas, whereas ownership of additional livestock in general was weakly associated with lower value of crop yield (about 5 percent) among households in the same high-potential areas.

Extension had a significant positive effect on value of crop yield in high-potential areas only, and there seems to be an inverted-U-shaped relationship between value of crop yield and number of extension visits received by the household. Households that received between one and five visits were associated with 31 percent more value of crop yield than those that received none. However, those that received between 6 and 10 visits were associated with 36 percent more value of crop yield, and those that received more than 10 visits were associated with 24 percent more value of crop yield.[22] These data suggest that repeated extension visits are more effective, although the marginal effect declines as other aspects of livelihoods on which extension also focuses become more profitable, so that resources are shifted into those areas. The reason for extension not having a significant positive effect in low-potential areas is likely the emphasis on improved seeds and chemical fertilizers, as number of extension visits was similar in the two areas (see Table 9.4). Improved seeds and chemical fertilizers are more appropriate in high-potential areas or where ample and reliable moisture is available. This finding is consistent with the limited impact of these inputs and extension found in Tigray in Chapter 5. Value of crop yield was higher by 47 percent and 56 percent on plots that used improved seeds or chemical fertilizers, respectively, in high-potential areas. Plots in low-potential areas on which crop residues were used were associated with lower value of crop yield, whereas those in both low- and high-potential areas on which household refuse was used were associated with lower value of crop yield. These results may seem surprising, but organic materials take longer to break down and can actually reduce the availability of soil nitrogen to crops if their carbon to nitrogen content is high (Giller et al. 1997).

The value of crop yield elasticity with respect to labor, animal draft power, and seed in low-potential areas were 0.15, 0.31, and 0.28, respectively, and 0.16, 0.01, and 0.19 in high-potential areas, although the elasticity with respect to animal draft power was not significant in the latter. In low-potential areas, the elasticities translate into marginal returns of 4.75, 10.05, and 9.08 birr per hectare for 1 percent increase in labor (equal to 4.4 man-days), animal draft power (0.5 animal-day), and seed (2.5 birr) per hectare, respectively.[23] In high-potential areas, the marginal returns are 4.20 and 4.87 birr for labor and seed, respectively. At the time of the survey, the average farm wage rate for men was about 4 birr per day, whereas renting an ox cost 5 birr per day. With these unit values used, and all other factors controlled at the margin, oxen (except in high-potential areas) and seed returned significant profits, but farm labor was substantially overpaid.

Population density had a negative influence on the value of crop yield, with elasticities of –0.28 and –0.29 in low- and high-potential areas, respectively. These contradict the Boserupian (Boserup 1965) optimistic perspective about the responses of households to population pressure and suggest that, under current conditions, crop production in high-potential areas will not be able to support its growing population, and so the trickle-down effect to low-potential areas cannot be justified.

The effects of access to infrastructure and services on value of crop yield were mixed, and the estimates are obtainable from the results of the reduced-form regression model only. For example, households in the high-potential areas and closer to an all-weather road were associated with lower value of crop yield, whereas those closer to a bus service station were associated with greater value of crop yield. Presence of an input cooperative was associated with greater value of crop yield in high-potential areas but lower value in low-potential areas, but access to credit had a positive effect in low-potential areas only.

Conclusions and Implications

This chapter has presented a large amount of primary empirical evidence based on sound scientific methodology on the factors (biophysical, socioeconomic, policy, and program) that influence adoption of various land management practices and modern inputs (including reduced tillage, contour plowing, crop rotation, crop residues, household refuse, manure, improved seeds, and chemical fertilizers), amounts of inputs used (labor, draft animal power, and seed), and value of crop yield on farm plots in the highlands of Amhara region. Survey data from a total of 434 households and 1,434 plots were used in the analyses. The evidence was presented separately by agricultural production potential (low and high). In the discussion of the evidence, however, the chapter focused on the influences of land redistribution and tenure, plot and farm size, household endowments (gender, education, and ox and livestock ownership), population density, and access to infrastructure and services (access to roads, markets, and credit). The effects of irrigation, stone terraces, extension, land management practices, and use of conventional inputs (labor, draft animals, and seeds) and modern inputs (improved seeds and chemical fertilizers) on value of crop yield were also discussed.

Econometric results show that value of crop yield was significantly higher on household plots in villages affected by land redistribution since 1991, suggesting that land redistribution may have served well in the past to equalize farmland holding across households, especially in improving access to farmland of landless households. In conjunction with the finding that larger plots and farms were associated with lower value of crop yields, the result may seem to suggest that reallocation of resources among households is desirable, especially if the market transactions are artificially suppressed. However, such gains in the past should not be a guide for the future. The current farming situation is desperate: average farmland holding per household is only 1.3 hectares, and more than half of the households own less than 1 hectare. In addition, current conditions and farm technology barely support an average production of 1 ton per hectare. Thus, it is difficult to envisage how households can effectively meet their food needs with further smaller plots and farms. Other viable alternatives should be considered. For example, larger farms also tend to be more fragmented, requiring more resources per unit of area to manage them efficiently. Therefore, consolidation of farms may be a more desirable approach to improve land productivity.

The results also show that improving tenure security of farmers would be very beneficial, as we find that plots on which households felt more secure (i.e., expecting to operate for the next five years) were associated with greater value of crop yield, especially in high-potential areas (about 60 percent more). A major source of tenure insecurity is fear of loss of land during redistribution, which can have a negative effect on the land rental market, as land-abundant households may not be willing to rent out land. This is because renting out land is believed to increase tenure insecurity by increasing the likelihood of that plot being redistributed, as renting out signals inability to farm (Holden and Yohanner 2002). Fortunately, the

Amhara regional government stopped land redistribution in 2000. This would help to increase tenure security, which in turn would help to increase and sustain higher yields and also strengthen the efficiency of the current land rental market.

Several of the other policy and program variables considered, including irrigation, extension, and use of modern inputs, had differential significant effects on value of crop yield in low- and high-agricultural-potential areas. The results show that extension and use of improved seeds and chemical fertilizers had significant positive effects on value of crop yield in the high-potential areas only. Irrigation, on the other hand, had substantial total effect in low-potential areas only. These results suggest that different strategies are needed for the different environments. For example, in the low-potential areas, the extension strategy should focus more on promoting soil and water conservation structures such as stone terraces, which were associated with 42 percent more value of crop yield in those areas. Relying on external inputs (chemicals fertilizers and improved seeds) in low-potential areas, which has been the strategy in the past, is not likely to be beneficial unless moisture availability issues are addressed.

In the high-potential areas, improving input delivery and extension services would be very beneficial. In addition, adopting policies and programs that improve farm management abilities of women and promoting more education for children (especially girls) would have long-run beneficial effects, as the results show that female-headed households and households with more dependents were associated with lower value of crop yields, especially in high-potential areas.

Though the effects of access to infrastructure and services were mixed, promoting more nonfarm income-earning activities, especially in areas close to towns and roads, where the opportunity costs of farm labor and of other agricultural factor inputs are higher or where more exit options out of agriculture exist, would also be helpful. In addition, adopting policies and programs that reduce population pressure would be beneficial, as the results show that more densely populated villages were associated with lower farming intensity in several instances and lower value of crop yield in both low- and high-potential areas. Else, the notion of the trickle-down effect from high- to low-agricultural-potential areas will remain just that because crop production in high-potential areas will not be able to support its own growing population.

Appendix: Least-Squares Regression Results to Examine the Robustness of the Negative Impact of Land Tenure (Owner-Cultivated Plots) on Value of Crop Yield (Ln [birr/ha]) in 1999 in the High-Agricultural-Potential Areas of the Highlands of Amhara Region

	High-potential areas (ordinary least squares)	
	Household fixed-effects model, full sample[a]	Households operating owner-cultivated and rented plots only[b]
Exogenous variables		
Plot-level factors		
Owner-cultivated	–0.023	–0.184
Expectation to operate	0.152	0.326
Ln size	–0.129**	–0.280***
Ln slope	–0.002	0.028*
Soil depth (cf. deep)		
Medium	0.048	0.106
Shallow	–0.039	0.255*
Soil color (cf. black)		
Brown	0.124	0.226
Gray	0.016	0.250
Red	–0.008	–0.068
Presence of gullies	–0.055	0.365*
Waterlogging problem	–0.246**	–0.183
Investments on plot		
Irrigation	0.051	–0.110
Stone terraces	0.146	0.199
Drainage ditch	0.038	–0.221*
Live fence	0.104	0.165
Fence	–0.039	0.084
Household-level factors		
Gender of head		
Ln age of head		–1.155***
Average education		0.054***
Ln size of farmland		–0.339***
Number of oxen		0.198
Tropical livestock units		–0.018
Village/district-level factors		
Land redistribution		0.351
Ln household density		–0.303***
Ln altitude		–1.778***
Ln rainfall		0.369
Subregional location		
Location (cf. Southern)		
Northern		0.399
Western		0.563
Eastern		0.750

(*continued*)

Appendix (continued)

	High-potential areas (ordinary least squares)	
	Household fixed-effects model, full sample[a]	Households operating owner-cultivated and rented plots only[b]
Endogenous variables		
Crops (cf. other crops)		
Barley only	0.168	0.115
Maize only	0.122	0.042
Wheat only	0.244	0.565***
Teff only	0.385***	0.458**
Other cereals	0.431***	0.356**
Cereal and other crops	0.702***	0.851***
Legumes only	0.658***	0.501*
Extension (cf. 0 visits)		
1–5 visits		0.338*
6–10 visits		0.311*
More than 10 visits		–0.077
Use of reduced tillage	–0.066	–0.476***
Use of contour plowing	–0.103	–0.534***
Use of crop rotation	0.083	0.119
Use of crop residues	–0.123	–0.239*
Use of household refuse	–0.186*	–0.649***
Use of manure	0.019	0.230
Use of chemical fertilizers	0.230***	0.242
Use of improved seeds	0.198*	0.427***
Ln amount of labor	0.219***	0.239***
Ln amount of draft power	0.132***	–0.030
Ln value of seed	0.215***	0.113*
Constant	4.963***	24.348***
F	10.770***	37.390***
R^2	0.511	0.826
Fixed-effect test[c]	2.740***	

Note: See Table 9.4 for detailed description of explanatory variables. Coefficients and standard errors are adjusted for stratification, weighting, and clustering of sample. At the time of the survey, US$1 ≈ 8.50 birr.

***, **, and *** mean that coefficient is statistically significant at the 10, 5, and 1 percent level, respectively.**

Ln means variable is transformed by natural logarithm.

n.e. means coefficient was not estimated because the associated variable was dropped to avoid dummy variable trap or because it perfectly predicted the outcome.

[a] In the household fixed-effects regression model, all variables that do not vary within households are dropped and a dummy variable for each household is included.

[b] Only households that operate both owned and rented plots are included here. Number of observations is 163.

[c] Test that the coefficients on the dummy variables for each household are jointly zero.

Notes

1. Subscripts *v, h, p,* and *t* refer to village, household, plot, and time, respectively.

2. Following the same line of argument, restrictions on land sales, as exist in Ethiopia, need not be a source of inefficiency.

3. The peasant administration is the lowest unit of government.

4. The classification of drought-prone versus non-drought-prone districts used by the Ethiopian Disaster Prevention and Preparedness Commission was adapted for defining agricultural potential, referring to drought-prone districts as low-agricultural-potential districts (located in the eastern part of the region) and non-drought-prone districts as high-agricultural-potential districts (located mainly in the west and southern tip of the region).

5. Districts that have more than 50 percent of their total area below 1,500 meters above sea level were excluded from the sample frame.

6. Observations with missing data, mostly uncultivated plots, were dropped, leaving 1,187 observations for analysis.

7. Land redistribution was recently phased out in the region. However, there were significant differences across regions with respect to its implementation leading up to the time of data collection. For example, in the Tigray region, land redistribution was stopped in 1991, and the policy of no future redistribution was made official by a land use and tenure policy in 1997. In the Oromiya region too, there has not been a land redistribution since 1992, and the regional government is currently developing its land use policy.

8. At the time of the survey, US$1 ≈ 8.50 birr.

9. On rented plots, bequeath refers to the expectation of transferring the rental contract to an heir in the event that the current contract holder is unable to continue farming.

10. Because of the different crops produced on a plot, total output was aggregated using one set of unit prices of crops for all households.

11. Monthly rainfall data for 1999 were obtained from the Meteorological Services Agency for weather stations located in the districts where the surveys were carried out, and elevation data were obtained from the geo-referenced Country Almanac Ethiopia Database.

12. Wag Hamra and Oromia zones were excluded from the sample frame because they were predominantly lowland (see note 5).

13. The selection of land management practices for the econometric analysis was based on those practices occurring on 10 percent or more of all plots.

14. The regression results of these are available on request.

15. One tropical livestock unit (TLU) is equivalent to one cow weighing 250 kg. Conversion factors for other types of animals, based on weights, have been estimated by ILRI.

16. The Hausman test is given by the chi-square value, $\chi^2 = (\hat{\beta}_{IV} - \hat{\beta}_{OLS})(Var_{IV} - Var_{OLS})^{-1}(\hat{\beta}_{IV} - \hat{\beta}_{OLS})$, where $\hat{\beta}$ and *Var* are the estimated coefficient and variance, respectively. Detailed test results are reported in the relevant tables of results.

17. Note that only continuous explanatory variables without zero values were transformed by natural logarithm.

18. Detailed results of log-likelihood ratio tests for the probit models and Chow tests for the linear models are shown in the relevant tables of results.

19. With the large number of explanatory variables, there is the potential for a multicollinearity problem. This was tested using variance inflation factors, which were in the acceptable range of less than 10 (Kennedy 1985).

20. The predicted impact of these and other discrete variables on value of crop yield can be calculated by taking the exponential of the relevant coefficient in Table 9.7 because the dependent variable is the logarithm of total output per hectare.

21. Thanks to Kei Otsuka for suggesting these methods for addressing the puzzle.

22. Discrete variables (rather than a continuous one) for extension visits were used in the regression analysis because of two problems. First, there were many zero values, and the logarithm of zero is not defined. Second, there was insufficient variation in the nonzero values for reliable continuous-variable estimation. The same applies to other inputs such as manure, chemical fertilizers, and improved seeds.

23. The predicted returns in birr to a 1 percent increase in input can be calculated by multiplying the elasticity with respect to that input in Table 9.7 by 3,252.91 or 2,576.46 birr, which are the average values of output per hectare in low- and high-potential areas, respectively (see Table 9.4).