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# Land Constraints and Agricultural Intensification in Ethiopia

## A Village-Level Analysis of High-Potential Areas

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## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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## ABSTRACT

Highland Ethiopia is one of the most densely populated regions of Africa and has long been associated with both Malthusian disasters and Boserupian agricultural intensification. This paper explores the race between these two countervailing forces, with the goal of informing two important policy questions. First, how do rural Ethiopians adapt to land constraints? And second, do land constraints significantly influence welfare outcomes in rural Ethiopia? To answer these questions we use a recent household survey of high-potential areas. We first show that farm sizes are generally very small in the Ethiopian highlands and declining over time, with young rural households facing particularly severe land constraints. We then ask whether smaller and declining farm sizes are inducing agricultural intensification, and if so, how. We find strong evidence in favor of the Boserupian hypothesis that land-constrained villages typically use significantly more purchased input costs per hectare and more family labor, and achieve higher maize and teff yields and high gross income per hectare. However, although these higher inputs raise gross revenue, we find no substantial impact of greater land constraints on net farm income per hectare once family labor costs are accounted for. Moreover, farm sizes are strongly positively correlated with net farm income, suggesting that land constraints are an important cause of rural poverty. We conclude with some broad policy implications of our results.



**Keywords: Ethiopia, land pressures, population density, farm sizes, agricultural intensification**

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# 1. INTRODUCTION

Few countries in the world are more synonymous with starvation and famine than Ethiopia. Highly agrarian and densely populated relative to its fragile natural resource base, Ethiopia appears to be a modern embodiment of the Malthusian prediction that unchecked fertility rates amid fixed land and water resources will lead to periodic famines (Malthus 1798). While Malthus's theory remains highly relevant to modern Ethiopia, so too does Boserup's (1965) seminal work on agricultural intensification in response to land constraints. Ethiopia has a long history of agricultural intensification through the adoption of technologies that either economize on labor (the ox-plow), preserve natural resources (various land structures, such as terracing, and the use of tree crops to preserve soil integrity), or maximize value per hectare (ha) (Ethiopia is the home of arabica coffee). However, with very rapid population growth in previous decades, it is also recognized that endogenous technological change may be inadequate and that policy-induced responses to population growth are more important than ever. The current government of Ethiopia therefore places a high priority on agricultural development.[1] To increase smallholder productivity, the government has enacted ambitious plans to develop and extend new seeds, chemical fertilizers, new crops, and new natural resource management practices (including irrigation). It has also made substantial investment in roads and agricultural extension services (Byerlee and Spielman 2007; Dercon et al. 2009; Dorosh and Rashid 2013) and enacted ambitious socioeconomic plans, such as reducing rural fertility rates (Pörtner, Beegle, and Christiaensen 2012), providing universal primary education, and developing secondary cities and towns (Government of Ethiopia 2010). Observers are generally more critical of land management institutions. The government still formally owns and tightly regulates the distribution and leasing of land, implicitly restricts migration, and has promoted controversial smallholder resettlement schemes and large commercial farms (Headey, Taffesse, and You forthcoming). These institutions might inhibit incentives to invest in land (Deininger, Ali, and Alemu 2007, 2011; Deininger et al. 2003), as well as migration (de Brauw and Mueller 2012) and the general demand for land-intensive technologies (Binswanger and Pingali 1988).

Yet despite the obvious importance of understanding adaption to land constraints, the existing literature on Ethiopian agricultural development has focused mostly on resource degradation, and that too in fairly specific geographic areas. An edited book by Pender, Place, and Ehui (2006) contains several similar studies, but with much greater focus on land degradation and land management. Kruseman, Ruben, and Tesfay (2006) use village-level data from 100 villages in Tigray, while Pender and Gebremedhin (2006) use household- and village-level data from the same survey for about 500 households. That particular region of Tigray has lower agroecological potential and poor access to sizable markets, meaning the results of these studies are unlikely to be nationally representative. In the same volume, Benin (2006) uses a survey conducted in 1999 and 2000 of 98 villages in the Amhara region, which contains a mix of high- and low-potential villages. Overall, these studies find mixed results with respect to the Boserupian hypothesis. Kruseman, Ruben, and Tesfay (2006) and Pender and Gebremedhin (2006) find positive effects of land constraints on fertilizer use per ha and labor per ha, but no impact on crop income per ha. Benin finds that land constraints lower the likelihood of using reduced tillage and lower the value of crop yield per ha in higher-density areas. While insightful, these three studies have three limitations: (1) the data are 13–14 years old, and much has changed in Ethiopia over this time; (2) two of the studies pertain to Tigrayan areas of exceptionally low agroecological potential and poor market access; and (3) Benin (2006) focuses substantially on cereal yields rather than one the more welfare-relevant indicator of total farm or total crop income per ha.

In this paper we instead adopt a broader geographic lens, primarily making use of a large and recent household survey specifically designed to specifically study agricultural intensification (see Section 2). The strength of our data is spatial richness, a wide array of intensification indicators, and a relatively large number of indicators of market access and agroecological potential, both of which are

[1] Ethiopia has the highest agricultural budget expenditure share in Africa, though the statistics may be inflated by the inclusion of the Productive Safety Net Program.

vitally important control variables given their joint association with farm sizes and intensification outcomes. However, our data are currently cross-sectional, thus precluding the use of panel techniques. Moreover, our survey focuses on higher-potential areas. Ethiopia has small farms in lower-potential areas as well, meaning that our results are unlikely to be nationally representative, though they are representative of a large geographic area and a large farming population (about 13 million people).

These data—as well as some insights from a literature review and focus groups conducted in 12 villages—are used to explore two interrelated objectives: First, we aim to understand the pattern and evolution of farm sizes and land availability in Ethiopia (Section 3). We descriptively discuss the relative roles of agroecology, government institutions, cultural norms, and demographic factors, and then conduct a brief analysis of farm size patterns and evolution using the Agricultural Growth Program Survey. Second, we aim to identify and quantify the drivers of agricultural intensification (Section 4). According to Boserup, farm sizes (at both the individual and community levels) are likely to be a key determinant of the demand for intensive technologies, such as plows, chemical fertilizers, high-yielding seeds, and improved natural resource management practices. Yet Binswanger and colleagues also emphasize that access to input and output markets is likely to be a commensurately important driver of agricultural intensification (Binswanger and Rosenzweig 1986; Pingali, Bigot, and Binswanger 1987; Pingali and Binswanger 1988). The rapid development of Ethiopia's road network, perhaps the fastest in Africa in recent decades (Dorosh and Rashid 2013), suggests that this may be an important factor. And of course, policy-induced intensification, particularly through the rapid expansion of Ethiopia's agricultural extension services (Davis, Swanson, and Amudavi 2009), is another potentially important driver of Agricultural intensification.

It will come as no surprise to readers familiar with Ethiopia that our concluding section (Section 5) yields nuanced findings in response to the challenges posed in the previous sections. On the one hand, we find strong support for the Boserupian intensification hypothesis, especially with regard to very tight associations between land constraints and purchased input costs per ha, farm labor per ha, cereal yields, and gross farm income. At the same time, farm income per ha net of these costs is not responsive to rising land constraints, suggesting that land constraints impose serious negative consequences for farm incomes, on average. Moreover, we find no evidence that land-constrained households are more likely to engage in off-farm work or more likely to send their children to school (suggesting income diversification in the future). Our concluding comments therefore offer some reflections on Ethiopia's rural development strategies in light of these important findings.

# 2. DATA AND METHODS

## Data

As noted above, this study primarily makes use of a recent household survey conducted in four main Ethiopian regions, the Agricultural Growth Program Survey (AGPS). This survey is the baseline for an intervention (the AGP) that seeks to provide technology, input, and marketing services to selected high-potential *woredas*, with a goal toward promoting agricultural intensification on small farms.[2] However, the AGPS also includes high-potential non-AGP *woredas*, and although the survey is not representative of the highlands (it excludes more drought-prone areas, for example), it can be thought of as broadly representative of high-potential Ethiopian highlands. The survey also covers a large geographic area—93 of Ethiopia's 450 highland *woredas*, with 304 enumeration areas (EAs), which are essentially villages, with 28 households typically surveyed in each village. Hence it provides very wide geographic coverage, which is essential for providing the much-needed variation in farming practices, farm sizes, and other factors of interest such as market access, agroecological potential, and extension services (most of these variables are measured at the EA level). Moreover, since the AGP intervention is very much focused on producing intensification and improved marketing outcomes, the survey contains a wide array of high-quality indicators of agricultural intensification.

The disadvantage is that it is not yet a panel survey, which would allow us to control for household fixed effects. For this reason, our empirical approach aggregates beyond the household to the EA or village level, under the assumption that unobservables—such as management skill—are netted out by this process (more on this below).

Table 2.1 shows the key indicators of agricultural and nonagricultural intensification used in this study, as well as the explanatory variables used, which fall under several categories: land size (household and EA levels), market access, agroecological controls, and household indicators. Asterisks also note those indicators that are measured at the EA/community level rather than the household level. As we will argue below, net farm income per capita is arguably the key indicator of welfare-relevant agricultural intensification, whereas the remaining variables capture more specific technological responses to changing land ratios. For nonfarm intensification, the AGP does not record nonfarm income per se but does record nonfarm labor efforts in terms of months worked. We also consider schooling access or investment as an important dynamic response to limited farming opportunities, particularly secondary education (primary education is becoming almost universal in highland Ethiopia). With respect to the variables, we measure farm size at both the household level and EA level average, as well as EA level inequality. In addition to land pressures, agroecological factors are another extremely important set of control variables, particularly as agroecology could determine both population density and intensification outcomes. Fortunately, we have both agroecological factors measured at the EA level from both the community questionnaire and from Geographic Information Systems (GIS) data.[3] Market access is another key driver of agricultural intensification and is measured here in terms of access to market towns and access to cities of at least 50,000 people. Farm policies and institutions at the community are measured in terms of access to cooperatives and other farmer groups. Finally, we also measure a number of potentially relevant household characteristics, particularly demographics, education, and wealth.

[2] See http://www.worldbank.org/projects/P113032/agricultural-growth-program?lang=en for more details.

[3] We thank Helina Tilahun and Mekamu Kedir for valuable research assistance with the GIS data, which was collected and processed by the Central Statistical Agency in conjunction with IFPRI.

**Table 2.1 Definitions of key indicators used in the study**

| Variable name | Definition/notes |
|---|---|
| ***Farm intensification*** | |
| Net and gross crop income per ha | Net income is less variable inputs. We calculate net income both with and without family labor costs. Family labor costs is the number of man-days in recent seasons multiplied by the local wage rate. Gross crop income is not net of any costs. |
| Net and gross farm income per capita | As above, but we estimate total farm income (net and gross) and divide by the surveyed EA population. |
| Total input cost per ha | DAP, urea, seeds, herbicides, pesticides, fungicides, tractor rental; this is measured without labor per ha. |
| Fertilizer per ha (kg) | DAP and urea in previous *belg* and *meher* seasons. |
| Improved seed per ha (kg) | Sum of basic and generation-one improved seeds. |
| Plow equipment index | PCA-generated index on ownership of six plow components.* |
| Handheld equipment index | PCA-generated index on ownership of wide range of equipment.* |
| Daily wage rate, men* | Average of community-reported wages across different seasons. |
| Maize yields | Yields of maize (kg). |
| Teff yields | Yields of teff (kg). |
| ***Nonfarm intensification*** | |
| Nonfarm work (yes = 1) | Whether any household member worked in nonfarm activities during the year. |
| Number of months off-farm work | Number of months household members worked in off-farm activities. |
| Secondary schooling | Percentage of EA children aged 12–18 years that are in school. |
| ***Farms*** | |
| EA cultivated area (ha) | Average crop area cultivated at EA level. |
| EA land inequality | As above, but coefficient of variation at EA level. |
| Proportion of farm < 1 ha | Proportion of farms in the EA that cultivate less than 1 ha. |
| ***Institutions*** | |
| Nearest market (km) | Community estimates of average distance (km) to nearest market town. |
| Near 50K city (min)* | GIS-based estimates of average travel time from EA to nearest 50K city. |
| Access to extension* | Dummy for whether there is a government extension office in EA. |
| Access to cooperative | Dummy for whether there is a farmer cooperative in EA. |
| Access to bank or MFI | Dummy for whether this institution exists in EA. |
| Access to savings and loans group | Dummy for whether there is a savings and loans group in EA. |
| ***Agroecology*** | |
| LGP | Length of growing period at *subkebele* level, used as dummy variables. |
| Average slope | Measured at average *woreda* level. |
| Elevation | Measured at average *woreda* level, used as dummy variables. |
| Soil fertility (%) | Subjective questions on three grades of soil quality: good, medium, poor. |
| Land slopes (%) | Subjective questions on shares of steep, hilly, and flat land. |
| ***Household controls*** | |
| Household size | Total number of household members. |
| Men/women aged 15–60 | Proxy for male and female labor force at household level. |
| Household head's sex (male = 1) | Dummy indicating whether the head is male or female. |
| Household head's age | Age of the household head in completed years. |
| Household head's education | By schooling levels completed, with other category for informal schools. |
| Wealth index | Principal components analysis on household assets. |

Source: Authors' construction.

Notes: The first principal component is used as an index. See Table A.1 in the appendix for descriptive statistics for the intensification and farm-size variables.
ha = hectare, kg = kilogram, DAP = diammonium phosphate fertilizer, EA = enumeration area (or "village"), GIS = geographic information systems data, MFI =s microfinance institution, PCA = principal components analysis.

## Models and Methods

Since Malthus, small and shrinking farm sizes have long been associated with agricultural crises and food insecurity. However, Boserup (1965) and von Thünen (1826) showed that land constraints, improved access to markets, or both can create positive pressures to intensify agricultural production, while in the modern era scientific research outputs have demonstrated the potential efficacy of policy-induced intensification (for example, the Green Revolution). From a welfare point of view, the question is whether intensification of agricultural production is rapid enough to compensate for reductions in farm sizes.[4] A second question is where this intensification will come from. In Boserup's theory, intensification is an endogenous adaptation on the part of farmers. Binswanger and others are more explicit in noting the influence of access to markets (M), agroecological potential (A), farm policies (P), and other local characteristics (X) on agricultural intensification. Thus, a more general theory of farm intensification specifies intensification indicators as a function of all of these factors. And since our focus is on village-level factors, we typically use village-level means or proportions (signified by the bars above each variable), yielding functions of the following form:

$$\frac{\bar{Y}_f}{\bar{L}} = f(\bar{L}, \bar{M}, \bar{A}, \bar{P}, \bar{X}), \quad (1)$$

where $\frac{\bar{Y}_f}{\bar{L}}$ is an intensification indicator (such as farm output, Y, per ha, L). The elasticity with respect to land constraints $(\frac{\bar{L}}{N})$ informs us of the magnitude of Boserupian intensification, controlling for the other drivers of intensification listed above.

Several important issues arise in estimating equation (1). First, Boserup's theory pertains to adaptation to a latent variable—land pressures. Strictly speaking, the most ideal measure of land constraints would be potential agricultural land per capita, where *potential* includes land not currently used but potentially cultivable.[5] In the absence of this more ideal indicator, researchers often measure *land pressures* as population density (that is, population per area of total land). However, using population density means several disadvantages, particularly in the Ethiopian context.

First, potential land may be a function of institutional factors. In Ethiopia, land is allocated to farmers by the state, and outside of renting land, most smallholders cannot obtain more land except through resettlement and migration or—wealth permitting—registering as a commercial farmer. For most peasants in the highlands, therefore, significant land expansion within their local area is rarely possible.

Second, when population density is defined with respect to *total land*, as it is in practice, areas that actually have little or no agricultural potential may be included, such as mountainous areas (a very relevant issue in Ethiopia) or areas of insufficient rainfall or soil quality.

Third, a practical measurement issue is that the GIS variables used to measure population density at disaggregated spatial units (that is, the EA level) are actually interpolated from much more aggregated and infrequent census data , with little *ground truthing* to verify on the ground the data that are collected. It is therefore not a priori clear that GIS-based indicators measure local population density with sufficient accuracy.

Our approach is instead to primarily rely on cultivated land per capita at the EA level as our proxy for land pressures. This measure does not rely on interpolation and is still likely to be a good proxy for our latent variable of interest, land constraints. As a variant of this, we also use the percentage of households in a village cultivating less than 1 ha of land. While the one-hectare threshold is somewhat arbitrary, it is worth noting that most Ethiopian households with several farm workers and an ox-plow can

[4] To see this, note that farm output (Yf) per capita (N) net of input costs, $\frac{Y_f}{N}$, is the product of agricultural output per unit of land (L) and land units per capita: $\frac{Y_f}{N} = \frac{Y_f}{L} \cdot \frac{L}{N}$ or $ln\frac{Y_f}{N} = ln\frac{Y_f}{L} + ln\frac{L}{N}$ in log terms. To maintain or increase farm output per capita, intensification (increased output per hectare) is therefore necessary if farm sizes are shrinking.

[5] *Potential* is a fuzzy concept, however, since it is presumably economic potential that matters, which is a continuous rather than dichotomous variable.

easily cultivate more than 1 ha. In other words, all but the most labor- or power-constrained households would not normally choose to cultivate less than 1 ha. Thus, the prevalence of farms smaller than 1 ha is highly likely to represent a land constraint.

A second estimation issue pertains to unobservables. By measuring all variables at the EA level we will likely be purging the regressions of many household unobservables that are normally distributed within a given village (for example, farmer management abilities, mental attitudes, or health variables). Moreover, it is also possible that taking EA (cluster)-level averages will reduce measurement error, provided that intracluster household errors are independent.[6] However, without a panel we may still have a potential problem of village unobservables. A particular concern with Boserup's hypothesis is that both agricultural intensification and land pressures are heavily influenced by agroecological potential, access to markets, and institutional factors (see equation (1) above). While institutional factors are, to a fair extent, country- or regionwide (for example, state ownership of land or restrictions on migration), agroecological potential and market access vary substantially, even throughout the highlands. This implies that if these two factors are not sufficiently well specified in the model, the positive correlation between these factors and farm sizes will lead to an upward bias on the coefficient on farm sizes in our intensification regression (that is, part of the impact of farm sizes on intensification should in fact be attributed to these other factors). As we noted above, we essentially address this problem through the best possible measurement: We have six indicators of agricultural potential, two indicators of market access, and multiple indicators of institutional access to inputs (such as cooperatives and extension services). While we cannot guarantee that this set of indicators fully observes all the latent factors of interest, we are confident that we have at least minimized omitted variable biases as best we can. Nevertheless, we still acknowledge that our estimates need to be interpreted carefully.

Finally, measurement errors will be an important problem in estimating equation (1). Since most intensification variables are measured in per ha terms (for example, fertilizer per ha) any under- or overestimation of farm size is likely to amplify measurement errors at smaller farm sizes (Beegle, Carletto, and Himelein 2012).[7] Hence misreporting of farm size amplifies per ha measurement error at very small farm sizes when the dependent variable is measured in per ha terms. We have taken several steps to reduce this problem. First, by averaging values to the EA level, we may reduce some of the noise in these intensification indicators. Second, we have excluded several EAs for which measurement errors appeared to be a problem. Third, we run sensitivity tests using two robust regressors that downweight outlying values.[8] We also note that in most of our regressions we use seemingly unrelated regressions to generate more efficient estimates. This may be particularly important if unobserved shocks affect multiple intensification outcomes (for example, local rainfall patterns).

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[6] One obvious source of intracluster correlation between errors is systematic mistakes made by particular enumerators. Unfortunately, we cannot control for that problem except through careful cleaning of the data.

[7] To see this, suppose (arbitrarily) that measurement error is +/– 0.2 hectare for farm sizes in the entire sample. For a farm size of 5 ha, this is only a +/– 4 percent error. But for a farm size of 0.5 ha, this is a +/– 40 percent error. Now suppose that we take an intensification indicator like total input cost per ha. If the true farm size is 0.5 hectare but the reported farm size is 0.3 ha, the reported value of input costs per hectare is 67 percent larger than the true value. Similarly, if the reported land area is 0.7 ha, the reported input costs per hectare are just 28 percent of the true value. Of course, if small farmers over report farm sizes and larger farmers underreport farm sizes, as the research by Beegle, Carletto, and Himelein (2012) suggests, then we have an issue of measurement bias. One reason for this bias among small farmers seems to be rounding (such as rounding up to 1 ha). In Ethiopia, the proliferation of measurement scales for land sizes (most of which are much smaller than a hectare) may mean this problem is not substantial.

[8] Specifically, we use the *qreg* and *rreg* commands in STATA. Note that LAD regressions are sometimes called least absolute value (LAV or MAD) models. *rreg* iteratively downweights outliers. Also note that other estimation frameworks could be considered in this kind of work—particularly seemingly unrelated regressions and clustered standard error approaches—but these frameworks address only efficiency issues (that is, they affect standard errors). In the presence of outliers, they will still yield coefficients that are not representative of the central tendencies of key relationships.

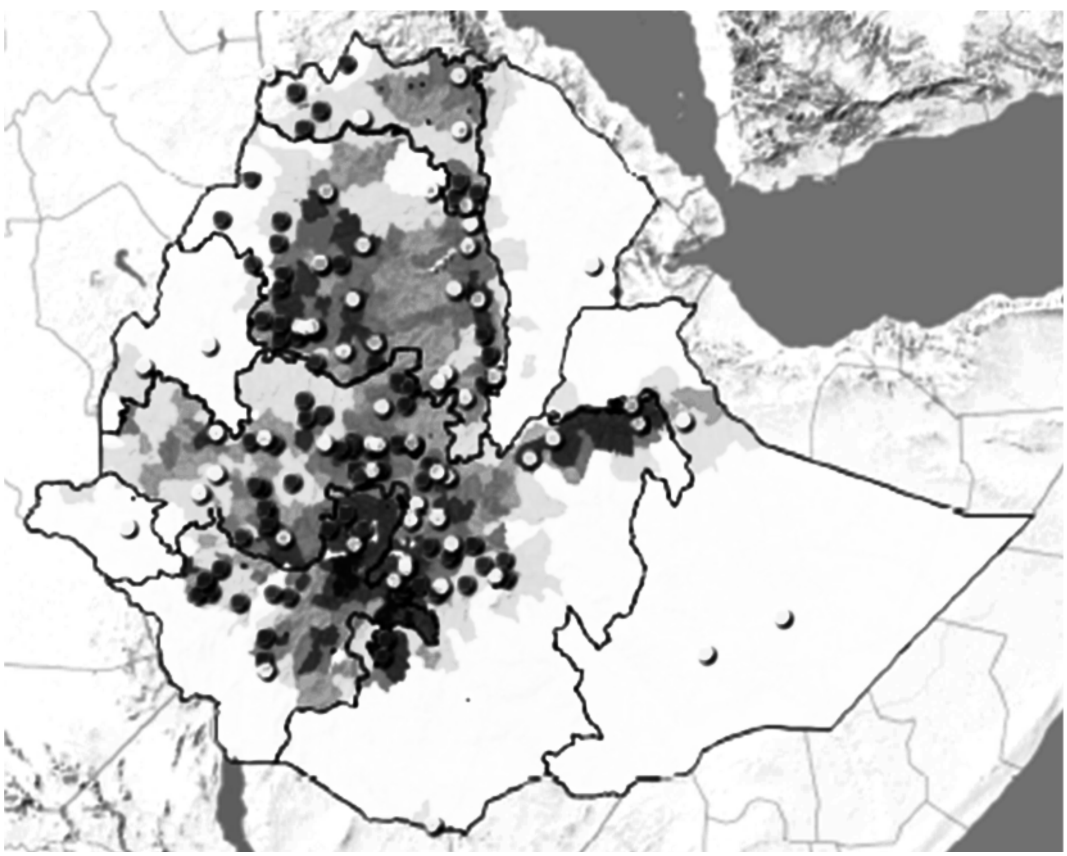
# 3. THE EVOLUTION OF FARMING LAND AND FARM SIZES IN ETHIOPIA

The pattern and evolution of farming land and farm sizes are primarily driven by agroecological potential and access to market (or infrastructure), as well as institutions of land management and migration. In this section we aim to briefly describe the prevailing agroecology and the institutional environment in the Ethiopian highlands.

## Agroecological Drivers of Rural Settlement Patterns

Ethiopia has always been and still remains a highly agrarian country, with rural settlement patterns strongly determined by agroecological factors. Figure 3.1 demonstrates this by mapping out district (*woreda*)-level population density data from the 2007 census. The darker, high-density areas of Figure 3.1 almost perfectly overlap with the Ethiopian highlands, while the lower-density, lightly colored areas constitute the Ethiopian lowlands. Despite occupying only around a quarter of total land area, the highlands contain approximately four-fifths of the population and have a long history of sedentary agriculture based on relatively good soils; reasonably high (but variable) rainfall; and a relatively low incidence of tropical pests and associated diseases, such as malaria from the mosquito and nagana from the tsetse fly, which also enabled the adoption of the plow.

**Figure 3.1 Agricultural Growth Program enumeration areas (dark circles), major markets (light circles), and *woreda*-level population density**



Sources: http://www.gafspfund.org/content/ethiopia. Market towns (light circles) are from FEWSNET, and population density at the *woreda* level is from the 2007 National Census of Ethiopia.

Notes: Population density categories (in population per square kilometer) from lightest to darkest are 0–31, 32–101, 102–139, 140–195, 196–537, 538 and above.

Yet even with the highlands there is tremendous agroecological and livelihood diversity. The southwest highlands (mostly in Oromia and Southern Nations, Nationalities, and Peoples' Regions) have relatively good potential and contain large areas in which population density exceeds 200 people per square kilometer. A few zones in this area have densities of 300–500 people, which is comparable to Rwanda. Mean farm sizes are well below 1 ha. The central and western highlands (parts of Oromia, much of Amhara, and Tigray) also have relatively high rainfall and good agroecological potential for the most part. Population densities typically vary between 100 and 200 people per square kilometer, and farm sizes are over 1 ha on average. Western Tigray and northern Amhara have areas that are somewhat unusual, with larger farms and substantial specialization in sesame seed production. The eastern highlands toward Dire Dawa, Harar, and Jijiga vary between low to medium rainfall but still have reasonable agroecological potential in many areas, with a mix of staple cereals (maize, sorghum), high-value crops (coffee, chat), and high-value livestock production (including live animal exports to the Middle East). Parts of these eastern highlands are high density, small-farm environments. Finally, eastern Tigray and northeastern Amhara are often considered drought-prone highland areas. As we noted above, previous work on Boserupian intensification focused on these areas, whereas such areas are excluded from the AGP.

In addition to density patterns, several other descriptive points are noteworthy. First, while there is very limited scope to expand agricultural area in the highlands, Ethiopia is still relatively land abundant in purely agroecological terms, largely because of the underpopulated, high-rainfall western lowlands, as well as some substantial irrigation potential in otherwise arid lowland areas. However, from an economic rather than an agroecological perspective, whether the lowlands offer significant opportunities for the expansion of smallholder farming is quite unclear. Parts of the western lowlands have substantial rains, but also significant soil constraints and a higher incidence of malaria, tsetse fly, and other tropical pests and diseases, which have inhibited sedentary plow-based crop farming and the efficacy of resettlement schemes in both the Derg and post-Derg eras (Hammond 2008; Kinsey and Binswanger 1993; Tereke 2007). One important exception is the informal smallholder settlement of western Tigray and northwestern Amhara, which has been quite a striking phenomenon in recent decades. The Borena plateau (southern Ethiopia in Oromia region) is better suited to livestock rearing than to smallholder crop systems. The Somali (south and east) and Afar (northeast) have sizable irrigation potential but also major constraints to exploiting this potential, including inter-regional migration restrictions and poor infrastructure (Headey, Taffesse, and You forthcoming). In addition to smallholder settlement of these areas, numbers cited in Headey, Taffesse, and You (forthcoming) show that (speculative) data on large farms in lowland areas suggest these lowland areas do have sizable potential for creating jobs, particularly seasonal jobs.[9] But with the exception of seasonal employment generation, land expansion in the lowlands will most likely do little to alleviate land pressures in the highlands.

### Institutional Drivers of Farm-Size Evolution

Ethiopia's historical and current land institutions are enormously complex, and frankly it is impossible to do justice to this complexity here. Table 3.1 instead summarizes the prevalent institutions in the current era (the 21st century), while the text briefly emphasizes the central points. Unlike many African countries, Ethiopia had no significant history of colonial land institutions. Up until 1974, Ethiopia had a highly unequal feudal land system, with the vast majority of the population operating as serfs for absentee landlords. This inequality was a major cause of the overthrow of the imperial regime in 1974 by the Communist Derg regime, which maintained power over most of the country until around 1990. Immediately after taking power, the Derg implemented a land reform proclamation in February 1975. This proclamation produced several radical changes (Deininger, Ali, and Alemu 2007; Deininger et al.

[9] In our focus group interviews we also heard that seasonal migration to irrigated farms in the Awash Valley was particularly important in parts of SNNP, such as Gara Godo. In that village, the interviewees claimed that every household in the village with a viable worker engaged in seasonal migration in the last harvest season. They also emphasized that this was hugely important in welfare terms, given the late and rather poor rains in recent years.

2003; Gebreselassie 2011; Kebede 2007). Officially, all land came under the ownership of the state but was given to farmers on use-right (usufruct) basis, and commercial large-scale farms were turned into state farms. Peasant associations were set up to redistribute land to farmers living in their jurisdiction, largely according to family size.[10] Another important aspect of the communist period were explicit and implicit restrictions on migration (such as the "use it or lose it" policy).

**Table 3.1 Overview of current legal land tenure regime in Ethiopia**

| Aspect of land tenure policy | Federal | State |
|---|---|---|
| ***Acquisition of land*** | | |
| Ways to acquire land | - Distribution, redistribution, donation, inheritance, lease or rent | - Not regulated by state |
| Time limit | - Only investors have a time limit | - Not regulated by state |
| Size limit | - Farm plots must be at least a certain size | - States and regions decide the minimum size |
| Residency requirements | - No residency requirement: government proclamation applies to *any* rural land | - Must be a rural resident of the region to receive rural land for free (contradicts federal law) |
| Regional differences | | - "Rural" residency requirement more relaxed in Amhara |
| ***Transfers*** | | |
| Permissible transfers | - Inheritance, donation to family, rent or lease to other farmers | - Not regulated by state |
| Rent/lease restrictions | - Only to other farmers or investors (rural or urban) willing to engage in agriculture and for a fixed period | - States decide on time limit for rent or lease, and size of plot (varies); some states stipulate permissible use of rented land |
| Inheritance restrictions | - Inheritor must be regional resident, willing to engage in agriculture, and minimum size requirement must be enforced; in case of divorce, the landholder cannot transfer land if he or she earns more than the minimum salary of government employee; other than divorce, inheritance only applies upon death of landholder | - Minimum plot size is dictated by irrigation status<br>- Rural residency requirement varies at state level for inheritance |
| Donation restrictions | - Recipient must be regional resident and family member willing to engage in agriculture | - Rural residency requirement varies at state level for donation |
| ***Redistribution and consolidation*** | | |
| Criteria | - Only upon community agreement, except for irrigable land | - Not regulated by state |
| Size requirement | - Redistributed land must meet minimum size requirement | - States determine minimum size |
| Consolidation | - Land consolidation is "encouraged" | |
| ***Loss of landholding rights: results from failure to use and protect the land*** | | |
| Criteria | - Federal provision exists for loss of land rights due to nonuse or lack of protection; states decide the conditions | - States determine the specific conditions<br>- Leaving land unused 1–3 years (varies)<br>- Nonfarming activity or income |

Source: Zewdu and Malek 2013.

When the Tigray People's Liberation Front (TPLF) defeated the Derg regime in the early 1990s, they engaged in a partial liberalization of the agricultural sector, as well as land redistributions in Tigray and Amhara, partly along the lines of political allegiance (Ege 1997). After the 1995 constitution was drafted, land management institutions devolved to the regions, albeit under reasonably inflexible federal laws. Apart from some modest redistributions, post-1995 land reforms have been marginal rather than

[10] However, Kebede (2007) finds evidence suggesting that imperial land distribution persisted to some extent into the Derg era. Nevertheless, on aggregate, land inequality is reasonably low in Ethiopia, but not as low as in some other socialist countries.

radical. Land is still owned by the state, migration still faces explicit and implicit restrictions, and even the introduction of land rental markets involves size restrictions.[11] Admittedly, some variation exists between regions in the implementation of these laws, though for the most part these differences seem marginal.

Finally, with rapid population growth, it is also worth considering how young people obtain land. Intrafamily inheritance of land is legally permissible (including intrafamily donations when parents are still living), but with high rates of fertility, younger generations will generally inherit much smaller farms than their parents did, even with some outmigration. Regional governments also guarantee access to land for all regional residents, provided they meet minimum farm-size laws. Many villages, however, do not have enough land to meet the requirements of younger generations, and whether the official land-size requirements are strictly enforced is unclear. Certainly, many datasets—including our own—show a high prevalence of very small farms (see below). An alternative does exist in the form of resettlement schemes (in 2002, the government stated that it planned to resettle 2.2 million voluntary migrants), but these are generally unattractive for most rural people because of malaria, vastly different agroecological conditions, poor infrastructure, and inadequate public support.[12] The alternative is migration to small towns, to cities, or to work overseas.

### Trends and Patterns of Farm Size Distribution

We conclude this section by reporting some important statistics on farm size distributions in the main highland regions. The top panel of Table 3.2 shows nationally representative statistics from the 2011–2012 Agricultural Sample Survey of the Central Statistical Agency (CSA), while the bottom panel shows analogous statistics from AGPS. As predicted by the population density data in Figure 3.1, average farm sizes in Ethiopia are very small by international standards, at 0.96 ha per holding, and correlate closely with population density.[13] The national average is raised by larger farm sizes in the most populous region of Oromia (1.15 ha) and in Amhara (1.09 ha), but lowered by much smaller farm sizes in the densely populated Southern Nations, Nationalities, and Peoples Region (SNNP) (just 0.49 ha). Tigray also has relatively small farms but is much less populous than the other three regions. Although variation is marked in average farm sizes, Gini coefficients of inequality do not vary greatly across regions and generally fall between 0.41 and 0.44 in the four highland regions.[14] Table 3.2 also shows statistics on the number of very small farms, defined as the percentage of holdings of less than 0.5 ha. Some 62 percent of SNNP farmholdings are less than 0.5 ha, a figure double the levels observed in Oromia and Amhara.

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[11] As of 2011–2012, statistics suggest that just 12 percent of cultivated land is rented (CSA 2012). Yet this figure in itself masks huge regional differences: The two largest regions, Oromia and SNNP, have rental rates of 8.7 percent and 5.7 percent, respectively, while Tigray and Amhara have rates of 19.5 percent and 17.9 percent, respectively (CSA 2012).

[12] Although some scathing critiques have been reported of recent resettlement programs (Hammond 2008; Tereke 2007), few if any rigorous evaluations exist. Nevertheless, the Ethiopian government had budgeted for US$100 per capita in its 2002 resettlement plans. It is difficult to imagine that this amounts to sufficient support. Moreover, no evidence to date exists showing that anywhere near 2.2 million people have thus far been resettled. In our focus group interviews, respondents in high-density areas thought that resettlement was a good idea in principle, but the challenges were typically too immense to make such schemes attractive enough to young farmers.

[13] *Farm size* refers to crop area per holding. In Ethiopia substantial amounts of grazing land are communal, so it is not obvious that including this is appropriate. Moreover, our interest is primarily in the crop or mixed crop–livestock systems, rather than in the livestock sector per se (especially since much of the specialized livestock sector exists in low-density lowland areas (pastoralist or agropastoralist).

[14] This is relatively low by international standards, and at the lower bound of the range of results reported by Kebede (2007) for the nonnationally representative Ethiopian Rural Household Survey villages. And while these land inequality coefficients are higher than expected in a socialist land system, we note that Ethiopia's level of land inequality is almost exactly the same as Vietnam's.

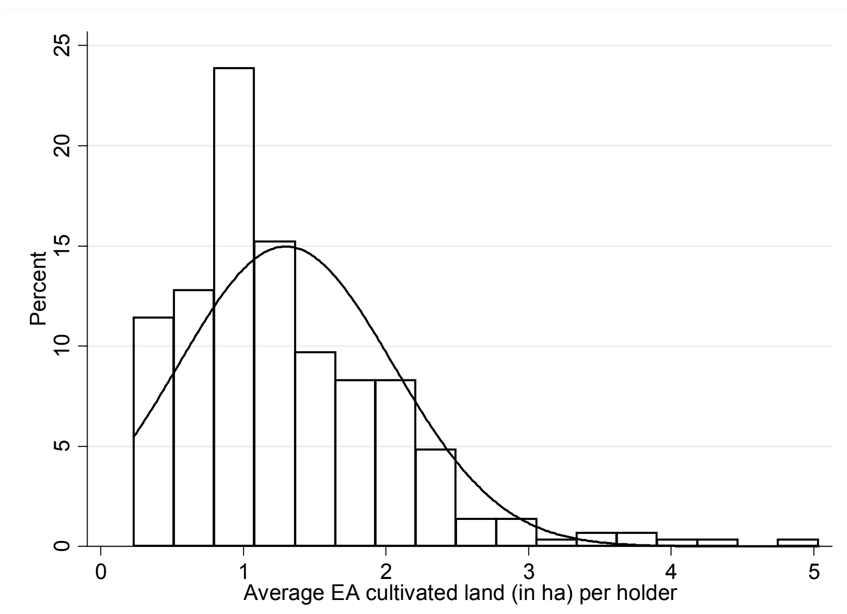
**Table 3.2 Farm distribution by major highland regions, 2011–2012**

| Panel A—Nationally representative statistics from Central Statistical Agency (2012) | | | | | |
|---|---|---|---|---|---|
| | **Oromia** | **SNNP** | **Amhara** | **Tigray** | **Ethiopia** |
| Average farm size (ha) | 1.15 | 0.49 | 1.09 | 0.91 | 0.96 |
| Farm size inequality (Gini, 0–1) | 0.43 | 0.44 | 0.41 | 0.43 | 0.46 |
| % with less than 0.5 ha | 30.0 | 61.7 | 33.4 | 41.4 | 39.7 |
| Total number of holders (millions) | 5.46 | 3.39 | 4.00 | 0.96 | 14.29 |
| **Panel B—Agricultural Growth Program Survey Statistics** | | | | | |
| **Variables/region** | **Oromia** | **SNNP** | **Amhara** | **Tigray** | **All AGP** |
| Average cultivated area (ha) | 1.32 | 0.93 | 1.37 | 1.56 | 1.46 |
| % with less than 0.5 ha | 18 | 35 | 22 | 17 | 23 |
| Number of holders* | 4.15 | 2.38 | 2.54 | 0.28 | 9.36 |

Sources Authors' calculations from CSA 2012 and AGPS data.
Notes: *The number of holders refers to the estimated number of holders in the population upon which the AGPS is based. ha = hectare, SNNP = Southern Nations, Nationalities, and Peoples Region AGP = Agricultural Growth Program.

The AGPS statistics on cultivated area (rather than holdings) at the bottom of Table 3.2 show a broadly similar pattern across regions, with the exception of Tigray, where the AGPS indicates much larger farms than does the CSA data for Tigray. This is as expected, since the AGPS oversamples the land-abundant areas of western Tigray, home to a number of large sesame farms in particular. Even so, large proportions of farmers cultivate less than 0.5 ha in the AGP sample, with the share varying from 17 percent in Tigray to 36 percent in SNNP. Figure 3.2 shows a histogram of average cultivated area per ha at the EA level for the 304 AGPS villages analyzed in this study. While admittedly not controlling for the agroecological potential of the land, Figure 3.2 nevertheless suggests substantial variation in average farm sizes across the highlands, though the bulk of the sample lies between 0.5 and 2 ha. We also note a few outliers in terms of EAs with very large farms.

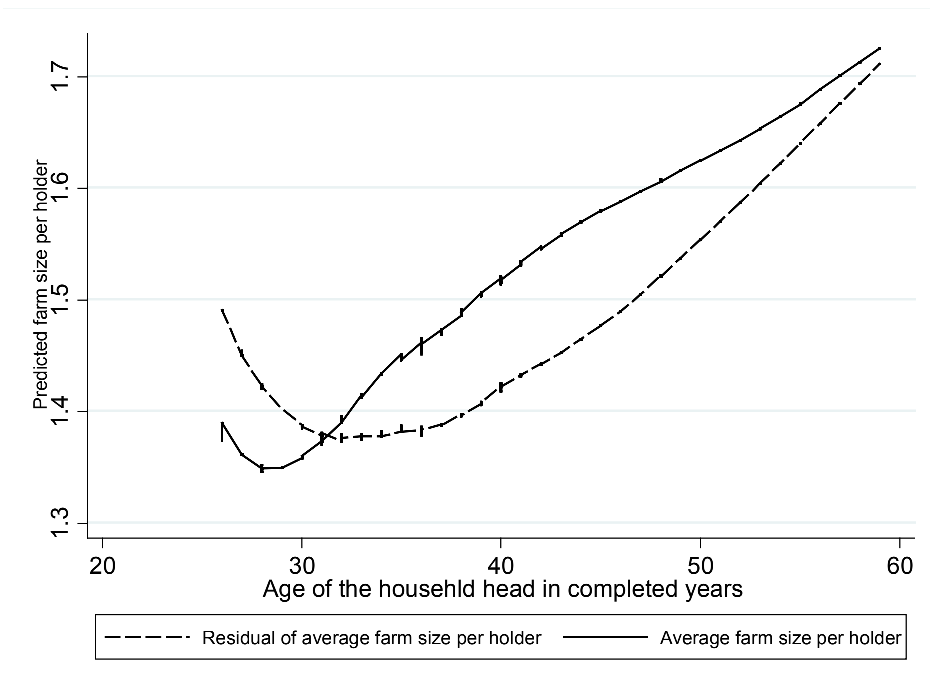
**Figure 3.2 A histogram of average cultivated land per capita at the enumeration area level**




Source: Authors' estimates from AGPS data.
Note: ha = hectare.

While Table 3.1 and Figure 3.2 offer interesting snapshots of farm size distributions across highland Ethiopia, they say little about evolution. Nationally, we know that average farm sizes declined from an estimated 1.4 ha per holding in the 1977 agricultural census to around 1.0 ha in the 2001/2002 census. Since the 2001/2002, the annual Agricultural Sample Survey data from the CSA have actually shown a slight increase in average farmholdings. Given that this result is somewhat surprising in light of continued rural population growth, we examine the issue from another angle by linking farm size to age of the household head using the AGPS. Our expectation is that if land is indeed a constraint, younger people will have much smaller farms than their elders. However, since age of the household head could be correlated with confounding factors, netting such factors out as much as possible is also clearly important. In particular, younger farmers may have less land because of smaller family size (a criterion in government land allocation) or insufficient wealth to rent more land. Hence we first regress household cultivated area against community variables (EA farm size, agroecological potential, market access) and household variables (wealth, education, and family size), and then use the residuals as an indicator of farm sizes net of confounding factors. The results of that regression are reported in the appendix, with all the variables listed above having sizable and significant explanatory power, and an R-squared of 52 percent. Lowess predictions of the raw farm size data and the residuals of average farm size per holder (standardized to the sample mean) are plotted against the age of male household heads from 25 to 60 years (Figure 3.3).[15]

**Figure 3.3 Younger farmers have much smaller farm sizes than older cohorts**




Source: Authors' calculations from AGPS data.

Notes: Residuals of farmholdings are the residuals of a regression of household farmholdings, average EA farm size, agroecological factors, market access, household wealth, education of the household head, and household family size. This regression is reported in the appendix.

[15] Note that after age 60 the gradient turns negative, presumably because older farmers give away land to their children. For this reason, however, we do not report the results for older populations.

Consistent with land constraints hypothesis, Figure 3.3 shows steep negative gradients between the two farm size indicators and the age of the household head, though the gradient is flatter after the confounding factors are netted out. But even with the farm size indicator net of confounding factors, the difference in farm sizes is significant. Farmers below the age of 38 have farm sizes that are almost 0.2 ha smaller than farmers aged 50 years and about 0.3 ha smaller than those aged 60 years. Of course, it is possible that these younger farmers will inherit more land as they get older, suggesting that some of the age–farmland gap observed in Figure 3.3 simply pertains to life cycle factors that cannot be observed in a one-off snapshot. On the other hand, the graph may underestimate land pressures insofar as it does not factor in landlessness, since younger landless households are not included in the sample. Certainly in the focus group discussions in the more densely populated areas of SNNP and Oromia, we heard some substantial discussion of young people not being able to obtain sufficient land, consistent with the farm size statistics reported in Table 3.2 and Figure 3.2. For many young rural Ethiopians, then, land appears to be a major constraint.

# 4. AGRICULTURAL INTENSIFICATION

In this section we focus on the relationships between land constraints and agricultural intensification, as well as other drivers of intensification. Virtually all of our dependent variables are measured in per ha terms, except for the two equipment indexes (plow and handheld), wages, and farm income per capita and a wealth–asset index (which are welfare measures rather than intensification measures). Also note that for the sake of brevity and because they are strictly exogenous variables of limited policy interest, agroecological controls (altitude, length of the growing period, sloping land, and soil) are not reported. However, the full results reported in the Appendix show that these indicators are more often than not individually significant and invariably jointly significant, which provides some assurance that the potentially confounding relationship between land pressures and agroecological potential is controlled for to a substantial extent.

Turning to the results of primary interest, Table 4.1 reports results for various nonlabor farm inputs; Table 4.2 reports results for wages, family labor, hired labor, and maize and teff yields; and Table 4.3 focuses on some of the more welfare-relevant variables, such as farm income per ha, farm income per capita, and average household wealth index scores. Note that although all regressions are linear, we also report elasticities of the intensification variables with respect to average farm size at the bottom of each table. Being scale neutral, these elasticities facilitate comparisons across different intensification indicators.

Starting with Table 4.1, in the first regression we observe a large and significant marginal effect of average farm sizes on fertilizers. A one-hectare increase in average farm size decreases fertilizer use by about 11 kilograms (kg) on average, with an elasticity of –0.82. Land inequality possesses a negative association with fertilizer use, as one might expect. Also of note is that the market access variables are important determinants of fertilizer use. An extra 10 kilometers to a local market reduces fertilizer use by about 1.8 kg per ha. Education and wealth are also positively correlated with fertilizer use, but the marginal effects are not very precise.

We find a similar pattern of results with respect to improved seed use in regression 2, with an even higher elasticity, along with higher standard errors as well. In regression 3 we regress all nonlabor variable input expenditures (in birr), which includes fertilizers, seeds, pesticides, and other chemicals. Consistent with the results for fertilizers and seeds, we find a large negative marginal effect of about 480 birr per ha, or just under US$30 per ha, with an elasticity of –0.88. Wealth and secondary education are other important determinants of expenditures on variable.

In the last two regressions of Table 4.1 show indexes of the ownership of plow equipment and handheld equipment (hoes, sickles, picks, axes, and so on). We had mixed expectations with regard to these indicators, particularly plow equipment. The plow has played an important part in substituting for labor in Ethiopia, particularly in the production of teff, which requires greater land preparation than other crops. On the other hand, the plow is important for land expansion as well as intensification, while feed constraints at higher population densities can also limit the use of the plow. Consistent with that ambiguity, we find a significant positive relationship between farm size and plow equipment, though the effect is small and only marginally significant at the 10 percent level. However, we note that the vast majority of households in our sample own at least one bovine that could potentially be used for plowing. Since plow equipment or animals can be borrowed or rented, we would not expect much relationship between land constraints and plow equipment. Handheld equipment also holds no relationship to average farm size, although farmland inequality slightly reduces the likelihood of owning both plow and handheld equipment.

**Table 4.1 Seemingly unrelated regressions of farm inputs with respect to average farm sizes and other determinants of intensification**

| Dependent variable | Fertilizer (kg per ha) | Improved seed (kg per ha) | All variable inputs (birr per ha) | Plow equipment index (standard deviation) | Handheld equipment index (standard deviation) |
|---|---|---|---|---|---|
| EA average farm size (ha) | –11.166*** | –2.016*** | –481.422*** | 0.166* | 0.015 |
| | (1.974) | (0.506) | (81.54) | (0.097) | (0.046) |
| EA farm coefficient variation | –8.478*** | –1.900* | 41.489 | –0.510*** | –0.248** |
| | (3.175) | (1.014) | (161.74) | (0.163) | (0.124) |
| Nearest market (km) | –0.188** | 0.01 | –6.21 | –0.007 | 0.010 |
| | (0.091) | (0.03) | (5.13) | (0.005) | (0.003) |
| Nearest city (minutes) | –0.572 | –0.24 | –9.729 | 0.064*** | –0.011 |
| | (0.446) | (0.15) | (17.56) | (0.022) | (0.014) |
| Extension office = 1 | 2.924 | 0.45 | 154.376 | 0.193 | 0.096 |
| | (2.543) | (0.71) | (108.53) | (0.145) | (0.091) |
| Savings credit co-op = 1 | 1.991 | 0.05 | –117.15 | –0.019 | –0.015 |
| | (2.522) | (0.69) | (96.522) | (0.109) | (0.074) |
| Savings and loan = 1 | –2.344 | 0.34 | –79.757 | –0.274** | –0.174** |
| | (2.50) | (0.89) | (100.674) | (0.119) | (0.081) |
| Bank/MFI = 1 | –1.25) | –0.882 | 62.459 | 0.248 | 0.301 |
| | (5.114 | (1.71) | (134.263) | (0.337) | (0.186) |
| Household heads with secondary education (0–1) | 76.542*** | 32.426*** | 3,205.614** | 0.687 | 2.407** |
| | (29.29) | (12.01) | (1,433.02) | (1.525) | (1.022) |
| Household heads with tertiary education (0–1) | 247.147 | –28.333 | –6,607.79 | –11.052 | –1.919 |
| | (286.40) | (35.71) | (12,675.7) | (11.49) | (3.558) |
| EA average wealth (standard deviation) | 1.798 | 1.403 | 137.345** | 0.003 | 0.111** |
| | (1.36) | (1.14) | (54.076) | (0.067) | (0.052) |
| No. of villages (N) | 282 | 281 | 277 | 286 | 286 |
| R-squared | 0.44 | 0.24 | 0.42 | 0.65 | 0.36 |
| Farm size elasticity | –0.82 | –1.85 | –0.88 | 0.61 | Not significant |

Source: Authors' calculations from AGPS data.

Notes: The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables and the Appendix for full results. The farm size elasticity at the bottom of this table is calculated at the medians of the dependent and independent variables.

EA = enumerated area, ha = hectare, km = kilometer, MFI = microfinance institution.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

Turning to Table 4.2, we first examine EA wages with respect to farm sizes. We find a modest marginal effect that is significant only at the 11 percent level. However, village wages are associated with greater wealth in a village, as well as the presence of household heads with tertiary education. In regression 2 we look at the use of hired labor per ha. We uncover a very small and marginally significant effect of 0.03 man-days per ha. This weak effect probably represents some contradictory forces: Smaller farms need to use land more intensively and may hire labor for that purpose, but larger farms are not likely to have adequate family labor, and hence they need to hire labor. Consistent with that inference, the next regression shows that more land-constrained villages use much more family labor per ha: about 40 man-days per ha, with an elasticity of –0.41. Farm size inequality bears a positive relationship with family labor per ha.

**Table 4.2 Seemingly unrelated regressions of wages, labor inputs, and cereal yields with respect to farm sizes and other determinants of intensification**

| Dependent variable | Enumeration area (EA) wages (birr) | Hired labor per hectare (man-days) | Family labor per hectare (man-days) | Teff yields (kg/ha) | Maize yields (kg/ha) |
|---|---|---|---|---|---|
| EA average farm size (ha) | 1.51 | 0.03* | –40.01*** | –334.84*** | –562.76*** |
| | (0.94) | (0.02) | (6.03) | (78.93) | (117.76) |
| EA farm coefficient variation | –1.41 | –0.051 | 31.83** | 118.91 | 91.09 |
| | (1.78) | (0.03) | (13.413) | (91.07) | (140.24) |
| Nearest market (km) | 0.05 | 0.01 | –0.14 | –0.38 | –1.44 |
| | (0.05) | (0.00) | (0.317) | (2.674) | (5.25) |
| Nearest city (minutes) | –0.28 | –0.01 | –1.98 | –11.57 | –9.75 |
| | (0.24) | (0.00) | (1.559) | (14.26) | (20.74) |
| Extension office = 1 | 0.92 | –0.019 | –18.23* | 187.09** | 31.21 |
| | (1.44) | (0.03) | (10.359) | (78.01) | (121.21) |
| Savings credit co-op = 1 | –1.24 | 0.083*** | 12.011 | 88.65 | –162.29 |
| | (1.18) | (0.03) | (8.067) | (82.08) | (115.57) |
| Savings and loan = 1 | 1.72 | –0.04 | –24.07*** | –5.056 | –4.13 |
| | (1.29) | (0.03) | (8.032) | (88.98) | (115.62) |
| Bank/MFI = 1 | –0.32 | –0.02 | 67.53*** | 43.11 | –167.34 |
| | (3.47) | (0.07 | (17.25) | (155.60) | (225.96) |
| Household heads with secondary education (0–1) | 1.76 | 0.66 | 58.4 | 550.6 | 4,724.9*** |
| | (16.88) | (0.43) | (117.9) | (1,116.1) | (1,477.7) |
| Household heads with tertiary education (0–1) | 123.30*** | –0.96 | –355.5 | –10,040.1*** | –6,288.7** |
| | (47.20) | (4.05) | (713.8) | (2,484.6) | (3,133.9) |
| EA average wealth (standard deviation) | 1.481* | 0.06** | 6.97 | 34.50 | 90.92 |
| | (0.84) | (0.02) | (4.42) | (40.147) | (68.91) |
| No. of villages (N) | 267 | 267 | 266 | 267 | 267 |
| R-squared | 0.32 | 0.29 | 0.44 | 0.35 | 0.39 |
| Farm size elasticity | Not significant | 0.00 | –0.41 | –0.53 | –0.54 |

Source: Authors' calculations from AGPS data.

Notes: The farm size elasticity at the bottom of this table is calculated at the medians of the dependent and independent variables. The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables and the Appendix for full results.
ha = hectare, kg = kilogram, km = kilometer, MFI = microfinance institution.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

The last two regressions in Table 4.2 focus on yields of maize and teff, the two most common crops in Ethiopia. We find quite large negative marginal effects of farm sizes on teff and maize yields, with a 1 ha reduction in land area predicting teff yields to increase by 335 kg on average, and maize yields to increase by 563 kg. In both cases the elasticity estimates are similar (–0.53 and –0.54 respectively). Farm size inequality has some tendency to raise yields but it is not significant. Access to an extension office raises teff yields (which may be related to the promotion of improved teff varieties in recent years through extension services). Education has somewhat ambiguous effects, with secondary education raising yields and tertiary education lowering yields.

Finally, Table 4.3 focuses on five indicators of more direct relevance to household welfare. The first two regressions focus on two measures of net crop income per ha. There are two advantages to using total crop income. First, if intensification involves switching away from cereals to higher-value crops, then crop income is a more relevant aggregate indicator than cereal yields. Second, as we showed in equation (1) above, if farm sizes shrink, then crop income per ha must increase to compensate for the loss of crop area.

**Table 4.3 Seemingly unrelated regressions of income and wealth variables with respect to farm sizes and other determinants of intensification**

| Dependent variable | Net crop income perhectare (birr), after excluding labor | Net crop income perhectare (birr), including labor | Gross farm income per capita (birr) | Net farm income per capita (birr) | Wealth index (standard deviations) |
|---|---|---|---|---|---|
| Enumeration area (EA) average farm size (ha) | –4,215.9*** | –681.7 | 757.7*** | 1,028.9*** | 0.12* |
| | (744.1) | (544.7) | (210.8) | (218.6) | (0.06) |
| EA farm coefficient variation | 243.3 | 360.2 | 579.5* | 681.8* | 0.18 |
| | (1,468.7) | (1,711.4) | (334.4) | (373.0) | (0.14) |
| Nearest market (km) | 3.06 | –55.7 | 4.5 | –11.5 | –0.01** |
| | (57.9) | (36.8) | (10.8) | (13.3) | (0.00) |
| Nearest city (minutes) | –293.7* | –119.1 | –29.9 | 3.4 | 0.01 |
| | (161.3) | (153.1) | (47.8) | (45.4) | (0.02) |
| Extension office = 1 | –543.10 | 554.6 | 217.7 | 341.7 | 0.13 |
| | (1,326.1) | (1,420.4) | (315.8) | (326.9) | (0.13) |
| Savings credit co-op = 1 | 865.2 | 489.3 | 633.3*** | 599.1** | –0.12 |
| | (952.1) | (1,001.3) | (233.0) | (233.3) | (0.12) |
| Savings and loan = 1 | 324.4 | 460.5 | 82.4 | 131.4 | 0.19 |
| | (843.3) | (861.5) | (242.1) | (234.2) | (0.14) |
| Bank/MFI = 1 | –1,137.0 | –2,796.8 | 103.8 | –320.2 | –0.17 |
| | (1,656.6) | (2,141.5) | (555.5) | (597.7) | (0.24) |
| Household heads with secondary education (0–1) | 11,406.7 | –761.2 | –922.4 | –1,510.7 | 3.55*** |
| | (12,297.1) | (11,570.3) | (2,600.6) | (2,635.1) | (1.28) |
| Household heads with tertiary education (0–1) | 80,905.5 | 81,412.2 | 20,240.9 | 11,782.5 | 7.59 |
| | (107,000.0) | (134,000.0) | (31,168.9) | (32,653.5) | (12.61) |
| EA average wealth (standard deviation) | 857.424* | 271.4 | 314.0** | 120.8 | |
| | (501.7) | (421.1) | (137.8) | (128.0) | |
| No. of villages (N) | 268 | 267 | 268 | 268 | 268 |
| R-squared | 0.26 | 0.20 | 0.32 | 0.36 | 0.24 |
| Farm size elasticity | –0.54 | Not significant | 0.09 | 0.84 | 0.06 |

Source: Authors' calculations from AGPS data.

Notes: The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. The farm size elasticity at the bottom of this table is calculated at the medians of the dependent and independent variables. See Table 2.1 for definitions of variables, and the appendix for full results.
ha = hectare, km = kilometer, MFI = microfinance institution.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

In regression 1 of Table 4.3 we look at crop income net of all variable costs, excluding labor. The coefficient attached to average farm sizes is very large, predicting that a 1 ha reduction in village farm size leads to a 4,216 birr (or US$250) increase in net crop income per ha, with a large elasticity of –0.54. However, given the large impact of land constraints on family labor per ha (Table 4.1), the addition of imputed family labor costs to other variable input costs in regression 2 greatly reduces the linkage between land constraints and net crop income per ha. The point estimate falls from 4,215 birr to 682 birr, although the latter coefficient is not significantly different from zero.

In regressions 3 and 4 we focus on gross and net farm income per capita, a variable we would expect to be strongly associated with total income and poverty in rural Ethiopia, where nonfarm incomes comprise a very small share of total income.[16] Gross farm income is significantly associated with more land access, with a coefficient of about 758 birr, but a relatively modest elasticity of 0.09. However, as expected, land access has a much larger impact on net farm income per capita (even after excluding family labor), with a coefficient of 1,029 birr, or US$61, and an elasticity of 0.84. In other words, a halving of farming area (that is, a reduction of 50 percent) is predicted to reduce net income per capita by 42 percent. By this measure land access would therefore appear to be a major determinant of welfare in rural Ethiopia.

In the last regression in Table 4.3, however, we observe only a modest effect of land constraint on the wealth index. One explanation of this may be that wealth indices perform quite poorly in Ethiopia, where ownership of modern assets (vehicles, phones, televisions) is extremely low, thus inhibiting variation in tangible assets.

### Sensitivity Tests

In addition to seemingly unrelated regressions, we also estimated the above models using a robust regressor to downweight outliers. Our rationale for this test was twofold. First, if land, in particular, is measured with error, then this could create problems for both the dependent variable and the key independent variable, with outlying observations being one possible manifestation of that problem. Second, with a relatively small sample (N varies from 265 to 288 villages depending on the variable used), a few unusual villages (such as the few lowland villages in the sample) could unduly influence results. However, we found no substantial differences in the coefficients derived with robust regressors, so we do not report them here.

A more important sensitivity test is the use of an alternative indicator of land pressures, the proportion of farms in a village that are below 1 ha. This variable has several potential advantages. First, it is generally argued that an average-sized family with access to a plow could harvest at least 2 ha. Smaller families with a plow could perhaps feasibly harvest only somewhere between 1 and 2 ha. But except for the most labor- and power-constrained ha, any average family would certainly feel land constrained if it could access only 1 ha or less. Such circumstances would obviously be strong motivations to intensify production.

A second reason to use this indicator is that it is less influenced by the presence of a handful of large farms in a village. A few large farms could substantially raise the village mean (which is why we also measured the coefficient of variation of farm sizes at the EA level), thereby giving the impression of little land constraints at the village level even though most households in the village may be unable to access more land. This would imply that the proportion of small farms might be a more accurate indicator of the latent variable of interest, land constraints. A scatterplot of the two indicators provides some evidence of these kinds of outliers (see Figure A.1 in the Appendix). Even so, the correlation between the two indicators is reasonably high (–0.83), as one might expect.

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[16] Note that we also regressed an indicator of off-farm work and secondary school enrollment against the covariates used in Tables 4.1, 4.2, and 4.3. We found no impact of land endowments on either indicator. From a dynamic welfare perspective, these results are not encouraging, but they are also not surprising. Secondary school enrollment is still very low in Ethiopia (though expanding rapidly), and enrollment seems much more a function of the physical presence of a local school rather than purposive household investments in human capital accumulation. In focus group surveys, respondents always stated that they considered education important, but they also emphasized the substantial costs of sending their children to relatively far-off secondary schools, and the uncertain returns given urban unemployment. In terms of off-farm work, the results are not surprising given that Ethiopia has one of the lowest rates of rural nonfarm employment in the world (see Headey, Taffesse, and You, forthcoming). However, future work should explore the relationship between off-farm income and land constraints. Unfortunately, nonfarm income data were not measured in the first round of the AGPS.

With that in mind, Table 4.4 reports the coefficients on this variable from regressions that are otherwise the same. Here, the coefficients represent the marginal impact of going from a village with no farms greater than 1 ha to a village in which all farms are greater than 1 ha. The results of these regressions are quite consistent with those in Tables 4.1, 4.2, and 4.3, but with a few minor differences. We find somewhat stronger results on the plow index (which declines markedly as small farms become more prevalent), and somewhat stronger results on daily wages. There is also some tendency toward more precise estimates, which may well reflect the fact that the prevalence of small farms is a better indicator of village land pressures than average farm sizes. But all in all, the results reaffirm the basic narrative derived from our core result: Signs of Boserupian intensification are clear in the higher-potential areas of Ethiopia, although this adaptation does not prevent land constraints from playing a major role in reducing farm incomes in these areas.

**Table 4.4 Results of a sensitivity test using the proportion of farms in a village (enumeration area) that are smaller than 1 hectare**

| Dependent variable | Fertilizer (kg per ha) | Improved seed (kg per ha) | All variable inputs (birr per ha) | Plow equipment index (standard deviation) | Handheld equipment index (standard deviation) |
|---|---|---|---|---|---|
| Farms smaller than 1 ha (0–1) | 28.3*** | 5.2*** | 1,380.6*** | –0.85*** | 0.01 |
| | (5.2) | (1.4) | (213.1) | (0.21) | (0.14) |
| No. of villages (N) | 265 | 266 | 261 | 270 | 269 |
| R-squared | 0.43 | 0.24 | 0.43 | 0.65 | 0.34 |
| Small farms elasticity | 0.87 | 2.01 | 1.05 | –1.31 | N.A. |
| **Dependent variable** | **Daily wages (birr)** | **Hired labor per ha (man-days)** | **Family labor per ha (man-days)** | **Teff yields (kg/ha)** | **Maize yields (kg/ha)** |
| Farms less than 1 ha (0–1) | –4.95*** | –0.08 | 125.4*** | 1,049.1*** | 1,720.0*** |
| | (1.86) | (0.05) | (15.9) | (188.5) | (295.2) |
| No. of villages (N) | 267 | 267 | 266 | 267 | 267 |
| R-squared | 0.31 | 0.28 | 0.45 | 0.38 | 0.42 |
| Farm size elasticity | –0.09 | | 0.54 | 0.69 | 0.69 |
| **Dependent variable** | **Net farm income per hectare (birr), after excluding labor** | **Net farm income per ha (birr)** | **Farm income per capita (birr)** | **Net farm income per capita (birr)** | **Wealth index (standard deviation)** |
| Farms smaller than 1 ha (0–1) | 13,859.5*** | 2,666.4 | –955.9** | –1,790.4*** | –0.38** |
| | (1,914.2) | (91,889.5) | (375.3) | (394.8) | (0.18) |
| No. of villages (N) | 268 | 267 | 268 | 268 | 268 |
| R-squared | 0.33 | 0.21 | 0.27 | 0.30 | 0.24 |
| Farm size elasticity | 0.75 | | –0.05 | –0.61 | –0.09 |

Source: Authors' calculations from AGPS data.

Notes: The farm size elasticity at the bottom of this table is calculated at the medians of the dependent and independent variables. The regressions also included all the control variables in Tables 4.1, 4.2, and 4.3, as well as agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables and the Appendix for full results.

kg = kilogram; ha = hectare.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

# 5. CONCLUSIONS

With its long history of food insecurity and famine, Ethiopia is an insightful case study for testing the Malthusian and Boserupian hypotheses, as well as the importance of policy-induced agricultural intensification. In this paper we find evidence that Ethiopia's already small farm sizes have been declining quite rapidly and that young farmers cultivate substantially less land than previous generations did. This stylized fact further emphasizes the need for either successful agricultural intensification or more rapid migration out of agriculture.

On the positive side, we do find strong support for Boserup's hypothesis, though some intensification indicators are more responsive than others. There is strong evidence that smaller farms apply more fertilizer and other purchased inputs like improved seeds, pesticides, and herbicides. Other inputs, such as the plow, have more ambiguous relationships given their usefulness in extending as well as intensifying land use. We also find strong evidence that family labor inputs per ha increase substantially as land pressures mount, though hired labor shows an opposing but mild relationship. Also as expected, cereal yields are strongly and positively associated with land pressures, as is gross farm income per ha (which incorporates higher-value crops) and farm income net of purchased inputs. However, when the opportunity cost of family labor is imputed with local wages, net farm income is unresponsive to land pressures. Moreover, as one would expect, we find that land constraints are strongly linked to lower incomes, especially net farm income per capita.

The results summarized above tell a story that is highly consistent with Boserup; and much more so relative to previous work testing the Boserupian hypothesis in Ethiopia (Pender, Place, and Ehui 2006). Nevertheless, the results are not necessarily encouraging in terms of the welfare implications of emerging land constraints. Under fairly crude assumptions, the UN expects Ethiopia's rural population to increase from 69 million people in 2010 to 90 million in 2030. The bulk of these 20 million extra people will be born in the land-constrained highlands. With limited potential for irrigation, low to moderate potential for smallholder land expansion into the lowlands, and the seemingly inevitable prospect of smaller farms getting even smaller, Ethiopia will require a mix of more successful agricultural intensification and much more rapid diversification out of smallholder farming.

How can this dual transformation be achieved? In terms of agricultural intensification, a range of research identifies important bottlenecks in the agricultural supply chain, particularly for seeds and fertilizers (Byerlee and Spielman 2007). Less widely researched are the supply chains for other labor-substituting inputs, such as pesticides, herbicides, and tractors. These inputs may well be increasingly important both for land expansion (where possible) and land intensification, especially if family sizes continue to reduce. Also somewhat neglected in the policy and research discourse in Ethiopia are higher-value crops. There are two issues here: increasing productivity and profitability for existing cash crop producers (for example, the large coffee sector), and encouraging small farmers currently focusing on staple crops to experiment more in the high-value sector, including nontraditional high-value crops. The growth of urban areas and improvement in transport and value chains will further facilitate this transition.

What about off-farm diversification? In more land-abundant areas, the last decade has seen a shift in emphasis from smallholder resettlement to large commercial farms, which may create sizable opportunities for seasonal employment. In some focus group discussions we found that seasonal employment in commercial farms in Awash and northwest Ethiopia has been a very important source of income diversification for land-constrained areas, but to our knowledge this has not been researched or quantified in the Ethiopian context.

In terms of nonfarm diversification, Ethiopia's industrial sector has long underperformed, but has sizable potential, given a large and growing economy. Nevertheless, the unusually small size of the rural nonfarm economy remains a puzzle, though small towns in Ethiopia are growing rapidly. The government has also expanded education quite rapidly, but secondary education enrollment has thus far increased only sluggishly in rural areas, and job creation for the newly educated class has been rather slow. Nevertheless, with very limited opportunities for land expansion in the highlands, education will surely be a critical investment in coming decades.

There are also long-standing perceptions that government regulations, the Productive Safety Net Program and land tenure institutions indirectly discourage rural–urban migration. These hypotheses warrant further research, though it is worth noting that the Ethiopian government has also invested substantially in urban infrastructure, including electricity, social services, and even public housing. Thus the net effects of the government's development strategy on rural–urban transformation is ambiguous, though in our view a rapid transformation should be unambiguously encouraged.

Finally, the government of Ethiopia has long recognized that slowing down rural population growth is a very desirable long-term objective in such a land- and water-constrained country. On this front some recent evidence suggests that government family-planning policies—particularly the health extension worker program—have been quite effective at reducing fertility rates (Pörtner, Beegle, and Christiaensen 2012). The evidence also suggests that expanding female secondary education and rural–urban migration would be effective in reducing fertility rates, in addition to family-planning policies.

These considerations reemphasize the fact that land constraints are a multifaceted problem requiring a range of solutions. On the positive front, the government has been quite cognizant of the importance of land constraints. The issue is therefore not one of neglect but is whether the design and implementation of strategies for economic transformation can be further improved. This would seem a critical area for future research.

# APPENDIX: SUPPLEMENTARY TABLES

**Table A.1 Descriptive statistics for the indicators of land constraints and agricultural intensification**

| Variable | Mean | Median | Standard deviation | Minimum | Maximum | No. of observations |
|---|---|---|---|---|---|---|
| EA average farm size | 1.3 | 1.1 | 0.8 | 0.2 | 5.0 | 279 |
| EA farm inequality | 0.3 | 0.2 | 0.2 | 0.0 | 1.1 | 279 |
| Proportion of farms of less than 1 ha | 0.47 | 0.46 | 0.28 | 0.0 | 1.0 | 279 |
| Net farm income per ha (birr), excluding labor | 10,928 | 8,524 | 8,286 | 1,153 | 54,229 | 279 |
| Net farm income per ha (birr), including labor | 5,445 | 3,543 | 13,297 | –14,000 | 36,894 | 279 |
| Gross farm income per ha (birr) | 12,067 | 9,722 | 8,887 | 1,626 | 54,865 | 279 |
| Net farm income per capita, excluding labor | 1,838 | 1,345 | 1,908 | –1,451 | 13,701 | 279 |
| Gross farm income per capita | 2,786 | 2,348 | 1,960 | 463 | 14,686 | 279 |
| Wealth index | 0.0 | –0.23 | 0.85 | –1.04 | 4.72 | 279 |
| Total purchased input costs (birr) per ha | 1,020 | 605 | 1,213 | 0 | 8,248 | 279 |
| Fertilizer (kg) per ha | 23.3 | 15.0 | 23.8 | 0.0 | 103.1 | 279 |
| Farms using fertilizer (%) | 50 | 60 | 30% | 0 | 100 | 279 |
| Improved seed (kg) per ha | 4.2 | 1.2 | 7.3 | 0.0 | 44.2 | 279 |
| Farms using improved seed (%) | 0.2 | 0.1 | 0.3 | 0.0 | 1.0 | 279 |
| Plow equipment index (standard deviation) | 0.2 | 0.3 | 1.3 | –2.8 | 3.9 | 279 |
| Handheld equipment index (standard deviation) | 0.0 | 0.0 | 0.7 | –1.9 | 2.0 | 279 |
| Hired labor per ha (man-days) | 80.0 | 20.8 | 149.8 | 0.0 | 906.8 | 279 |
| Family labor per ha (man-days) | 123.1 | 106.7 | 72.9 | 0.8 | 324.0 | 279 |
| Adult wages (birr) | 26.1 | 24.8 | 10.4 | 6.9 | 70.4 | 279 |
| Teff yields (kg) | 866 | 700 | 687 | 134 | 5,200 | 229 |
| Maize yields (kg) | 1,404 | 1,148 | 1,047 | 200 | 6,916 | 265 |

Source: Authors' estimates.
Notes: See Table 2.1 for definitions of variables.
EA = Enumeration area, ha = hectare, km = kilometer; m = meter, kg = kilogram.

**Table A.2 Correlations between farm sizes, market access, and agroecological conditions**

| Variable | EA farm size | EA farm inequality | Nearest market | Nearest city | Mean LGP | Mean elevation | Mean slope | Fertile soil | Flat land | Area cultivated | Secondary education | Wealth index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average EA farm size | 1 | | | | | | | | | | | |
| EA farm inequality | –0.22 | 1.0 | | | | | | | | | | |
| Nearest market (km) | 0.03 | 0.11 | 1.0 | | | | | | | | | |
| Nearest city (minutes) | 0.38 | –0.24 | 0.20 | 1.0 | | | | | | | | |
| Length of growing period | –0.24 | 0.06 | –0.09 | –0.17 | 1.00 | | | | | | | |
| Mean elevation | –0.47 | 0.13 | –0.12 | –0.54 | 0.27 | 1.00 | | | | | | |
| Mean slope | –0.20 | –0.03 | 0.07 | 0.20 | –0.01 | 0.14 | 1.00 | | | | | |
| Fertile soil (% of crop land) | 0.03 | –0.04 | –0.06 | –0.01 | 0.30 | –0.04 | –0.06 | 1.00 | | | | |
| Flat land (% of crop land) | 0.15 | 0.00 | –0.15 | –0.10 | –0.24 | –0.07 | –0.29 | 0.24 | 1.00 | | | |
| Farm area cultivated (%) | –0.50 | 0.03 | 0.05 | –0.22 | 0.04 | 0.25 | 0.14 | –0.20 | –0.09 | 1.00 | | |
| % of heads with secondary education | –0.07 | 0.04 | –0.09 | –0.11 | 0.12 | 0.12 | –0.07 | 0.06 | 0.05 | 0.01 | 1.00 | |
| Wealth index | 0.19 | 0.00 | –0.14 | 0.01 | –0.24 | –0.11 | –0.25 | –0.04 | 0.23 | –0.13 | 0.13 | 1 |

Source: Authors' estimates.

Notes: See Table 2.1 for definitions of variables.
EA = Enumeration area, LGP = length of growing period, km = kilometer.

**Table A.3 Full results corresponding to Table 4.1 in the main text (including agroecological controls)**

| Dependent variable | Fertilizer (kg per ha) | Improved seed (kg per ha) | All variable inputs (birr per ha) | Plow equipment index (standard deviation) | Handheld equip. index (standard deviation) |
|---|---|---|---|---|---|
| EA average farm size (ha) | –11.16*** | –2.01*** | –481.4*** | 0.166* | 0.015 |
| | 1.974 | 0.506 | 81.54 | 0.097 | 0.046 |
| EA farm coefficient variation | –8.478*** | –1.900* | 41.489 | –0.510*** | –0.248** |
| | 3.175 | 1.014 | 161.745 | 0.163 | 0.124 |
| Nearest market (km) | –0.188** | 0.01 | –6.218 | –0.007 | 0.001 |
| | 0.091 | 0.03 | 5.137 | 0.005 | 0.003 |
| Nearest city (minutes) | –0.572 | –0.244 | –9.729 | 0.064*** | –0.011 |
| | 0.446 | 0.154 | 17.565 | 0.022 | 0.014 |
| Extension office = 1 | 2.924 | 0.457 | 154.376 | 0.193 | 0.096 |
| | 2.543 | 0.715 | 108.53 | 0.145 | 0.091 |
| Savings credit co-op = 1 | 1.991 | 0.055 | –117.151 | –0.019 | –0.015 |
| | 2.522 | 0.697 | 96.522 | 0.109 | 0.074 |
| Savings and loan = 1 | –2.344 | 0.345 | –79.757 | –0.274** | –0.174** |
| | 2.503 | 0.897 | 100.674 | 0.119 | 0.081 |
| Bank/MFI = 1 | –1.259 | –0.882 | 62.459 | 0.248 | 0.301 |
| | 5.114 | 1.715 | 134.263 | 0.337 | 0.186 |
| Household heads with secondary education (0–1) | 76.542*** | 32.426*** | 3,205.614** | 0.687 | 2.407** |
| | 29.295 | 12.015 | 1,433.02 | 1.525 | 1.022 |
| Household heads with tertiary education (0–1) | 247.147 | –28.333 | –6,607.79 | –11.052 | –1.919 |
| | 286.407 | 35.713 | 12,675.7 | 11.49 | 3.558 |
| EA average wealth (standard deviation) | 1.798 | 0.16 | 137.345** | 0.003 | 0.111** |
| | 1.36 | 0.358 | 54.076 | 0.067 | 0.052 |
| Altitude 1,000m–1,500m | 5.581 | 1.403 | –31.444 | –0.204 | –0.265 |
| | 3.809 | 1.145 | 166.938 | 0.429 | 0.256 |
| Altitude3 1,500m–2,000m | 0.171 | 1.135 | –394.728** | 0.129 | –0.15 |
| | 4.161 | 1.376 | 186.629 | 0.435 | 0.26 |
| Altitude4 2,000m–2,500m | –0.486 | 1.983 | –485.296** | –0.274 | –0.222 |
| | 4.545 | 1.638 | 207.873 | 0.442 | 0.265 |
| Altitude5 2,500m–3,000m | 4.629 | 3.791 | 101.903 | –0.02 | –0.176 |
| | 6.644 | 2.444 | 293.762 | 0.483 | 0.3 |
| Altitude6 > 3,000m | –22.5*** | –1.947 | –1,271.9*** | –1.3*** | –0.504* |
| | 5.594 | 1.837 | 316.043 | 0.452 | 0.272 |
| LGP2 150–210 days | 19.291*** | 1.724 | 452.7*** | 0.346* | 0.078 |
| | 3.946 | 1.489 | 159.106 | 0.188 | 0.177 |
| LGP3 210–300 days | 30.6*** | 3.420** | 698.4*** | 0.387* | 0.323* |
| | 4.434 | 1.577 | 204.424 | 0.206 | 0.189 |
| LGP4 > 300 days | 19.578*** | 2.964* | 186.108 | 0.433 | –0.08 |
| | 5.265 | 1.757 | 232.638 | 0.28 | 0.224 |
| Fertile land (% total) | –0.056 | 0.005 | –0.539 | –0.005** | –0.003* |
| | 0.048 | 0.015 | 2.487 | 0.002 | 0.002 |
| Flat land (% total) | 0.069 | 0.021 | 4.076* | 0.010*** | 0.001 |
| | 0.049 | 0.017 | 2.299 | 0.002 | 0.002 |
| Oromia dummy | –17.8*** | –6.593*** | –92.0 | –0.931*** | –0.565*** |
| | 5.07 | 1.823 | 228.7 | 0.234 | 0.188 |

**Table A.3 Continued**

| Dependent variable | Fertilizer (kg per ha) | Improved seed (kg per ha) | All variable inputs (birr per ha) | Plow equipment index (standard deviation) | Handheld equip. index (standard deviation) |
|---|---|---|---|---|---|
| Amhara dummy | –10.83*** | –4.398*** | –121.7 | –0.601*** | –0.28 |
| | 3.91 | 1.539 | 163.5 | 0.201 | 0.177 |
| Southern Nations, Nationalities, and Peoples' Region dummy | –31.64*** | –7.416*** | –704.4*** | –2.404*** | –0.781*** |
| | 5.312 | 1.881 | 253.7 | 0.265 | 0.205 |
| Constant | 36.96*** | 7.146** | 1,426.9*** | 0.416 | 0.823** |
| | 8.854 | 2.787 | 364.534 | 0.593 | 0.392 |
| No. of villages (N) | 282 | 281 | 277 | 286 | 286 |
| R-squared | 0.441 | 0.238 | 0.415 | 0.651 | 0.356 |

Source: Authors' estimates.

Notes: The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables.

kg = kilogram, ha = hectare; EA = enumerated area, km = kilometer; m = meter, LGP = length of growing period, MFI = microfinance institution.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

**Table A.4 Full results corresponding to Table 4.2 in the main text (including agroecological controls)**

| Dependent variable | EA wages (birr) | Hired labor per ha (man-days) | Family labor per ha (man-days) | Teff yields (kg/ha) | Maize yields (kg/ha) |
|---|---|---|---|---|---|
| EA average farm size (ha) | 1.511 | 0.033* | –40.001*** | –334.844*** | –562.764*** |
| | 0.942 | 0.02 | 6.038 | 78.936 | 117.768 |
| EA farm coefficient variation | –1.418 | –0.051 | 31.831** | 118.917 | 91.092 |
| | 1.781 | 0.035 | 13.413 | 91.072 | 140.248 |
| Nearest market (km) | 0.058 | 0 | –0.142 | –0.384 | –1.445 |
| | 0.051 | 0.001 | 0.317 | 2.674 | 5.256 |
| Nearest city (minutes) | –0.289 | –0.009 | –1.983 | –11.571 | –9.754 |
| | 0.249 | 0.006 | 1.559 | 14.266 | 20.745 |
| Extension office = 1 | 0.924 | –0.019 | –18.253* | 187.096** | 31.213 |
| | 1.441 | 0.035 | 10.359 | 78.018 | 121.214 |
| Savings credit co–op = 1 | –1.241 | 0.083*** | 12.011 | 88.655 | –162.295 |
| | 1.184 | 0.031 | 8.067 | 82.086 | 115.574 |
| Savings and loan = 1 | 1.727 | –0.041 | –24.079*** | –5.056 | –4.133 |
| | 1.297 | 0.03 | 8.032 | 88.981 | 115.624 |
| Bank/MFI = 1 | –0.324 | –0.016 | 67.538*** | 43.113 | –167.348 |
| | 3.474 | 0.078 | 17.255 | 155.601 | 225.96 |
| Household heads with secondary education (0–1) | 1.768 | 0.668 | 58.45 | 550.688 | 4,724.92*** |
| | 16.883 | 0.43 | 117.943 | 1,116.16 | 1,477.76 |
| Household heads with tertiary education (0–1) | 123.35*** | –0.964 | –355.51 | –14,000*** | –6,288.72** |
| | 47.205 | 4.055 | 713.857 | 2,484.6 | 3,133.93 |
| EA average wealth (standard deviation) | 1.481* | 0.060** | 6.979 | 34.508 | 90.926 |
| | 0.847 | 0.024 | 4.424 | 40.147 | 68.91 |
| Altitude 1,000m–1,500m | –7.156 | –0.351*** | 15.201 | 69.125 | 294.574 |
| | 6.737 | 0.07 | 16.789 | 168.621 | 190.508 |

**Table A.4 Continued**

| Dependent variable | EA wages (birr) | Hired labor per ha (man-days) | Family labor per ha (man-days) | Teff yields (kg/ha) | Maize yields (kg/ha) |
|---|---|---|---|---|---|
| Altitude3 1,500m–2,000m | –13.358** | –0.351*** | 7.682 | 48.305 | –65.697 |
| | 6.782 | 0.071 | 17.139 | 181.539 | 187.825 |
| Altitude4 2,000m–2,500m | –13.777** | –0.419*** | 4.403 | –102.012 | –541.392** |
| | 6.855 | 0.074 | 17.592 | 188.62 | 231.637 |
| Altitude5 2,500m–3,000m | –10.969 | –0.379*** | 28.342 | –113.044 | –424.398 |
| | 7.156 | 0.088 | 24.385 | 293.687 | 329.108 |
| Altitude6 >3,000m | –24.371*** | –0.530*** | –45.130** | –1,002.5*** | –2,566.246*** |
| | 6.878 | 0.079 | 21.922 | 270.334 | 363.178 |
| LGP2 150–210 days | –5.462* | –0.036 | 58.682*** | 396.284*** | 826.788*** |
| | 3.024 | 0.055 | 16.772 | 138.9 | 251.066 |
| LGP3 210–300 days | –7.198** | 0.002 | 68.848*** | 557.693*** | 1,176.056*** |
| | 3.216 | 0.058 | 17.327 | 176.022 | 315.18 |
| LGP4 > 300 days | –8.791** | –0.076 | 80.512*** | 446.666** | 753.491** |
| | 3.551 | 0.074 | 22.098 | 203.699 | 341.814 |
| Fertile land (% total) | 0.004 | 0 | –0.231 | 2.595* | 2.734 |
| | 0.026 | 0.001 | 0.157 | 1.568 | 2.439 |
| Flat land (% total) | –0.011 | 0.001 | –0.096 | 4.580*** | 2.968 |
| | 0.023 | 0.001 | 0.178 | 1.501 | 2.292 |
| Oromia dummy | –1.006 | –0.07 | –23.341 | –261.256 | –325.248 |
| | 3.149 | 0.064 | 19.755 | 179.688 | 341.889 |
| Amhara dummy | 0.66 | –0.065 | 4.953 | 121.244 | 40.389 |
| | 2.985 | 0.058 | 16.923 | 138.071 | 247.248 |
| Southern Nations, Nationalities, and Peoples' Region dummy | –2.124 | –0.069 | –87.688*** | –665.520*** | –1,216.656*** |
| | 3.253 | 0.07 | 21.656 | 206.13 | 350.607 |
| Constant | 44.543*** | 0.643*** | 161.268*** | 293.999 | 1,485.373*** |
| | 7.453 | 0.123 | 30.867 | 310.839 | 419.619 |
| No. of villages (N) | 267 | 267 | 266 | 267 | 267 |
| R-squared | 0.321 | 0.291 | 0.439 | 0.349 | 0.387 |

Source: Authors' estimates.

Notes: The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables.

kg = kilogram, ha = hectare; EA = enumerated area, km = kilometer; m = meter, LGP = length of growing period, MFI = microfinance institution.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parenthesis.

**Table A.5 Full results corresponding to Table 4.3 in the main text (including agroecological controls)**

| Dependent variable | Net crop income per hectare (birr), after excluding labor | Net crop income per hectare (birr) | Gross farm income per capita (birr) | Net farm income per capita (birr) | Wealth index (standard deviations) |
|---|---|---|---|---|---|
| EA average farm size (ha) | –681.725 | –4,215.9*** | 757.776*** | 1,028.929*** | 0.119* |
| | 544.77 | 744.134 | 210.839 | 218.619 | 0.064 |
| EA farm coefficient variation | 360.197 | 243.339 | 579.581* | 681.879* | 0.175 |
| | 1,711.41 | 1,468.79 | 334.491 | 373.093 | 0.14 |
| Nearest market (km) | –55.7 | 3.057 | 4.479 | –11.58 | –0.010** |
| | 36.82 | 57.94 | 10.801 | 13.347 | 0.004 |
| Nearest city (minutes) | –119.193 | –293.785* | –29.955 | 3.444 | 0.014 |
| | 153.11 | 161.305 | 47.8 | 45.443 | 0.021 |

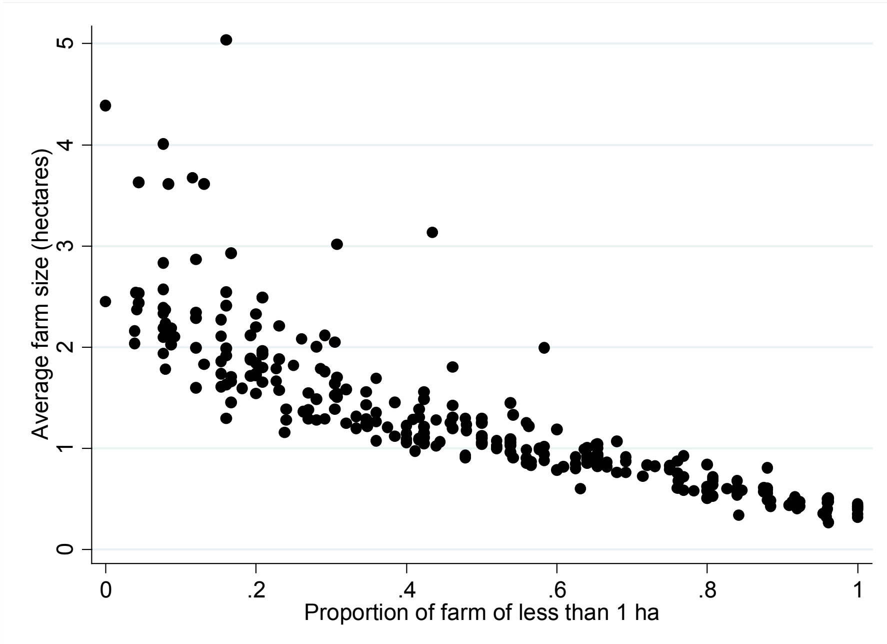
**Table A.5 Continued**

| Dependent variable | Net crop income per hectare (birr), after excluding labor | Net crop income per hectare (birr) | Gross farm income per capita (birr) | Net farm income per capita (birr) | Wealth index (standard deviations) |
|---|---|---|---|---|---|
| Extension office = 1 | 554.688 | –543.103 | 217.766 | 341.752 | 0.128 |
| | 1,420.45 | 1,326.1 | 315.827 | 326.906 | 0.125 |
| Savings credit co-op = 1 | 489.394 | 865.268 | 633.325*** | 599.131** | –0.121 |
| | 1,001.3 | 952.166 | 232.998 | 233.337 | 0.116 |
| Savings and loan = 1 | 460.59 | 324.403 | 82.418 | 131.404 | 0.187 |
| | 861.536 | 843.372 | 242.173 | 234.218 | 0.136 |
| Bank/MFI = 1 | –2,796.86 | –1,137.09 | 103.871 | –320.291 | –0.167 |
| | 2,141.59 | 1,656.68 | 555.525 | 597.715 | 0.243 |
| Household heads with secondary education (0–1) | –761.267 | 11,406.7 | –922.444 | –1,510.77 | 3.555*** |
| | 11,570.4 | 12,297.2 | 2,600.63 | 2,635.19 | 1.282 |
| Household heads with tertiary education (0–1) | 81,412.24 | 80,905.56 | 20,240.91 | 11,782.52 | 7.585 |
| | 134,000 | 107,000 | 31,168.9 | 32,653.6 | 12.611 |
| EA average wealth (standard deviation) | 271.477 | 857.424* | 314.018** | 120.812 | |
| | 421.184 | 501.705 | 137.813 | 128.058 | |
| Altitude 1,000m–1,500m | –1,433.46 | –1,926.13 | –1,360.55 | –1,523.95 | –0.684** |
| | 2,067.59 | 2,295.07 | 1,244.13 | 1,225.45 | 0.295 |
| Altitude3 1,500m–2,000m | –5,099.3*** | –7,471.6*** | –2,267.666* | –2,138.534* | –0.751** |
| | 1,957.68 | 2,299.26 | 1,255.74 | 1,235.24 | 0.311 |
| Altitude4 2,000m–2,500m | –5,372.06** | –7,969.69*** | –2,293.83* | –2,266.58* | –0.752** |
| | 2,114.4 | 2,438.98 | 1,257.65 | 1,235.56 | 0.315 |
| Altitude5 2,500m–3,000m | –6,789.05*** | –8,202.21*** | –2,209.03* | –2,378.288* | –0.925*** |
| | 2,551.55 | 2,696.61 | 1,259.34 | 1,243.67 | 0.352 |
| Altitude6 > 3,000m | –8,012.67*** | –15,600*** | –3,432.40*** | –2,125.78 | –1.007*** |
| | 2,469.5 | 3,086.82 | 1,316.56 | 1,309.59 | 0.323 |
| LGP2 150–210 days | 145.04 | 2,532.617** | 407.905 | –40.633 | –0.773*** |
| | 1,203.91 | 1,207.14 | 346.304 | 363.689 | 0.294 |
| LGP3 210–300 days | 1,431.602 | 5,075.512*** | 917.251** | 206.284 | –0.776** |
| | 1,461.1 | 1,601.96 | 365.713 | 394.741 | 0.343 |
| LGP4 > 300 days | 1,843.61 | 6,186.57*** | 1,392.61*** | 559.193 | -1.213*** |
| | 2167.09 | 2,258.21 | 524.401 | 561.096 | 0.362 |
| Fertile land (% total) | 54.70*** | 53.750*** | 12.23*** | 9.729** | 0 |
| | 16.979 | 19.24 | 4.336 | 4.179 | 0.003 |
| Flat land (% total) | –6.059 | –8.867 | 1.217 | –0.956 | 0.004* |
| | 19.52 | 20.024 | 5.059 | 5.096 | 0.002 |
| Oromia dummy | 3,081.950* | –930.808 | 621.339 | 1,180.912*** | 0.884*** |
| | 1,627.13 | 1,737.89 | 416.333 | 449.065 | 0.31 |
| Amhara dummy | –206.454 | –1,107.43 | 67.948 | 173.8 | 0.611** |
| | 1,355.21 | 1,256.18 | 360.786 | 392.313 | 0.301 |
| Southern Nations, Nationalities, and Peoples' Region dummy | 2,804.511 | –3,070.36 | –203.927 | 1,003.436* | 0.587* |
| | 2,207.6 | 2,238.11 | 554 | 591.355 | 0.324 |
| Constant | 6,255.539* | 17,606.11*** | 1,402.482 | 277.264 | 0.192 |
| | 3,726.6 | 4,072.47 | 1,462.5 | 1,430.92 | 0.424 |
| No. of villages (N) | 268 | 267 | 268 | 268 | 268 |
| R-squared | 0.202 | 0.26 | 0.317 | 0.358 | 0.238 |

Source: Authors' estimates.

Notes: The regressions also included agroecological controls for altitude, length of the growing period, soil quality, and slope. See Table 2.1 for definitions of variables, and the appendix for full results.
kg = kilogram, ha = hectare; EA = enumerated area, km = kilometer; m = meter, LGP = length of growing period, MFI = microfinance institution.
*, ** and *** indicate significance at the 10%, 5% and 1% level. Standard errors are in parenthesis.

**Figure A.1 Scatterplot of the two land intensification indicators**




Source: Authors' estimates.
Notes: The correlation between the two indicators is –0.83.
ha = hectare.

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