Poverty, Resource Use and Intensification Strategies of Smallholders under Population Pressure in Southern Ethiopia

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Department of Economics and Resource Management
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Table of Contents

Acknowledgements i
Table of Contents v
Introduction to the thesis 1
1. Introduction 1
1.1. Poverty, market imperfections and livelihood strategies of smallholders 1
1.2. Population pressure, land degradation and farm intensification 2
2. Summary of main findings 6
3. Conclusions and some policy implications 10
3.1. Conclusions 10
3.2. Some policy implications 11
References 15
Between Malthus and Boserup: Farm size-productivity relationship under population pressure 21
Abstract 21
1. Introduction 21
2. Theoretical framework 24
2.1. Population pressure, farm size and intensification 24
2.2. Market imperfections and the inverse relationship 26
2.3. Heterogeneous land quality and the inverse relationship 29
2.4. Hypotheses 30
3. Description of the study area and data 31
4. Econometric methods and variable specification 34
5. Results and Discussion 37
5.1. Farm household level analysis 37
5.2. Plot level explanations 38
6. Conclusions 39
References 41
Too Poor to Invest?
Poverty and Farm Intensification in Southern Ethiopian Highlands 57
Abstract 57
1. Introduction 58
2. The setting 60
3. Theoretical model 61
4. Methodology 67
4.1. Testing of hypotheses 67
4.2. Econometric methods 70
4.3. Data and variable specification 71
5. Results and Discussion 73
5.1. Population pressure and intensification in perennial crop 73
5.2. Livestock and perennial intensification 74
5.3. Too poor to invest? 75
6. Conclusions 80
References 81
Are the poor forced to cut the branch they are sitting on?
Perennial crop harvesting decisions of food insecure smallholders 95
Abstract 95
1. Introduction 95
2. Theoretical framework 97

2.1. Hypotheses 102
3. Data and methods 102
3.1. Study area, data and variable specification 102
3.2. Simulation model 103
3.3. Econometric methods 104
4. Results and Discussion 106
4.1. Simulation results 106
4.2. Econometric results 107
5. Conclusions 109
References 111
Appendix: Simulation results for the optimal rotation period 116
Soil degradation, poverty, and farmers' willingness to invest in soil conservation 123
Abstract 123
1. Introduction 124
2. The study area and data collection 126
3. Theoretical Framework 127
3.1. Hypotheses 133
4. Methodology 134
4.1. Administration of the WTP questions for CVM 134
4.2. Econometric methods and estimation 136
5. Results and Discussion 138
5.1. Farmers' perceptions of land degradation: Descriptive results 138
5.2. Factors affecting farmers' willingness to invest in soil conservation: Empirical results 139
6. Conclusion 141
References 143
Appendix A: Questions on perceptions of degradation and Willingness to invest in soil conservation 151
Appendix B: Distribution of shadow wage rate 153
Appendix C: Farmers' rankings of land degradation problems 155

Introduction

Introduction to the thesis

1. Introduction

The majority of the Ethiopian population lives in rural areas and agriculture is the mainstay of the country's economy, contributing about 45 percent of the gross domestic product (GDP) and employing more than 85 percent of the population. The majority of the rural population resides in the highlands with altitude reaching up to 3000 meters above sea level (Khairo *et al.* 2005). The highlands are densely populated with smallholders operating 0.25 to 2 hectares of land, predominantly rain-fed subsistence farming. The use of modern agricultural technology is limited, oxen and family labour being the major inputs. Most of the agricultural land in the highlands is degraded, mainly because of soil erosion and nutrient depletion (Hurni, 1988; Tegene, 1992; Bewket and Sterk, 2003). Declining soil fertility and increasing land scarcity associated with growing population are limiting food security in the country. Consequently, most of the rural population lives in chronic poverty. The smallholders continue struggling to escape the poverty traps by employing different livelihood and land use intensification strategies. Their livelihood strategies are as diverse as the production problems they face. The concern is how far these strategies would help the smallholders to achieve their objectives given existing institutions and known available technologies. In the following sections, we provide a theoretical basis for analysis of these issues.

1.1. Poverty, market imperfections and livelihood strategies of smallholders

The concept of livelihood strategy encompasses activities that generate income and other kinds of choices, including cultural and social choices, that come together to make up the primary occupation of a household (Ellis, 1998). Smallholders diversify income from allocations of their assets for various reasons, such as coping with shocks or minimizing risk, and self-provision of goods or services due to market imperfections (Ellis, 1998; Barrett *et al.* 2001). Livelihood can, therefore, be defined as the opportunity set afforded to an individual or a household through asset endowments and the chosen allocation of these assets across various activities to generate a stream of benefits, most commonly measured in terms of income (Reardon and Barrett, 2000).

Poverty plays an important role in livelihood strategy choice of smallholders.[1] Some households may be poor in assets or may face liquidity constraints, leading them to give high priority to current consumption and this may undermine environmental conservation (Holden *et al.*1998). Vulnerability of the poor to shocks, risks, or food insecurity increases with the extent of poverty they are in, leading to different livelihood strategies. Identifying poverty traps and persistent structural poverty using an asset–based approach is, therefore, important to better understand the role of poverty and vulnerability in households' choice of livelihood strategies and for designing better poverty reduction strategies (Carter and Barrett, 2006). Evidences from southern Ethiopia indicate that wealth and assets such as livestock holding, size of cultivated land, labour supply, and access to markets are important in the farm households' choice of different livelihood strategies (Demissie and Workneh, 2004).

Farmers, although with limited resources, use a variety of coping mechanisms that range from impoverishment to improving the natural resource base when facing land degradation and small land sizes (Scherr, 2000). However, the smallholders' land improvement activities can be adversely affected by imperfections in factor markets (de Janvry *et al.*1991; Udry, 1996). Rural markets in many developing countries are imperfect with implications on the efficiency in agricultural production and land resource management (Holden *et al.* 2001). The rural poor operating under imperfect labour markets and credit constraints may not be able to use land improving technology, but may employ more of the abundant labour for producing food crops even through land degrading production activities. Only those households with more capital may be able to adopt a capital intensive technology.

1.2. Population pressure, land degradation and farm intensification

Land degradation through soil erosion and nutrient depletion is recognized as a number one agricultural problem in developing countries, including Ethiopia (FAO, 1995; Drechsel *et al.* 2001a). Higher nutrient depletion rates have been recorded in the East African Highlands than other regions of SSA, and the major reason was attributed to high population pressure and

[1] The notion of poverty has been conceptualized in broad terms and multiple dimensions of human wellbeing, including not only material deprivation (measured by an appropriate concept of income or consumption) but also lack of access to education and health services, social and political exclusion and vulnerability and exposure to risk (World Bank, 2001). The concept of poverty used in this study agrees with these broad and multidimensional aspects of poverty, but as in many empirical studies measurement problems limit us to mainly focus on measurable aspects like income and asset poverty. However, as many studies have highlighted, there are important interactions between the different dimensions, making it possible to use assets and income as relevant proxies for deprivation of human wellbeing in the context of pervasive poverty prevalent among rural households in southern Ethiopia.

land-use intensity. The highlands of Burundi, Rwanda and Kenya were considered as the most affected areas in East Africa due to rural population densities exerting higher pressure through decreasing farm sizes and fallow periods on soil fertility (Drechsel *et al.* 2001a, 2001b). Ethiopia, with Haiti and Nepal, is an example of countries where population-driven upland degradation and at times ecological collapse has taken place in the world (FAO, 1995). According to Grepperud (1996), some highland areas of Ethiopia were turning to more severe soil erosion categories as the actual population exceeded the low-technology carrying capacity of the land.

The relationship between population growth and land degradation has long been contrasted by the Malthusian and Boserupian views. According to Malthus (1798), population grows exponentially while food production increases arithmetically. The size of landholding per person will decrease as population increases. The pressure due to intensification of marginal lands when expansion is no longer feasible will lead to a decline in per capita output and consequently income. The environment will also deteriorate due to over-utilization of the existing land and clearing of forest lands for more cultivable land, firewood and construction materials. This has been backed up by neo-Malthusians as they argue that people will continue to expand and destroy the capacity of the land in order to avoid starvation from declining production as a result of population pressure (Cleaver and Schreiber, 1994). According to these authors, rapid population growth is the principal factor for the downward spiral in environmental resource degradation, agricultural stagnation and poverty. Cleaver and Schreiber (1994) argued for strong synergies and causality chains between rapid population growth, land degradation and poor agricultural performance. FAO (1995) also considered population pressure as an important factor in determining vegetation loss, especially in areas with limited land reserves and energy sources. Overgrazing and improper agricultural management were also counted as major factors in land degradation.

However, the Malthusian view has been challenged by an opposing theory of induced innovation that views population pressure as an independent variable that stimulates productivity enhancing agricultural intensification (Boserup, 1965). According to this view, increasing population density will lead to more intensive land use systems through shortened fallow periods, increased investment in land, and soil fertility management. Some recent case studies (e.g., Machakos in Kenya) also confirm that population growth leads to agricultural intensification and land conservation thus reducing soil erosion (Kates *et al.* 1993; Tiffen *et* *al.* 1994). Such intensification may be delayed or fail to take place, however, due to lack of suitable technology or economic, institutional and policy conditions to favour the process (Boserup, 1965). Ruthenberg (1980) provides a farming systems analysis of the intensification processes in tropical farming systems resulting from increased population pressure and passing from shifting systems through fallow systems to permanent upland systems which include perennial crops and irrigation. Binswanger and Ruttan (1978) argued that agricultural intensification may not necessarily follow population growth as the adoption of technology remains low in many developing countries in Africa, resulting in declining yields. According to Scherr (2000), farmers first experience degradation and its welfare effects as population or market pressure increases but may not respond until the effects become more pronounced, and some responses may even destroy resources. Weak institutional development and poor functioning of land, labour and credit markets in many rural areas of developing countries limit capacity of the poor to mobilize labour, machinery, critical cash, or other resources even for highly profitable and effective investments (de Janvry *et al.* 1991; Reardon and Vosti, 1995). However, some case studies have shown that farmers even under severe population pressure have managed their lands with sustained use to date (Scoones and Toulmin, 1999).

The forgoing literature review has shown contrasting theories and case studies especially on the relation between population pressure, land degradation and farm intensification. On the one hand, Malthus and Boserup agree on the importance of population growth as a factor influencing people to act on their land resource. On the other hand, they seem to differ in anticipating the consequences on land resources and production of human responses to the population growth. Followers of each have tried to substantiate the theories through empirical studies. But no consensus has been reached as the empirical evidence is not uniform, some showing that the Boserup effect can not be achieved everywhere due to institutional limitations and market imperfections.

The major theoretical underpinnings discussed in the above also consider larger farming systems such as changes from shifting cultivation to fallow and thereby permanent cropping systems. This leaves us with some basic questions:

1. How are Malthusian and Boserupian theories relevant for rural highlands which are already densely populated, still facing high population growth rate, and with households operating small land sizes with low level of technology?

2. With limited non-farm employment and rapid population growth, will the farmers in these areas be able to follow Boserup's induced innovation hypothesis? What enabling environments are available or lacking for this to happen?

3. How do the smallholders intensify? Do they intensify through use of more labour, purchased inputs, irrigation or through crop choices and cropping patterns?

4. What land use strategies do the farmers follow in such situations of high population density and chronic poverty? Do they use land degrading or productivity and conservation enhancing strategies? What determines farmers' investments in productivity and conservation of land resources?

5. What determines the decisions of the farmers on production and harvesting of soil conserving perennial food crops?

These questions are far-reaching and need large-scale studies and probably time series data to be answered. However, this PhD dissertation, in the four papers included, attempts to address some of these issues and aims to provide new insights based on empirical evidence in a densely populated area of southern Ethiopia (Figure 1). The dissertation consists of four papers that assess the theoretical foundations and empirical arguments presented above. Together, they provide fresh insights and a better understanding of the constraints, opportunities and tradeoffs faced by smallholder farmers under high population pressure. The study area in southern Ethiopia, Wollaita, is one of the most densely populated areas in the country and perhaps in Africa with rain-fed, subsistence-oriented and agricultural-based livelihoods. The thesis, using farm household and plot level data from this area, fills a gap for the lack of plot level soil quality indicators in previous studies on farm size-productivity relationship (Paper I); assesses the role of asset poverty in farm households' decision to invest in a perennial food crop by specifically looking into a synergy between a perennial food crop, livestock and land assets (Paper II); extends the Faustmann rotation model to fit the local situation with imperfect markets and uses it to assess the harvesting decisions of the farm households for the perennial food crop (Paper III); and investigates how poverty and market imperfections affect farm households' willingness to invest in soil conservation (Paper IV). By way of motivating the reader, a brief summary of each paper is provided below, before some conclusions are drawn based on the key findings of all the four papers.

2. Summary of main findings

In this section, a summary of the four papers highlighting on the rationale, objectives, methods and major findings is presented. The reader is encouraged to see the full results in context. The underlying assumption in all the papers is that individual farm households allocate time and other resources in order to achieve utility or income maximization, given their resource endowments and constraints. A theoretical model that assumes farm households who operate under imperfect market conditions and asset poverty is used as a general decision framework. Primary data collected through a cross-sectional farm household survey from a densely populated village in southern Ethiopia is used for all the papers. The interpretation of analytical results was enriched through field observations and qualitative information gathered through discussions with farmers, researchers, policy makers and development agencies operating in the area.

Paper I: Between Malthus and Boserup: farm size-productivity relationship under population pressure

The aim of this paper is to analyze the relationship between farm size and land productivity under intense population pressure. We ask if higher levels of land use intensification may lead to an inverse farm size-productivity relationship. The paper extends past work using plot specific land quality attributes. We build a theoretical framework that reviews previous assumptions about the relationship between population pressure, farm size and intensification, and the roles of market imperfections, or heterogeneous land quality for the inverse farm size-productivity relationship.

Farm household and plot level data were used for the empirical analysis. First, we tested whether population pressure and market imperfections explain the inverse farm size-productivity relationship at the farm household level. Next, we applied a household random effects (RE) model on the plot level data and tested for the effects of observed plot quality attributes.

The results from farm household level analysis of the farm size-productivity relationship exhibited persistence of the inverse relationship for all the regressions that tested for different hypotheses such as labour market imperfections, population density, and asset poverty. The household level analysis did not fully support the labour market imperfection explanations for the inverse relationship; family workforce endowments were insignificant in all the regressions and their inclusion did not change the inverse relationship. This may indicate that labour is abundant while marginal returns to labour are very low. When we included a range of observable soil quality indicators in the regression, using plot level data, the inverse relationship became positive and statistically insignificant. These results imply that it is important to control for land quality when this type of analysis is carried out and analysis at plot level is preferable to be able to do this well. Matched plot panel data would be required to control for unobservable time-invariant plot characteristics.

An inverse relationship after controlling for land quality may reflect the increased intensification efforts undertaken by some households under conditions of land scarcity when markets are imperfect. In line with this, we included a dummy for presence of a perennial food crop and the amount of fertilizer applied on a plot in the regression. Both variables were positively and significantly related to productivity but the farm size variable was still insignificant although its positive sign increased in magnitude. The elasticity of productivity in response to population pressure was low, less than 0.5 and 0.3 at household and plot levels of analyses respectively. The intensification efforts of the households, most probably being constrained by credit market imperfections, lack of livestock, and asset poverty, were not sufficient to get them out of the Malthusian trap. Policies that enhance the availability and use of credit for productive purposes could help to boost the smallholders' intensification efforts through increased use of productivity-enhancing purchased inputs, e.g., fertilizer and improved seeds. This is important for increasing the propensity of households to cope with declining land availability under population pressure. However, also this strategy has clear limitation on the small farms in the study area given that the production is rain-fed and the population growth continues at a very high rate while off-farm employment opportunities are very limited.

Paper II: Too poor to invest? Poverty and farm intensification decisions in Southern Ethiopian highlands

This paper analyzes farm intensification decisions of smallholders by investigating how land scarcity, imperfect markets, available technologies, and livestock and land endowments shape farm intensification decisions. The rationale of the paper is to test whether asset poverty, market imperfections and subsistence constraints under land scarcity force farm households to intensify production in starchy perennials. Using a two-period intensification model with crop-livestock interactions, we investigated whether there are significant synergy effects between livestock and a perennial food crop (enset) and if poverty in livestock assets can lead to a poverty trap. Parametric and non-parametric methods such as fractional response, Tobit and OLS models and kernel density distributions were used in the empirical analyses of farm household data and to further test the links between asset poverty and farm intensification. In this paper, farm intensification is measured in terms of enset area share of cropped area and enset stock per unit of cropped area (see Figure 2 for the structure of enset).

The results indicated that increasing land scarcity contributed to intensification in the production of the perennial, and crop-livestock interactions facilitated the process of farm intensification. Livestock ownership appears to be a key to more successful intensification in response to population pressure even if land poverty also appears to stimulate investment in perennials. Livestock- and land-poor households appeared to be less able to intensify and got lower returns to their investment than more livestock-rich but land-poor households. The results also indicated that the most asset-poor household group had more limited access to off-farm income, has poorer access to formal credit markets and stood out with less crop production per consumer unit. However, the livestock change analysis revealed that this poorest household group also was able to rebuild their livestock endowments to the same level as other households after a few years, indicating an ability of breaking out of the household group-specific poverty trap.

Paper III: Are the poor forced to cut the branch they are sitting on? Perennial crop harvesting decisions of food insecure smallholders

This paper provides a comprehensive quantitative study on farm households' harvesting decisions of a perennial food crop, enset. The perennial is a staple starchy crop that takes 4-5 years to reach maturity, but evidence shows that many households harvest this crop before its physiological maturity, sometimes after less than two years. By doing so, they forgo some future consumption as they lose higher yield obtained from a mature plant. The paper assesses whether poor households are caught in a poverty trap and are compelled to cut down the seeds in order to meet immediate consumption needs. First, we calibrated a simple simulation model in order to assess the relevance of a Faustmann rotation model in our case study area. We used experimental production data to estimate a simple growth function for the starchy perennial crop, enset. The simulation results indicate, as expected, that higher discount rates shorten the rotation period.

With imperfect labour and land markets and borrowing constraints, individual households may have idiosyncratic discount rates, depending on their poverty status. This may imply different harvesting strategies in terms of rotation times. We therefore expanded the Faustmann rotation model to account for local situations and integrated this into our empirical analysis. Based on the expanded Faustmann optimal rotation model and using cross-sectional data, the empirical analysis investigated factors related to average rotation period, proportion of young plants harvested, and the number of young plants harvested. The econometric methods applied in the analysis include OLS, fractional response and Cragg's models.

The empirical study finds that food insecurity is the key driving factor for early harvesting of the starchy perennial crop. The results reveal that food insecure households could be in a vicious circle of food insecurity: early stage harvesting may help them to alleviate the immediate subsistence constraints, but it reduces future availability as fewer plants are saved to reach full maturity. The paper provides quantitative explanations for the underlying reasons for the early harvesting decisions. It also contributes to the existing literature on the application of the Faustmann rotation model in developing country conditions, using a perennial crop which has not been studied elsewhere.

Paper IV: Soil degradation, poverty, and farmers' willingness to invest in soil conservation

This paper analyzes farm households' perceptions of land degradation and their willingness to invest in soil conservation activities. Households consider soil erosion and nutrient depletion to be the most important land degradation problems on private farms in the study area, with gully formation being an additional problem on communal land. About 45% of the sample households ranked soil erosion as the most serious problem on their farms followed by nutrient depletion (41%).

Based on assumptions of land and labour market imperfections and thus non-separability of production and consumption decisions, we used a two-period investment model (Bellman equation) to identify the determinants of farm households' willingness to invest in soil conservation on their private farms. The contingent valuation method (CVM) was used to elicit farmers' willingness to invest in soil conservation in terms of in-kind labour contribution and cash payments, the two possible payment vehicles.

Both OLS and Tobit regression results for the willingness to invest in soil conservation on private farms in terms of labour contribution and cash payments indicate that livestock wealth in tropical livestock units (TLU) has positive correlation with the willingness to pay (WTP) both in labour days and in cash. The econometric results revealed that a unit increase in TLU would lead to an increase in WTP by 7.84 birr and 27 person days. The results also indicated that the shadow wage rates are very low which could be attributed to labour abundance, limited employment opportunities and financial constraints in the area. Methodologically, the WTP studies that employ both labour and cash as payment vehicles could provide more sensible results than those using only cash. Farm households are generally willing to invest in beneficial conservation practices that are less cash-intensive and able to use locally available labour resources.

3. Conclusions and some policy implications

3.1. Conclusions

Farm households in the highlands of southern Ethiopia, including Gununo, are largely subsistence farmers who struggle to feed their growing family size with meager produce from declining farmland. They operate under conditions of asset poverty, and their land resource is degraded by erosion and nutrient depletion. Non-farm employment is limited and markets for labour, land, and credit are imperfect.

Our findings from Paper I have shown that despite some evidence of intensification in the area, there was no autonomous technical change resulting from the process of induced innovation. Although the household level farm size-productivity relationship showed an inverse relationship, it vanished with inclusion of land quality attributes in the plot level analysis. Intensification strategies of the poor in terms of fertilizer use and other improved technologies are constrained by financial limitations and asset poverty. Another important finding of future interest is the household intensification strategy pursued through investing in a starchy perennial crop which is at the same time productivity enhancing, land conserving, and important for family food security. Paper II has taken further account of this finding and investigated the relationship between intensification of the perennial crop and asset poverty. It finds a positive and significant synergy between productivity of this crop and livestock ownership, facilitating the process of intensification. These findings lead us to conclude that although land scarcity could lead to farm intensification, livestock assets play a major role in this process. Livestock-and land-poor farmers had lower land productivity and lower returns to their scarce resources while livestock-rich but land-poor households had higher land productivities. Paper III also concluded that the starchy perennial crop (enset) is a food security crop which is harvested by poor households even at its immature stage to meet immediate family needs. The consumption needs of large households and persistent food insecurity problems in the area enhanced the early harvesting of this crop by the poor, leaving less for the future. As paper IV concludes, the capacity of the farm households to invest in soil conservation is constrained by asset poverty and liquidity constraints. Their willingness to invest in labour or cash increases with livestock wealth and non-farm income motivates cash payments for soil conservation. However, employment opportunities are limited, making labour relatively more abundant (low shadow wages for family workers) and cash more scarce.

What perspectives do these findings offer for the future smallholder farming in Gununo and similar areas? The livelihood strategies of many farm households seem to be determined by asset endowments (e.g., land and livestock) and many families seem to be caught up in the poverty trap. The elasticity of production with respect to population density was 0.45 for our household level analysis and 0.23 for the plot level analysis. This indicates a low productivity response to population pressure, indicating only a modest intensification to cope with decreasing land availability. Will this be sufficient for large number of households to escape the poverty trap? What solutions can we foresee to bring them out of this stagnation and negative trend in income per capita? And what policies may help induce a more elastic response to population pressure and facilitate more sustainable and productivity-enhancing intensification?

3.2. Some policy implications

In considering development pathways out of poverty it would be useful to consider the productive assets that households have (e.g., labor, land and livestock). If we start with the basic resource, land, the major bottleneck is land scarcity. The option of changing the actual land size through clearing new agricultural land is no longer possible, and irrigation is not an immediate option due to absence of easily divertible rivers. Technological and institutional changes seem to be the remaining options. Technological options refer to application of new technologies, such as high-yielding varieties that are resistant to pests and diseases and droughts, improved livestock breeds, and more productive land management. Institutional options include land reforms, market linkages and contract farming arrangements, credit provision, and expanding opportunities for off-farm employment to absorb surplus labor.

In line with these, the following development pathways are suggested for Gununo farmers.

1. *Building agro-forestry systems with improved livestock and forage development*

   Agro-forestry systems with early maturing perennials could be a possible solution for such densely populated land scarce areas. This includes both food and cash perennial crops such as enset, coffee, and various fruit crops. These can be integrated with existing root-crop system by way of intercropping. Agro-forestry practices with green manuring can help not only to improve production but also to enhance land quality for sustainable food supply. An important integration to this system is to start intensive livestock husbandry with improved livestock breeds and forage development. The positive synergy between enset and livestock where the latter provides manure for crop production and crop residues are used as feed for livestock strongly supports this strategy. What is needed is a concerted policy effort to introduce improved breeds, forage species and early maturing and nutritious perennial crops. Focusing on forages that conserve soil fertility on the one hand and provide feed and fodder for livestock on the other is important to further develop the integration of fodder and crop production.

2. *Strengthening off-farm income activities and enabling institutions*

   Off-farm income generation will create additional income sources, but may also be used to boost agricultural production or to shift to agro-industry sector. Development policies such as rural electrification, credit provision, capacity development in business skills and education for children are needed to induce and accelerate this process, along with investments in rural enterprises and agri-business development. Non-farm activities like petty trade in agricultural and non-agricultural commodities are possible income strategies for the asset-poor households. This can be further enhanced if capital constraints are addressed and infrastructure is developed to reduce transaction costs. An important corollary to this would be to define policy options that strengthen linkages between the farm and non-farm sectors through clearly defined rights to land and farm-level investments.

According to a recent study in Southern Ethiopia (Holden and Tefera, 2008), family size has a direct negative effect on income welfare of the rural households. The study also documented the recent 'Rural Land Administration and Use Proclamations' by the Ethiopian government and implementation processes in different regions including Southern Ethiopia. According to the proclamations, the minimum size of land which is given to a household shall not be less than 0.5 hectare for annual crops and 0.25 for perennials, while irrigated land cannot exceed 0.5 hectare (ibid). While such proclamations and implementation processes are found promising, they may need further clarifications and local specific strategies for proper implementations in areas with mixed crop-livestock, annual-perennial systems where the average land ownership is already below 0.5 hectares but average family size has reached more than 7 persons.

3. *Establishing market linkages*

In order to build agro-forestry systems which sustain production and flourishing non-farm activities, we need a functioning market system where inputs and outputs are easily exchanged. Improved livestock and perennial crop production needs more inputs but also brings extra production for markets. Linking the farmers to input and output markets becomes essential in this process. The policy measures may include improvements in infrastructure (e.g. road), seed supply mechanisms for new varieties or improved breeds, crop and animal health control services, strengthening of local institutions for marketing, credit schemes, and storage services. Supporting farmers to enhance production and processing of enset for the type of product that has high demand in the national market (e.g. bulla and kocho) is one specific option for the area. Policies that facilitate market conditions while encouraging sustainable land use in the area are crucial (Templeton and Scherr, 1999).

4. *Promoting suitable conservation and water harvesting efforts*

As mentioned above, the agro-forestry system will generally help to conserve the soil resource in addition to sustaining production. However, promotion of conservation activities that combine locally available materials such as green manuring, composting, and mulching with terracing or soil bunds are also needed. Fertilizer use should be complemented with these water conserving techniques if needed to be productive without depleting soil nutrients. Another important strategy is to utilize the seasonally available surface water and groundwater resources for small-scale complimentary irrigation. This is being attempted in several semi-arid areas of Ethiopia through community based watershed management programs. An important policy implication for this is that extension workers need to share knowledge with farmers regarding these integrated approaches to land and water management and help them in choosing appropriate and cost-effective methods and designing effective farmer organization for collective action. The role of researchers in finding appropriate intercropping and mixed cropping techniques in consultation with the farmers is equally important. Research is needed to develop useful prototypes and models on different water harvesting techniques for the suggested development pathways to be successful.

5. *Providing family planning services*

Curbing of population growth through family planning is an important step that needs to be considered together with those measures raised in the foregoing sections. However, various cultural factors, religious beliefs and demand for more children as family workforce may limit successfulness of family planning in a given community. Thus, family planning services should be planned carefully, starting with awareness creation, education and step wise implementation of the services.

Finally, realizing more productive and sustainable development pathways would require interventions at different levels to relax multiple constraints. This calls for a concerted and collaborative effort by policy makers, researchers, development workers (governmental and non-governmental), the private sector and the farmers themselves to unleash new opportunities and create incentives for farmers to invest in development pathways out of poverty and technological stagnation.

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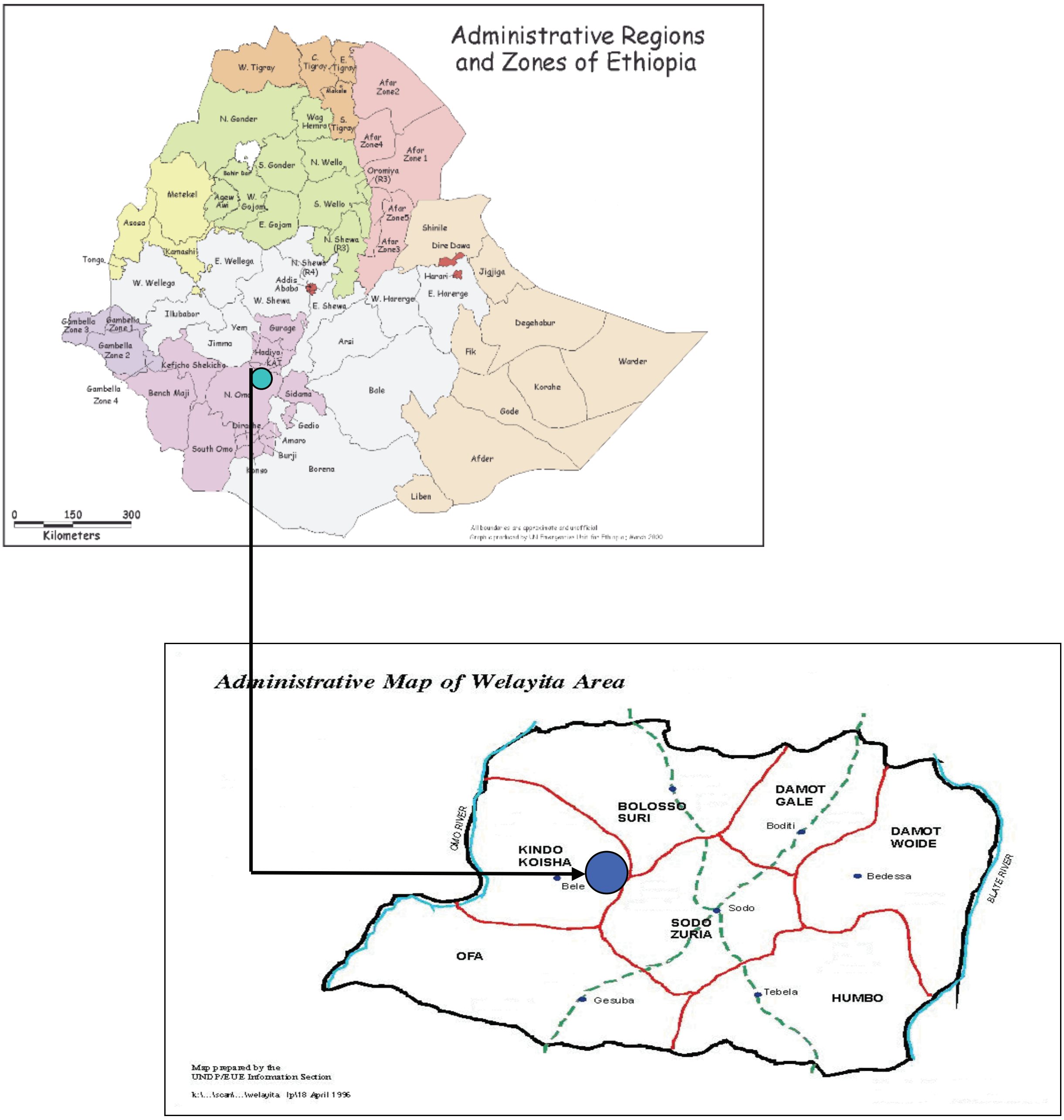
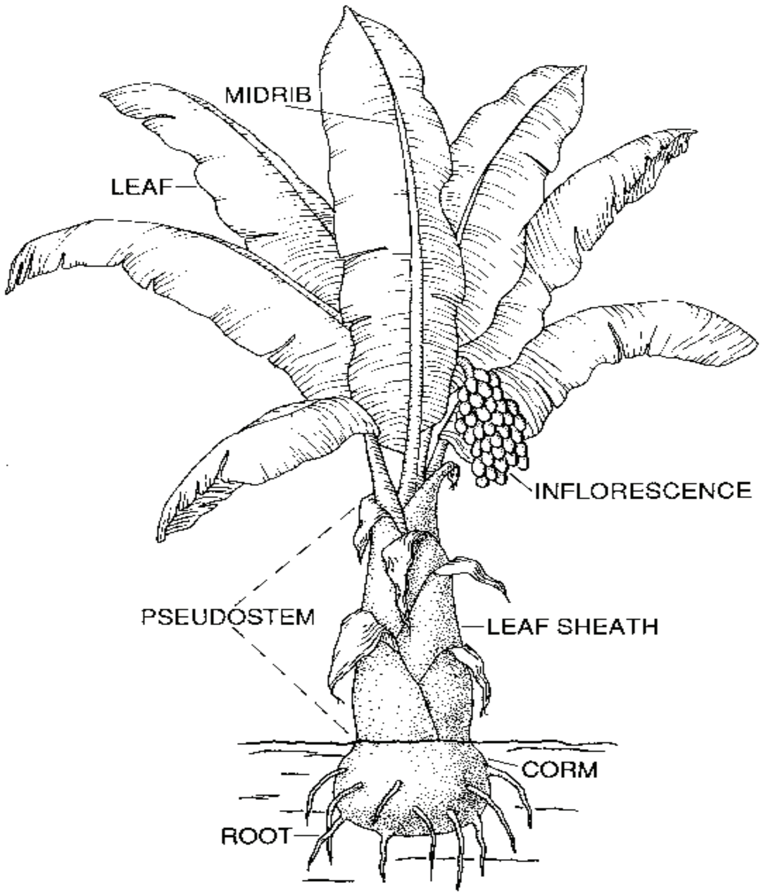


Legend: SNNPR Study zone (Wolaita) Study area

Figure 1: Location of the study area



From Brandt *et al.* 1997

Figure 2: The structure of enset plant and its parts

Paper I……

Between Malthus and Boserup: Farm size-productivity relationship under population pressure

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Abstract

Most national, regional and village level studies on the farm size-productivity relationship have suffered from lack of data to directly control for effects of land quality differences. Most of these studies also attribute the inverse farm size-productivity relationship to market imperfections. We use farm household and plot level data collected from a densely populated village in Southern Ethiopia to assess whether market imperfections or observed plot attributes can explain the inverse relationship. At farm level we assess the extent to which the inverse relationship can be explained by expansion of cropped area or by increasing yields on cropped area and whether market imperfections can explain the inverse relationship. The plot level data allows testing the inverse relationship in yield response when controlling for observable land quality variables. The farm household level analysis revealed an inverse relationship (IR) between farm size and land productivity both in the area expansion and yield response models with an overall elasticity of productivity to population pressure that was less than one (0.45). The inverse relationship could be attributed to labour market imperfections. The significance of the IR disappeared in the yield analysis at the plot level when controlling for land quality and this reduced the population pressure response elasticity in yields at plot level from 0.23 to zero. The study thus reveals added insights by combining analysis at farm household and plot levels. Both market imperfections and land quality contribute to explain the inverse relationship in the study area but market imperfections also contribute to reduce the inverse relationship.

JEL classification: C21, C23, Q12

Key words: farm size; productivity; inverse relationship; subsistence agriculture; Ethiopia.

1. Introduction

About 88% of Ethiopia's population is living in the highlands that constitute over 95% of the regularly cultivated land (FAO, 1986). These areas have high population pressure leading to

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continuous cultivation practices (Shiferaw, 1998; Elias, 2002). As population increases, farm size reduces either due to partitioning in the inheritance process (Kuhnen, 1998) or due to land redistributions. This leads to shortened fallow periods or even to permanent cultivation systems. However, the effects of population growth on agricultural productivity are argued differently. The Malthusian hypothesis considers the imbalance between population and food production, under constant agricultural productivity, as a threat to human survival (Malthus, 1798) while Boserup (1965) viewed population growth as a precondition for development since it eventually forces the society to intensify land use. According to the latter, increasing population density will lead to more intensive land use systems through shortened fallow periods, increased investment in land, soil fertility management (manuring), and shifts from hoe cultivation to animal traction. The latter activity of moving from hoe cultivation to animal traction could, however, be reversed at an extreme situation of land shortage when small sizes become uneconomical for mechanization.

Using farm household data collected in 1999, we have examined the relationship between farm size and productivity in a densely populated highland area of Southern Ethiopia. The area is typically characterized not only by high population density but also by a rapid annual population growth rate of 4.8% (Elias, 2002). As a result, the land area under cultivation increased from 50% in 1988 to about 81% in 2001 (Figure 1). This has led to a decline in land under bush and trees from 13% to about 2% and, in the same period, grassland has also declined from 37% to 13%. The average landholding is about half a hectare and technological change is nearly stagnant.

Some previous studies on the relationship between farm size and land productivity have compared small farms with big mechanized farms where supervision of hired labour may cause less use of labour on large farms and this may lead to an inverse relationship (IR) between farm size and land productivity. In our study area, however, all farms are small but we investigate whether an inverse relationship can also be found among such small farms in response to varying farm level population pressure. We investigate if the IR occurs due to labour market imperfections leading to application of more family labour on smaller farms or due to subsistence constraints such that food requirements of households have led them to intensified food production, as farm size gets smaller.

An inverse relationship would also indicate that intensification options still exist, implying that marginal returns to non-land factors of production are still positive, and markets for these non-land factors do not function well. If population pressure (or land scarcity) leads to intensification through use of more labour per unit of land without use of more of other yield enhancing inputs, this may also indicate imperfection in credit markets that prevent the use of fertilizer and improved seeds. If land scarcity leads to more use of labour and other non-land inputs (e.g. fertilizer, seeds) per unit of land, then this may lead to the Boserup-type of intensification which entails technical change. Here, we adopt the type of definition used by Holden, *et al.*, (2005) to distinguish between Boserupian and Malthusian development paths. For the Boserupian path, income should grow faster than the population with utility growing over time. Utility or income per capita declines over time if the Malthusian path is in place. We specifically consider productivity response to population pressure by looking into the approximate percentage change in productivity brought by a 1% increase in population density where farm level population density is calculated as consumer units per total farm size. If this productivity-population elasticity is greater than one, then a Boserupian development pathway holds.

This study benefits from using both household and plot level data. Household level data is used to assess the relationship between total farm size and average crop output per total farm size, area share cropped and average yield on area cropped. This captures two types of intensification, cropped area expansion within farms and yield increase on cropped land. In Africa the majority of production increase has taken place through area expansion but in the study area, area expansion is moving towards its limits. Plot level data is used to further examine the yield response and controlling for whether IR relationship in yield response on cropped land may be explained by smaller farms having better land quality. Lack of such a test has been a weakness of many earlier studies of the IR relationship at regional and village level (Heltberg, 1998; Benjamin, 1995). Using cross-sectional data from farm households in one area comprising of only two adjacent Peasant Associations (PAs - the lowest administrative units in the rural setting), has also an advantage of facing no or minimum problems regarding heterogeneity due to climate, infrastructure, market access and other environmental factors. We can generally consider them as one big village.

The rest of the paper is organized as follows. Section 2 provides a theoretical framework. Section 3 describes the study area and the data. Section 4 deals with econometric estimations and variable specification. Section 5 discusses the results and Section 6 concludes.

2. Theoretical framework

Many studies conducted in developing countries support the view that there is an inverse relationship (IR) between farm size and land productivity (Berry and Cline, 1979; Carter, 1984; Barrett 1996; Benjamin and Brandt, 2002). However, their explanations differ. Some attribute the inverse relationship to surplus family labour (Carter, 1984; Reardon et al., 1996) or to supervision constraint on hired labour (Heltberg, 1998) while others attribute it to unobserved land quality (Bhalla and Roy, 1988; Benjamin, 1995). Byiringiro and Reardon (1996) account the inverse relationship to higher land conservation efforts on small farms. Recently, Assuncao and Ghatak (2003) showed that heterogeneity in farmer skills and imperfect credit markets could lead to the inverse relationship. Both Lamb (2003) and Chen *et al.,* (2003) attributed the inverse relationship in smallholder agriculture to a combination of factors such as heterogeneous land quality, market imperfections and measurement error in the farm size variable.

In the following sub-sections, we re-visit some of these issues and provide a theoretical framework that would enable us to assess the farm size-land productivity relationship in the study area.

2.1. Population pressure, farm size and intensification

According to the Malthusian hypothesis, increased food production will spark off population growth until further increases in food production are limited by a stagnant production capacity of land while increased population density will expose the rural households to starvation and migration (Malthus, 1798). According to Boserup (1965), however, population growth is independent of food production and is the key determinant of land use intensification. It leads to smaller land holdings that will be intensified with more purchased inputs and other technologies and thereby increase land productivity. Following Boserup, several studies took place in developing countries seeking for explanations for the impact of population on agricultural intensification or agricultural development at large (Kates *et al.,* 1993; Tifften *et al.* 1994; Christiansen *et al.,* 1995; Meertens *et al.,* 1996). Intensification can take place in different forms. Ruthenberg (1980) provides a broad farming systems analysis of intensification processes in tropical farming systems resulting from increased population pressure as passing from shifting systems through fallow systems to permanent upland systems which include perennial crops and use of irrigation. Kates *et al.*, (1993:7) defined intensification as "increased utilization or productivity of land currently under production". This could take place through either increased cultivation frequency on land within cultivation cycle (area intensification), application of higher labour input per area unit (labour intensification) or use of higher capital input per area unit (capital intensification). In a nutshell, factors such as labour, fallow, yield, technology and population density could be considered as key indicators of intensification.

When average grain production per farm size falls as the size of the farm increases, it implies the inverse relationship (IR) between farm size and land productivity. We see from eqn. (1) that the IR relationship at farm level can be split in a yield effect and area expansion effect as farm sizes get smaller. The yield effect ($\frac{\partial q}{\partial A}$) may come from more use of inputs (*I*) per unit land cropped. In this case, intensity of farm input or technology use is inversely related to farm size:

$$\begin{gathered}\frac{Q}{A} \equiv \frac{Q}{A^*} * \frac{A^*}{A} \equiv q * \frac{A^*}{A} \\ \frac{\partial\left(\frac{Q}{A}\right)}{\partial A} \equiv \frac{\partial q}{\partial A} + \frac{\partial\left(\frac{A^*}{A}\right)}{\partial A} \\ \frac{\partial\left(\frac{I}{A}\right)}{\partial A} < 0 \Rightarrow \frac{\partial q}{\partial A} < 0\end{gathered} \tag{1}$$

where Q stands for crop output, $\frac{I}{A}$ indicates input use intensity, q is yield, A is farm size and A^* is cultivated area. This implies that intensity of production and productivity should be higher on smaller farms than on larger farms in an area. Holden and Yohannes (2002) asserted that this effect may appear in cross-section data when local factor markets are imperfect.

With perfect markets, intensification could mean more use of inputs and credit over time but the IR would not be observable in a cross-section. But these may not be the choices that farm households can make, given imperfect markets. With missing labour, land, and oxen rental markets, farm households with smaller farms will intensify by using all their labour in their farm activities. As Pagiola and Holden (2001) and Holden *et al*., (2001) have demonstrated, we can model the following simple production function to explain this.

$$Q = Aq\left(\frac{L}{A},\frac{O}{A},\frac{O^i}{A},H^z\right) \tag{2}$$

where $q(.)$ for yield function, L is family labour input, O is oxen traction input, O^i stands for other inputs or technologies, H^z refers to fixed farm and household characteristics, and others are as defined above. The inverse relationship between farm size and productivity can be shown as:

$$\frac{\partial\left(\frac{Q}{A}\right)}{\partial A} < 0 \text{ may imply } \frac{\partial q}{\partial A} < 0 \text{ or } \partial\frac{\left(\frac{A^*}{A}\right)}{\partial A} < 0 \text{ or both.} \tag{3}$$

A strong IR is necessary to avoid the Malthusian trap with population growth if there are few or no off-farm opportunities. Farm level population pressure may be expressed as consumer units (*C*) per farm size:

$$\frac{\partial\left(\frac{Q}{A}\right)\left(\frac{C}{A}\right)}{\partial\left(\frac{C}{A}\right)\left(\frac{Q}{A}\right)} \text{ is } \begin{Bmatrix} >1 \text{ if Boserupian path} \\ <1 \text{ if Malthusian path} \end{Bmatrix}$$

An extremely strong Malthusian scenario would be required for there not to be an IR relationship in such a constrained economy. Households with small farms may not be able to use intensifying technology due to cash constraints or lack of access to credit and this could push them in this direction when area expansion opportunities are exhausted. On what follows, more explanations and a framework for assessing the implications of market imperfections on productivity are provided.

2.2. Market imperfections and the inverse relationship

The implications of market imperfections on productivity have been studied in different parts of the world (de Janvry *et al*., 1991; Barrett, 1996; Udry, 1996; Heltberg, 1998; Holden *et al*., 2001). Holden *et al*., (2001), in their study carried out in villages of the Ethiopian highlands, found that land and labour market imperfections affected productivity. However, they did not find a significant inverse farm size-productivity relationship, and they attributed this to the small variation in farm sizes in the study area. Such variation is likely to be smaller in areas where land redistributions have been used more recently to balance the relation between farm sizes and household sizes. In their study area such redistribution had taken place very recently. In our study area, the last redistribution was before 1979. Since then, only new households were receiving land from PA's common land and mainly from their parents through inheritance.

In many developing countries, markets for land may be thin or non-existent. For example, land in Ethiopia is state property and cannot be sold. This may contribute to the failure of farm households to adjust their own holdings to their family labour (Heltberg, 1998). Alternatively, farm households may engage into land renting. However, land rental markets are also subject to imperfections due to sharecropping arrangements or interlinked markets (Kassie and Holden, 2007) and tenure insecurity (Alemu, 1999). Land rental markets that operate through share tenancy do not clear like ordinary markets, as the price mechanism does not function like in ordinary markets. Several studies have revealed high transaction costs in land rental markets in Ethiopia (Ghebru and Holden in press; Deininger *et al*., in press).

Labour market imperfections are due to either imperfect information in labour search that may lead to misallocation of labour, moral hazard related to hired labour (labour activities are complex and difficult to monitor), seasonality in demand for labour in rain-fed agriculture or limited off-farm employment opportunities (Binswanger and Rosenzweig, 1986). While small farmers rely mainly on family labour, relatively larger farmers may depend on hired labour that may face moral hazard problems. Whenever there is no off-farm employment opportunity and an alternative source of income for the family members to meet subsistence needs, smallholders have no choice but use the entire workforce in operating their farm, regardless of efficiency.

Consider a simple household model where the household has the following utility function:

$$U = U\left(Y, L_e\right) \tag{4}$$

where, Y refers to income from crop production after variable costs, it is restricted form of profit; L_e is leisure.

The production function from where Y is derived is simply an extension of the yield function in equation (2):

$$Q = Q\left(\overline{A}, L, O^x, O^{pi}, O^{npi}, H^z, H^k\right) \tag{5}$$

Subject to cash constraint for purchased inputs: $O^{pi} = O^{pi}\left(FI, NFI, Cr\right)$

where Q is quantity produced, $\overline{A}$ is fixed land, L is labour input, O^{x} is oxen (traction power), O^{pi} is other purchased farm inputs and is a function of credit (Cr), farm (FI) and non-farm (NFI) income. O^{npi} is other non-purchased farm inputs, H^{z} H^{k} refer to fixed household and farm characteristics, respectively.

We assume a well behaved production function: $Q_i = \dfrac{\partial Q}{\partial i} > 0, Q_{ii} < 0$. We assume imperfect substitutability between the inputs and diminishing returns to variable input. Assuming missing land and labour markets and credit market imperfections, Y depends on land, labour input (L), output prices (p_q), and prices of purchased inputs (p_x):

$$Y = Y\left(p_q, \overline{A}, L, p_x\right) \tag{6}$$

Subject to labour constraint:

$$L + L_e = T$$

Now, the household's utility maximization problem can be expressed as:

$$U = \max_{L, L_e, O^{pi}} U\left(\left[p_q Q\left(\overline{A}, L, O^{pi}\right) - p_x O^{pi}\right], L_e\right) \tag{7}$$

By solving the first-order conditions (FOCs) from the utility maximization, we find the point where the marginal value product of labour equals the shadow wage rate ($\omega*$)[2].

$$p_q \frac{\partial Q}{\partial L} = \frac{\partial U}{\partial L_e} \Big/ \frac{\partial U}{\partial Y} = \omega* \tag{8}$$

where $\dfrac{\partial Q}{\partial L} > 0, \dfrac{\partial^2 Q}{\partial L^2} < 0$

How is the shadow wage affected by the endowments of land and family time? Consider two households with the same family labour endowment but different farm sizes. Large farms have a lower marginal utility of income or a higher marginal utility of leisure for the same amount of family labour endowment while small farms have the opposite. Figure 2 indicates that the household with a smaller farm reaches the point where marginal value product of labour equals the shadow wage rate ($\omega*$) at a lower level of shadow wage/marginal value product. This implies that households with small farms allocate more family labour on farm and thus have higher output per unit of land. There is a positive marginal return to labour as long as they work more per unit of land and provided that land quality is the same.

The use of purchased inputs is also credit constrained. The FOC for the purchased inputs is:

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[2] Marginal utility of leisure divided by the marginal utility of income gives a shadow wage rate.

$$\frac{\partial U}{\partial O^{pi}} = \frac{\partial U}{\partial Y}\left(p_q \frac{\partial Q}{\partial O^{pi}} - p_x \right) = \left[p_q \frac{\partial Q}{\partial O^{pi}\left(Cr, FI, NFI\right)} \right] - p_x = 0 \tag{9}$$

Equation (9) indicates that the household will intensify using purchased inputs when the marginal value product of the input is equal to its marginal cost (unit price). The left side of the last term shows, however, the use of purchased input is dependent on credit availability or liquidity constraints.

2.3. Heterogeneous land quality and the inverse relationship

It is obvious that land productivity is directly affected by its quality among other factors. Many national, regional and district level studies have suffered from lack of farm specific data to control for land quality when analyzing the farm size-productivity relationship. Bhalla and Roy (1988) recommended the use of more geographically disaggregated data in order to efficiently capture the unobserved soil fertility effects. Other studies (Benjamin, 1995; Chen et al., 2003) used the instrumental variable approach to control for land quality when testing for the inverse farm size-productivity relationship. Heltberg (1998) used two-way fixed effects on a household panel data set from Pakistan to control for time invariant land quality through household fixed effects, and yet he underlined the difficulty to successfully control for the unobserved land quality when analyzing national and regional data.

As mentioned in the introduction, our analysis is based on data from a village survey where household and plot level land use and land quality information has been collected in detail. The analysis carried out at plot level allows us to control for observable land quality by incorporating a range of land quality indicators. Plot sizes were measured using measurement tapes during the field survey, making this dataset better than typical farm household data collected in African conditions. Based on the cross-sectional sample collected from one area, we expect no or minimum unobserved heterogeneity due to climate, environmental factors, infrastructure or access to markets. Within village-heterogeneity due to household characteristics (e.g. ability) or other socio-economic factors (e.g. preferential access to credit by those participating in extension package) cannot be ruled out. For the latter case, we control for these factors in our analysis of the inverse relationship.

2.4. Hypotheses

Based on the theoretical framework and conditions discussed above, we hypothesize the following:

H1: Smaller farms with relatively more family labour endowment, if faced with imperfections in the land and labour markets, use more family labour per unit land or expand the area under crop production and that leads to the inverse relationship (IR).

H2: Smaller farms intensify through the use of other inputs or technologies, like fertilizer, or by switching to other crops that provide higher returns per unit of available land[3].

Hypotheses H1 and H2 pull in direction of a Boserupian development pathway and a strong IR would be consistent with this.

H3: Households with smaller farms are poorer (Malthusian hypothesis) and have lower income /capita than those with larger farms because they are unable to fully compensate for the smaller farm sizes through intensification by increasing yields because:

H3a: Smaller farms have poorer access to credit

H3b: Poor credit access limits use of purchased inputs

H3c: Smaller farms use less purchased inputs per unit of land

H3d: Smaller farms have lower yields than larger farms unless they use more labour to substitute for the lower levels of purchased inputs

H3e: Poorer access to credit for purchased inputs causes households with smaller farms to use more labour as a substitute for purchased inputs[4]

H4: The yield part of the inverse farm size-productivity relationship at farm level is explained by unobserved land quality. Smaller farms are characterized by better land quality.

H4a. The inverse relationship disappears when the analysis is done with farm plot level data and plot level land quality variables are included.

If H3 and H4 are true, there will be only a weak or non-existing IR and this is consistent with a strong Malthusian or neo-Malthusian development pathway.

[3]The crop choice could also be tied to hypothesis 1 as some crops like enset may require more labour per unit land but also give more output value per unit land.

[4] This implies that the elasticity of substitution between inputs matters for the outcome and degree of substitution.

3. Description of the study area and data

The data used for this study were collected as part of a large farm household survey for an EU-Project on 'Economic Policy Reforms, Agricultural Incentives and Soil Degradation in Less Developed Countries'. The data were collected from a random sample of 142 households in two adjacent Peasant Associations (PAs) in Gununo, a highland area in Kindo Koisha Wereda, Wollaita administrative zone of Southern Ethiopia, located about 405 km south of Addis Ababa. The survey was carried out during the summer of 1999 in collaboration between Awassa College of Agriculture and the Agricultural University of Norway, currently the Norwegian University of Life Sciences (UMB). The farm-household level data included a wide range of farm household characteristics such as household composition and structure, household consumption expenditure, expenditure on farm inputs, crop and livestock production, crop and livestock sales and purchases, credit, off-farm income sources, household preferences and perceptions. Data on biophysical and technology characteristics such as plot history, crop production, fertilizer and manure use, sharecropping activities, land quality and degradation indicators, conservation activities, and perennial crop inventory were collected at plot level. Data from 141 farm households were used for this study; one household was dropped from our analysis since information on plot level land quality indicators for this farm household was not complete. For plot level analysis, we used data from 557 cropped plots operated by these 141 farm households.

Gununo is one of the most densely populated areas in Ethiopia. According to the population census of 1994 (CSA, 1996), the population density in the study area was 575 persons/km^2 which was much higher than the national average density of 84 persons/km^2 (Elias, 1998). We also calculated the density for 2001 based on the population and land data found from the Gununo Development Agent Office and found a density of 756 persons/km^2. However, the farm level population density, as we calculated from our farm household sample in 1999, was as high as 1685 persons/km^2. The average family size for the sample households was 7.5 persons with about 54% of the sample population at the age of 15 or younger, which could indicate a high rate of population growth in the area. A recent study also indicated that the annual growth rate in the study area is very high (4.8%) compared to the national rate, which is about 3% (Elias, 2002). This has an important implication given the diminutive landholdings and low level of technologies used in the area. An average land holding of about 0.63 ha has been recorded for the area in 1987 (Belay, 1992), and average size of own land holding for the sample households in 1999 was 0.45ha. The distinction between small and large farms in the study area is relative (Table 1), only 2 out of 141 sample household farms slightly exceeded 2 hectares. The kernel density distributions for farm size per capita and total farm size in *timad*[5] are skewed (see Figures 3 and 4).

In Table 1, we divide the households into four equal sized groups based on the farm size per consumer unit. The descriptive statistics for household level data indicates that 50% of the households (the first two quartiles) own land below the sample average holding, i.e., less than 1.82 *timad*. Those households in extreme land poverty, who own 0.62 *timad* on average, were composed of relatively young household heads with an average age of 39 years and with an average family size of nearly the same as the overall average size. But they have more workforce and oxen per unit area of land than other groups. This group also used more inputs (labour, manure and oxen) per unit area of land except for fertilizer. Fertilizer use per unit area of land did not show any regular pattern, which could be a result of rationing through extension packages. However, households with higher landholding have applied more fertilizer per unit land compared with the extreme land poor group. On the other hand, the number of young enset plants per unit area of land is declining with farm size per consumer unit, and this may indicate that smaller farms are intensifying through this high calorie food crop to fulfill their food needs. Although land productivity in terms of total value of crops in birr/*timad* declined with farm size/consumer unit, returns to labour increased with farm size/consumer units. Consistent with our theoretical framework (equation 8), the marginal return to labour remained positive but decreasing with increasing labour input per unit of land. Similarly, the land-poor group seems to have higher income per unit area of land than the land-rich group, but it has lower income per capita. These results may have implications for interpretations of the econometric relationships and results that we are going to turn to in the following sections.

The farm households utilize their small holdings by practicing intercropping, relay cropping, and crop rotation. Fallowing in the study area is very rare. Taking the advantage of bi-modal rains, Gununo farmers grow a wide range of crops. They grow perennial crops such as coffee and enset very close to homesteads where they add farmyard manure while annual crops, such as root crops, cereals and pulses are grown in the fields far away from the houses. As land sale is illegal and all land is state owned in Ethiopia, land rental markets play an alternative

[5] One *timad* is a quarter of a hectare.

role to balance factor ratios. However, participation in land rental markets in the area is low, only 7% of the 141 sample households rented in land while 13% have rented out. During our interview, households expressed their interest to rent in land if available in the vicinity. Due to water erosion and continuous cultivation, the area has serious nutrient depletion problems. Most nutrients and organic matter in the agriculturally most important soils in the area (Eutric Nitosols) are said to be concentrated within the top few centimeters of the soil, exposing it to erosion that may cause a decline in productivity (Belay, 1992; SCRP, 1996).

Due to land scarcity, the average cattle holding per household is not more than 4 animals. Feeding is mainly through saved crop-residue, cut and carry system or by tethering in front yards or private grass lands. The households keep livestock for draught power, dairy and meat products, manure, transport, prestige, and for security during emergencies. Cattle constitute the major part of the household herd, oxen playing an important role for traction while cows are kept for breeding and dairy products. Farmers in Gununo use both oxen plow and hoe cultivation methods in their farming activities. Hoe cultivation is practiced perhaps due to small farms that do not require traction power and for perennials such as enset. However, about 58% of the households do not own oxen (Table 1) and the oxen rental market is limited as only 7% of the households participated in oxen rental markets (Table 2). They also depend mainly on family labour. Only 9% of the sample households have hired in labour during the study period (Table 2). Non-participation of the majority (81%) of the sample households in the labour market may indicate the existence of labour market imperfections in the area. This may also be due to the fact that farms are small and the need for hired labour is low. This limits opportunities for exploiting labour markets to reduce disguised unemployment.

The extent of non-participation in labour, land and oxen rental markets (81%, 80.3% and 93%, respectively) indicates severe factor market imperfections in the study area. But markets for food crops seem to function relatively better. About 97% of the households participated in buying and 53% in selling food crops, although these are limited to local markets[6]. Access to formal credit is limited and mainly linked to fertilizer and improved seed supply through extension package. But, farmers receive credit from relatives and local institutions for consumption smoothing, family events and other investments. Off-farm activities are also limited in the area, indicating under-developed markets and high transaction costs that limit

[6] Food crop markets may not be equally well developed for all crops.

trade in non-agricultural activities. Markets for intermediate inputs such as manure, straw and own seeds are either very thin or nonexistent.

4. Econometric methods and variable specification

Testing for farm size-productivity relationship

The following is a linear regression function useful for cross-section or pooled data to analyze the inverse relationship between farm size and productivity (Carter, 1984):

$$Y_i = \alpha + \beta X_i \tag{10}$$

where, Y_i is total value of annual crop output per unit of land for household i and X_i is farm size. We can extend equation (10) by incorporating other relevant variables that would affect productivity:

$$Y_i = \alpha + \beta_1 X_i + \beta_2 X_i^h + \varepsilon_i \tag{11}$$

where X_i^h is farm household characteristics and assets, and ε_i is the error term.

Equation (11) is estimated using OLS for farm-household level data. We will have two estimations according to equation (1): first, using total value of crops per farm size and second using total value of crops per cultivated area.

We also estimate area expansion effects by considering the ratio between cultivated area and farm size:

$$\frac{A^*}{A} = \alpha + \beta_1 X_i + \beta_2 X_i^h + \varepsilon_i \tag{11a}$$

where $\frac{A^*}{A}$ is the ratio between cultivated area and farm size, and other variables are as defined above.

We use a quasi-likelihood estimation method within framework of generalized linear models (GLM) for this fractional dependent variable because the predicted values from OLS regression may lie outside the range of 0 and 1, and the conditional variance is not likely to be independent of the conditional mean (Papke and Wooldridge, 1996). The cultivated area share lies between 0 and 1 as only few households have rented-in land and even those rented-in plots were too small to make the cultivated area exceed the total farm size.

For plot level data analysis, equation (11) can be expanded as follows:

$$Y_{ip} = \alpha + \beta_1 X_i + \beta_2 X_{ip}^{sq} + \beta_3 X_{ip}^h + \mu_i + \varepsilon_{ip} \tag{12}$$

where: Y_{ip} is output value from plot p per unit of land for household i, X_{ip}^{sq} is observed plot characteristics, X_{ip}^{h} is plot in-variant farm household characteristics, β s are parameters to be estimated, μ_i refers to unobserved plot in-variant household attributes such as farming skills, risk, household time preference, etc. and plot variant attributes (e.g. soil fertility), and ε_{ip} is the error term.

With the assumption that μ_i is uncorrelated with X_{ip}^{h}, equation (12) is estimated using a household random effects (RE) model. A range of plot level variables designed to capture land quality were included in the RE model for plot level estimation. Household fixed effects could have been used to control for unobserved household and plot characteristics that are plot invariant and to control for intra-group correlation due to unobserved cluster effects (Heltberg, 1998; Udry, 1995; Wooldridge, 2002). However, the variables of interest do not vary over plots within households and would not be captured by the fixed effects model as these important variables will be excluded from estimation during the differencing process. Using RE enables us to include these variables. We included as many household level variables as possible in our OLS model for the farm household level analysis.

Variable specifications

The dependent variables for the productivity analysis at household level was total output value of crops per total farm size, and decomposed to yield per unit cropped land and area share of cropped land. Only the yield response could be examined with the farm plot level data. Output value was calculated by multiplying crop produce from each plot by average local producer prices. We used the same average prices for both net sellers and buyers of the agricultural outputs because all outputs in the area are traded in the local market and thus we assume low transaction costs in these output markets. Outputs from both main and intercropped (minor) crops were included in the output value from intercropped plots.

Based on our theoretical framework and estimation specifications in equations (10) and (11), we used a number of explanatory variables for the household level farm size-productivity relationship analysis. Female workforce and male workforce refer to family labour in adult-equivalent units per unit of land (*timad*). We expect both to have positive effects on productivity. For some activities, there is a distinct division of labour between female and male workforce. The problem of moral hazard is not expected in this specific situation, as nearly all labour is family labour.

Livestock ownership in terms of total livestock units (TLU) may have positive effects on yield as it can supply more manure or can solve cash liquidity problems but may also cause a smaller share of the farm to be under crops if it is set aside for fodder production. Manure and fertilizer applied in each plot have been recorded, and the use of these inputs is expected to improve soil quality and positively affect productivity. However, endogeneity problems may limit the direct use of these variables in the analysis. We included models where we have used the predicted values for fertilizer. It is expected that use of fertilizer will improve soil fertility and thereby productivity of the land. We did not include manure as livestock is included in the regression and may capture both the immediate and lagged effect of manure on productivity. Endogeneity problems may also be expected in using off-farm income as an explanatory variable, and we could not find good instruments for tackling this problem. We excluded this variable from the productivity regression, as we think all the variables that could affect this endogenous variable are already included in the regression. We were also not able to use crop choice due to endogeneity problems. But we included a dummy for enset presence in one of the plot level models.

We expect farm size, workforce, dependency ratio, and livestock asset to correlate with the cultivated area share, equation (11a). Farm size may have positive relation if small farmers are not intensifying through area expansion. Availability of workforce can facilitate area expansion, and higher dependency ratio may also lead to area expansion in order to fulfill subsistence requirements.

A range of plot level land quality indicators are used in order to control for land quality variations in the plot level analysis that was based on equation (12). Steep slope and shallow depth are expected to negatively affect productivity. Sandy soils may have lower productivity due to low moisture retention. As plot distance increases, households may not be in a position to add farmyard manure. Such plots are therefore likely to have lower productivity. Conservation structures are present on some of the sloping plots and length of conservation structures was included as a control variable in two of the models in the plot level analysis. Homestead plots covered by enset plants where much of the manure is applied may be more productive than distant plots covered by annual crops. Enset is expected to help for moisture retention due to its canopy. Use of fertilizer is expected to boost productivity on the plot. The definition and description of all the variables used for the farm size-land productivity analyses at both levels are shown in Table 3.

5. Results and Discussion

The results from the econometric analysis are based on the farm household level as well as plot level data. We first present findings from the household level analysis which focused on the total farm production response and its decomposition into a cropped area share response and a yield response as well as the role of market imperfections. And then, we present findings of the farm plot level analysis which also tested the effect of land quality on farm size-land productivity relationship.

5.1. Farm household level analysis

In order to test for the inverse relationship hypothesis, we first run a simple OLS regression of log of total value of crop output per unit land on log of farm size based on equation (10). The coefficient of the farm size is found to be negative and significant at 1% level (Table 4, regression column 1). This result indicates that there is an inverse relationship between farm size and land productivity (See also Figure 5). The IR still holds when we include male and female workforce (regression column 2) in order to test for the labour imperfection hypothesis (H1) at farm level. Both male and female workforces were insignificant, which may indicate that households with more male and female labour lack relative advantages that affect land productivity. This may be due to the existence of surplus labour in a situation where most farmers have small farm sizes. The result did not clearly prove the hypothesis that the IR is attributed to labour market imperfections although the magnitude of farm size was slightly reduced when we added these variables. An additional test by including variables for assets and household characteristics (regression column 3) did not eliminate the inverse relationship. Livestock asset was positively and significantly correlated with productivity, and this could be plausible because livestock supply manure for soil improvement creating crop-livestock synergies that contribute to intensification. The inverse relationship persisted even after we included predicted values of fertilizer (regression column 4) although the magnitude declined. Fertilizer has positive but insignificant correlation with land productivity. Households with older heads are more productive than those otherwise.

The share of cultivated area decreased with farm size, indicating intensification through area expansion by smaller farms (Table 4a). In this regression the labour force was also significant and with a positive sign showing that labor intensification takes place through area expansion. The yield regression (total value of crops per cultivated area) still identified a significant inverse relationship between farm size and the yield (Table 4b). When seeing whether the IR relationship in yield could be explained by labour market imperfections, incorporation of the workforce variables reduced the inverse relationship which became insignificant although the labour force variables were insignificant. Livestock assets were still positive and significant. The inverse relationship disappeared when we included the amount of fertilizer used (predicted) but strangely the sign of the fertilizer variable was negative, pointing in direction of a likely omitted variable bias that could be related to land quality. The analysis at plot level may be better for the yield response assessment as it allows careful control for observable land quality characteristics.

The farm level analysis revealed a significant IR that was related to expansion of cropped area and yield intensification in response to shrinking farm sizes. Elasticity of the total output per farm size to increasing population pressure was about 0.5 indicating a clear Malthusian scenario. The IR was at least partly explained by market imperfections in labour markets. The plot level analysis below will provide more insights into whether the yield response may be explained by market imperfections or land quality differences.

5.2. Plot level explanations

Table 5 presents the RE regression models for equation (12) with robust standard errors adjusted for clustering at household level. Different variables were sequentially introduced to control for observed plot invariant farm household as well as plot variant attributes. Similar to the household level analysis, we started with a simple linear form and we found a weak and insignificant negative response to farm size (regression column 1). The negative sign disappeared with the inclusion of a range of soil quality indicators in the regression (regression columns 2). Shallow and medium depth soils were found to be less productive than deep soils, and land productivity declined with distance from house. Inclusion of workforce strengthened the non-inverse relationship but its relation with productivity was insignificant (regression column 3). Livestock asset was positively but insignificantly correlated with productivity (regression column 4). Investment in soil conservation may be correlated with poorer land quality and this could possibly explain its negative sign. The presence of enset on a plot and the predicted amount of fertilizer used were positively and significantly correlated with productivity (regression column 5). Enset is associated with higher input use (labour and manure) and higher output.

The plot level analysis showed that the inverse relationship in yields at the household level analysis may be due to omitted soil quality variables that we were able to include in the plot level analysis. Thus, the observed plot level attributes were able to partially explain the inverse relationship. The findings indicate that although the smallholder farmers were engaged in some farm intensification through expansion of their cropped areas and through use of more labour and manure per unit of land (Table 1), they were not able to respond sufficiently to lead them to a Boserupian development path.

6. Conclusions

This paper has used farm household and plot level data to test the inverse relationship between farm size and land productivity and to explain the main correlates for this relationship. The farm household level analysis of farm size-productivity relationship indicated the existence of an inverse relationship and this was partly explained by intensification through expansion of the cultivated area and partly by a yield increase on cultivated area. Labour market imperfections appeared to explain the intensification through area expansion while the yield response to labour was less significant. This may imply abundance of family labour and low yield response to additional labour unless complementary inputs like manure and fertilizer are available. Poor access to fertilizer is related to poor access to credit and this pulls in direction of a Malthusian scenario and appears to affect most households in the area. We may therefore conclude that although market imperfections may be an important reason for an inverse relationship between farm size and land productivity they may also in this kind of extreme case contribute to reduce the intensification opportunities and thus reduce the IR.

The availability of land quality indicators for direct use in the plot level analysis helped us to test the hypothesis that the inverse relationship for yields on cropped land is due to variations in land quality. We found that the IR for yield at farm level could be due to omission of observed soil quality attributes such as soil type, soil depth and conservation investments that have a role in explaining the inverse relationship between farm size and land productivity.

The descriptive findings discussed in section 3 indicated that small farms have intensified using higher labour and manure inputs as well as by producing more enset plants per unit area of land, land productivity was higher than in larger farms, and they received more credit per unit area of land (Table 1). But, the total income/capita was much lower for the small farms and they used less fertilizer than larger farms probably due to financial constraints. This can be expected as only 50% of the households have received credit and most of them (87%) received it for non-agricultural purposes, mainly for consumption smoothing and other family events, which could be a sign of persistent poverty in the area. The elasticity of productivity to population pressure calculated from the household level econometric analysis was also low (0.45) and that from yield response at plot level analysis was much lower ((0.23), indicating the insufficiency of the intensification efforts to induce a Boserupian type of development path. We used population-weighted farm size for the separate regression employed to directly estimate these elasticities (See Table A1 in Appendix).

Overall, it seems that the farm households in Gununo are not able to invest in capital inputs that would enable them to off-set the limitations they face due to small size farms and rapid population growth, and they are therefore caught in the Malthusian trap. A further in-depth study on intensification strategies of the households could provide additional information on possible ways out of this trap. The results generally suggest that micro-level farm size-productivity relationship studies that combine household and plot level analyses by identifying plot level characteristics that can control for land quality are more informative as compared to regional and national level analyses which lack these observed plot level attributes. Doing repeated surveys of the same households and plots can further strengthen the quality of this type of analysis.

Policies that enhance availability and use of credit for productive purposes combined with addressing temporary consumption needs are suggested to boost smallholder farmers' intensification efforts to the level where growth in income exceeds population growth. Such policies have to be combined with policies to expand off-farm and non-farm opportunities and promote education of women and family planning.

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Table 1: Means of some major variables for the sample hhs by farm size/consumer unit

	farm size in *timad*/consumer unit				
Variables	<=0.235	0.235-0.347	0.347-0.566	>0.566	All farms
No of hhs	36	34	35	36	141
%	25.5	24.1	24.8	25.5	99.9
Household characteristics					
Average age	39	42	43	42	42
Average family size	7.1	8.0	8.3	6.4	7.5
Consumer units	4.1	4.3	4.4	3.3	4.0
Assets and human resources					
Average own holding in *timad*	0.62	1.27	2.00	3.36	1.82
Farm size per consumer unit	0.14	0.29	0.44	1.10	0.50
Share of cultivated land	0.76	0.68	0.62	0.46	0.63
Oxen/*timad*	0.28	0.54	0.31	0.16	0.32
TLU/*timad*	3.35	2.50	1.67	0.87	2.10
Male workforce/*timad*	8.85	1.47	1.09	0.45	2.98
Female workforce/*timad*	6.93	1.69	1.02	0.54	2.59
Total workforce/*timad*	15.88	3.16	2.11	0.99	5.57
Young enset plants/*timad*	411.70	233.90	144.95	122.96	228.76
Total enset plants/*timad*	635.75	490.93	294.99	266.41	421.93
Harvested enset plants/*timad*	162.07	86.89	75.24	66.77	98.05
Number of hhs with: No ox	30	16	18	17	81
One ox	6	14	12	15	47
2 or more oxen	0	4	5	4	13
Input use intensity					
Oxen days/*timad*	62.53	31.04	13.00	14.75	30.44
Family labour days/*timad*	442.53	185.26	147.80	121.93	225.48
Hired labour days/*timad*	2.13	0.83	1.86	0.23	1.26
Manure in kg/*timad*	548.46	618.58	338.41	214.01	427.84
Fertilizer in kg/*timad*	8.96	9.01	11.61	9.96	9.89
Credit in birr/*timad*	325.47	90.36	80.90	15.57	128.95
Income and returns					
Farm income in birr/*timad*	460.15	398.86	300.25	138.78	323.63
Off farm income in birr/*timad*	1173.63	450.15	143.17	113.01	472.59
Total income in birr/*timad*	1633.78	849.01	443.42	251.79	796.22
Total value of crops in birr/*timad*	2161.40	1102.25	1060.43	859.34	1070.48
Return to labour in birr/*timad*	3.98	8.78	10.04	9.37	8.02
Farm income in birr/capita	31.64	45.47	71.68	66.57	53.83
Off farm income in birr/capita	60.97	49.76	35.38	43.36	47.42
Total income in birr/capita	92.61	95.23	107.06	109.93	101.25

Table 2: Number of households participated in input and output markets

Type of market	Hire/rent in /borrow/buy		Hire/rent out/lend/sell		Non-participation	
	Number	%	Number	%	Number	%
Labour	13	9.2	15	10.6	115	81.0
Land rental	10	7.0	18	12.7	114	80.3
Oxen rental	10	7.0	0	0.0	132	93.0
Credit	76	53.5	0	0.0	66	46.5
Fertilizer	101	71.1	0	0.0	41	28.9
Seed	137	96.5	0	0.0	5	3.5
Livestock	51	35.9	65	45.8	56	39.4
Food crops	138	97.2	75	52.8	3	2.1

Table 3: Definition and overview of variables

Variable	Description of the variables	Mean	Expected signs
Household level analysis			
tvcha	Total value of crops in birr/farm size	683.081	Dep. var
tvcha1	Total value of crops/cultivated area	1070.483	Dep. var
Farm size	Own holding in *timad*	1.821	+/-
Area share	Cultivated area/farm size	0.629	
Age	Age of household head in years	41.582	+/-
Education	Education of household head in years	1.865	+
Male workforce	Male workforce/*timad*	2.981	+
Female workforce	Female workforce/*timad*	2.593	+
Total workforce	Total workforce/*timad*	5.574	
conwor	Consumer-worker ratio	1.106	+/-
TLU/*timad*	Total livestock units/*timad*	2.095	+
Fertilizer use	Fertilizer use in kg/*timad* (predicted)	1.871	+
Farm plot level analysis			
tvcha2	Total value of crops in birr/*timad*	2049.484	Dep. var
Farm size	Farm size in *timad*	2.147	+/-
Distance	Distance of a plot from house	42.218	-
Soil type	Soil type =1 if sandy, =0 otherwise	0.621	-
slp1	Slope (<10%)	0.583	+
slp2	Slope (10-30%)	0.368	+
slp3	Slope (>30%)	0.048	reference
sde1	Soil depth (<30cm)	0.327	-
sde2	Soil depth (30-60cm)	0.517	-
sde3	Soil depth (>60cm)	0.156	reference
Conservation structure	Length of conservation structure in meters	17.754	+
Presence of enset	Dummy for presence of enset plant on the plot	0.223	+
Fertilizer use	Fertilizer use in kgs/*timad* (predicted)	3.671	+

Table 4: Farm household level explanations for farm size-productivity relationship (OLS dependent variable: Log of output value per *timad*)

Explanatory variables	Linear relation	Testing for labour imperfections	Including assets	Including predicted fertilizer
	(1)	(2)	(3)	(4)
Log of Farm size in *timad*	-0.462***	-0.412***	-0.507***	-0.493***
	(0.062)	(0.135)	(0.111)	(0.114)
Log of male workforce/*timad*		0.023	-0.009	-0.008
		(0.103)	(0.090)	(0.090)
Log of female workforce/*timad*		0.037	0.013	0.018
		(0.089)	(0.057)	(0.058)
Age			0.011**	0.011**
			(0.004)	(0.005)
Education			0.023	0.021
			(0.022)	(0.021)
Consumer-worker ratio			0.039	0.042
			(0.482)	(0.491)
Log of TLU/*timad*			0.104***	0.103***
			(0.035)	(0.035)
Log of fertilizer/*timad* (predicted)				0.046
				(0.073)
Constant	6.295***	6.274***	5.776***	5.779***
	(0.062)	(0.084)	(0.536)	(0.539)
R-squared	0.267	0.258	0.333	0.330
Number of observations	141	141	141	141

Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4a: glm regression results for cultivated area share

Explanatory variables	Cultivated area/farm size
Farm size	-0.185***
	(0.054)
Total workforce/*timad*	0.085**
	(0.042)
Consumer-worker ratio	0.229
	(0.533)
TLU/*timad*	0.061
	(0.086)
Constant	0.223
	(0.639)
Log pseudo likelihood	64.509
Number of hhs	141

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4b: Yield response to farm size (OLS dependent variable: log of output value/cultivated area)

Explanatory variables	Linear relation	Testing for labour imperfection	Including assests	Including fertilizer (predicted)
	(3)	(2)	(3)	(4)
Log of farm size	-0.282**	-0.094	-0.171	-0.003
	(0.127)	(0.243)	(0.226)	(0.236)
Log of male workforce/*timad*		0.069	0.077	0.053
		(0.115)	(0.097)	(0.099)
Log of female workforce/*timad*		0.062	0.063	0.055
		(0.103)	(0.080)	(0.081)
Age			0.013**	0.012**
			(0.005)	(0.005)
Education			0.022	0.031
			(0.021)	(0.020)
Consumer-worker ratio			0.085	0.095
			(0.091)	(0.091)
Log of TLU/*timad*			0.077**	0.086**
			(0.037)	(0.038)
Log of fertilizer/*timad* (predicted)				-0.162**
				(0.081)
Constant	6.975***	6.786***	6.194***	6.237***
	(0.149)	(0.267)	(0.281)	(0.276)
R-squared	0.027	0.030	0.112	0.137
Number of observations	141	141	141	141

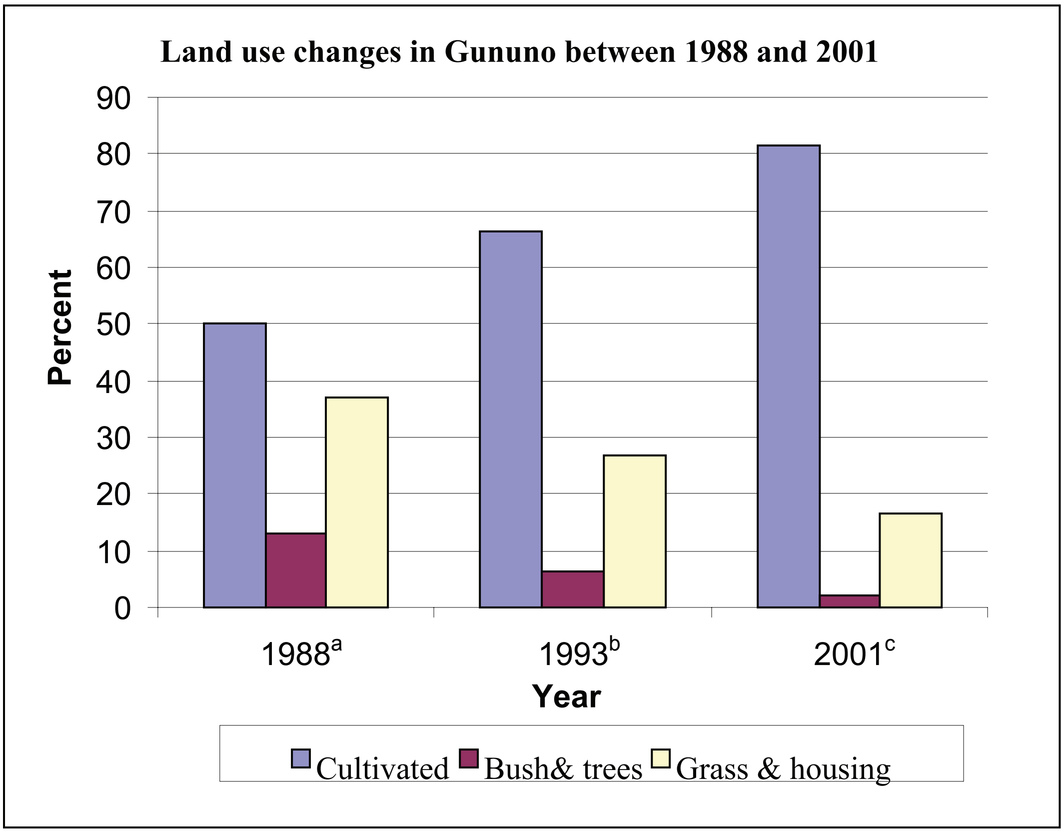
Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5: The effects of observed soil quality attributes on farm size-productivity relationship (random effects results from plot level analysis) [a]

Explanatory variables Dependent variable = output value per *timad*	Linear relation (1)	With soil quality (2)	Imperfect labour? (3)	Livestock asset (4)	Conservation & fertilizer (5)
Farm size	-0.113	0.004	0.239	0.248	0.258
	(0.093)	(0.104)	(0.304)	(0.290)	(0.286)
Distance from house		-0.417***	-0.409***	-0.429***	-0.198***
		(0.064)	(0.062)	(0.062)	(0.058)
Soil type (1=sandy)		-0.340	-0.288	-0.223	-0.556***
		(0.213)	(0.204)	(0.215)	(0.197)
Slope (<10%)		0.585	0.598	0.604	0.026
		(0.468)	(0.455)	(0.459)	(0.441)
Slope (10-30%)		0.331	0.344	0.372	-0.011
		(0.505)	(0.497)	(0.503)	(0.478)
Shallow soil depth (<30 cm)		-1.071***	-1.069***	-1.057***	-0.588**
		(0.279)	(0.278)	(0.275)	(0.259)
Medium soil depth (30-60cm)		-0.499**	-0.484**	-0.467**	-0.113
		(0.231)	(0.220)	(0.211)	(0.224)
Male workforce/*timad*			0.021	0.020	-0.058
			(0.089)	(0.083)	(0.082)
Female workforce/*timad*			0.301	0.270	0.297
			(0.327)	(0.303)	(0.306)
TLU/*timad*				0.113	0.004
				(0.081)	(0.081)
Length of conservn structure					-0.098**
					(0.043)
Dummy for enset presence					1.083***
					(0.225)
Fertilizer/*timad* (predicted)					5.011***
					(1.011)
Constant	6.412***	7.913***	7.740***	7.764***	-0.893
	(0.109)	(0.596)	(0.601)	(0.600)	(1.710)
walad chi2	1.468	75.993	78.784	92.188	213.441
prob>chi2	0.226	0.000	0.000	0.000	0.000
sigma_u	0.276	0.615	0.539	0.547	0.627
sigma_e	2.317	2.100	2.100	2.100	1.955
rho	0.014	0.079	0.062	0.063	0.093
Number of hhs	141	141	141	141	141
Numberof obs	557	557	557	557	557

Robust standard errors adjusted for clusters at household level; * significant at 10%; ** significant at 5%; *** significant at 1%

[a]: all continuous variables are log transformed



Source: a=Juma, 2000 b=Tessema, 1994 c=Gununo DA office, 2001

Figure 1: Land use changes in Gununo between 1988 and 2001

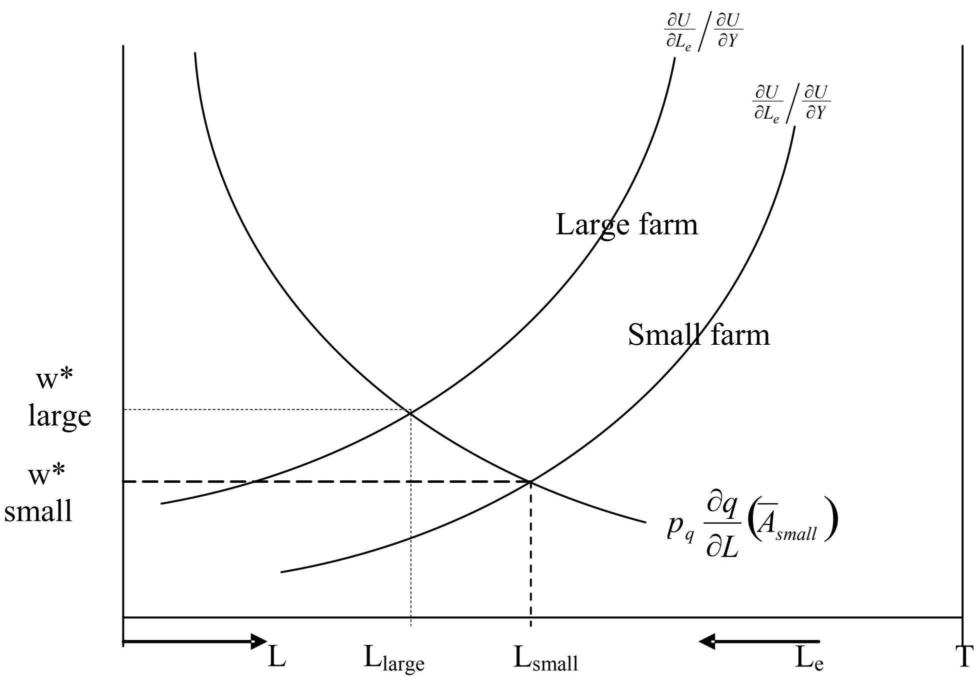


Figure 2. The effect of family labour endowments on shadow wage for different-size farms

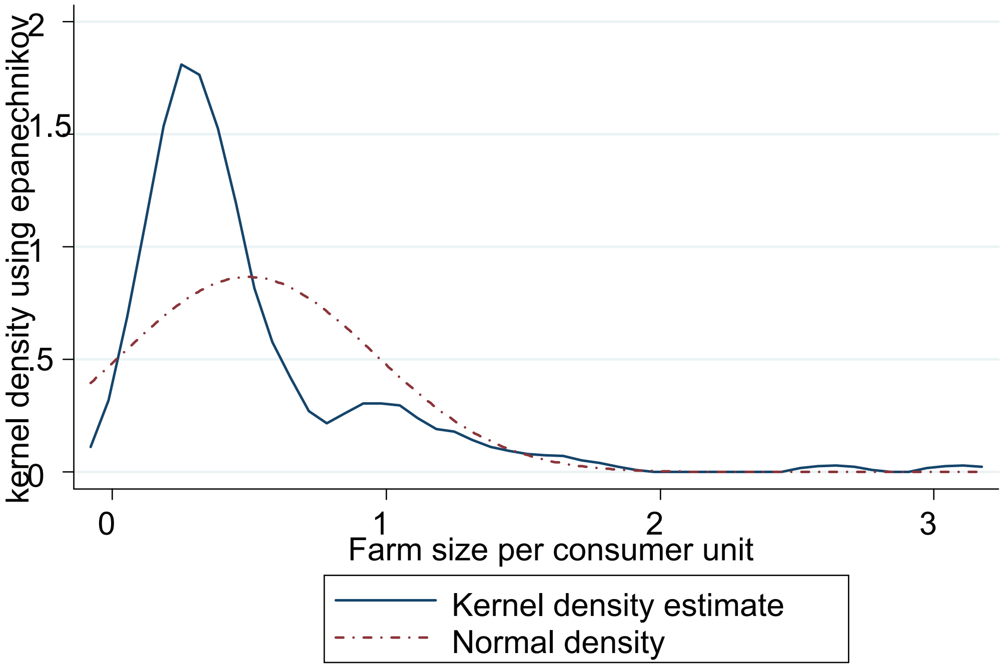


Figure 3: Kernel density distribution of farm size/capita

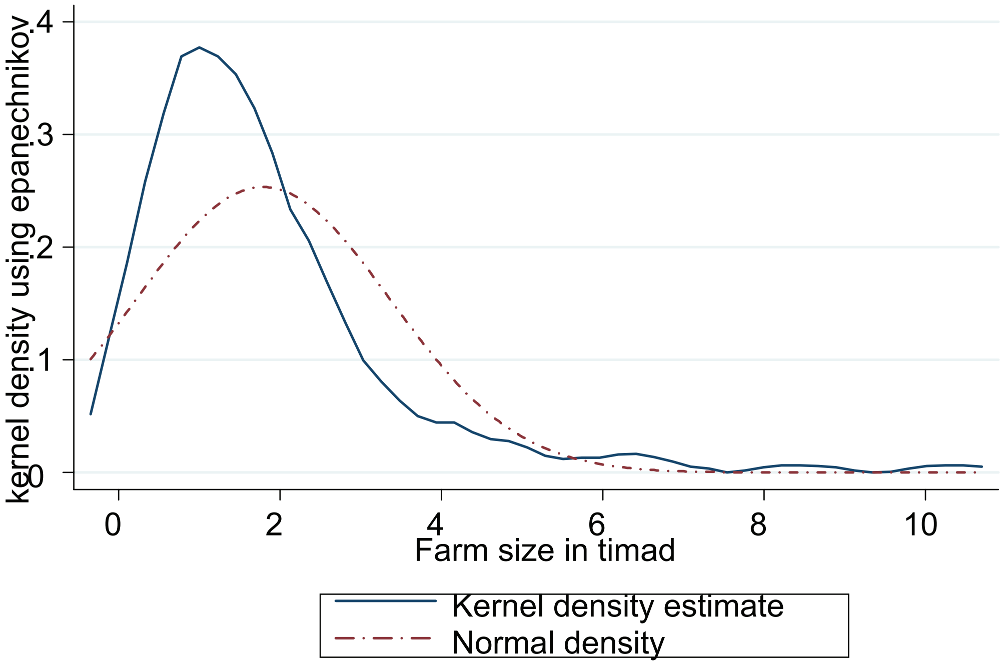


Figure 4: kernel density distribution of farm size in *timad*

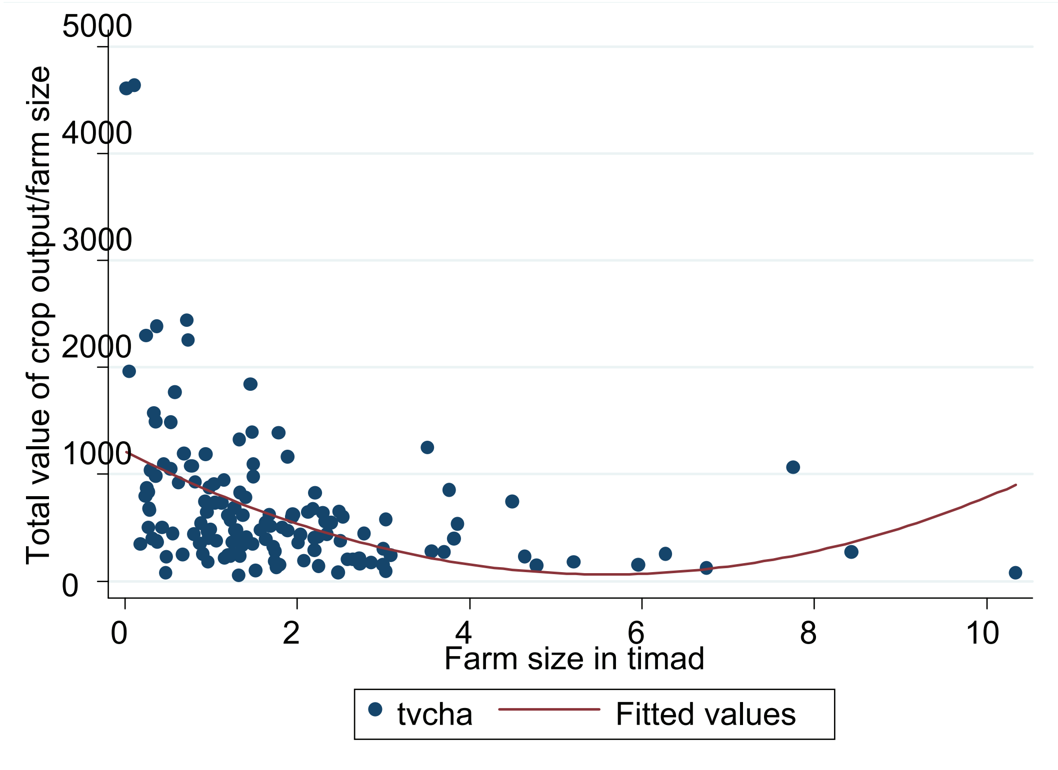


Figure 5: Relationship between farm size and productivity

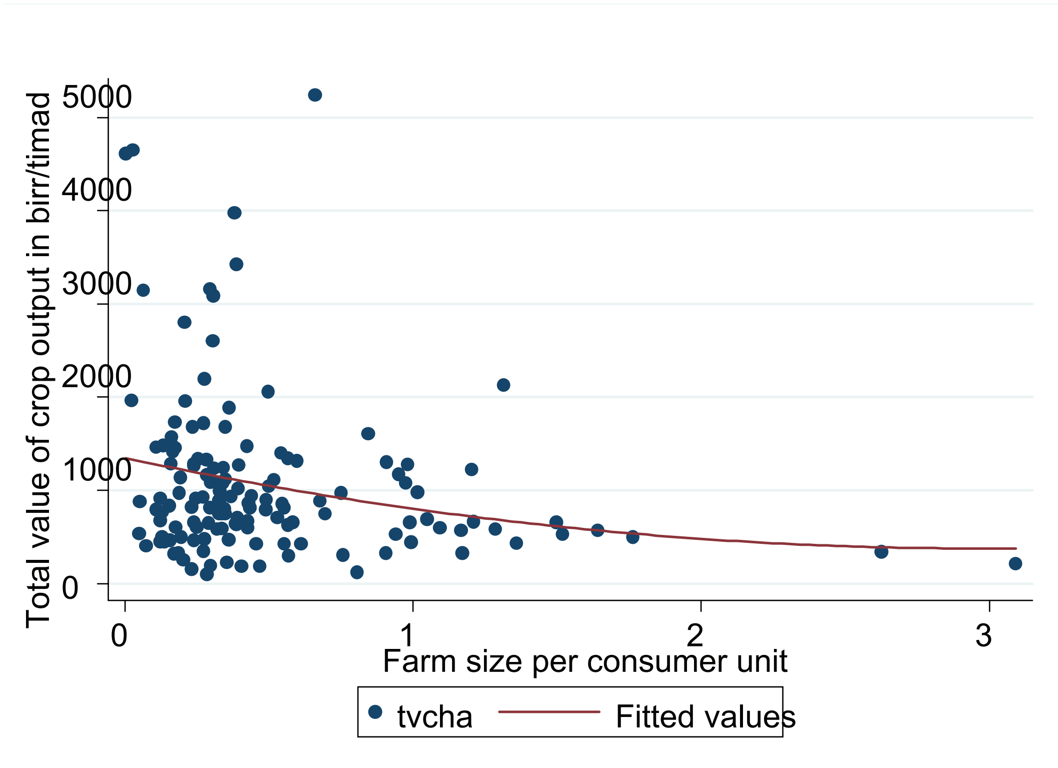


Figure 5a: Relationship between farm size and productivity

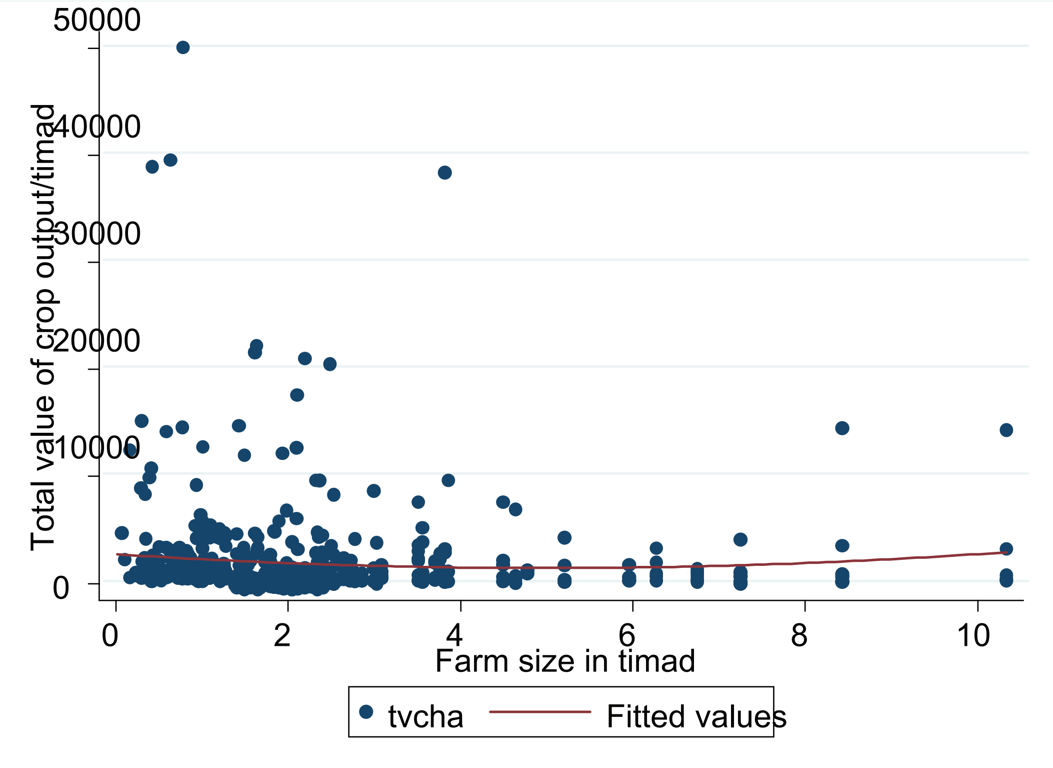


Figure 6: Plot level farm size-productivity relationship

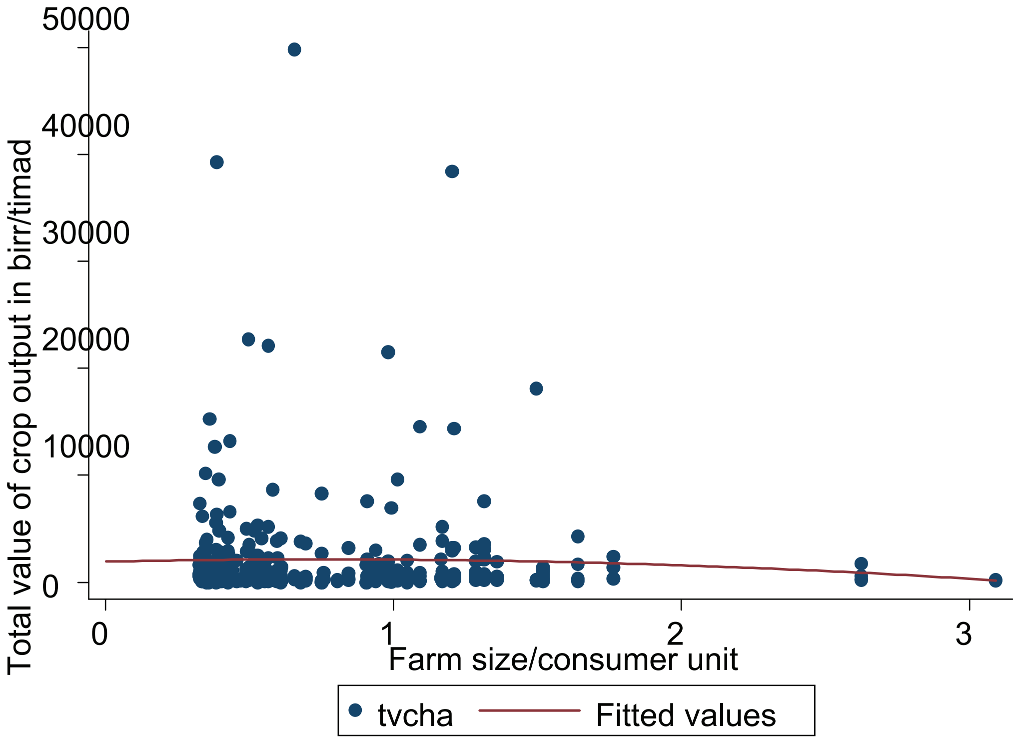


Figure 6a: Plot level farm size-productivity relationship

Appendix

Table A1: Effect of population pressure on farm size-productivity relationship

Explanatory variables	Household level analysis (OLS)	Plot level analysis (RE)
	Log of output/farm size	Log of yield (output/*timad*)
Log of farm size/consumer unit	-0.449***	-0.232**
	(0.058)	(0.104)
Constant	5.715***	6.173***
	(0.088)	(0.149)
R-squared	0.25	
Wald chi2(1)		5.00
Prob > chi2		0.025
sigma_u		0.185
sigma_e		2.317
rho		0.006
Number of households	141	141
Number of observations	141	557

Robust Stdandard Errors in parantheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Older enset plants nearest to homestead, and younger ones ready for transplanting

Paper II ...

Enset leaves used for animal feed (front yard)

Too Poor to Invest?

Poverty and Farm Intensification in Southern Ethiopian Highlands

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Abstract

This paper analyses farm intensification decisions of smallholders in Wolaita, one of the most densely populated areas in Southern Ethiopia. Using a two-period intensification decision model (Bellman equation), the paper assesses how increasing land scarcity, imperfect markets, and available technologies; consisting of livestock and annual and perennial crops; and endowments of land and livestock, shape the intensification decisions of the households. The model and the empirical analysis investigate the interactions between crops and livestock and the extent to which crop-livestock interactions are important for intensification through investment in the perennial and in production of annual crops. Furthermore, we assess whether land- and livestock-poor households are caught in a poverty trap and are too poor to invest or whether poverty forces them to invest more.

Parametric and non-parametric methods were used in the empirical analysis, including fractional response, Tobit and OLS models and kernel density distributions. We found that increasing land scarcity contributed to intensification in the production of the perennial and that crop-livestock interactions facilitated intensification. Thus livestock- and land-poor households appeared to be less able to intensify and got lower returns to their investment than more livestock-rich but land-poor households. They were also more severely credit-constrained than the other less poor household groups, possibly making it difficult for them to increase their livestock holding. However, a follow-up survey four years later revealed that they had been able to rebuild their livestock endowment to the level of other household groups.

Key words: Land scarcity, poverty, crop-livestock interactions, enset, investment in intensification, two-period model, Ethiopia

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1. Introduction

Agricultural intensification is driven by population pressure, technologies, market access, prices, and institutions (Boserup 1965, Ruttan and Hayami, 1984). However, poor households are found to have high discount rates or short time horizon, possibly inhibiting their long-term investment (Holden *et al*., 1998). They may not have sufficient resources and lack the necessary market access to intensify their production and sustainably improve their land. Poor households facing imperfect markets are not able to maximize profit and are less likely to diffuse risk successfully due to fewer assets for collateral and fewer stocks (Holden and Binswanger, 1998). So, they could be too poor to invest in farm intensification and resource improvements. However, empirical evidence indicates that poor households may respond in different ways to increased pressure on land from population growth. Some cope with the situation by expanding land to more fragile areas or harvesting more trees (Grepperud, 1996) and others could adopt technical and institutional innovations and improve the land resource base (Ekobom and Bojo, 1999). The effect of poverty on intensification decisions also depends on the type of poverty, whether it is welfare or asset poverty. Reardon and Vosti (1995) focused on what they call "investment poverty" by considering the ownership (access) of different asset categories as they affect investment decisions.

There is a growing empirical literature that investigates whether low-wealth agents can accumulate assets over time or whether they are in a poverty trap (Zimmerman and Carter 2003; Lybbert et al. 2004; Carter and Barrett 2006). Some studies showed that households facing credit constraints are able to smooth consumption with relatively low asset buildings (Deaton 1992; Rosenzweig and Wolpin 1993) while others have found little direct evidence of the use of asset stocks for consumption smoothing (Kazianga and Udry 2004). On the other hand, some evidence of asset smoothing, dependent on dynamic assets thresholds, were documented (Barrett et al. 2006; Lybbert and Barrett, forthcoming; Santos and Barrett 2006).

Regardless of all these, there are relatively few studies that have closely investigated investment and intensification decisions of asset-poor households who depend on production of livestock and perennial crops. This study contributes to fill this gap.

This study focuses on a densely populated area in Southern Ethiopia and asks whether population pressure and poverty undermine investment or whether investment becomes an essential means of survival for poor and severely land-constrained households. Livestock and a perennial food crop, enset[7], are important components of their farming system, both requiring investments to sustain the production. We aim to answer the following questions: Why do some farm households intensify enset production more than others? Can the poor afford to invest in production of this perennial? In other words, are the poor too poor to invest or does poverty force them to invest more in production of this perennial? Is livestock an essential component of the farming system and can lack of livestock lead to a poverty trap?

We develop a theoretical dynamic model with crop-livestock interactions and demonstrate that important synergy effects between livestock and perennial food crop production may lead to a poverty trap for asset-poor households that lack access to markets for credit. We use a unique and very detailed household and farm plot level data set from one of the most densely populated areas in Southern Ethiopia to analyse intensification and investment decisions and how these are related to asset stocks of households. We find that livestock- poor households were less able to intensify their crop production. Our analysis using cross-section data from 1999 indicated that land- and livestock-poor households were in a poverty trap and severely credit-constrained. However, the livestock change analysis from 1999 to 2003 revealed that these groups were able to rebuild their livestock endowment, most probably through livestock sharing contract arrangements.

[7] Enset (*Ensete ventricosum*) is a banana-like perennial crop produced in southern and southwestern regions of Ethiopia for its food from pseudostem and underground corm. It supports more than 15 million people in the country as a staple or co-staple food crop as well as for other uses.

The paper is organized as follows. Section 2 of the paper gives a description of the study area. The theoretical model is developed in section 3. Section 4 describes the econometric methods and data, followed by presentation and discussion of results in section 5. Concluding remarks are provided in section 6.

2. The setting

The study area, Gununo in Wolaita in the highlands of Southern Ethiopia, is one of the most densely populated areas of Ethiopia and also one of the poorest areas as measured in form of asset holdings per household (Deininger *et al*. 2007). The annual population growth rate has been estimated to be as high as 4.8% (Elias, 2002)[8]. Belay (1992) estimated it to be 523 persons/km^2. Since then all land that can be cultivated with the available technology has been brought under cultivation, leaving no possibility for area expansion. As a result of the population increase, land area under cultivation increased from 50 percent in 1988 to about 81 percent in 2001. Only two percent of the land remained under bush and trees and 13 percent as grassland. About 54 percent of the sample population is 15 years old or younger as a result of the rapid population growth. The average land holding had in 1999 reached 0.45 hectares. If we assume that the land holdings cover 81% of the land in the study area, the average population density was about 1350 persons/km^2 at the time we carried out the survey (1999).

The perennial crop, enset, is an important staple food crop in the area. Apart from human food, different parts of enset serve as animal feed, wrapping material, tying material for house construction, and medicine. As a perennial, enset also serves as a financial and food reserve that may be used to buffer against shocks like annual crop failures, to pay taxes and social

[8] The national annual population growth rate is 3%.

obligations (Dougherty, 2005; Brandt *et al.* 1997; Shank and Ertiro, 1996). It is also documented that enset helps in minimizing land degradation and improving soil fertility due to its canopy, and is preferred for sustainability of the farming system (Shank and Ertiro, 1996).

Livestock in form of cattle, goats, sheep and donkeys are common in the area. Crop residues (straw and enset leaves), grass and grazing lands provide fodder for animals and the animals provide manure for the crops, especially for enset.

3. Theoretical model

We develop a dynamic theoretical model that captures investments in perennial crops and livestock. This model assumes that the household does not consume all its income in the current period as long as it has prospects about living in the future. This implies that the household faces a trade-off between consumption and investment for the future. The model assumes that the household makes this trade-off by equalizing the (discounted) marginal utilities of consumption over time.

We assume that there is no labour market because we study an area with limited market access and limited off-farm employment opportunities. There is also a very high population density. The economy is, therefore, characterized by labour abundance and low marginal return to labour. The variation in labour endowment across households cause some variation in the shadow wages across households but the transaction costs in the labour market are too big for these to be eliminated through labour exchange. We treat the labour endowments as household "public goods", meaning that they are used for crop production, animal production and investment in an implicit balanced (rational) way based on diminishing marginal return to labour in each type of activity.

There is a relatively egalitarian land distribution causing all households to face land scarcity and high population pressure on the land but local variation in this population pressure is important in the following empirical analysis. There is no market for land in the model as land sales are prohibited.

The household has four types of stocks; labour, land, perennial crop and livestock. We assume that they may choose to deplete or invest in two of these over time, the perennial and livestock[9]. One of the stocks is tradable[10], livestock, while the perennial is non-tradable as a stock but it may be harvested and the output sold.

We assume that household consumption is equal to income net of investment. This income is generated based on the resources available to the household. These include a limited amount of land (A). A part of the land is planted with the perennial (A^E), the remaining land is planted with other (annual) crops (A^O) or fodder crops for the livestock (A^F). The initial stock of the perennial, S_t^E, may be harvested in the first period, S^{Eh}, or kept for the future.

The harvested product from the perennial,

$$E^O = kS^{Eh} = kS^{Eh}\left(s, A^{Eh}, S_t^E; L^F, L^M\right) \tag{1}$$

is a linear function of the harvested stock, and the harvested stock is a function of the harvested area, the plant density, s, and the initial stock of enset. Harvesting is conditioned by household labour endowments of female and male labour, L^F and L^M. k is a multiplicative constant.

---

[9] For simplicity we ignore land degradation and conservation and human capital investments and health in this model.
[10] Land is a non-tradable due to prohibition of sales, and labour is non-tradable due to prohibition of slavery, limited access to off-farm employment, and transaction costs limiting local trade in labour.

Animal fodder (F) is a byproduct of the perennial (when harvested) and of other crops, and the main product of grazing land, $F = F\left(A^{Eh}, A^{O}, A^{F}\right)$.

Manure production is a function of the livestock stock, $M = M\left(T_t^S\right)$, and may be used (M^E) to enhance the growth of the perennial (future benefit), or on other (annual) crops (M^O) to enhance current period production. Using manure on the perennial is therefore an investment. This implies that there are synergies between perennial and livestock production when these manure-perennial and fodder-livestock productivity effects are sufficiently large. Annual crop production is a function of land, manure and household labour endowments of male and female labour, L^M and L^F.

$$O^O = O^O\left(A^O, M\left(T_t^S\right) - M^E; L^F, L^M\right) \tag{2}$$

We assume that fodder is tradable while manure is not. Livestock products, except manure, and the animals themselves are tradable. It is assumed that livestock production in the current period is a function of the initial stock of animals, and the amount of fodder made available through own production net of sale/purchase, that is

$$T^O = T^O\left(T_t^S, F^o\left(A^{Eh}, A^O, A^F\right) - F^T; L^F, L^M\right) \tag{3}$$

F^T is the net sale of fodder and is negative for net buyers of fodder. We assume the usual well-behaved production functions.

We use a Bellman equation to capture the dynamic household problem. We frame it as a per consumer unit consumption problem to acknowledge that the poor households face a minimum subsistence requirement that limits their freedom and ability to invest for the future.

Wealth per consumer unit is also what matters as a poverty indicator. The maximization problem may be formulated as follows:

$$V\left(\frac{A}{C},\frac{S_t^E}{C},\frac{T_t^S}{C}\right)=\underset{A^{Eh},A^{Ep},A^O,A^F,F^t,M^E,T^{ST}}{Max}\left\{U\left(\frac{Y_t}{C}\right)+\beta V\left(\frac{A}{C},\frac{S_{t+1}^E}{C},\frac{T_{t+1}^S}{C}\right)\right\} \tag{4}$$

subject to:

a) Income constraint

$$Y_t=Y\left(\begin{array}{l} p^E kS^{Eh}\left(s,A^{Eh},S_t^E;L^F,L^M\right)+p^O O^O\left(A^O,M\left(T_t^S\right)-M^E;L^F,L^M\right)+ \\ p^T T^O\left(T_t^S,F^O\left(S^{Eh},A^O,A^F\right)-F^T;L^F,L^M\right)+p^F F^T+ \\ p^T T^{ST}+\overline{R} \end{array}\right) \tag{5a}$$

b) Enset stock change

$$S_{t+1}^E=(S_t^E-S^{Eh}\left(s,A^{Eh},S_t^E\right))+S^{Ep}\left(s,A^{Ep}\right)\left(1+e\left(\frac{M^E}{A^{Ep}}\right)\right) \tag{5b}$$

c) Livestock change

$$T_{t+1}^S=\left(T_t^S-T^{ST}\right)\left(1+\tau\right) \tag{5c}$$

d) Land allocation constraint

$$A=A_t^E-A^{Eh}+A^{Ep}+A^O+A^F \tag{5d}$$

where e and τ are application intensity and natural growth rate, respectively.

The first order conditions for the theoretical model become:

$$A^{Eh}:\frac{\partial U}{\partial\left(\frac{Y_t}{C}\right)}\frac{1}{C}\left(p^E\frac{k\partial S^{Eh}}{\partial A^{Eh}}+p^T\frac{\partial T^O}{\partial F}\frac{\partial F^O}{\partial S^{Eh}}\frac{\partial S^{Eh}}{\partial A^{Eh}}\right)=\beta\frac{\partial V}{\partial\left(\frac{S_{t+1}^E}{C}\right)}\frac{1}{C}\frac{\partial S^{Eh}}{\partial A^{Eh}}+\lambda^A \tag{6a}$$

This means that the marginal utility of current harvesting of the perennial in form of value of crop and livestock output is equal to the sum of the marginal benefit of keeping the perennial stock to the next period and the marginal value of land. The equation also illustrates the interaction between perennials and livestock in terms of the perennial providing fodder for the livestock.

$$A^{Ep}:\beta\frac{\partial V}{\partial\left(\frac{S_{t+1}^{E}}{C}\right)}\frac{1}{C}\left\{\frac{\partial S^{Ep}}{\partial A^{Ep}}\left(1+e\left(\frac{M^{E}}{A^{E}}\right)\right)+S^{Ep}\frac{\partial e}{\partial\left(\frac{M^{E}}{A^{Ep}}\right)}\frac{M^{E}}{\left(A^{Ep}\right)^{2}}\right\}=\lambda^{A} \tag{6b}$$

This means that the discounted marginal return to enset planting should be equal to the shadow value of land. We assume there would be diminishing returns to manure when applied to the perennial and diminishing future return to planting of the perennial when access to manure is limited due to the missing market for manure and limited stock of animals.

$$A^{O}:\frac{\partial U}{\partial\left(\frac{Y_{t}}{C}\right)}\frac{1}{C}\left(p^{O}\frac{\partial O^{O}}{\partial A^{O}}+p^{T}\frac{\partial T^{O}}{\partial F}\frac{\partial F^{O}}{\partial A^{O}}\right)=\lambda^{A} \tag{6c}$$

The marginal return to planting of other crops should be equal to the shadow value of land.

$$A^{F}:\frac{\partial U}{\partial\left(\frac{Y_{t}}{C}\right)}\frac{1}{C}p^{T}\frac{\partial T^{O}}{\partial F^{O}}\frac{\partial F^{O}}{\partial A^{F}}=\lambda^{A} \tag{6d}$$

The marginal return to land used for fodder production is also equal to the marginal value of land. With homogenous land quality we could equate these first four FOCs.

$$F^{T}:\frac{\partial U}{\partial\left(\frac{Y_{t}}{C}\right)}\frac{1}{C}\left(-p^{T}\frac{\partial T^{O}}{\partial F}+p^{F}\right)=0 \tag{6e}$$

Participation in the fodder market is ensuring that the marginal return to fodder in livestock production is equal to the market price for fodder.

$$M^E : \frac{\partial U}{\partial\left(\frac{Y_t}{C}\right)} \frac{1}{C} p^O \frac{\partial O^O}{\partial M^O} = \beta \frac{\partial V}{\partial\left(\frac{S_{t+1}^E}{C}\right)} \frac{1}{C} \frac{S^{Ep}}{A^{Ep}} \frac{\partial e}{\partial\left(\frac{M^E}{A^{Ep}}\right)} \tag{6f}$$

The marginal return to manure on annual crops is equal to the discounted marginal future benefit of using manure to enhance growth of the perennial.

$$T^{ST} : \frac{\partial U}{\partial\left(\frac{Y_t}{C}\right)} \frac{1}{C} p^T = \beta \frac{\partial V}{\partial\left(\frac{T_{t+1}^S}{C}\right)} \frac{1}{C} (1+\tau) \tag{6g}$$

The marginal utility of selling or purchasing livestock in the current period is equal to the discounted marginal future benefit of keeping livestock for the future.

Equations (6a), (6b), (6f) and (6g) demonstrate the intertemporal tradeoffs for the non-tradable perennial and the tradable livestock. Equations (6a) and (6c) illustrate the synergies between crop and livestock production in terms of crops providing fodder for the livestock. Manure is a function of the initial stock of animals and is an input in production of other crops and production of perennials for the future.

A credit constraint would cause the discount rate to become endogenous and possibly make livestock-poor households unable to buy livestock and thus benefit from the crop-livestock synergies.

The non-separability conditions (market imperfections) of the model make all endogenous variables functions of all the exogenous parameters including initial endowments. At the same time there is interdependence between the endogenous variables and this implies that the first order conditions have to be interpreted with caution. The number of endogenous variables in the model also makes it too complicated to derive the comparative statics results. The fact that the stock variables also are endogenous, the trade-off and synergy effects that we have demonstrated with the first order conditions, and the structure of the model, make it impossible to derive a pure reduced form model that could yield unbiased estimators of the parameters related to these endogenous stock variables. We may therefore rather interpret the regressions as multiple correlations where the directions of causality are less evident in the dynamic setting.

We apply the model to the study area in Southern Ethiopia. We tentatively draw the following hypotheses based on the theoretical model:

H1. Households cope with increasing land scarcity by investing more in perennial production.

H2. There are synergy effects between livestock and perennial production causing livestock to be important for the land productivity and thus the ability to cope with increasing population pressure.

H3. Land- and livestock-poor households are credit constrained and are caught in a poverty-trap (too poor to invest)

We explain in next section how we test the hypotheses by combining nonparametric and parametric methods.

4. Methodology

4.1. Testing of hypotheses

We test the hypotheses by combining nonparametric and parametric methods. We divide the household sample in four equally sized groups based on relative asset poverty in land and livestock endowments per consumer unit. We then apply kernel density graphs to assess the distributions of key variables for each group and compare these graphically. We also apply t-tests to test for significance of differences in means for these four groups.

We test hypothesis H1 by assessing the "determinants" (asset variable correlations) of:

a) Area share under enset production of households. We assess whether the area share is positively correlated with land scarcity (negatively correlated with land endowment per consumer unit).

b) Total stock of enset per unit of land. We assess whether it increases with increasing land scarcity.

c) Total stock of enset (number of plants) per consumer unit. We assess whether it is negatively correlated with land scarcity.

d) Young stock of enset (planted within the last two years) per consumer unit. We assess whether it is positively or negatively correlated with land scarcity.

We test H2 by including livestock endowments per consumer unit in the models listed above. In addition we include the following two models with

e) Total value of crop production per unit of land. We test whether it is higher for households with more livestock endowment per consumer unit. We also assess how land productivity is correlated with population pressure/land scarcity.

f) Total value of crop production per consumer unit. We test whether it is positively correlated with livestock endowment per consumer unit. This model also assesses how crop production per consumer unit is correlated with land scarcity.

We also use kernel density distributions for the four household groups to assess how the livestock endowment is correlated with enset stock and value of crop production per consumer unit.

We test H3 by assessing the following relationships;

g) Whether the poorest of the poor, that is, the group that falls in the category land- and livestock-poor households is less able to invest because of poor access to credit.

h) Whether livestock poverty is correlated with poor credit access and lower investment in enset planting,

i) Whether the poorest of the poor get lower returns to their intensification in crop production resulting in lower value of crop production per consumer unit,

j) Whether hypothesis H2 should be maintained because of significant synergies between crop and livestock production,

k) Whether the poorest of the poor are able to increase their livestock holding to benefit from crop-livestock synergies.

We combine the parametric models and nonparametric graphs to test the hypothesis.

Based on the theoretical model and hypotheses we have normalized the explanatory variables wrt consumer units (*C*), that is, divided all variables by *C* and run the following models;

Enset area share model

$$\frac{A_t^E}{A} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, z^h\right) \tag{7a}$$

Enset stock per consumer unit model

$$\frac{S_t^E}{C} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, z^h\right) \tag{7b}$$

Enset stock per farm size model

$$\frac{S_t^E}{A} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, z^h\right) \tag{7c}$$

Enset investment (young stock of enset) per consumer unit model

$$\frac{sA^{Ep}}{C} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, \frac{\overline{Cr}}{C} z^h\right) \tag{7d}$$

Land productivity (value of crop production) per unit of land model

$$\frac{TVC}{A} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, \frac{\overline{Cr}}{C}, z^h\right) \tag{7e}$$

Value of crop production per consumer unit model

$$\frac{TVC}{C} = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, \frac{\overline{Cr}}{C}, z^h\right) \tag{7f}$$

Livestock change model (changes from 1998 to 1999 and from 1999 to 2003)[11]

$$\Delta T = corr\left(\frac{L^F}{C}, \frac{L^M}{C}, \frac{A}{C}, \frac{T_t^S}{C}, \frac{Ox}{C}, \frac{\overline{R}}{C}, \frac{\overline{Cr}}{C}, z^h\right) \tag{7g}$$

where $\frac{\overline{R}}{C}$ is exogenous income per consumer unit and $\frac{\overline{Cr}}{C}$ is credit access per consumer unit.

4.2. Econometric methods

The area share of enset is a proportion that lies between 0 and 1. When the dependent variable is a proportion, the use of linear models such as ordinary least squares (OLS) will not give efficient estimates. The predicted values from OLS regression may lie outside the range of 0 and 1 (Papke and Wooldridge, 1996) and the conditional variance is not likely to be independent of the conditional mean. The traditional logit transformation on the data as a solution to this problem has some drawbacks because transformation is not possible for values of 0 and 1 if the dependent variable includes these boundary values, as is the case in our data. Papke and Wooldridge (1996) developed alternative (quasi-likelihood) estimation methods, within framework of generalized linear models (GLM), for regression models with such fractional dependent variables. Their assumption is that there is an independent, not

[11] The major survey was carried out in 1999 and studied 142 sample farm households. The livestock changes are based on the information collected in this year and in 2003 (foolow-up survey).

necessarily identically distributed, sequence of observations $\{(x_i, y_i)_{: i=1,2\ldots N}\}$, where $0 \leq y_i \leq 1$ and N is the sample size. Then for all *i*,

$$E(y_i \mid x_i) = G(x_i\beta) \tag{8}$$

where $G(.)$ is a known function satisfying $0<G(z)<1$ for all $z \in \mathrm{R}$, ensuring that the predicted value of *y* lie in the interval (0,1). Based on this assumption, Papke and Wooldridge (1996) provide a particular quasi-likelihood method, namely the Bernoulli log-likelihood function

$$l_i(b) \equiv y_i \log\left[G(x_i b)\right] + (1-y_i)\log\left[1-G(x_i b)\right] \tag{9}$$

which is well defined for $0<G(.)<1$. This model was used to estimate equation (7a).

Tobit models were used to estimate the enset stock per consumer unit equations (7b) and per farm size (7c) and the enset investment equation (7d) because of censoring at zero for some observations. Ordinary least squares were used for the remaining models, (7d)-(7g). Standard errors were estimated through bootstrapping (with 500 replications) in all the models, using STATA 9.2.

4.3. Data and variable specification

Data for this study were collected from 142 randomly selected farm households in the Gununo area, Wolaita administrative zone, Southern Ethiopia. The survey was carried out in June and July 1999, and detailed socio-economic and farm plot level data were collected. Descriptive statistics of key variables used in this analysis is provided in Table 1. Enset stock was measured in total number of enset plants, either per consumer unit or per hectare. Exogenous income comprised food aid, remittance and gifts. Logarithmic transformation was used for some of the variables with skewed distributions.

In order to assess some of the important variation in asset poverty in our sample, we divided the households in four equally sized groups based on their land endowment per consumer unit and their livestock endowment per consumer unit. This gives the following categories of households; 1) Land-poor and livestock-poor, 2) Land-poor and livestock-rich, 3) Land-rich and livestock-poor, and 4) Land-rich and livestock-rich. The terms “rich” and “poor” are used in a purely relative sense, as from an outside perspective the whole sample qualify to be land-poor in a more objective sense. It is how these four categories perform relative to each other that are the focus of this study. Figure 1 shows the livestock endowment distribution within and across the four household categories using kernel density distributions. Figure 2 similarly shows the enset stock distributions. We carried out a Kolmogorov-Smirnov test based on cumulative distribution functions and the result showed that the differences across the four household categories are statistically significant (p-value=0.000). Table 2 presents the means and standard errors for key variables by household category.

5. Results and Discussion

We have used a combination of methods to test our hypotheses. We organize the presentation and discussion based on the three hypotheses we want to test.

5.1. Population pressure and intensification in perennial crop

Our first hypothesis (H1) was that households cope with increasing land scarcity by investing more in perennial production. We can see from Table 3 (column 2), which presents the results from the enset area share regression, that the land endowment per consumer unit (llandcu) was highly significant and with a negative sign. The same is also illustrated in Figure 3. The negative correlation is strong, indicating that households respond to land scarcity by putting a relatively larger share of their farm under the perennial enset. Land poverty therefore appears to stimulate investment in perennials.

When we look at column 4 in the Table, with the Tobit regression on total stock of enset per unit of land, we see that land endowment per consumer unit is highly significant and with a negative sign which is consistent with the result in the area share model. Enset stock per unit of land is higher in farms with higher population pressure.

But how strong is this intensification response? We see from column 3 that the enset stock per consumer unit was not significantly correlated with the population pressure variable. When we assess the population pressure effect on investment in the perennial in column 5, we also here see no significant effect of population pressure on the investment in enset per consumer unit. We cannot reject hypothesis one, as land scarce households invest more per unit of land than less land scarce households, while investment per consumer unit was not significantly different for more or less land scarce households.

5.2. Livestock and perennial intensification

Our second hypothesis (H2) was that there are synergy effects between livestock and perennial production causing livestock to be important for the land productivity and thus the ability to cope with increasing population pressure.

We start by looking at how livestock endowment per consumer unit (tlucu) is related to the share of enset area in Table 3 (column 2). We see that it is highly significant and with a positive sign. This indicates that households with more livestock also have a larger area share of enset stock. This may be because manure from the livestock increases the productivity of enset but also because residues from enset harvesting are used as animal fodder. When we look at column 4 we also see that the livestock endowment is significant and positively correlated with enset stock per farm size. “Livestock-rich” households thus also tend to be more “enset-rich”.

We will now look at the land productivity by studying value of crop production per consumer unit and value of crop production per unit of land. Our hypothesis should imply that both of these should be positively correlated with livestock endowment per consumer unit. We see from Table 4 that this is the case; we find a significant positive correlation in both cases. The distribution of value of crop production per unit land across and within the different household groups is also illustrated in Figure 4, using kernel density estimation. The figure shows that “land-poor and livestock-rich” households are having higher land productivity than the other household categories. But also the “land-poor and livestock-poor” appear to have higher land productivity than the “land-rich” household categories. They respond to population pressure by intensification but are less able to do so than the group with similar land endowment but more livestock endowment. The differences also come out in Table 2.

Livestock appears to be a key to more successful intensification in response to population pressure. Therefore, we cannot reject hypothesis H2.

5.3. Too poor to invest?

Our third hypothesis (H3) stated that the household category that is "land-poor and livestock-poor" is credit constrained and are caught in a poverty-trap (too poor to invest).

We first look at the extent of credit access for the different groups using kernel density graphs, see Figure 5. It clearly illustrates that this household category to a larger extent are credit constrained than the other categories and this may limit their ability to invest in livestock. Table 2 also shows that this household group has significantly lower mean access to credit than others, while it appears from Figure 5 that only some of the households within the group have such access.

We then proceed to test how credit access may be related to investment in perennials because it is not obvious that credit access would be used for such investment. In Table 3 (column 5), the model with enset investment per consumer unit, we see that credit access[12] per consumer unit was significantly and positively correlated with enset investment. We cannot be sure about the direction of causality but at least there is a significant correlation. When we look at Figure 6, which shows the distribution of investments in enset per consumer unit within and across the household categories also it is not so evident that this most asset-poor household group invests less, while, if we look back to Figure 2, this group tends to have a lower total stock of enset per consumer unit.

[12] Credit access in this study refers to the amount of accessible credit in birr.

Our analysis so far does not assess carefully the returns to investment for the different groups. If the household group that is both "land-poor and livestock-poor" also experience lower returns to their investments this is another link that possibly may indicate a vicious spiral or poverty-trap. To assess this we look at total value of crop production per consumer unit and its distribution across and within the different household groups in Figure 7. We see from the figure that this most asset-poor household group stands out clearly with less crop production per consumer unit. This may indicate that their investment efforts give lower returns, at least in the short-run, and this leads to consumption poverty unless they are able to diversify through getting additional off-farm income. However, such income access is also limited and highly skewed within this group as well as within the other household groups as can be seen from Figure 8. Another option would be selling of livestock for consumption-smoothing purposes but that would enhance the livestock-poverty. Tables 2 and 3 illustrated how important livestock endowments are for enset intensification and investment. Livestock-poor households who also are land-poor may therefore be in a poverty-trap as they need livestock in order to increase their returns to investment in the perennial crop. We will therefore look at the marginal responses to livestock and land endowments per consumer unit on value of crop production per unit land and per consumer unit.

The fact that we used log-transformed variables for crop productivity, land and livestock endowments in Table 4 implies that the parameters for these variables also represent the elasticity estimates. We found that a 1% increase in the land endowment per consumer unit resulted in a 0.78% decrease in land productivity per unit land and a 0.7% increase in value of crop production per consumer unit. This illustrates that land access is important for income generation and that intensification only partly compensates for the higher land scarcity. We also see that a 1% increase in livestock endowment per consumer unit increases land productivity per unit land by 0.12% and value of crop production per consumer unit by 0.16%.

As the last important piece in the puzzle we look at changes in the livestock endowment. We classified the households in the four groups based on their asset endowments in May 1999. However, we also have records of their livestock endowments one year earlier, in May 1998, and four years later, in 2003. We are therefore able to assess how the change in livestock endowments is affected by initial endowment levels and to assess in particular whether the "land-poor and livestock-poor" household group from 1999 still remains livestock-poor in 2003. That is our last test of the "too poor to invest"-hypothesis.

The results of three regression models are presented in Table 5. Limited access to credit may also affect investment in livestock. The first model in the table is included to demonstrate that naive model estimation may yield biased results that lead to wrong conclusions. The livestock endowment variable used in this model is the livestock endowment after the change in livestock holding. This endowment may not only be due to planned investment in livestock but also due to shocks like death of animals or distress sales to cope with other shocks. This may thus be a case of reverse causality. The naive interpretation of this model would be that households with more livestock endowment invest more to increase their livestock endowment and that the livestock-poor may be too poor to invest in livestock. The more proper interpretation may, however, be that livestock-poor households are livestock-poor because they experienced circumstances which reduced their livestock endowment during last period.

The second model in Table 5 therefore uses the livestock endowment before the change to more appropriately address the direction of causality from endowment to change. We see in this model that the livestock endowment variable (tlu98cu) is significant (at 10% level only) and with opposite sign, indicating that those with lower livestock endowment try to increase their livestock endowment more than the relatively livestock-rich. However, the model could explain relatively little of the one-year changes in livestock holding, probably due to the risk involved in keeping livestock.

In the third model in Table 5 we assess the determinants of change in livestock endowment from 1999 to 2003, assuming that this may capture whether land- and livestock-poor households are trapped and have not been able to rebuild their livestock holding. In this model, where explanatory power is higher, we find that the livestock endowment variable is highly significant and with a negative sign, pointing in direction of asset-smoothing in the longer run. Households with higher livestock endowment are likely to be close to the optimal level of livestock given other resource and market constraints.

We hypothesized that limited access to credit is also likely to affect investment in livestock. However, the credit access variable is not significant in any of the models for livestock change. This may indicate that households use other methods to increase their livestock holding.

Male and female labour became significant and with positive signs, while age became significant with negative signs in the last livestock change model. This indicates that labour is important for the buildup of livestock and old age may limit this capacity. The sex of household head variable was also significant and with a negative sign indicating that male-headed households increased their livestock holding less than female-headed households, which was surprising. However, male-headed households also have more male labour (a variable with positive significant effect) than female-headed households.

Marginal returns to additional land and additional livestock are likely to be different for land-rich vs. land-poor and for livestock-rich vs. livestock-poor households and thus for the four household categories. Due to the relatively small sample size we get if we run the regressions for each group separately, we did the analyses for land-poor vs. land-rich households first, and then for livestock-poor vs. livestock-rich households afterwards. The marginal responses to land and livestock are presented in Table 6 for crop productivity per consumer unit.

When we compare the elasticity for land-poor vs. land-rich households in Table 6, we see that a 1% increase in the land endowment per consumer unit increased crop production per consumer unit by 1.32% for the land-poor and by 0.54% for the land-rich, and by 0.93% for the livestock-poor vs. 0.67% for the livestock-rich. The other revealing result in that table, demonstrating that there is an optimal livestock holding size relative to land size, is that a 1% increase in livestock endowment per consumer unit leads to a 0.19% increase in crop production per consumer unit for the livestock-poor households, while it leads to a 0.38% decrease in crop production per consumer unit for the livestock-rich. The latter may be because more land has to be used for fodder production if the livestock holding size increases too much and that may be at the expense of crop production. It may also be because the livestock-rich households put less emphasis on crop production.

6. Conclusions

This study has shown that households in one of the most densely populated areas in the Ethiopian highlands respond to increasing land scarcity by intensifying their agricultural production through integration of a perennial crop enset, livestock and annual crops. We developed a theoretical dynamic household model, which closely resembled the rational behaviour of households. We use the model to demonstrate the important synergies and trade-offs between the various components that the households have to make.

Our empirical analysis revealed that livestock-poor households were less able to intensify their crop production. The cross-section data from 1999 indicated that the group of households being both land-poor and livestock-poor were in a poverty trap and perhaps too poor to invest as they were found to be more severely credit-constrained than other household groups. However, investigation of livestock changes from 1998 to 2003 revealed that also this household group was able to rebuild its livestock endowment and they therefore turned out not to be too poor to invest. Although this group was found to be more severely credit constrained than the other household groups, the credit constraint appeared not to prevent the build-up of its livestock endowment. A system of livestock-sharing contracts appears to be one explanation for this and merits further study.

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Table 1: Summary Statistics of variables used in enset intensification analysis

Description of variables*	Variable name	Mean	Std. Dev.
Consumer units/household	consu (cu)	6.115	3.050
Land per consumer unit	landcu	0.320	0.276
Enset area share of farm size	ensaresh	0.109	0.099
Total enset stock per farm size	ensetha	227.557	315.548
Total enset stock per consumer unit	stockcu	49.864	45.997
Enset stock of <=2 years old per consumer unit	es02cu	26.057	25.222
Age of hh head in years	age	41.592	13.696
Sex of house hold h head = 1 if male; 0 otherwise	sex	0.901	0.299
Education of the hh head in years	educ	1.852	3.013
Exogenous income per consumer unit	exogincu	5.098	14.510
Male workforce per consumer unit	mwfcu	0.299	0.154
Female workforce per consumer unit	fwfcu	0.312	0.133
Total livestock units per consumer unit for 98	Tlu98cu	0.447	0.352
Oxen per consumer units	oxecu	0.084	0.121
Credit access per consumer units	craccesscu	87.669	124.641
Total value of crops per farm size	tvcha	655.840	591.737
Total value of crops per consumer units	tvccu	152.172	122.281

* Land is measured in *timad*, and 1 *timad* = 0.25 ha; income, value and credit are in birr (ETB).

Table 2: Socio-economic characteristics of the sample hhs by land holding

Variables	Land-poor		Land-rich	
	Livestock-poor	Livestock-rich	Livestock-poor	Livestock-rich
No of HHs	36	35	36	35
Mean age	43(1.917)	37(2.094)	41(2.199)	45(2.808)
Mean educ.	1.6(0.453)	2.1(0.541)	1.5(0.407)	2.2(0.611)
fmlysiz	8.7(0.658)	7.6(0.913)	7.2(0.520)	6.3(0.419)
consu	7.2(0.561)	6.0(0.642)	6.1(0.416)	5.2(0.334)
cwratio	1.757(0.057)	1.883(0.102)	1.739(0.130)	1.613(0.054)
owh	0.957(0.124)	0.974(0.132)	2.595(0.309)	2.649(0.273)
ensarea	0.103(0.018)	0.123(0.021)	0.156(0.026)	0.223(0.031)
ensaresh	0.123(0.020)	0.142(0.016)	0.069(0.010)	0.104(0.017)
stockcu	33.651(6.370)	50.230(7.302)	38.296(4.769)	78.075(9.743)
es02cu	18.975(3.497)	28.026(4.736)	22.651(3.718)	34.877(4.592)
landcu	0.126(0.010)	0.155(0.008)	0.455(0.038)	0.545(0.058)
tlucu	0.153(0.020)	0.544(0.032)	0.244(0.024)	0.819(0.072)
oxecu	0.007(0.004)	0.113(0.020)	0.048(0.012)	0.173(0.026)
mwfcu	0.275(0.021)	0.278(0.021)	0.301(0.033)	0.342(0.026)
fwfcu	0.315(0.018)	0.292(0.018)	0.337(0.030)	0.304(0.020)
exogincu	2.616(1.136)	2.981(1.686)	9.081(3.136)	5.670(3.086)
nonfarincu	94.621(38.617)	53.425(20.140)	40.151(8.032)	61.717(19.285)
tvcha	748.229(130.365)	984.121(99.930)	389.637(41.906)	506.339(73.617)
tvccu	77.313(8.345)	148.188(17.005)	169.675(21.003)	215.153(25.412)
crecu	12.146(2.999)	11.998(3.383)	9.476(2.308)	18.123(6.097)
craccescu	45.662(10.058)	104.276(18.198)	105.331(30.367)	96.103(18.790)

Standard errors in parenthesis

Table 3: GLM and Tobit model results for enset area share, stock and investment equations

Variable name	GLM results	Tobit results		
	Enset area share	Enset stock/cu	Enset stock/ha	Enset investment (es02/cu)
llandcu	-0.849***	0.35	-254.74***	-0.19
	(0.16)	(0.29)	(65.39)	(0.33)
mwfcu	0.265	1.47	317.22	0.74
	(0.72)	(1.07)	(248.23)	(1.66)
fwfcu	1.132*	1.07	304.40	1.17
	(0.67)	(1.60)	(265.16)	(1.93)
ltlu98cu	0.264***	0.51***	49.21***	0.49***
	(0.08)	(0.15)	(18.31)	(0.19)
age	0.002	0.001	-0.88	0.01
	(0.01)	(0.01)	(1.80)	(0.01)
sex	0.419	-0.29	-81.82	-0.01
	(0.34)	(0.41)	(67.86)	(0.62)
educ	0.022	0.03	26.27*	-0.01
	(0.02)	(0.03)	(13.66)	(0.04)
lexogincu	-0.046	-0.10**	-14.53**	-0.03
	(0.03)	(0.04)	(6.01)	(0.05)
craccescu				0.001**
				(0.01)
constant	-3.854***	3.38***	-164.91	1.62
	(0.60)	(1.31)	(184.61)	(1.59)
sigma_cons		1.24***	284.72***	1.66***
		(0.23)	(41.41)	(0.26)
Prob > chi2	0.00	0.00	0.00	0.04
Number of obs.	142	142	142	142

Bootstrapped standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: OLS models of total value of crop production per consumer unit

Variable name	Landprod/ha	Crop prod/cu
llandcu	-0.776***	0.703***
	(0.123)	(0.137)
mwfcu	-0.073	-0.188
	(0.485)	(0.524)
fwfcu	-0.262	-0.377
	(0.630)	(0.580)
ltlu98cu	0.125*	0.163**
	(0.064)	(0.069)
loxecu	-0.006	-0.001
	(0.045)	(0.048)
age	0.004	0.004
	(0.005)	(0.005)
sex	0.036	0.028
	(0.308)	(0.311)
educ	0.005	-0.002
	(0.023)	(0.023)
lexogincu	-0.020	-0.010
	(0.022)	(0.023)
craccescu	0.001*	0.001
	(0.000)	(0.001)
Constant	5.266***	5.509***
	(0.589)	(0.532)
R squared	0.248	0.309
N	142	142

Bootstrapped standard errors in parentheses. *: significant at 10%; **: significant at 5%; ***: significant at 1%,

Table 5: OLS models of livestock change from 1998 to 1999 and from 1999 to 2003

Variable name	Livestock Change 98-99	Livestock Change 98-99	Livestock Change 99-03
Landcu	-0.057	0.533	0.420
	(0.305)	(0.357)	(1.038)
mwfcu	-0.221	-0.117	4.744**
	(0.866)	(0.825)	(1.992)
fwfcu	1.071**	0.931*	2.907*
	(0.515)	(0.564)	(1.528)
tlu99cu	0.693**		-4.719***
	(0.273)		(1.065)
tlu98cu		-0.722*	
		(0.375)	
stockcu	-0.001	0.001	0.003
	(0.002)	(0.002)	(0.006)
Age	-0.009	-0.009	-0.045***
	(0.008)	(0.008)	(0.017)
sex	-0.038	-0.048	-1.628**
	(0.181)	(0.174)	(0.814)
educ	-0.040	-0.006	-0.129
	(0.043)	(0.041)	(0.120)
Exogincu	0.006	0.007	-0.003
	(0.005)	(0.006)	(0.015)
craccescu	0.001	0.001	-0.002
	(0.001)	(0.001)	(0.002)
Constant	-0.201	0.054	2.555**
	(0.453)	(0.502)	(1.219)
R-squared	0.048	0.052	0.315
N	142	142	142

Bootstrapped standard errors in parentheses; *: significant at 10%; **: significant at 5%; ***: significant at 1%

Table 6: Value of crop production per consumer unit for land-poor vs. land-rich households and for livestock-poor vs. livestock-rich households, selected variables from OLS models.

Var. name	Land-Poor Crop prod/cu	Land-Rich Crop prod/cu	Livestock-Poor Crop prod/cu	Livestock-Rich Crop prod/cu
llandcu	1.316***	0.541**	0.934***	0.671***
	(0.369)	(0.243)	(0.219)	(0.188)
ltlu98cu	0.147	0.097	0.189**	-0.381**
	(0.109)	(0.110)	(0.085)	(0.176)
R-squared	0.304	0.124	0.386	0.196
N	71	71	72	70

Bootstrapped standard errors in parentheses. *: significant at 10%; **: significant at 5%; ***: significant at 1%

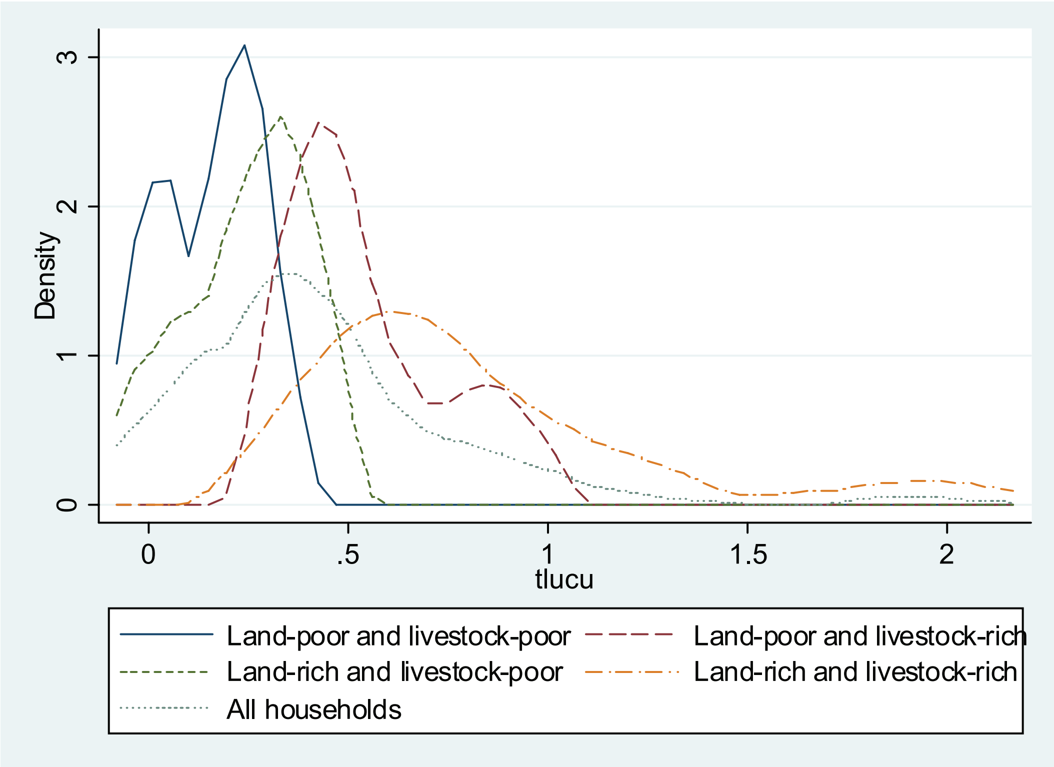

Figure 1. Livestock (tropical livestock units per consumer unit) for the different household categories.

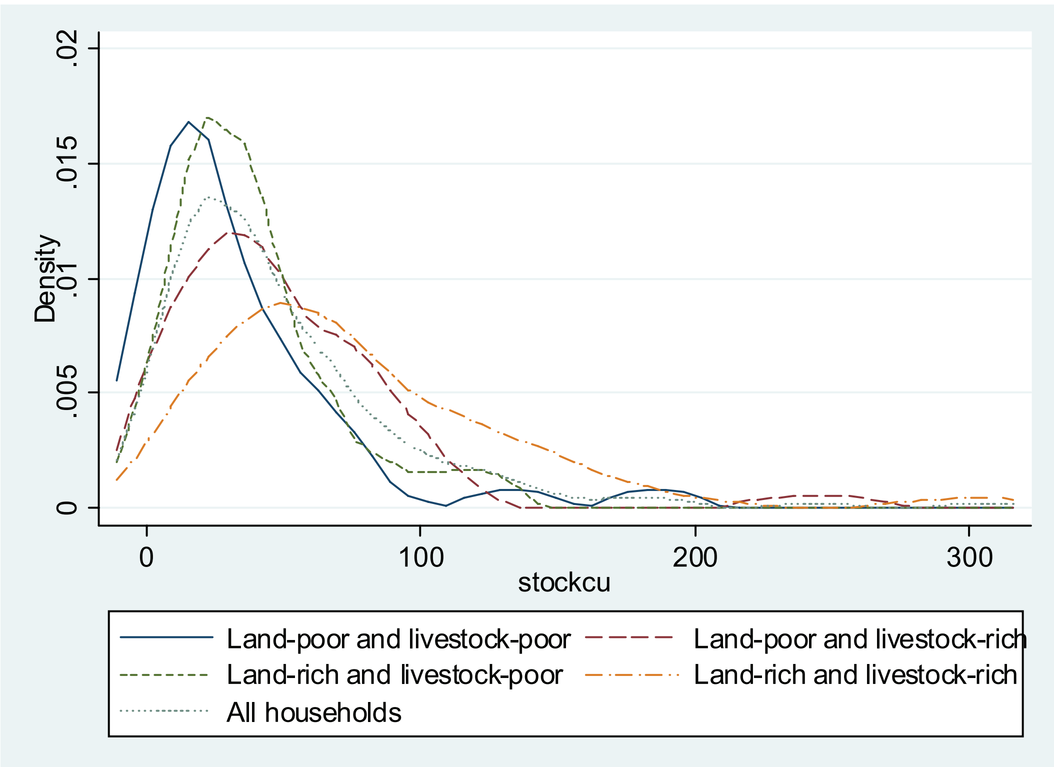

Figure 2. Enset stock by land and livestock category of households

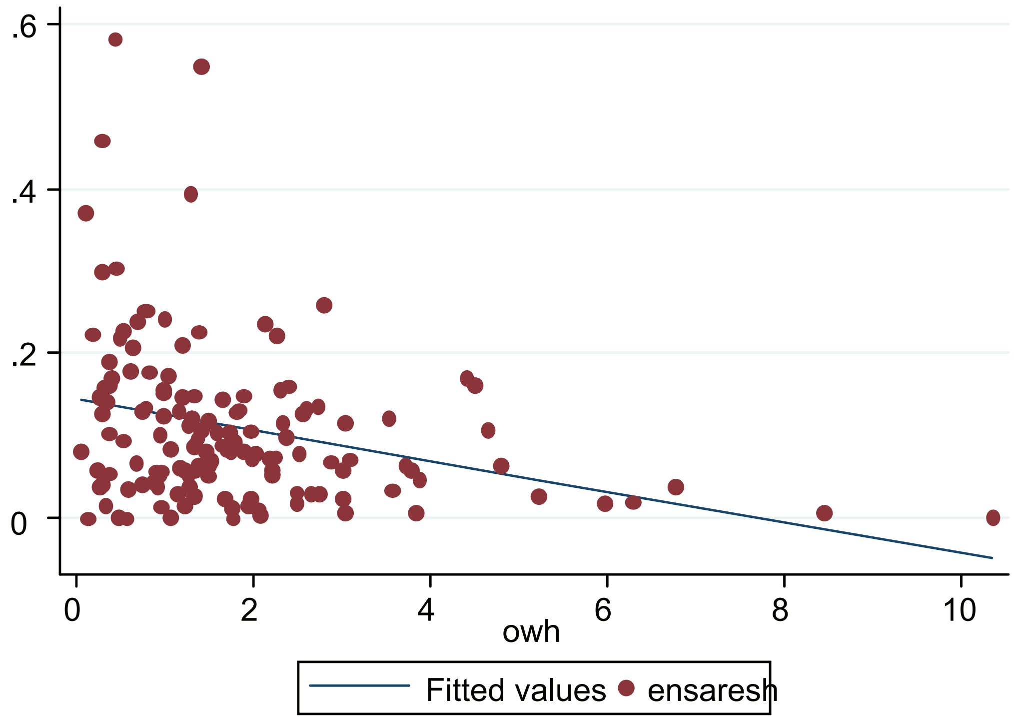

Figure 3: Enset area share as a function of own land holding

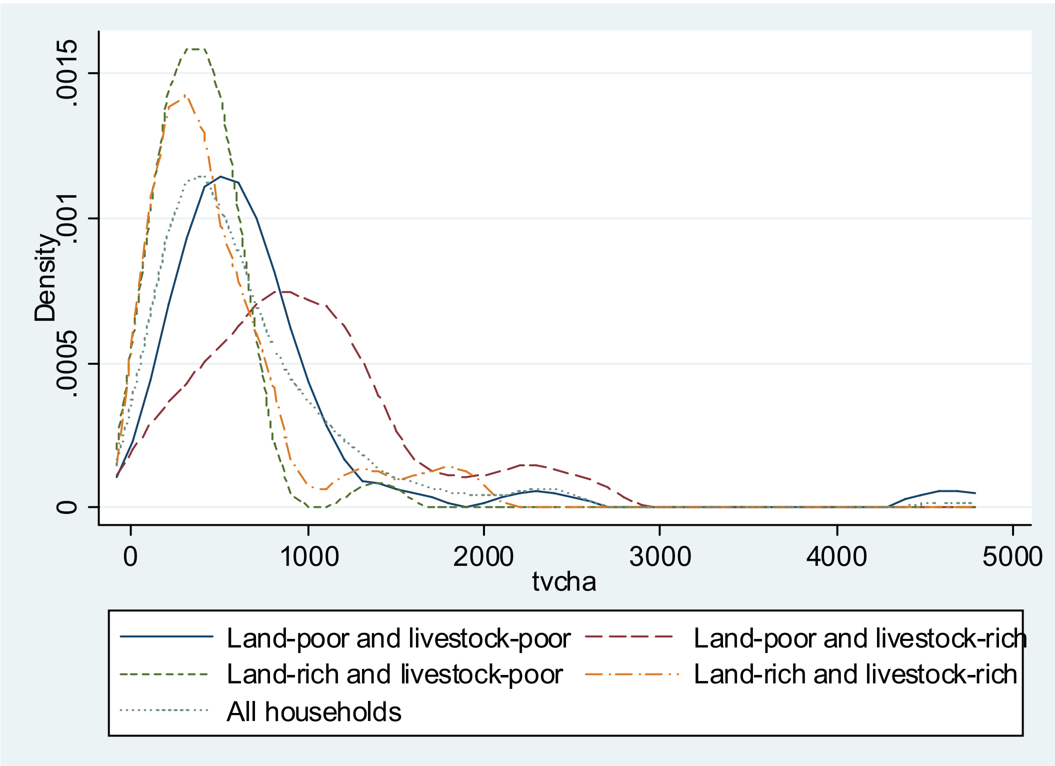

Figure 4. Crop productivity per hectare for the different household categories

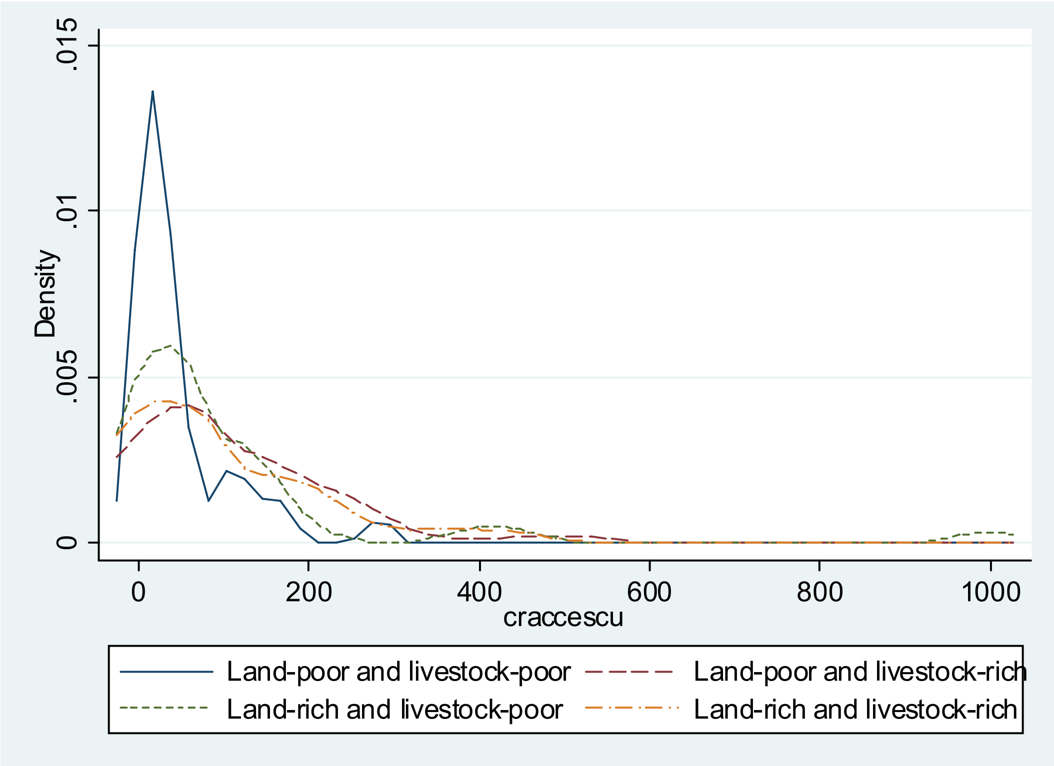

Figure 5. Credit access per consumer unit for the different household categories.

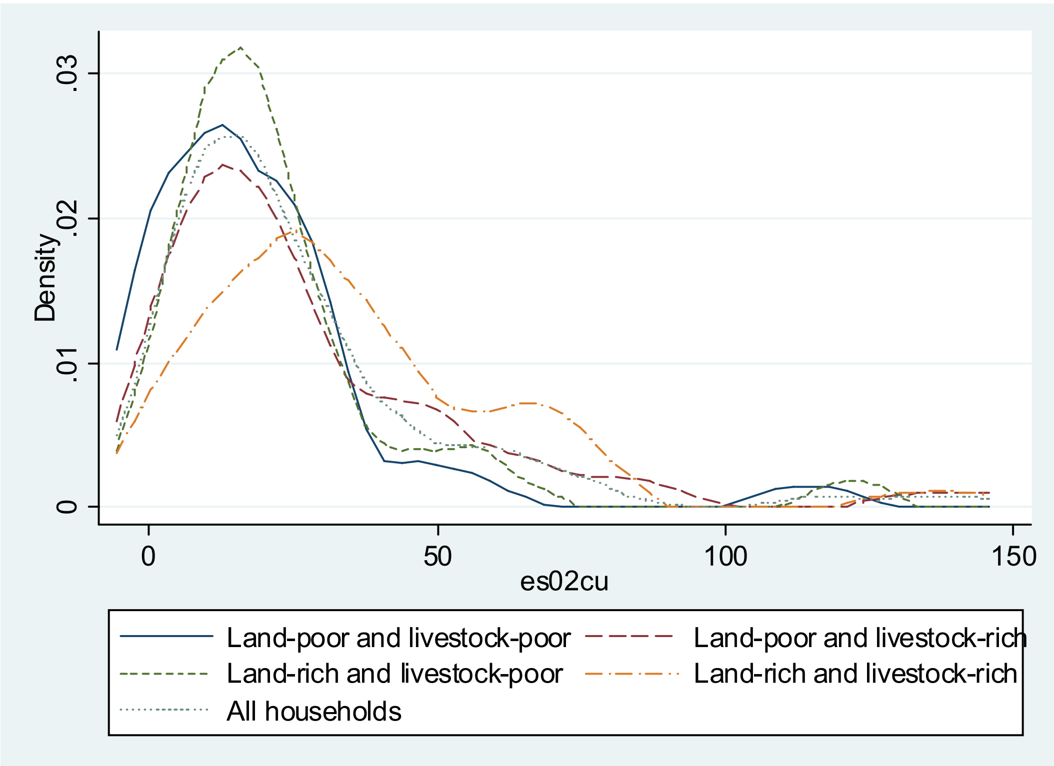

Figure 6. Investment in enset for the different household categories

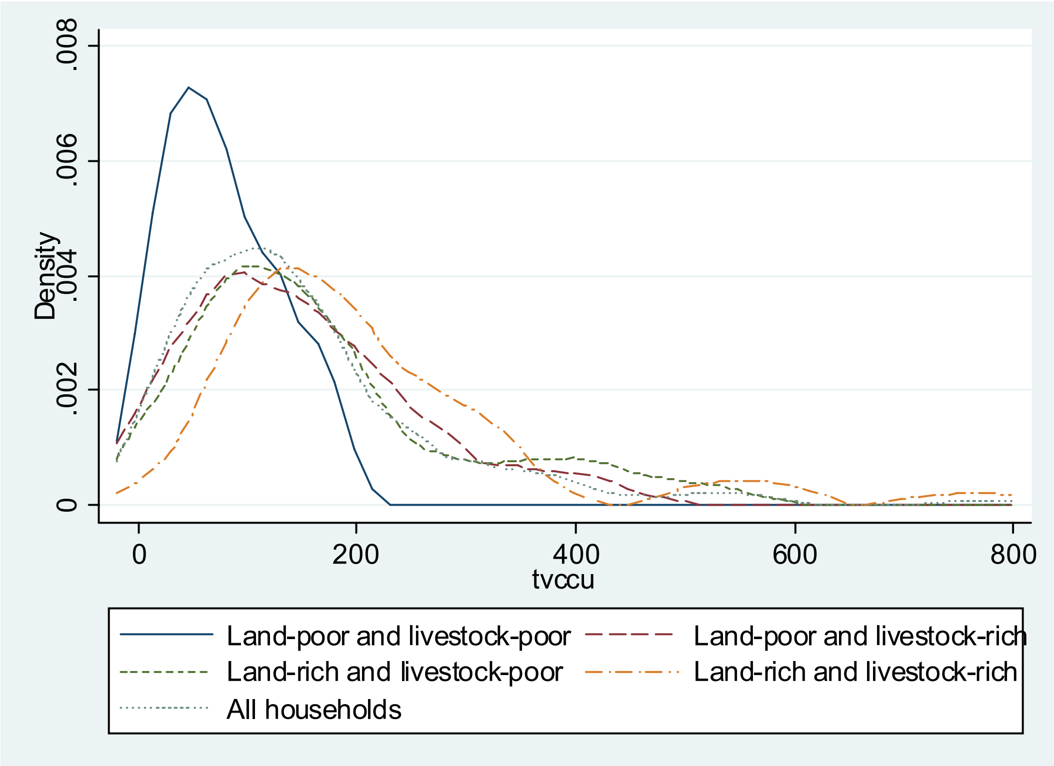

Figure 7. Value of crop production per consumer unit for the different household categories

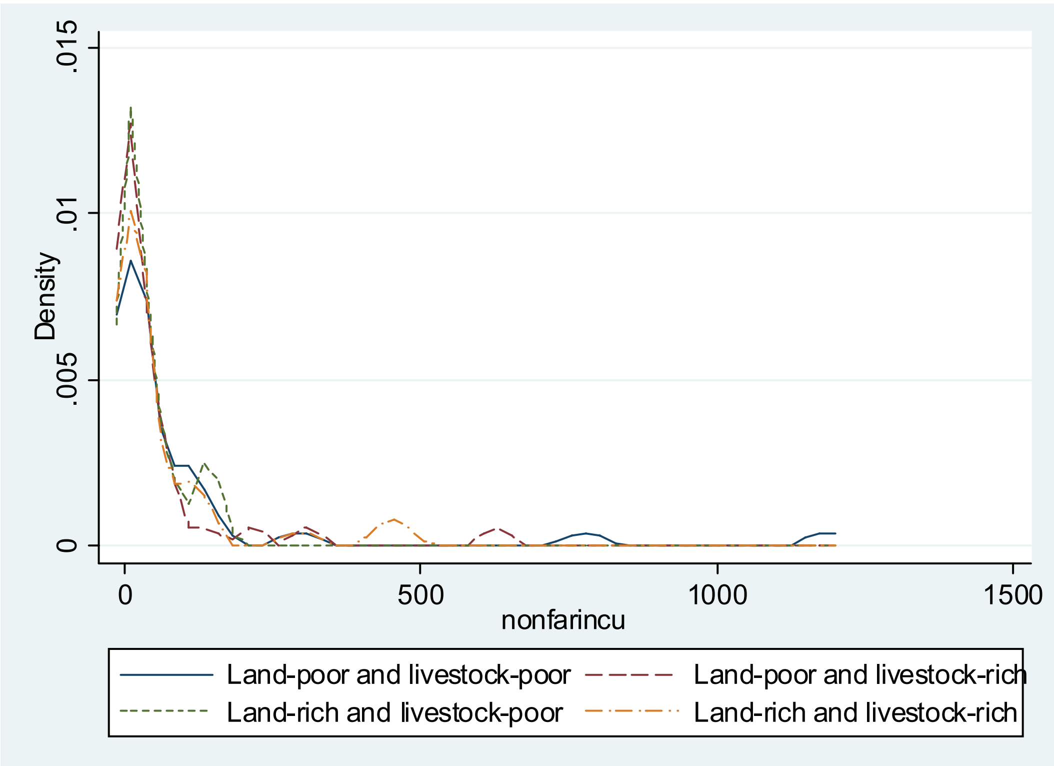

Figure 8. Access to non-farm income per consumer unit by household group

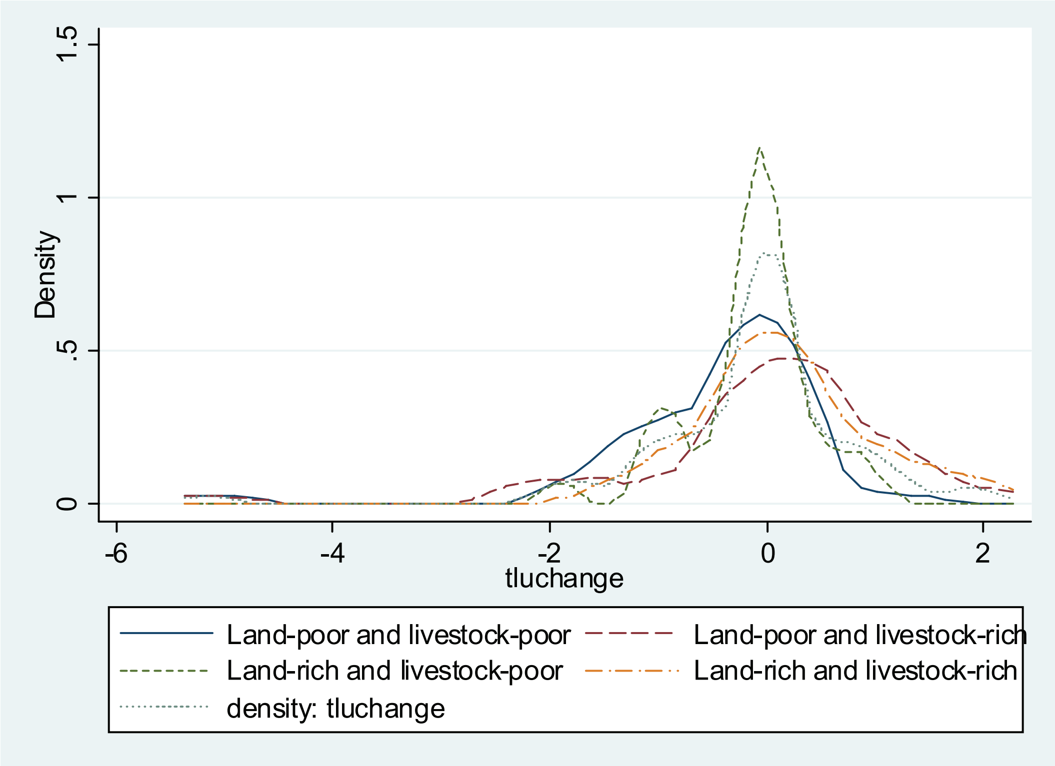

Figure 9. Change in livestock holding from May 1998 to May 1999 by household group

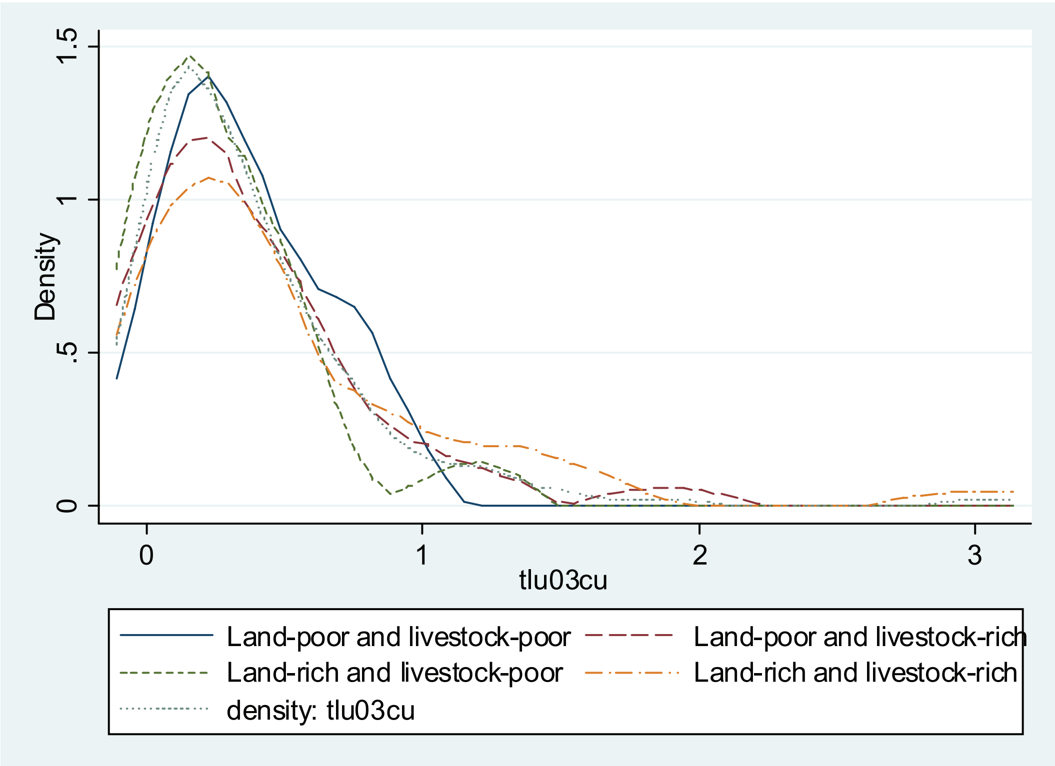

Figure 10. Livestock endowment per consumer unit four years later by household group

'*bulla*'-quality food processed
from enset pseudostem

A woman scraping enset pseudostem
for '*kocho*' food

Paper III

Other uses of enset (rope)

Are the poor forced to cut the branch they are sitting on?

Perennial crop harvesting decisions of food insecure smallholders

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Abstract

Does poverty lead to a vicious circle where the poor harvest their own seeds in order to survive in the short run? We test this in a densely populated area in Southern Ethiopia, where the main staple crop, enset, is a perennial crop that takes 4-5 years to reach maturity, but is frequently harvested at a much earlier stage. We assess the relevance of the Faustmann rotation model in our study case area. We calibrate a simple simulation model using experimental production data for enset. The simulation results indicate that higher discount rates shorten the optimal rotation period. With imperfect labour, land and credit markets, individual households have their own discount rates that depend on their poverty status. This implies different harvesting strategies in terms of rotation length. Using cross-sectional data from a survey of 142 randomly selected households, we investigate factors related to average rotation period, proportion of young plants harvested, and number of young plants harvested, applying OLS, fractional response, and Cragg's models respectively. The analysis suggests that food insecurity is the major factor for early harvesting of the perennial crop. Food insecure households could therefore be in a vicious circle, where early stage harvesting helps them to alleviate the immediate subsistence constraints but reduces future availability as fewer plants are saved to reach full maturity.

Key Words: Farm households, perennial food crop, early harvesting, Faustmann model, Southern Ethiopia

1. Introduction

Ethiopia is one of the poorest countries in the world where the majority of its rural population lives in poverty and in a state of chronic food insecurity (FAO, 2006). Most of the highlands in rural areas of Southern Ethiopia are prone to drought and seasonal food shortages. The smallholders in these densely populated areas produce for subsistence on depleted soils using simple technologies. Short term responses of the smallholders when they lose annual crops due to drought or rain failures vary from selling animals to reducing the frequency and amount of food they consume per day. One of their long-term strategies to cope with this persistent situation is diversifying production into perennial crops, which are relatively drought tolerant. The most important of these perennial food crops is enset (*Ensete ventricosum*), a banana-like perennial crop. Food is obtained from pseudostem and underground corm. Enset supports more than 15 million people in the country as a staple or co-staple food crop (Zippel, 2002). Enset has also many non-food uses such as animal feed, wrapping material, construction material, and medicine.

Some studies in the highlands of Southern Ethiopia provide scattered information on the role of enset for food security (Shank and Ertiro, 1996; Brandt *et al.,* 1997; Tsegaye and Struik, 2002; Nicodimos, 2005). According to Brandt *et al.* (1997), enset contributes to the stability of food supply because it can be: harvested at any stage over a several year period, harvested at any time during the year, stored for long period without being spoiled, and survive stress years that reduce other food sources. Shank and Ertiro (1996:35) expressed enset's year-round food contribution to the farm household as follows:

"…Enset is most popular because it is a 'living refrigerator' from which the family can conveniently take as much food as it likes any time during the season."

Based on their study in Southern Ethiopia, Tsegaye and Struik (2001) concluded that the cultivation of enset in densely populated areas under low input conditions can sustain the population better than any other crop grown in the country, especially if supplemented with legumes and vegetables for proteins and vitamins. In line with this, Amede *et al.* (2004) from their studies in Ethiopian highlands suggested that a shift from cereal-dominant to enset-legume dominant farming system would contribute positively to food security because of the high energy yield of enset and its protective functions for the land, in addition to the advantages mentioned above.

Enset plant gives higher yield when harvested at its maturity (Tsegaye and Struik, 2000; 2001). However, early harvesting of this crop is not an uncommon phenomenon, but previous studies did not reach any consensus regarding the reasons for the early harvesting. Some attribute such immature harvesting to family food shortage or short-term food needs (Alemu and Sandford, 1991; Alemu *et al*., 1994), while others attribute it to land shortage for transplanting all the suckers (Shank and Ertiro, 1996). The latter also added that intermediate aged plants (2-3 year old) could be harvested as they enhance fermentation due to their sweet and juicy nature.

This paper provides a quantitative study on factors related to harvesting decisions of the farm households by addressing the following questions: Why do some farm households harvest enset at early age (up to two years old) while others harvest at a later stage? Are poor households caught in a vicious circle of poverty in the way that they need to harvest their own seeds in order to survive in the short run? We consider the extension of the Faustmann rotation model based on recent theories and evidence about the role of imperfect markets. When labour markets are imperfect and off-farm employment opportunities limited, harvesting cost becomes a function of the endowment of family labour, implying the need for the extension of the standard Faustmann model in identifying the optimal rotation period for the perennial crop. Imperfect capital markets may also make the farm households smooth income (consumption) from enset over time. This may mean that enset stands are not cut independently and two perfectly similar stands may not be cut at the same time. Harvesting time will vary across households according to their subjective discount rates (Tahvonen, 1998).

The paper is organized as follows. Section 2 provides a theoretical framework followed by a discussion of the econometric methods in Section 3. Section 4 presents both simulation and econometric results and discussion, while Section 5 concludes.

2. Theoretical framework

In a forestry single rotation model, the rule is to cut the trees when the value of the additional growth of timber is just equal to the interest that could have been earned on the money gained if the timber is harvested. But the single rotation model assumes that the trees are not going to be replaced after being cut, thus there is no opportunity cost of land (Clark, 1990). The situation is different when we consider a multiple (continuous) rotation problem where the household uses the land to repeatedly plant and harvest the trees. We consider enset (a perennial food crop) plantation and assume that a household harvests enset plants every year and replants the area. Following the Faustmann principle, the optimal rule is to harvest when the value of the current annual increment is equal to the forgone earnings in terms of interest from the enset product sale and the rental value of land. In this way, any delay in harvest also delays the receipt of profits from future stands.

The value of a single enset plant depends on its biomass and quality of products that can be extracted. The biomass of the enset plant (S) is a function of biological growth over time (t), i.e., the stock value is dependent on age and can be written as pS_t. p is the net price after deducting harvesting and processing costs (C^v), i.e., $p = P - C^v$, with P as the market price for Kocho (major food product from enset). We assume S_t to be a simple concave function increasing in time (t). Assuming constant price and costs, and an infinite time horizon, the household's problem is to maximize the following net present value (NPV) from the plot of all future harvests (Clark, 1990):

$$\underset{T}{Max}\, NPV = \frac{\left(P - C^v\right) S_T - C^F}{e^{\delta T} - 1} \tag{1}$$

where T refers to harvesting time (rotation period), C^F refers to fixed (per unit land) production costs, and δ is the discount rate.

The conventional Faustmann model assumes perfect markets with exogenous and market-determined product prices, costs and discount rates. However, this study deals with a subsistence constrained economy with market imperfections, especially in intertemporal markets (credit and insurance). Poor households face a minimum subsistence requirement that limits their choice to delay harvest as a future investment. Subsistence constraints and market imperfections make the discount rates subjective and household-specific as they depend on asset poverty and household characteristics (Holden *et al.,* 1998). In other words, the discount rates become a function of household endowments and characteristics including food security (W): $\delta = \delta\left(W\right)$; $\quad \delta'_W < 0$

Holden *et al.* (1998), in their study of rural households in Zambia, Indonesia and Ethiopia, found that poverty leads to higher rates of time preference: consumption now is given relatively higher value than consumption in the future among poorer households. Under such circumstances, the households will have different optimal rotation periods depending on asset poverty, degree of food insecurity, and household characteristics.

According to Tahvonen (1998), using the Faustmann rotation under imperfect land and capital markets may lead to deviation from the optimal policy because credit rationing may shorten rotation as the optimal age becomes forest-owner specific. Tahvonen *et al*. (2001) also demonstrate that with binding credit constraints, harvesting decisions depend on owner-specific characteristics such as non-forest income and wealth. However, Tahvonen (1998) lacked data on forest age classes and only studied *in situ* preferences with competitive capital markets without the bequest motive. His study was also restricted to cases with zero rate of interest and zero non-forest income. Tahvonen *et al*. (2001) further developed a model which determines an infinite chain of rotations by a non-linear difference equation under borrowing constraints instead of assuming constant rotation period. With binding borrowing constraint, a stationary solution depends on forest owner-specific factors and consumption jumps up at the harvesting dates. The rotation period varies over time, depending on initial wealth. These authors also assume one even-aged stand. In our study case, the households own different age classes of enset.

These models by Tahvonen and colleagues demonstrate that relaxing the perfect market assumptions modifies the optimal rotation. At the same time the analytical models become very complex, and they do not capture all the imperfections found in the study area: Market imperfections not only affect credit but also labour and land markets. We thus extend the Faustmann model to consider imperfect labour markets, in addition to the credit market already discussed, and do it in a way that is analytically simple.

If we assume imperfect or missing labour market, the costs of production (C^F) and harvesting (C^v) are determined by each household's shadow wage, which again is a function of its labour endowment: $C^v = C^v\left(L\right)$ and $C^F = C^F\left(L\right); C' < 0$. In other words, the cost is lower for households with a larger labour endowment as they will have low shadow wage rates in the presence of limited off-farm employment opportunities. Prices for the perennial food crop in the study area are assumed to be exogenous as markets for output work better with a participation rate of more than 95% in the sample.

Based on these deviations from the perfect credit and labour markets case, we need to modify the Faustmann model presented in equation (1):

$$\underset{T}{Max}\, NPV = \frac{\left(P - C^{v}\left(L\right)\right)S_T - C^F\left(L\right)}{e^{\delta(W)T} - 1} \tag{2}$$

Equation (2) implies that discount rates and costs become household specific. The solution procedure is, nevertheless, the same as for the standard Faustmann model, and the optimal rotation can now be derived by differentiating the NPV in equation (2) with respect to T and equating to zero to get the following:

$$\frac{\left(pS_T\right)'}{pS_T - C^F\left(L\right)} = \frac{\delta\left(W\right)}{1 - e^{-\delta(W)T}} \tag{3}$$

where $\left(pS_T\right)' = \frac{\partial\left(pS_T\right)}{\partial T}$

By rearranging equation (3), we get the following expression:

$$\left(pS_T\right)' = \delta\left(W\right)\left[pS_T - C^F\left(L\right)\right] + \delta\left(W\right)\frac{pS_T - C^F\left(L\right)}{e^{\delta(W)T} - 1} \tag{4}$$

Equation (4) states that the enset plants should be harvested at age T when the growth in the value of the plants (the left hand side term) equals the opportunity cost of postponing harvest. The opportunity cost consists of the two familiar terms from the Faustmann formula: the cost of delaying the net income in one year (first term on the right hand side) and the opportunity cost of land (the second term on right hand side).

In reduced form, the optimal harvesting time (T^*) can be written as a function of the exogenous variables of the model:

$$T^* = \tilde{f}\left(P - C^{v}\left(L\right), C^F\left(L\right), \delta\left(W\right)\right) = \hat{f}(P, L, W) \tag{5}$$

While the model above describes important aspects of the farm decisions under imperfect markets, an important aspect is not included (as it is technically very complex, see Mitra and Wan, 1986). Farm households must fulfill their food requirements every year, and the enset harvesting decision is influenced by that. They manage multiple age enset plots on their farms. If a household has mature enset plants, it is possible that the harvest from these will fulfill their food needs. Otherwise, the household will harvest many of the young enset plants for food, shortening the rotation period. The rotation length therefore also depends on the available stock of enset plants in different age groups. Similarly, the labour endowment included in the above model does not explicitly show the food need of the family. Considering number of consumer units in the household would count for this. We can therefore extend equation (5) to include the enset stocks and consumption needs:

$$T^* = f\left(P, L, W, S_1^e, S_2^e, S_3^e, C_u\right) \tag{6}$$

where S_1^e, S_2^e and S_3^e refer to the enset stock on the farm consisting of young (< 2 years), intermediate (2-4 years) and mature (> 4 years) enset plants, respectively, and C_u is consumer units in the household.

The sign of these variables (comparative statistics) are given below and follow from standard presentations of the Faustmann model, e.g. Clark (1990) and Hyde and Newman (1991):

$f_P' < 0$: A higher output price leads to a shorter rotation period;

$f_L' < 0$: Higher labour endowments lower the household's shadow wage, increasing the net price and lowering the fixed costs. The effect on T^* is similar to an output price increase (only relative prices matter);

$f_W' > 0$: Higher wealth and food security lowers the discount rate, which increases in the optimal rotation period.

$f_{S_1^e}' < 0, f_{S_3^e}' > 0$: The availability of mature enset stand on farm will lengthen the rotation period as enough food can be obtained from a mature plant. On the other hand, the household will have shorter rotation period if the enset stand in his/her farm consists of few mature but large stand of young enset stock.

$f_{C_u}' < 0$: There is a need for more food for a household with larger number of consumer units, and this shortens the rotation period.

In agronomic, biological and ecological studies, the concept of Maximum Sustainable Yield (MSY) is commonly introduced as the optimal rule. As is well known (e.g., Clark, 1990), the economic optimum that can be found from equation (3) converges to MSY when the discount rate is set to zero:

$$\frac{\left(pS_T\right)'}{pS_T - C^F\left(L\right)} = \frac{1}{T} \tag{7}$$

Equation (7) indicates that we can maximize the average annual economic yield given by the left hand side. Such maximization usually suggests longer rotation periods as compared to the economic optimal rule with positive discounting.

In order to assess the relevance of the modified Faustmann model in our case study area, we have calibrated a simple simulation model and assessed the relationship between the optimal rotation period and alternative discount rates. Experimental production data from Southern Ethiopia (Tsegaye and Struik, 2001) were used to estimate a simple growth function for enset. The simulation model is also used to approximate how high the discount rate can go before it leads to a very myopic behaviour and enset harvesting at very young age (before 2 years).

2.1. Hypotheses

Based on the theoretical framework, we put forward the following hypotheses:

1. Households with few mature enset plants on their farms will harvest the young ones to satisfy their food need, hence have a shorter rotation period.
2. Households with high labour endowments will have longer rotation periods.
3. Large families (consumer units) have higher food requirements and this shortens the rotation period.
4. Wealthier households with larger livestock and land holdings have longer rotation period.
5. Food insecure households harvest young enset plants to fulfill family food requirements, leading to shorter rotation period.

3. Data and methods

3.1. Study area, data and variable specification

Gununo is located at about 405 km southwest of Addis Ababa at an elevation between 1880 and 1960 m.a.s.l. The area has mean rainfall of about 1300mm and an average temperature of 19.5^{o}C (Amede *et al.,* 2001). Gununo is known for its high population density of more than 700 people/km^2, leading to a reduced average land holding of less than half a hectare (ha), the majority owning about 0.25 ha.

The farming systems of Gununo are characterized by a mixed crop-livestock production with enset-root crop-maize dominance. From our survey of 142 households in 1999, we found that much of the cultivable land was allocated for Sweet potato followed by maize and enset. But the households diversified their production with up to 14 crops in different plots, the smallest plot being 0.06 *timad* (142.5 m^2) of land on average (Table 1). Enset is known to be less susceptible to drought compared to other major food crops such as maize and sweet potato. It contributes considerably to energy requirement in the food system of the area. For our sample households, it contributed 39% of calorie supplied by the major food items (maize, sweet potato, enset, and haricot beans) consumed from own production in the previous year. Enset is the only available high-energy food from late February to the end of May, the period where the other two major food components, maize and sweet potato, are limited or not available. About 82 percent of the households expressed having food security problems, about 92 percent of them have faced the problem at least three times, and 31 percent more than five times during the last ten years (Table 2). The households mentioned drought and poor land quality as major reasons for food insecurity. Even more households, 92% of the sample, reported that they have faced an increasing food deficit during the last five years due to reduced farm size by partitioning to adult sons, declining land productivity, and increasing family size.

Data for this study were collected from 142 randomly selected farm households surveyed in 1999. The data included information on household characteristics, production, consumption, expenditures, income, farm characteristics, and perceptions and preferences. The information collected on the stock and number of harvested enset plants was in age intervals, such as number of plants harvested at the age of up to 2 years, number of those harvested between 2 and 4 years old, and those harvested when older than 4 years. The summary statistics of variables used for the analysis and hypotheses of their expected relation to the dependent variables is presented in Table 3. The dependent variables were average year of harvesting (rotation period), proportion of young enset stock harvested from the total harvest, and number of harvested young stock per consumer unit. The average rotation period was found by weighing the harvested enset plants of different age groups by the number of plants harvested in each age group. As indicated in the theoretical framework, wealth in terms of land holding, intermediate and mature enset stock, and livestock are expected to have positive correlation with the rotation period, but a negative one with the proportion and number of young enset plants harvested. Food insecurity and number of consumer units in the household are expected to shorten the rotation period and to be positively related to early harvesting.

3.2. Simulation model

Following Pearse (1967), Clark (1990), and Hyde and Newman (1991), we used experimental data of output from harvested enset plants being measured bi-annually in Southern Ethiopia (Tsegaye and Struik, 2001) and calibrated the model to estimate a simple growth function of the enset plant. We used village average price and harvesting costs for this. Then, we derived the optimal rotation period using different discount rates and for two scenarios: one for a single period rotation model, and one for a multiple period rotation (Faustmann) model. Consistent with the theoretical results, higher discount rates are assumed to shorten the rotation period (see also Alvarez and Koskela, 2005; Tahvonen, *et al.,* 2001). The details of the simulation exercise are presented in the Appendix.

3.3. Econometric methods

The implications of the theory and simulation model were tested using different econometric methods on the data collected. We used the ordinary least squares (OLS) with robust standard errors for analysing factors related to the optimal harvesting period (T^*). Based on our theoretical framework and equation (6), the dependent variable is a function of labour endowment, wealth in terms of land and livestock assets, enset stock, and household characteristics, including food insecurity. The regression model can be specified as:

$$T^* = \alpha + \varphi S_1^e + \phi S_2^e + \psi S_3^e + \mu L^m + \omega L^f + \gamma TLU + \beta A + \eta F + \theta Z^h + \varepsilon \qquad (8)$$

where T^* is optimum rotation period, S_1^e, S_2^e and S_3^e are number of young, intermediate age and mature enset plants, respectively; L^m and L^f refer to household male and female labour endowment respectively, TLU is livestock in tropical livestock units, A refers to land holding, F refers to food insecurity; α is constant term, φ, ϕ, ψ μ, ω, γ, β, η and θ are parameters to be estimated, ε is error term.

The second dependent variable used in our analysis was proportion of early harvested enset plants. We applied a generalized linear model (GLM), namely a logit quasi-maximum likelihood estimator (QMLE). The dependent variable is a proportion and using linear models such as ordinary least squares (OLS) will not give efficient estimates. The predicted values from OLS regression may lie outside the range of 0 and 1 (Papke and Wooldridge, 1996) and the conditional variance is not likely to be independent of the conditional mean. The traditional logit transformation of the data as a solution to this problem has some drawbacks as transformation is not possible for values of 0 and 1 of the dependent variable, and our data include these boundary values. Papke and Wooldridge (1996) developed alternative (quasi-likelihood) estimation methods, within the framework of generalized linear models (GLM), for regression models with such fractional dependent variable. Their assumption is that there is an independent, not necessarily identically distributed, sequence of observations $\{(X_i, S_i): i = 1, 2, ..., N\}$, where $0 \le S_i \le 1$ and N is the sample size. Then for all i,

$$E(S_i / X_i) = G(X_i \beta) \qquad (9)$$

where $G(.)$ is a known function satisfying $0 < G(Z) < 1$ for all $Z \varepsilon R$, ensuring that the predicted value of y lies in the interval [0,1].

Based on this assumption, Papke and Wooldridge (1996) provide a particular quasi-likelihood method, namely the Bernoulli log-likelihood function

$$l_i(b) \equiv S_i \log\left[G(X_i b)\right] + (1 - S_i)\log\left[1 - G(X_i b)\right] \qquad (10)$$

which is well defined for $0 < G(.) < 1$.

On the basis of equation (6) we specify the following empirical model to be estimated using the logit quasi-maximum likelihood estimator (QMLE).

$$\frac{S_2}{S_{ht}} = \alpha + \varphi S_1^e + \phi S_2^e + \psi S_3^e + \mu L^m + \omega L^f + \gamma TLU + \beta A + \eta F + \theta Z^h + \varepsilon \qquad (11)$$

where $\frac{S_2}{S_{ht}}$ is proportion of young enset stock harvested[13] to the total harvest, and all other variables are as defined above.

The third dependent variable we considered was the number of young enset plants harvested per consumer unit. Three out of 142 farm households do not have enset plants, and some households did not harvest at all during the study period. So, we remain with 134 households who have harvested enset from at least one age group. Forty out of these harvested at early stage. A Censored Tobit model can be used for dependent variables with corner solution outcomes:

$$S_{ht}^* = \alpha + \varphi S_1^e + \phi S_2^e + \psi S_3^e + \mu L^m + \omega L^f + \gamma TLU + \beta A + \eta F + \theta Z^h + \varepsilon \qquad (12)$$

$$S_{ht} = 0 \quad \text{if } S_{ht}^* \le 0$$

$$S_{ht} = S_{ht}^* \quad \text{if } S_{ht}^* > 0$$

where S_{ht} refers to number of enset plants harvested per unit of land, and other variables are as defined in equation (8).

[13] We considered harvesting of up to two years old enset plants as early stage harvesting; plants older than this age give higher yield per plant.

The standard Tobit model has a limitation in the way that the decision whether to harvest at all and how much to harvest if decided to do so are determined as a single mechanism. How ever, some explanatory variables may differently affect the decision to harvest and the decision on how much to harvest. For this reason we used Cragg's two-tiered model which nests the Tobit model by using the truncated normal distribution (Cragg, 1971). A general specification of Cragg's model can also be found in Wooldridge, 2002: p538):

$$f\left(y/x\right)=\left[1-\Phi\left(x\gamma\right)\right]^{1[y=0]}\left\{\Phi\left(x\gamma\right)\left[\Phi\left(\frac{x\beta}{\sigma}\right)\right]^{-1}\left[\phi\left(\frac{\{y-x\beta\}}{\sigma}\right)\frac{1}{\sigma}\right]\right\}^{1[y>0]} \tag{13}$$

The sum of the log-likelihood of the Probit model and the log-likelihood of the truncated model in a single ML regression gives the log-likelihood of the Cragg model.

4. Results and Discussion

4.1. Simulation results

Using experimental production data for enset from the study area (Tsegaye and Struik, 2001), we have calibrated a simulation model to graphically determine the optimal harvesting time for enset as well as assess different assumptions of the Faustmann model in relation to varying discount rates. The detailed results are presented in the Appendix.

The current net value of a standing enset plant in birr per *timad* was calculated based on Table A1. The value increases at an increasing rate until the plant reaches age of 3.5 years and then at a decreasing rate until it reaches year 4 where the value reaches a plateau and soon starts declining (Figure A1).

In table A6, we calibrated equation (4) but without the second term on the right hand side of the equation. This corresponds to the optimal harvesting time for enset under the assumption of a single rotation. The results indicate that the optimal harvesting time at 10% discount rate is about 4.2 years. Consistent with the theoretical results the rotation period shortens to 3.9, 3.5, and 3 years when the discount rate increases to 30%, 50% and 70%, respectively (Figure A2).

Adding the opportunity cost of land, i.e., using the complete Faustmann formula, leads to shorter optimal rotation periods of 3.9, 3.6 and 3.2 years with 10%, 30% and 50% discount rates, respectively (Table A7 and figure A3). Discount rates higher than 50% will lead to a myopic behaviour of early harvesting, i.e., harvesting of younger than 2 years old enset plants.

The economic optimum converges with the biological maximum (maximum sustainable yield) for zero discount rate. Table A8 shows the simulation exercises with this assumption, and the rotation period (4 years) is longer than in the Faustmann model with positive discount rates (Figure A4).

Table 4 summarizes the simulation exercises we carried out to identify the optimal harvesting time for enset at different discount rates and in the single and multiple rotation models. In a single rotation model, households with high discount rates (70%) will harvest at the age of about 3 years. However, in the multiple rotation models, the households will engage in early harvesting of younger than 2 years old enset plants for discount rates above 50 %. The rotation periods from the latter model assert the theoretical arguments that the economic optimal rotation age is shorter than the biological maximum, which in this case is 4 years. This simulation result also suggests that the mean harvesting time (3.5 years) that we identified from the survey data is optimal for slightly higher than 30% discount rates.

4.2. Econometric results

In this analysis, we use three dependent variables, namely average *rotation period*, *proportion* of young plants harvested, and *number* of young plants harvested. The focus is on the rotation period, but adding the other two variables is expected to reinforce the findings on the first one. For example, the presence of younger enset stock reduces harvesting period and this should be affirmed by a positive relation of this stock with the young enset plants harvested. Similarly, food insecurity is expected to shorten rotation period and we expect it to have positive relation with the other two dependent variables. Thus the three dependent variables and resulting regression models should investigate the same phenomenon and test the same hypotheses, but from slightly different angles. The econometric models that test the effects of enset stock, labour endowment and wealth (assets) on the three dependent variables are presented in Table 5.

a) Testing for effects of enset stock (H1)

The OLS regression results for the average rotation time in Table 5 (regression column 1) indicate that the households with more of young enset stock have shorter average rotation period. The fractional response regression (GLM) results (regression column 2) indicated that households with a larger young enset stock harvested higher proportion of immature enset plants. The Cragg model used to analyze factors related to the number of young enset stock harvested per consumer unit (regression column 3) also supported these results. The number of young stock on farm is positively related with both the probability and the amount of young enset stock harvested per consumer unit. Both models show that the number of the intermediate age enset stock available on farm helps not to harvest the young ones. The insignificance of mature (older than 4 years) enset stock could indicate that most of the plants are harvested below this age.

b) Testing for the effects of labour endowment (H2)

The coefficients for male and female workforce are relatively small and statistically insignificant in all three regression models. This could be due to a general labour abundance in the area as off-farm employment is limited, making the labour constraint relatively unimportant.

c) Testing for the effects of large families (H3)

We find that the coefficient for consumer units in the household is positive and significantly related with the proportion and number of young enset plants harvested. It also has an expected negative sign with the harvesting time although insignificant. A plausible interpretation is that the households' food requirements are important in the harvesting decision, and having large families and consumption needs lead to early harvesting.

d) Testing for the effects of assets (H4)

Wealth in terms of assets such as land and livestock can relax credit and subsistence constraints of the households and lead to longer rotation periods. In our econometric analysis, both farm size and number of livestock turned out to be statistically insignificant although they have expected signs.

e) Testing for the effects of food security (H5)

Households who faced food insecurity for more than three times during the last 10 years do have shorter rotation period as compared to those who were food secure[14]. Those who faced food insecurity problems for about five times within the last 10 years harvested higher proportion and number of immature enset plants. This coincides with our *a priori* expectation and supports previous studies which find that food insecurity could lead to early harvesting of enset (Shank and Ertiro, 1996; Brandt *et al.,* 1997). The area is drought prone and poorer households face frequent food shortages. During such times, households would harvest the available young enset plants to augment the food supply for their families.

Negative and significant relations of years of schooling of household head with both proportion and number of young enset plants harvested could mean better educated household heads have better access to other income sources to fulfill family food requirements. We find no significant differences between male and female headed households.

In summary, and related to the five major hypotheses presented in the theory chapter, we find: (i) strong evidence for the composition of the enset stock to influence the rotation period, with a large stock of young enset plants leading to shorter rotation; (ii) no evidence for families with a large labour forces harvesting earlier; (iii) there is some evidence that larger family size (consumer units) leads to early harvesting; (iv) limited evidence of a higher assets stocks leading to longer rotation periods; (v) food insecurity has a significant impact and leads to shorter rotations. Overall, subsistence needs appear to be the driving force behind early harvesting.

5. Conclusions

Enset is a perennial crop with multiple uses, and a number of factors can affect the harvesting decisions of households. The theoretical model and simulation results confer that the optimum rotation time and economic average yield decrease when discount rate increases. As poverty increases the household's discount rate, poor households are likely to engage in early harvesting practices. The empirical analysis has revealed that food insecurity is a major factor that pushes households to early harvesting of enset plants. The average rotation time is shorter

[14] Food insecurity can be endogenous variable but we were not able to instrument it from the available data. We run regression without the variable (food insecurity) and found that it did not significantly affect the results for the other variables.

and the proportion of harvested young plants from the total harvest is higher for food insecure households.

These findings suggest that food insecure households could be in a vicious circle. While early stage harvesting may help to alleviate immediate subsistence constraints, it also reduces future availability as fewer plants are saved to reach full maturity. Generally, a targeted policy intervention in the form of safety nets in order to mitigate food shortage during drought years is needed if enset plants are to fully mature and give higher yield. Optimizing land allocation between different crops by increasing the relative share of enset and its complementary food crop, beans, may also maintain a sustainable supply of energy and other nutrients from the small landholdings.

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Table1: Land allocation for various crops in Gununo highlands (1998-99 season)

Major crop type	No of hhs	Total area cropped (*timad*)	Average area cropped (*timad*/hh)
Sweet potato	130	31.64	0.24
Maize	46	24.06	0.52
Enset	124	22.44	0.18
Teff	41	17.40	0.42
Coffee	92	9.65	0.11
Barley	34	9.15	0.27
Haricot Beans	24	7.40	0.31
Faba Beans	19	7.14	0.38
Taro	15	3.51	0.23
Chick Pea	12	3.17	0.26
Irish Potato	14	1.88	0.13
Yam	4	0.23	0.06
Sorghum	1	0.17	0.17
Wheat	1	0.12	0.12

Source: Compiled from own survey

Table 2: Food security conditions in Gununo highlands

Food insecurity and causes	No of hhs facing the problem	% of sample
Food insecure households	**117**	**82.4**
Frequency of food security problem		
1-2 times during the last 10 years	6	4.2
3-5 times during the last 10 years	71	50.0
6-10 times during the last 10 years	40	28.2
Causes for food insecurity		
Drought	118	83.1
pest/disease	96	67.6
poor land quality	112	78.9
land degradation	69	48.6
land shortage	96	67.6
Lack of oxen	73	51.4
lack of labour	31	21.8
lack of of-farm employment	72	50.7
lack of cash to buy food	82	57.6
non-availability of food to buy	27	19.0
too large family size	94	66.2

Source: Own survey

Table 3: Summary statistics of variables used in enset harvesting analysis

Variable name	Definition of variables	Mean	Std. Dev.	Expected signs avyrhar	rh02	eh02cu
avyrhar	Average year of harvesting (optimum rotation period)	3.50	1.08	depvar	depv	depvar
rh02	Proportion of early harvested enset from the total harvest	0.21	0.35	depvar	depv	depvar
eh02cu	Up to 2 years old enset plants harvested per consumer unit	3.15	6.90	depvar	depv.	depvar
landcu	Land holding in *timad* per consumer unit	0.33	0.28	+	-	-
ies02cu	Stock of up to 2 years old enset plants per consumer unit	30.12	28.13	-	+	+
ies24cu	Stock of intermediate age* enset plants per consumer unit	23.99	22.98	+	-	-
ies4cu	Stock of >4 years old enset plants per consumer unit	8.99	12.63	+	+/-	+/-
mwfcu	Male workforce per consumer unit	0.30	0.16	-	+	+
fwfcu	Female workforce per consumer unit	0.31	0.13	-	+	+
consu	Consumer units	6.16	3.10	-	+	+
tlucu	Tropical livestock units per consumer unit	0.45	0.36	+	-	-
foodinsecat	Cat. for food insecurity=1 if secure, 2 if faced insecurity for 1-2 times, 3 if faced insecurity 3-5 times, and 4 if faced insecurity for 6-10 times during the last 10 years	0.81	0.39	-	+	+
sex	Dummy = 1 if sex of the house hold head is male	0.90	0.30	+	-	-
educ	Education of household head in years	1.91	3.07	+	-	-

* Intermediate age refers to 2-4 years old enset plants

Table 4: Optimal rotation and maximum sustainable yield for enset

Model	Annual discount rates 0	0.1	0.3	0.5	0.7	0.9
Optimal age for single rotation	-	4.2	3.9	3.5	3.0	?
Optimal age for multiple rotations	4*	3.9	3.6	3.2	?	?

* At δ=0, the economic optimum converges with the maximum sustainable yield (MSY).

Table 5: Regression results for rotation time and factors related to early harvesting of enset

Dependent variables: average harvesting time (avyrhar), proportion of young stock harvested(rh02), and number of young stock harvested per consumer units (eh02cu)			
Explanatory variables	avyrhar	rh02	eh02cu
Farm size in *timad*/consumer units(cu)	0.358	-0.803	0.140
	(0.311)	(1.125)	(0.644)
Enset stock ≤ 2 years old/cu	-0.013***	0.059***	0.029***
	(0.003)	(0.016)	(0.008)
Enset stock of 2-4 years old/cu	0.009	-0.073***	-0.031***
	(0.006)	(0.023)	(0.010)
Enset stock of >4 years old/cu	0.006	0.031	0.018
	(0.010)	(0.021)	(0.014)
Male workforce/cu	-0.312	0.575	-0.462
	(0.747)	(1.533)	(1.178)
Female workforce/cu	0.299	0.000	-0.739
	(0.847)	(1.895)	(1.250)
Consumer units	-0.034	0.236***	0.144***
	(0.029)	(0.089)	(0.049)
Tropical Livestock Units/cu	0.287	-1.556	-0.518
	(0.219)	(1.128)	(0.535)
Food insecure for 1-2 times in past 10 years[R]	-0.378	1.187	0.912
	(0.413)	(1.087)	(0.709)
Food insecure for 3-5 times in past 10 years	-0.773***	1.506**	0.690*
	(0.258)	(0.595)	(0.416)
Food insecure for 6-10 times in past 10 years	-0.701**	0.888	0.371
	(0.325)	(0.749)	(0.446)
Sex	0.429	-0.945	-0.473
	(0.298)	(0.856)	(0.507)
Education	0.039	-0.189**	-0.130**
	(0.030)	(0.085)	(0.053)
Constant	3.727***	-2.884**	-1.171
	(0.623)	(1.456)	(0.930)
R_squared	0.29		
Log likelihood		-44.557	-180.669
Prob > chi2			0.021
BIC		-520.587	
Number of observations	134	134	139

Robust standard errors in parentheses; * significant at 10%, **significant at 5%, *** significant at 1%

[R] The reference for food insecurity dummies =1 if food secure during the last 10 years

Appendix: Simulation results for the optimal rotation period

Using experimental data for twice transplanted enset plants, simulations were carried out to determine optimal harvesting time (rotation period) for the perennial food crop (enset) based on Clark (1990), Hyde and Newman (1991), and Pearse (1967). The simulation results are presented in Tables A1-A4, and are supported with graphical illustrations (Figure A1-A4) and brief explanations.

A basic growth function of enset plant

Table A1: Net value of a standing twice transplanted enset plant based on experimental growth rate

Age [a] (years)	output [a] gm m^{-2}	Output(S) kg/*timad*	Price(p)[b] birr/kg	Gross value(pS) birr/*timad*	Fixed cost[c] bir/*timad*	Net value (pS-C)	Average yield(pS)/T
2	287	718	1,3	933	50	883	467
2,5	396	991	1,3	1288	50	1238	515
3	604	1509	1,3	1962	50	1912	654
3,5	811	2026	1,3	2634	50	2584	753
4	919	2298	1,3	2987	50	2937	747
4,5	831	2078	1,3	2701	50	2651	600
5	448	1120	1,3	1457	50	1407	291

[a] Source: Tsegaye and Struik (2001). [b] Net of harvesting and processing costs.
[c] Fixed time costs for replanting and managing the land.

Figure A1 below shows a basic growth function of an enset plant. It grows at an increasing rate until 3.0-3.5 years and continues to grow until 4 years but at a decreasing rate. After 4 years the biological growth declines after decay. This indicates that keeping the plant after 4.5 years is an economic loss for the household, even if no capital and land costs are considered.

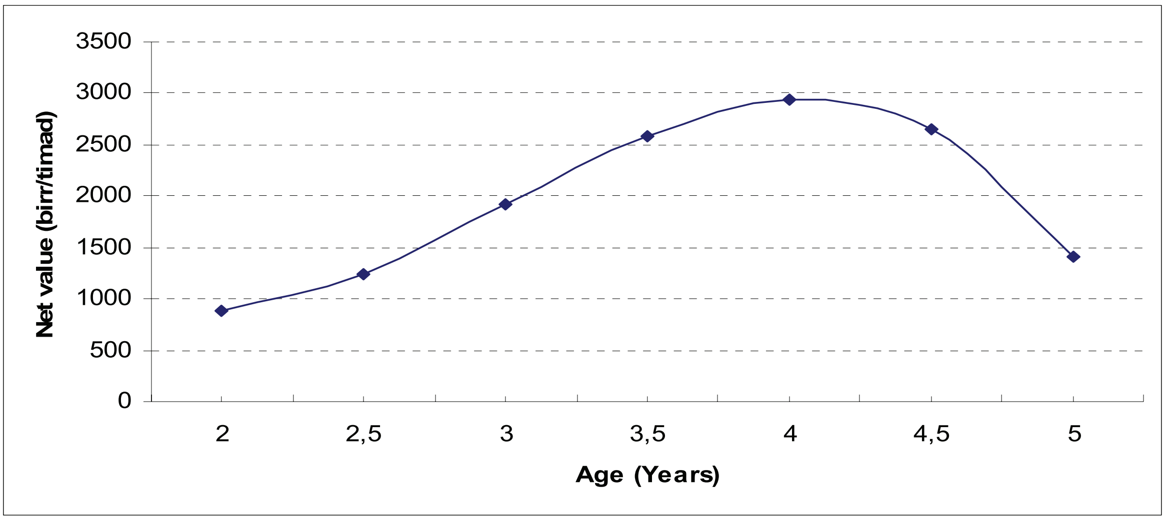

Figure A1: Net current values of a standing enset plant (birr/*timad*)

Graphical determination of the optimal rotation

a) Single rotation

Table A2: Computing annual growth and cost of delaying the annual net income

Aget (years)	gross value (S_t)	net value (S-C)	marginal growth	Cost of delaying harvest for one year = $(S_t)*\delta$				
				0,1	0,3	0,5	0,7	0,9
2	933	883		88	265	442	618	795
2,5	1288	1238	711	124	371	619	867	1114
3	1962	1912	1347	191	574	956	1338	1721
3,5	2634	2584	1345	258	775	1292	1809	2326
4	2987	2937	705	294	881	1469	2056	2643
4,5	2701	2651	-572	265	795	1325	1856	2386
5	1457	1407		141	422	703	985	1266

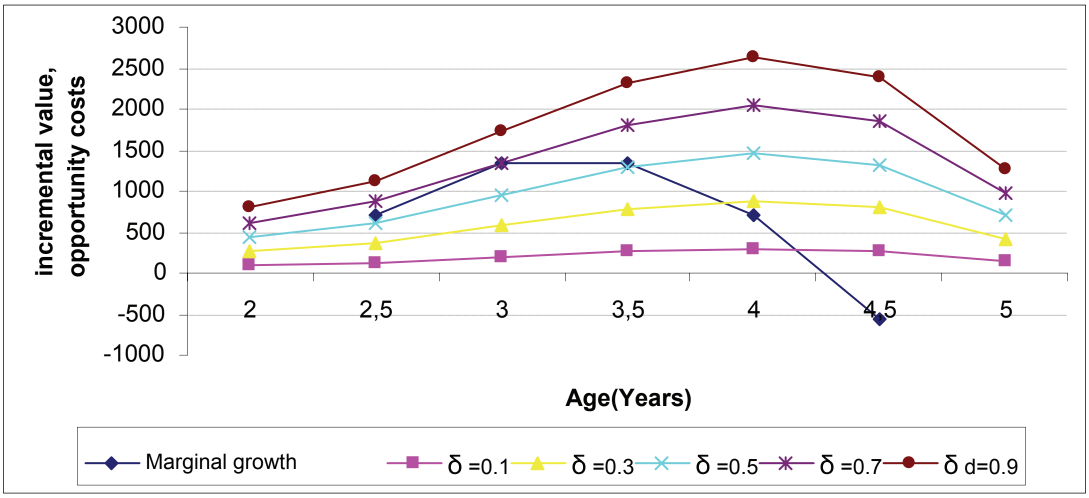

Figure A2: Graphical determination of optimal harvesting time for enset plants under single rotation condition

Figure A2 indicates that the optimal rotation period at 10% discount rate for single rotation is 4.2 years. This shortens to 3 years when the discount rate increases to 70%. It compares marginal growth with cost of delaying harvest for one year. However, it does not consider the opportunity cost of utilizing the land for the existing stand of trees (Hyde and Newman, 1991; Clark, 1990).

b) Multiple rotations

In the following Table, we use the standard Faustmann rotation formula to consider the opportunity costs of land tied with the standing enset plants. The optimal harvesting time (rotation period) decreases in this case compared to the single rotation case (Figure A3).

Table A3: Calculations to determine optimal rotation period based on Table A1.

Age (years)	gross value (S_t)	net value (S_t-C)	Relative growth rate	Discount rates for δ /(1-EXP((-δ*t))) 0,1	0,3	0,5	0,7	0,9
2	933	883		0,55	0,66	0,79	0,93	1,08
2,5	1288	1238	0,55	0,45	0,57	0,70	0,85	1,01
3	1962	1912	0,69	0,39	0,51	0,64	0,80	0,96
3,5	2634	2584	0,51	0,34	0,46	0,61	0,77	0,94
4	2987	2937	0,24	0,30	0,43	0,58	0,75	0,93
4,5	2701	2651	-0,21	0,28	0,40	0,56	0,73	0,92
5	1457	1407		0,25	0,39	0,54	0,72	0,91

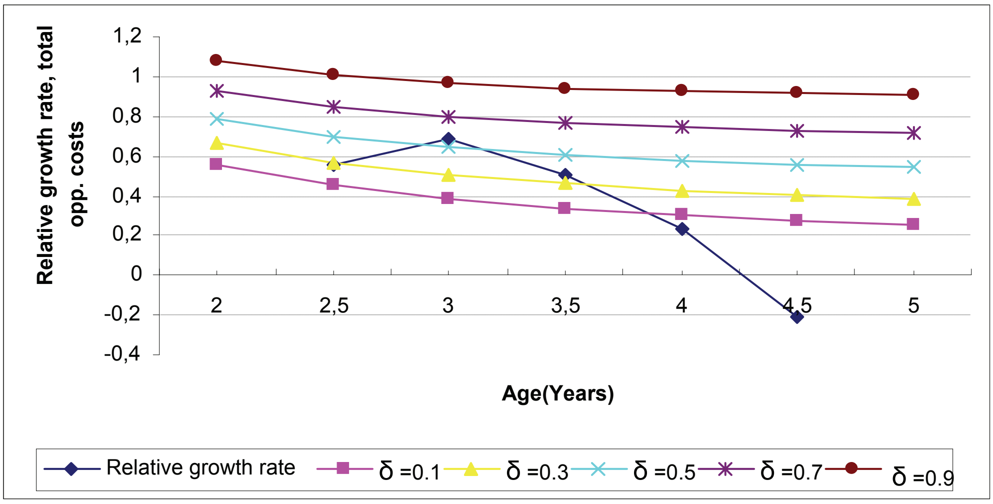

Figure A3: Graphical determination of optimal harvest time for a continuous rotation condition

Figure A3 shows the optimal rotation periods at different discount rates for multiple (continuous) rotations. The optimal rotation period is found by equating the relative growth rate with the total opportunity costs, i.e., cost of annual net income and opportunity cost of land (equation 4). At 10% discount rate, the optimal rotation period is about 3.9 years which is shorter than the previous model. Harvesting at any time shorter than 3 years becomes optimal for the households when the discount rates rise to 70% in this multiple rotation period. This means, higher discount rates lead to early harvesting of enset.

c) Maximum Sustainable Yield (MSY)

The economic optimum shown by Figure A3 converges with the biological maximum (maximum sustainable yield) when δ=0, and the optimal rotation period is longer in this case (See Table A4 and Figure A4).

Table A4: Convergence of economic optimum with biological maximum (MSY)

Age (t)	1/t	Relative growth rate	Average yield=(S-C)/T	Marginal growth
2	0,50		442	
2,5	0,40	0,57	495	711
3	0,33	0,70	637	1347
3,5	0,29	0,52	738	1345
4	**0,25**	**0,24**	734	705
4,5	0,22	-0,22	589	-572
5	0,20		281	

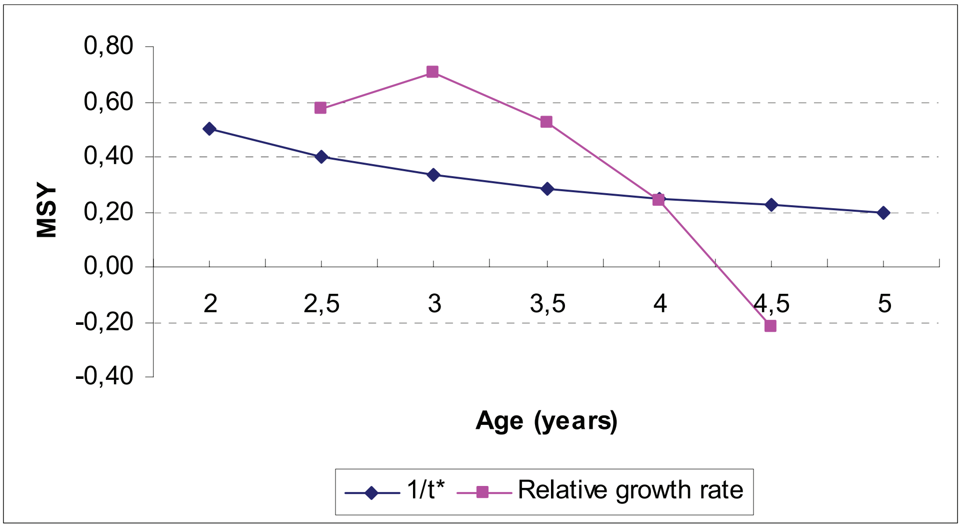

Figure A4: Convergence of economic optimum to biological optimum at zero discount rate

The optimal rotation period now becomes 4 years.

Paper IV

Soil degradation, poverty, and farmers’ willingness to invest in soil conservation

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Abstract

This paper assesses farm households’ perceptions of land degradation, and presents empirical results of the factors affecting their willingness to invest in (or pay for) soil conservation practices in Gununo highlands of southern Ethiopia. Based on data collected from 142 randomly selected farm households operating 563 plots, the majority of the farm households in Gununo are aware of the severity of land degradation in their villages and especially on private farms, in terms of soil erosion and nutrient depletion. Contingent valuation (CV) results indicate that about 96% of the respondents were willing to contribute own labour to conserve soil on their farms. When the payment is in cash, about 73% were willing to pay. Ordinary least squares and Tobit regression results show that asset and cash poverty undermines the willingness of the farmers to contribute in labour or pay in cash for soil conservation investment. The results generally suggest that any policy intervention on soil conservation activities need to understand the role of assets and cash availability in enhancing farm households’ willingness to invest in soil conservation. Wealth of livestock contributes to higher conservation investment activities. It is also important to note that in areas where there is abundance of labour and shortage of cash, the WTP studies that employ labour days as payment vehicle can provide more sensible results than those which use only cash as payment vehicle. Soil conservation primarily requires labour input, and imperfections in credit and labour markets may create shortage of cash and abundance of labour.

Key Words: soil degradation, poverty, willingness to invest, Ethiopia

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1. Introduction

Soil degradation is one of the severe biophysical problems to sustainable agriculture in rural Ethiopia, particularly in the densely populated highlands (Tegene, 1992; Hurni, 1988; Bewket and Sterk, 2003). The degradation, in terms of soil erosion and nutrient depletion, has contributed to the low productivity of agriculture in these areas (Shiferaw and Holden, 1998; Elias, 2002; Gebremedhin and Swinton, 2003).

According to some estimates, Ethiopia loses about 1.5 billion tons of topsoil per year from the highlands caused by erosive rainfall on less protected soils (Tadesse, 2001). The country's average annual soil loss rates on cultivated land were estimated at 42 t/ha. It may reach up to 170 t/ha in the highlands, while soil formation rates are only about 2 t/ha (Hurni, 1983b, 1988). A study in the highlands of southern Ethiopia also indicated that increasing population pressure and land shortage have resulted in shortened fallow periods and cultivation of more marginal lands leading to further deterioration of the soil resource. Deforestation and overgrazing have also become contributing factors for the degradation of community lands (Ayele, 1998).

Soil erosion is a serious problem also on the Nitosols of Gununo highlands (our study area) taking away the deep, fertile, and productive topsoil from the severely eroded cultivated land. The average annual net soil loss rate on cultivated fields of Gununo was estimated at 75 tons/ha which is much higher than the national average (Tegene, 1992). Other qualitative studies in this area (Jonfa, *et al.* 1997; Elias, 1998; Dea, 1998; Tessema, 1998) revealed that farmers in Gununo are well aware of the severity of the soil degradation problem in their villages and especially its effect on their production. Our study also indicated that about 45% of the sample households perceived soil erosion as the most important agricultural problem followed by nutrient depletion (41%) on private lands. When control measures are not taken, soil loss from water erosion might lead to irreversible changes in soil productivity and stagnation of agricultural production, resulting in food shortages that directly affect the food security situation in the country (Sonneveld and Keyzer, 2003). However, there are few conservation structures used by farmers in the study area (Elias, 1998). Even among those who operated plots where conservation structures were built through the Soil Conservation Research Project (SCRP) that operated in the area in the 1980s, a large number of them have partially or fully removed the structures (Tadesse and Belay, 2004). Similar results have been reported in other parts of the Ethiopian highlands (Shiferaw and Holden, 1998).

A number of studies have attempted to explain why farmers, while in agreement with scientific evidence on the severity of soil degradation on their farms, are not adopting soil conservation structures but rather partially or totally removing the structures that have been introduced by external projects (Shiferaw and Holden, 1998; Alemu, 1999; Holden and Shiferaw, 2002; Gebremedhin and Swinton, 2003; Tadesse and Belay, 2004). Some of the reasons include tenure insecurity, poverty, land and technology characteristics, and weak perception of degradation problem. This paper aims to: (a) assess farm households' perception of soil degradation on private farms and community land, (b) identify factors affecting farm households' willingness to invest in soil conservation on their private land in highland areas of southern Ethiopia. The paper attempts to add to previous studies by analyzing the willingness to pay both in terms of labour and cash based on responses of the same sample to separately asked open-ended willingness to pay questions.

The rest of the paper is organized as follows. Section 2 presents the study area, data and collection methods. Section 3 provides a theoretical framework for the analysis. Section 4 deals with methodology, including design and administration of the WTP questionnaire, econometric methods for estimation, hypotheses and variable specification. Section 5 discusses the results followed by conclusion in section 6.

2. The study area and data collection

This study is based on cross section data collected from randomly selected farm households in Gununo highlands of Wolaita Zone, Southern Nations Nationalities and Peoples Region of Ethiopia, located at about 405 km south west of Addis Ababa. The area lies on an elevation extending from 1800 to 2100 m.a.s.l., and receives an average annual rainfall of 1330 mm (SCRP, 1996). Mixed farming, crop-livestock production, is the common practice with the lion's share being root crops. The soils are Eurotic Nitosols, which are characterized by very deep weathering and leaching (Elias, 1998).

The data were collected in 1999 as part of a general farm household survey by an EU-funded research project. The survey provides detailed information about production activities, input use, expenditures and income, household and farm characteristics, perceptions, and willingness to invest in soil conservation. The survey used mainly a structured questionnaire for the face-to-face interviews. The data are drawn from a random sample of 142 households, operating 563 plots at the time of the survey.

The basic socio-economic characteristics of the farm households are presented in Table 1. Oxen ownership is one of the wealth indicators in this area. The majority of the sample households, 58%, do not own oxen, and 91% of those who own oxen have only one ox. The average land holding of the households without oxen is very small (1.2 *timad*[15]) and they earn lower average farm and off-farm income than those owning oxen. They also receive less credit, on average, than ox owners. The average number of workforce (male and female) and

[15] 1 *timad* = 0.25ha

other livestock in TLU is also higher for those who own oxen. This indicates that those households with no oxen are operating under more severe asset and cash constraints. On the other hand, the households without oxen have a higher calculated shadow wage rate (0.40 birr/day) than those with oxen (0.28 birr/day), which suggests relatively more labour abundance for the latter. The shadow wage rate for the whole sample (0.34 birr/day) is also very low, reflecting a general labour abundance with limited off-farm employment opportunities.

The results from the contingent valuation survey indicate that about 96 and 73 percent of the respondents expressed willingness to invest in labour and in cash, respectively. About 94% of those who do not own oxen and 100% of oxen owners were willing to contribute labour. For cash contribution, 68% of households without oxen and 78% of those with oxen were willing to pay. About 40 (28 %) out of the 142 farm households have conservation structures on some of their plots; 93% of these were soil bunds constructed through "food- for-work" projects targeted at household level.

3. Theoretical Framework

Adoption of any technique to conserve soil is costly, either directly through investments undertaken or indirectly by production foregone in the short-term. The techniques might take productive land out of production without increasing overall short-term productivity of land. The decision to invest in conservation is, therefore, based on the households' considerations of current costs and future benefits unless they have been imposed from an external agency, for example, through some food-for-work (FFW) projects. When we are not in a position to compare these costs and benefits directly in a market, we need to use other valuation methods to put value on them.

Various methods are used for valuing non-marketable items such as soil conservation practice. The two widely used methods are (i) revealed preferences which use current transactions to help estimate how much people value certain non-marketed goods (for example, hedonic pricing and travel cost methods), and (ii) stated preferences where hypothetical questions on their willingness to pay for a particular effect are presented to people (contingent valuation). Our study is based on the stated preferences that involve finding farm households' willingness to pay for soil conservation activity in order to maintain productivity of its farm. Holden and Shiferaw (2002) assert the relevance of contingent valuation method (CVM) for such a study in rural economies of developing countries where markets are often imperfect (or missing) and where preferences cannot be revealed through the market mechanism.

A number of theoretical and methodological issues and criticisms have been raised concerning the application of the CVM in developing countries. As Whittington (1989) argued, posing hypothetical questions to low income households who mostly are illiterate might not be fruitful. However, it has been shown by a number of studies that CVM can actually be meaningfully applied in developing countries (Whittington *et al*. 1993, 1996; Navrud and Mungatara, 1994; Swallow and Woudyalew, 1994; Georgiou *et al*. 1997; FAO, 2000). Some other studies that used CVM in the Ethiopian context have been documented in Asrat *et al.* (2004), who also applied the CVM approach to study the willingness to pay for soil conservation practices in the southeastern part of the country. Tegene (1999) suggested a wider use of the CVM in Ethiopia for environmental and other non-priced projects, based on his findings that the method was applicable even for people who are illiterate and without prior exposure to such valuation methods.

Unlike other environmental valuation methods, CVM responses to WTP questions go directly to the theoretically correct monetary measures of utility (or welfare) changes (Perman *et al.* 1999; Shiferaw *et al*. 2004). The households will be willing to invest in soil conservation if they perceive that the new technology (soil conservation structure) would help them at least to maintain the productivity of their land, which otherwise would deteriorate due to erosion and other land degradation factors. CVM has mostly been applied to pure consumers. However, rural households in developing countries are entities that usually operate under imperfect market conditions and their production and consumption decisions are non-separable. Assume that the farm household maximizes utility from total income and leisure:

$$U = U\left(y, L_e\right) \tag{1}$$

given $y = pq\left(\overline{A}, L_a, Z^f, Z^h\right) + w\overline{L}_n$

$$L_e = \overline{L} - L_a - L_c - \overline{L}_n$$

where y is income generated from farm production and non-farm activities, L_e is leisure, $\overline{A}$ and $\overline{L}$ are land and family labour endowments, respectively, L_a, $\overline{L}_n$, and L_c are labour input in farm production, labour allocated to non-farm activities, and labour that the household is willing to allocate to constructing soil conservation structures, respectively. *w* is the wage rate in non-farm activities, $w\overline{L}_n$ is non-farm income that is assumed exogenous due to labour market constraints, and *p* refers to price of output produced. $q(.)$ is a concave production function where the inputs are complementary. Z^h is household characteristics and endowments, and Z^f is other farm characteristics.

The model in equation (1) is a static model based on a one period utility function. However, investment in soil conservation is an intertemporal problem where the investment is made to protect future consumption. The land quality is affected by soil erosion and nutrient depletion processes, as well as by soil and water conservation investments. The farm household faces a choice of whether to allocate his/her labour to farm production and non-farm activities to generate current income, to allocate some of the labour to soil conservation activities to maintain or even improve the productivity of the land in order to boost future income, or for leisure. Hence, we formulate a simple model to account for the dynamics of investment in soil conservation structures. The maximization problem faced by the household can be expressed by a two-period Bellman's equation (Holden *et al.* 2006):

$$V\left(\bar{A}_t, \bar{L}_t\right) = m\,\mathrm{ax}\left\{U\left(y_t, L_{et}\right) + \delta V\left(A_{t+1}, \bar{L}_{t+1}\right)\right\} \tag{2}$$

Subject to:

$$y = pq\left(\bar{A}_t, L_{at}, Z^f, Z^h\right) + w\bar{L}_{nt}$$

$$\bar{L}_t = L_{at} + L_{ct} + \bar{L}_{nt} + L_{et}$$

$$A_{t+1} = \phi\left(q_t, L_{ct}\right)\bar{A}_t\,; \quad \phi'_q < 0;\; \phi'_{L_{ct}} > 0$$

$$\bar{L}_{t+1} = \bar{L}_t$$

where δ represents the household's discount rate, ϕ is the degradation function, and t and $t+1$ refer to current and next periods. All other variables are as defined above.

This optimization problem can be solved with respect to the choice variables L_{at} and L_{ct} by setting up the problem as:

$$V\left(\bar{A}_t, \bar{L}_t\right) = \max_{L_{at}, L_{ct}} \left\{ \begin{aligned} & U\left(pq\left(\bar{A}_t, L_{at}, Z^f, Z^h\right) + w\bar{L}_{nt}, \bar{L}_t - L_{at} - L_{ct} - \bar{L}_{nt}\right) \\ & + \delta V\left(\phi\left(q_t\left(\bar{A}_t, L_{at}, Z^f, Z^h\right), L_{ct}\right)\bar{A}_t, \bar{L}_t\right) \end{aligned} \right\} \tag{3}$$

The first order conditions (FOCs) of the maximization problem are[16]:

$$\frac{\partial V\left(\bar{A}_t, \bar{L}_t\right)}{\partial L_{at}} = \frac{\partial U}{\partial y}\frac{\partial q}{\partial L_{at}}p - \frac{\partial U}{\partial L_e} + \delta\frac{\partial V}{\partial A_{t+1}}\frac{\partial \phi}{\partial q_t}\frac{\partial q_t}{\partial L_{at}}\bar{A}_t = 0 \tag{4}$$

[16] We normalized the price of output to one for convenience. In a cross-section data there is no price variation in the village.

$$\Leftrightarrow \frac{\partial U}{\partial y}\frac{\partial q}{\partial L_{at}}p = \frac{\partial U}{\partial L_e} - \delta \frac{\partial V}{\partial A_{t+1}}\frac{\partial \phi}{\partial q_t}\frac{\partial q_t}{\partial L_{at}}\overline{A}_t$$

$$\frac{\partial V\left(\overline{A}_t, \overline{L}_t\right)}{\partial L_{ct}} = -\frac{\partial U}{\partial L_e} + \delta \frac{\partial V}{\partial A_{t+1}}\frac{\partial \phi}{\partial L_{ct}}\overline{A}_t = 0 \qquad (5)$$

$$\Leftrightarrow \delta \frac{\partial V}{\partial A_{t+1}}\frac{\partial \phi}{\partial L_{ct}}\overline{A}_t = \frac{\partial U}{\partial L_e}$$

Equation (4) implies that the household will allocate labour to farm activities when the marginal utility of income from marginal value product of agricultural labour equals the marginal utility of leisure minus current value of future land quality loss due to current production activities. Similarly in equation (5), the household will allocate its labour to soil conservation if current value of future benefits from conserving the soil is equal to the marginal utility of leisure. We determine L_{at} and L_{ct} by solving equations (4) and (5) simultaneously.

The reduced form for the labour that the household is willing to allocate for soil conservation can be written as:

$$L_{ct} = f\left(\overline{A}_t, \overline{L}_t, w, \delta, \overline{L}_{nt}, Z^f, Z^h\right) \qquad (6)$$

With market imperfections, discount rates become household specific and thus depend on household and farm characteristics, mainly on wealth and cash availability, e.g. non-farm income: $\delta = \delta\left(Z^f, Z^h\right)$ (Holden and Shiferaw, 2002).

We were not able to measure the actual labour allocated to soil conservation (i.e., L_{ct}) because most of the soil conservation structures in the study area were constructed by food-for-work projects through public participation over several years, and thus it is hard to obtain information on how much labour an individual household has contributed to the existing structure. Moreover, there is a certain public goods aspect related to the investments as the conservation structures normally cover more than one plot and the establishment affects several plots below. Hence, L_{ct} refers to labour that a household is willing to invest in soil conservation (WTP), not the actual labour invested in conservation. In the econometric analysis we use WTP for either labour contribution or cash payment.

With missing labour and land markets and credit constraints, farm households tend to have high shadow prices for cash and low shadow value of labour. The shadow wage rate (z) can generally be defined by total differentiation of the single period utility function (equation (1)): $\frac{dy}{dL_e} = \frac{\partial U / \partial L_e}{\partial U / \partial y} = z$, i.e. the shadow wage rate is the ratio between marginal utilities of leisure and of income. In other words, how much income are households willing to give up for one day of work? This is closely related to the question asked in the WTP for soil conservation, and we therefore use the households' willingness to pay in cash and labour as a proxy for the shadow wage rate: $z \approx \frac{WTP^c}{WTP^l}$. WTP^c and WTP^l refer to willingness to pay in cash and labour, respectively

This rate is a function of household labour, other asset endowments, non-farm income, and household characteristics:

$$\frac{WTP^c}{WTP^l} = f\left(\bar{L}, w\bar{L}_n, TLU, \bar{A}, Z^h\right) \tag{7}$$

where, TLU is livestock in tropical livestock units. The other symbols are as defined above.

3.1. Hypotheses

With market imperfections, the level of farm household's WTP for soil conservation depends on various factors, such as shadow wage rate, poverty and household characteristics, and not only farm characteristics. If markets (for example, credit markets) were perfect, then farm households' WTP would depend only on farm characteristics and profitability considerations as they could address cash liquidity problems through these credit markets. Based on our theoretical model above, we hypothesize the following:

H1: Households' asset poverty and cash constraints reduce their willingness to pay in both cash and labour.

H2: Households with higher labour endowment will have higher WTP in labour days.

H3: Labour allocated to soil conservation on land with higher slopes is more rewarding and increases the households' WTP.

H1 implies that household's asset holding, such as livestock holding, is expected to positively correlate with the WTP both in cash and labour days, as asset rich household could easily exchange the assets and hence may not face liquidity constraints. Land holding may positively relate when we consider it as wealth, but may negatively contribute if it takes more of the labour for farming by relaxing land constraints. Income variables can also capture wealth. Non-farm income will relax cash constraints and increase WTP in cash. But it can also negatively contribute to WTP, especially in labour days if the household is too inclined to off-farm activities and when such income is not invested on-farm.

H2 states that the availability of productive labour will generally increase household's WTP in soil conservation. Male and female workforce will have positive correlation directly with labour contribution and indirectly for cash payment. More productive labour may mean more activities (if available) to generate more income which would alleviate cash constraints and increase the WTP in cash.

H3 is forward looking in assuming the household's action is based on future benefits. The household is willing to invest more on plots with higher slopes as responses from conserving such plots is expected to be higher than from gentle slopes. Thus, the proportion of sloping land from the total farm size is expected to be positively related with the WTP in both labour and cash.

Household heads with better education are expected to understand the consequences of degradation and be willing to invest more in soil conservation. Older age may shorten planning time horizon and reduce the WTP; or it may relate to farm experience and increase willingness to improve the soil for better productivity. The sign is ambiguous.

When we consider equation (7), labour endowment will be negatively correlated with the shadow wage as more productive labour with limited off-farm employment opportunity reduces the shadow wage rate. Non-farm income will have positive correlation as it relaxes liquidity constraint and thereby reduce shadow price of cash. But it may also show negative sign if labour endowment effects overweigh. Wealth (e.g. TLU) can also relax liquidity and reduce discount rates, and hence have positive sign.

4. Methodology

4.1. Administration of the WTP questions for CVM

Our questions on the willingness to invest in soil conservation were administered as part of a larger rural household survey which generated detailed information about production activities, input use, expenditures and income, household and farm characteristics, perceptions, and willingness to invest in soil conservation. In order to avoid entry limitations, we asked some questions related to soil degradation before the questions on willingness to invest. First, the respondents were asked about their perceptions of the most important degradation problems on their farms and in the community at large. Severity of each degradation type was ranked at on-farm, communal land, and community levels (See Appendix A and Table 3). Subsequently, the willingness to pay (WTP) was solicited using open-ended questions. Open-ended questions are one of the three common valuation techniques used in CVM studies, the other two being dichotomous choice and iterative bidding (Shiferaw *et al.* 2004).

With open-ended questions, the respondents are asked for their maximum willingness to pay with no value being suggested to them. This has an advantage of avoiding a starting point bias although the respondents may find it relatively difficult to answer such questions, especially where they have no prior knowledge of trading with the commodity in question (Mitchell and Carson, 1989). Some researchers indicated that using open-ended questions might lead to large non-response rates and respondent reports of lower payments than their maximum WTP (Mekonnen, 2000). We asked a follow-up why question whenever a respondent was not willing to pay. Few households were not willing to invest labour in soil conservation. Most of the respondents who reported zero WTP when asked in terms of cash attributed their responses to lack of money.

The payment vehicle may also significantly influence the level of WTP and ease the decision on valuation of the non-marketed resource. The farm households were asked to state the maximum amount of money (cash) they were willing to pay per year as well as the number of days (labour days) they were willing to contribute per year to conserve soil on their farm in order to maintain productivity (See appendix A for the scenario and the WTP questions). The WTP responses used in the econometric analysis were taken from responses for questions 2.1a and 2.5a. Using labour days as a payment vehicle is reasonable since farmers were more endowed with labour than cash, and typically were using their own labour as the main input in conservation. For some families labour could be abundant and cheap (Tegene 1999; Asrat *et al*. 2004) so that they may express the true willingness to pay. Focusing on labour days instead of on cash payment, which they have no prior knowledge of trading for soil conservation investment, may help us to get a better understanding of the farm households' WTP for soil conservation.

4.2. Econometric methods and estimation

We aimed at estimating the determinants of household's willingness to invest in soil conservation in terms of labour days and cash (birr[17]), i.e. the amount of contribution or payment[18]. We carried out a household level analysis, but previous studies have shown that physical (plot) characteristics may play a significant role in determining the intensity of investment in soil conservation (Gebremedhin and Swinton, 2003; Hagos and Holden, 2006). We have tried to control this by including some of the physical characteristics such as proportion of sloping area, soil type, average distance of plots from house, and existing length of conservation structure in the econometric analysis.

Based on our theoretical framework provided in section 3, a regression model can be fitted as:

$$WTP_i = \beta X_i + u_i \tag{8}$$

[17] Birr is the Ethiopian currency.
[18] Only 5 out of 142 households have shown zero WTP in labour-days in responding to the open ended questions. Three of them mentioned lack of family labour as the reason for their unwillingness to invest labour in soil conservation.

where X_i is a vector of explanatory variables that affect the respondent's WTP, β is coefficients to be estimated, and u_i is the error term normally distributed with mean 0 and constant variance σ^2. OLS was used to fit this model for the WTP in labour (person) days, as only 5 out of the 142 households have reported zero WTP.

When we used cash as a payment vehicle, the number of households who reported zero WTP increased to 39. The WTP outcome is a corner solution outcome where zero is the minimum and all the positive WTP are more than zero. The use of OLS for such data set will lead to inconsistent estimation of the parameters, and the analysis for such outcomes fits into the standard censored Tobit framework (Wooldridge, 2002). The Tobit model used in our empirical analysis takes the following form:

$$y_i^* = \beta' X_i + \varepsilon_i \tag{9}$$

$$y_i = 0 \text{ if } y_i^* \le 0$$

$$y_i = y_i^* \text{ if } y_i^* > 0$$

where y_i^* is an underlying latent variable representing willingness of farmer i to invest in soil conservation, y_i is a limited dependent (observed) variable representing the amount of money promised by the farmer. X_i is a vector of explanatory variables, β' s are vectors of unknown parameters measuring the effect of these exogenous variables on willingness to invest, and ε_i is an error term assumed to be independently and normally distributed with zero mean and a constant variance σ^2.

The farmer is observed to be willing to invest if $y_i = y_i^*$, no willingness is observed otherwise. The Tobit model can also provide us with marginal effects of each variable on the probability of willingness and expected amount of investment (ibid):

$$E(y_i) = \Phi(z)E(y_i^*) \tag{10}$$

where E(y_i^*) is the expected value of y_i for those farmers that have already expressed willingness, and Φ is the cumulative normal distribution function at z where z= $X\beta_i/\sigma$). Equation (10) can be differentiated in terms of X_i to get an equation for marginal effects.

The Tobit model is also used to estimate the shadow wage shown in equation (7).

Detailed information on the definition, descriptive statistics and expected signs of the specific variables used in the empirical analysis is provided in Table 2.

5. Results and Discussion

5.1. Farmers' perceptions of land degradation: Descriptive results

Table 3 displays farmers' perceptions of land degradation on their farms and communal land. Soil erosion and nutrient depletion are the most important land degradation problems on private farms in the study area. On communal land, gully formation is added to these two problems. Specifically, about 45% of the sample households ranked soil erosion as the most serious problem on their farms followed by nutrient depletion which was perceived as the most serious problem by 12% of the households and as the second most serious problem by 41% (Figure 4). Soil erosion is ranked first (31%) even in communal lands followed by nutrient depletion and gully formation (Figure 5). These perceptions are in line with findings from previous studies (Tegene 1992; Hurni 1983, 1988; Elias, 2002). Overgrazing is not seen as a problem by the majority neither on private farms nor communal land. This could be due to the fact that domestic animals are grazing while tied around homesteads or fed through "cut and carry" system.

5.2. Factors affecting farmers' willingness to invest in soil conservation: Empirical results

The econometric analysis for the factors affecting farmers' willingness to invest (WTP) in soil conservation was separately carried out for the two payment vehicles, person-days and birr. Table 4 shows OLS results for the WTP in person-days/year, and Table 5 presents Tobit regression results for the WTP in birr/year.

a) Testing for the effects of asset and cash poverty (H1)

Livestock wealth in terms of TLU shows an expected positive and significant association with the households' willingness to invest in person-days and in birr per year, supporting our first hypothesis that asset poverty may limit the willingness of the households to invest in soil conservation. However, the number of oxen owned by the household has a negative and significant relationship with the WTP in either of labour or cash. Previous adoption studies in the area indicated that farmers removed conservation structures due to difficulties for oxen plowing, among other reasons (Tadesse and Belay, 2004).

Non-farm income shows a significant and negative relationship with the household's willingness to contribute a given amount of labour for soil conservation. The reason could be high off-farm income which means higher opportunity cost of their labour. The positive and significant relation of non-farm income with the WTP in cash could be an indicator for the willingness of the household to pay in cash instead of labour when liquidity constraint is relaxed. But dummy for access to credit is insignificant. During our interviews, we found that the majority of the households received credit mainly from informal sources and 87% of them used it for non-agricultural purposes.

b) Testing for the effects of labour endowment (H2)

Male and female workforce has an expected positive sign but statistically insignificant correlation with the WTP in both person-days and birr per year. This may show abundance of family labour in the area. When we include the endogenous wage rate in the regression, livestock ownership and oxen ownership remain the same. But non-farm income becomes insignificant, probably due to high correlation with the shadow wage as we can see from Table (6). It is plausible that the shadow wage rate is negatively and significantly correlated with the WTP in person-days but positively and significantly related to the WTP in birr. The distribution of the shadow wage across the sample seems to have been affected mainly by the distribution of the WTP in cash (see kernel density graphs in figures 1-3).We could not find instruments to predict the shadow wage rate, the reason for running the regression with and without it.

c) Testing for the effects of slope (H3)

For this hypothesis, we consider the proportion of the area with higher slopes from household's farm size and see its correlation with the WTP. The proportion of sloping area has expected positive sign but it is statistically insignificant for both person-days and birr, which could be due to the low number of plots under high slopes. Other farm characteristics such as average distance from house and the length of conservation structures on the farm are also insignificant. Soil type has a negative sign for both and is significant for the WTP in cash: the household is less willing to pay in cash for sandy soils as compared to clay soils.

Household characteristics such as age, sex and education are statistically insignificant. But education becomes significant for the WTP in birr; households with more years of schooling are willing to pay cash for soil conservation. The positive and significant relationship of previous extension visit with the willingness to pay in person-days indicates that households might have received advises on the importance of investment in soil conservation, creating positive awareness.

Both payment vehicles indicate similar factors to affect the willingness to pay for soil conservation. The estimated shadow wage rate from our analysis is birr 0.48/person-day. The average market wage rate that revealed in the area during the survey period was birr 5/person-day, which is much higher than the one estimated directly. This just confirms the impression of very limited off-farm employment opportunitites, and a low shadow wage rate, and that farmers would prefer payment in labour than cash. The median and maximum range for the WTP in birr is 6 and 365 per year respectively. The median for the WTP in person-days is 45 with the maximum range of 720 per year.

6. Conclusion

This paper has attempted to assess farm households' perceptions of land degradation and to elicit farmers' WTP for soil conservation practices in Gununo highlands of Southern Ethiopia. Farmers perceived land degradation mainly in terms of soil erosion and nutrient depletion especially on private farms.

The empirical findings indicate that livestock wealth, other than oxen, plays an important role for the willingness to pay both in terms of person-days and birr. The econometric results revealed that a unit increase in TLU would lead to an increase in willingness to invest by birr 6.74. For the labour contribution, this result went up to 27 extra person days. The shadow wage rate calculated from this study is very low (0.48 birr/day) compared with local wage rates at the time of the study which on average was about 5 birr/day. This may indicate labour abundance, cash scarcity and limited employment opportunity. This is supported by positive and significant relation of non-farm income with the WTP in cash although its magnitude is small in both regressions. Non-farm income affects the shadow wage positively. A negative and significant correlation of oxen ownership with the WTP in both regressions is still puzzling, which could be attributed to incompatibility of the conservation technology with the need of space for oxen ploughing; the households were thinking soil bunds. There are no stone terraces in the area; the majour soil conservation structures available are soil bunds, which in most cases are considered inconvenient for turning the oxen plough.

The study generally suggests that asset poverty is the key factor in limiting farmers' willingness to invest in soil conservation on their farm. Another policy issue that needs emphasis is the role of awareness creation through extension visits to raise conservation incentives of the farm households. This study has shown that households who had contacts with extension workers regarding soil and water conservation in previous years had positive willingness to invest labour. It is also important to note that in cash-scarce and labour abundant rural Ethiopian communities (such as those in Gununo) the WTP studies that employ labour days as payment vehicle can provide more sensible results than those which use cash only as payment vehicle. This is particularly the case when we talk about investments like soil and water conservation which primarily require labour inputs.

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Table 1: Basic socio-economic characteristics of sample households

Characteristics	No ox	Own ox**	All samples
Number of households (HHs)	82	60	142
Proportion of HHs in sample (%)	58	42	100
Percent of female-headed HHs	16	3	11
Number of HHs owning plots with conserv. structure	24	16	40
Number of HHs with no conservation structure	58	44	102
Number of HHs willing to contribute labour	77	60	137
Mean WTP in person days per year	53	96	71
Number of HHs unwilling to contribute labour	5	0	5
Number of HHs willing to pay in cash	56	47	103
Mean WTP in birr per year	21	27	24
Number of HHs unwilling to pay in cash	26	13	39
Mean family size (persons)	6.3	9.0	7.5
Mean female HH members (persons)	3.2	4.4	3.7
Mean male HH members (persons)	3.2	4.7	3.8
Mean female workforce (persons)	1.7	2.1	1.9
Mean male workforce (persons)	1.5	2.2	1.8
Mean consumer units	3.5	4.9	4.1
Dependency ratio	1.7	1.7	1.7
Mean farm size (*timad**)	1.2	2.6	1.8
Mean operational holding (*timad*)	1.1	2.6	1.7
Mean Tropical Livestock Units (TLU)	1.4	3.8	2.2
Mean farm income (Birr/year)	241	621	401
Predicted farm income (Birr/year)	70	143	101
Mean non-farm income (Birr/year)	356	501	417
Mean Credit (Birr/year)	57	106	78

*1 *timad is* about 0.25 hectares

** Only one household owns 3 oxen, 12 households own 2 oxen each, and the rest own one ox each.

Table 2: Definition of variables and mean statistics

Definition of variables	Mean	Standard deviation	Expected signs	
			labour	birr
Maximum willingness to pay per year in person days	71.01	82.46	Dep. var	
Maximum willingness to pay per year in birr	23.60	49.69		Dep. var
Age of household head in years	41.59	13.70	-/+	-/+
Sex =1 if the household head is male; =0 if the head is female	0.89	0.31	+	+
Education in number of school years	1.85	3.01	+	+
Own land holding in *timad*	1.78	1.58	-/+	+
Male workforce	1.76	1.15	+	+/-
Female workforce	1.87	1.12	+	+/-
Number of oxen owned	0.52	0.68	+	+
Other livestock in TLU	2.20	2.15	+	+
Non-farm income in birr	343.91	841.58	+/-	+
Access to credit = 1 if the household has access; = 0 otherwise	0.85	0.36	+	+
Average distance of plots from the house in meters	35.07	45.65	-	-
Length of conservation structure in meters	11.31	25.59	+/-	+/-
Proportion of sloping area	0.82	0.68	+	+
Soil type = 1 if most plots are on sandy soil; = 0 otherwise	0.63	0.49	+	+
Extension visit = 1 if advised on soil & water conservation issues in previous years ; = 0 otherwise	0.38	0.49	+	+
Shadow wage rate	0.48	1.05	-	+
Shadow wage/consumer unit	0.14	0.28	Dep. variable	
Male workforce/consumer unit	0.43	0.16	-	
Female workforce/consumer unit	0.48	0.20	-	
Own holding in *timad*/consumer unit	0.49	0.46	+/-	
TLU/consumer unit	0.57	0.45	+	
Non-farm income/consumer unit	92.11	225.70	+	

Table 3: Farmers' perception of on-farm and communal land degradation problems in Gununo

Major land degradation problems	Percent of households perceiving the degradation problems (Ranking)*			
	1	2	3	Total
Private land (on-farm)				
Erosion	44.6	3.6	0.7	48.9
Nutrient depletion	11.5	41.0	2.9	55.4
Overgrazing	2.2	5.0	2.2	9.4
Communal Land				
Erosion	30.9	0.7	3.6	35.2
Nutrient depletion	0.7	25.2	7.9	33.8
Gully formation	NP	4.3	27.3	31.6
Overgrazing	2.2	2.2	7.2	11.6
Deforestation	1.4	1.4	8.7	11.5

*Ranks: 1=most important problem 3=least important problem NP=Not priority

Table 4: Determinants of willingness to invest in soil conservation (OLS results)

Explanatory variables	Max. WTP in person days	With endogenous wage rate
Age	-0.584	-0.492
	(0.514)	(0.539)
Sex	4.367	1.439
	(16.989)	(18.759)
Education	2.127	2.802
	(2.727)	(2.684)
Own holding (Land)	1.325	0.388
	(4.862)	(4.971)
Average distance from house	0.131	0.104
	(0.083)	(0.087)
Conservation structure in meters	0.175	0.192
	(0.291)	(0.296)
Soil type	-2.113	-7.659
	(11.781)	(12.063)
Proportion of sloppy area	9.736	10.104
	(7.472)	(7.743)
Shadow wage rate		-13.158***
		(4.229)
Male workforce	8.471	8.696
	(6.061)	(6.536)
Female workforce	6.076	3.840
	(5.611)	(5.985)
Number of oxen	-43.656**	-46.303**
	(18.776)	(18.697)
Other livestock in TLU	27.236***	27.666***
	(9.680)	(9.607)
Non-farm income	-0.012***	-0.007
	(0.004)	(0.006)
Access to credit	3.456	3.229
	(15.684)	(17.908)
Extension visit	21.766**	24.757**
	(10.953)	(10.841)
Constant	1.293	13.157
	(31.837)	(34.688)
R-squared	0.382	0.387
N	142	137

Robust standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01

Table 5: Determinants of willingness to invest in soil conservation (Tobit results)

Explanatory variables	WTP in birr	Marginal effects	With endogenous Wage rate
Age	-0.377	-0.268	-0.227
	(0.453)		(0.289)
Sex	20.441	13.429	1.758
	(19.098)		(12.336)
Education	3.363*	2.392	1.933*
	(1.848)		(1.155)
Own holding (Land)	-2.236	-1.590	0.474
	(3.862)		(2.420)
Average distance from house	-0.042	-0.030	0.015
	(0.109)		(0.067)
Conservation structure in meters	0.096	0 .068	0.041
	(0.196)		(0.121)
Soil type	-18.076*	-13.099	0.678
	(10.159)		(6.521)
Proportion of sloppy area	3.599	2.559	4.206
	(7.330)		(4.677)
Shadow wage rate			37.893***
			(2.944)
Male workforce	2.812	2.000	-3.093
	(5.635)		(3.627)
Female workforce	1.616	1.150	2.809
	(4.881)		(3.128)
Number of oxen	-22.258**	-15.830	-17.238**
	(11.222)		(7.005)
Other livestock in TLU	9.474***	6.738	9.041***
	(3.464)		(2.152)
Non-farm income	0.010*	0.007	0.005
	(0.006)		(0.004)
Access to credit	-11.555	-8.506	-23.139**
	(14.373)		(9.288)
Extension visit	16.591	10.147	11.029*
	(10.516)		(6.640)
Constant	-1.935		-0.010
	(29.049)		(18.820)
Log likelihood value	-582.694		-521.478
sigma	53.642***		32.927***
	(3.826)		(2.314)
Prob > chi2	0.002		0.000
Number of observations	142		137

Standard errors in parenthesis; Significance level: *p< 0.10, **p< 0.05, *** p<0.01

Table 6: Tobit results of the determinants of shadow wage (WTP/WTW)

Explanatory variables	Shadow wage rate (shwagecu)	T-Ratio
Age	-0.003	-1.508
	(0.002)	
Education	0.021**	2.093
	(0.010)	
Male workforce	0.078	0.205
	(0.379)	
Female workforce	0.052	0.169
	(0.306)	
Own holding	-0.133*	-1.964
	(0.068)	
TLU	0.087	1.326
	(0.065)	
Non-farm income	0.001***	3.463
	(0.000)	
Constant	0.082	0.255
	(0.320)	
sigma	0.307***	13.936
	(0.022)	
Prob > chi2	0.001	
Number of observations	137	

Standard errors in parenthesis; Significance level: *p< 0.10, **p< 0.05, *** p<0.01

Appendix A: Questions on perceptions of degradation and Willingness to invest in soil conservation[19]

1. Perception questions

1.1. What are the most important degradation problems on your farm and in your community?

Type of degradation	*on on-farm* Rank*	*communal land* Rank*	*overall for community* Rank*
Erosion (loss of soil)			
Gully formation			
Nutrient depletion			
Overgrazing			
Deforestation			
Loss of local varieties			
No serious problem			

---

* Rank=1 for the most important problem

1.2. Do you see that yields on your farm have changed over time?

Yes _______ No_________

If yes, have they increased? _____________; Why increased? _________________________.

Or have they decreased? ________________; Why decreased? ________________________.

1.3. Where are the problems of land degradation in your village largest (in terms of effect on total production for human utilization)?

Private land: _______ Communal land_______ No problem_________.

1.4. Explain the main problems which still exist:

Main problem: ____

Second problem: ____

Third problem: ____

1.5. What are the causes of this (these) problem(s)?______________________________

____

1.6. Do you expect the community to solve the problem on your private farm?

Yes_______ No__________; If yes, explain why_________________________

____

[19] This is only a part of a comprehensive questionnaire which also collected all other variables used in this analysis.

2. Willingness to invest questions

2.1. How many mandays are you (your household) willing and able to invest in your own farm to conserve it?

2.1a. Maximum mandays your household is willing to invest in conservation of your farm in one year: Mandays _________

2.1b. Maximum mandays your household is willing to invest per year to maintain conservation structures: Mandays _________

2.2. How many mandays (maximum) of conservation effort would your household be willing to invest per year in order to stop land degradation for all future? Mandays __________

2.3. How many mandays are you willing to work extra (maximum) per year to increase your (average total) production with 100kg (1 quintal) per year of your main staple crop?

Staple crop______ Mandays_____ current price of the staple crop______

2.4. How many mandays extra are you willing to work this year in order to increase next year's production of your main staple crop with 100kg? Mandays_______

2.5a. How much birr (maximum) are you willing to pay for conservation of your farm in one year? Birr___________

2.5b. How much would you be willing to pay (maximum) in birr this year in order to stop land degradation from next year and for all future? Birr___________

Appendix B: Distribution of shadow wage rate

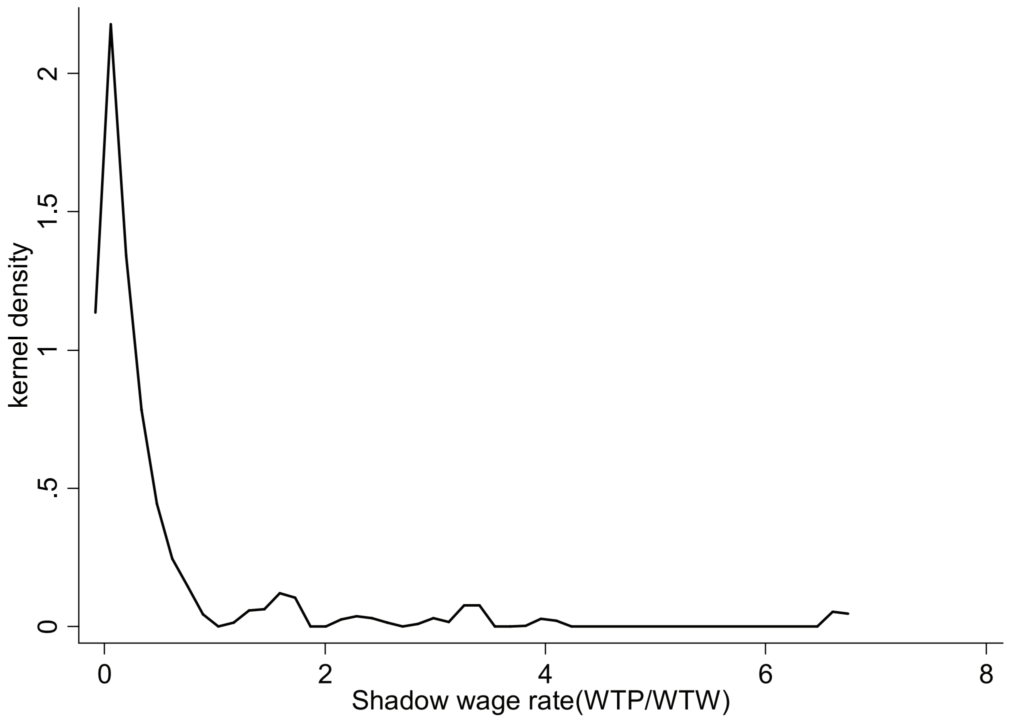

Figure 1: Distribution of shadow wage rate over 142 sample households

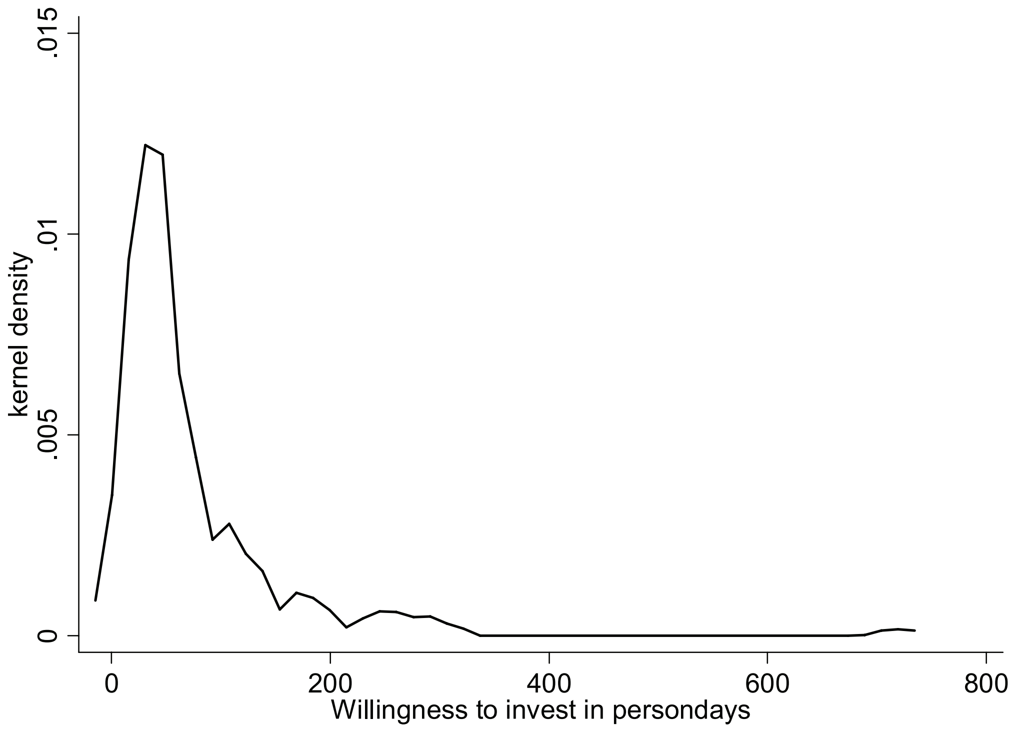

Figure 2: Distribution of WTW over 142 sample households

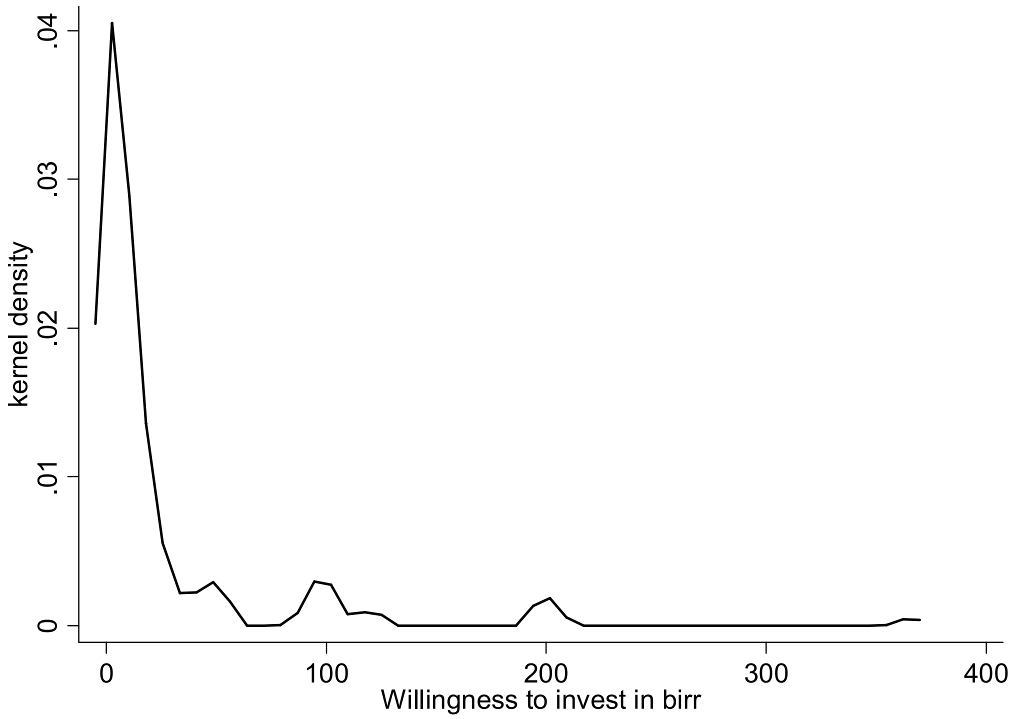

Figure 3: Distribution of WTP over 142 sample households

Appendix C: Farmers' rankings of land degradation problems

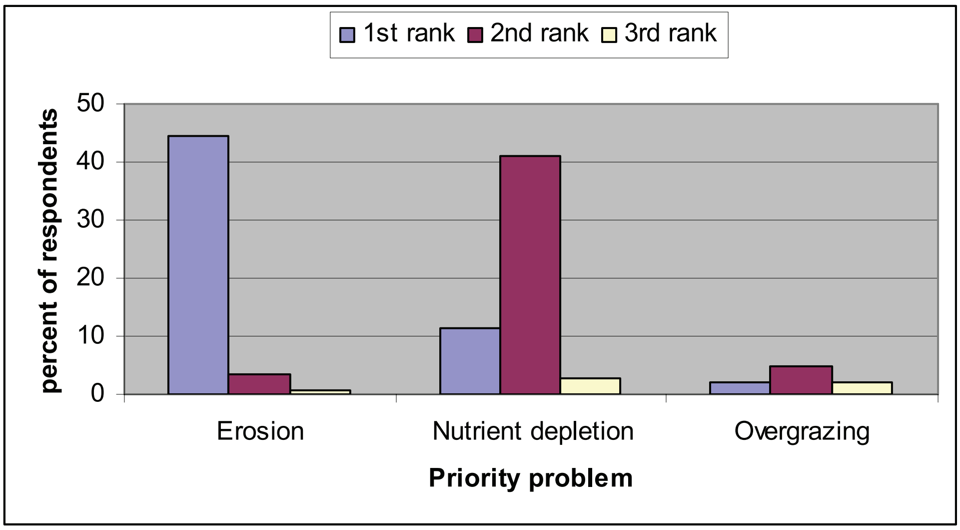

Figure 4: Farmers' ranking of land degradation problems on private farms

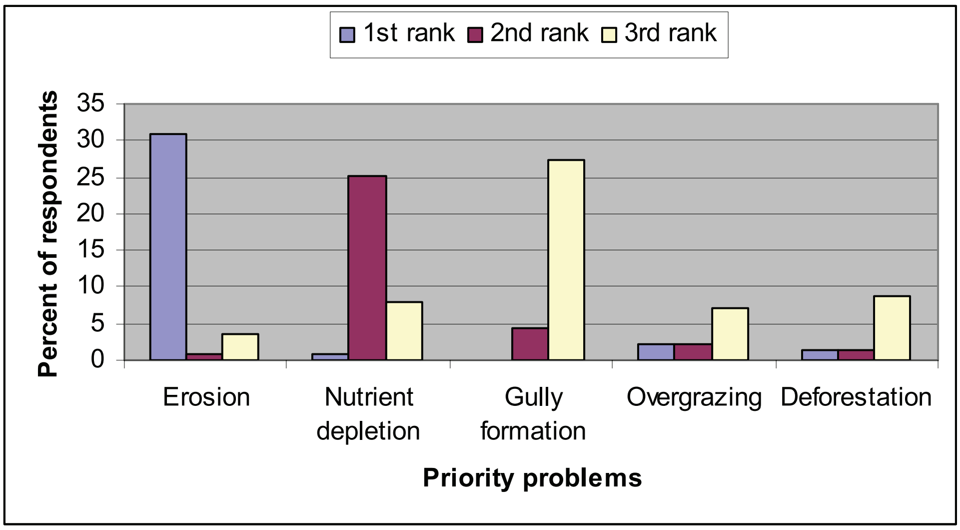

Figure 5: Farmers' ranking of land degradation problems on communal land

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The dissertation investigates resource use and intensification strategies of smallholders facing poverty and population pressure. It comprises an introduction and four independent papers. Based on data collected from a densely populated highland in Southern Ethiopia, paper I analyzes the farm size-land productivity relationship under population pressure.The inverse relationship (IR) at farm household level is partly explained by intensification through expansion of the cultivated area and partly by a yield increase on cultivated area. The plot level analysis suggests that the IR for yield at farm level could be due to omission of observed land quality attributes. Intensification strategies through the use of improved technologies are constrained by financial limitations and asset poverty. Paper II explores the relationship between the intensification of a starchy perennial crop (enset) and asset poverty. Enset is known to be productivity enhancing, land conserving, and a food security crop. A positive and significant synergy exists between productivity of this crop and livestock ownership, facilitating the process of intensification. Livestock- and land-poor farmers had lower land productivity and lower returns to their scarce resources, while livestock-rich but land-poor households had higher land productivity. Paper III assesses households' harvesting decisions of the perennial and finds that consumption needs of large households and persistent food insecurity problems in the area enhance early harvesting of this crop by the poor, leaving less for the future. Early harvesting for immediate susbsistence requirements reduces future availability and puts the households in a vicious circle of poverty. Paper IV identifies factors affecting conservation investment decisions of the farm households. It concludes that their capacity to invest in soil conservation is constrained by asset poverty and liquidity constraints. Their willingness to invest in labour or cash increases with livestock wealth and non-farm income motivates cash payments.

Professor Stein Holden and Professor Arild Angelsen were Worku's main and co-supervisors.

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