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WOODLOT DEVOLUTION IN NORTHERN ETHIOPIA: OPPORTUNITIES FOR EMPOWERMENT, SMALLHOLDER INCOME DIVERSIFICATION, AND SUSTAINABLE LAND MANAGEMENT

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ABSTRACT

This paper explores the patterns and determinants of empowerment, income generation, and environmental sustainability under varying degrees of woodlot management in Tigray, Ethiopia. Our analysis is based upon a survey of 120 collectively managed woodlots, devolved to varying degrees, and 66 households that have recently received small plots of community land for tree planting. We find that more devolved woodlot management empowers resource users by providing greater autonomy regarding the management of woodlots, and in particular the ability to make decisions about the harvest of woodlot products. Our economic analysis indicates that grass is by far the most important product being harvested from woodlots. There has been very limited harvesting of higher value products such as poles and fuelwood, which are in very short supply in the region. Labor inputs declined, and average annual net benefits improved as woodlots were more devolved, indicating that devolved woodlots are more economically efficient. Woodlots were generally perceived to be associated with positive changes in environmental conditions such as the slowing of erosion and gully formation, and the maintenance of biodiversity. However, greater environmental benefits were associated with less devolved woodlots. This study highlights the trade-offs inherent in varying levels of woodlot management. Though woodlots are perceived to provide significant environmental functions, restrictions regarding harvesting high value products are limiting the potential for smallholder income diversification and empowerment, two critical components of poverty alleviation in Ethiopia.

Keywords: Devolution, Empowerment, Ethiopia, Income generation, Poverty, Sustainability, Woodlots

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1. INTRODUCTION

Many governments in sub-Saharan Africa are decentralizing and devolving responsibility of managing natural resources to local administrations, user groups, and individuals (Lind and Cappon 2001). The implicit assumption of devolution is that it leads to more equitable and sustainable use of natural resources, resulting ultimately in improvements in welfare, and poverty reduction among resource users. This paper explores an example of woodlot devolution in the highlands of northern Ethiopia, and its potential for raising smallholders out of poverty. We consider the potential for woodlot devolution to influence three factors central to poverty alleviation: empowerment of local communities and user groups, income generation opportunities, and environmental sustainability.

The paper is organized as follows. The next section provides background information, and a theoretical framework for our hypotheses about the empowerment, income, and environmental sustainability effects of woodlot devolution. We then describe the study area and survey, as well as the methods used in our analysis. We explore the determinants of community and household empowerment, the benefits and costs of woodlot management, and the determinants of changes in environmental conditions under varying degrees of woodlot devolution using both descriptive and econometric analyses. We conclude with a summary and discussion of policy implications emanating from the study.

2. BACKGROUND, THEORETICAL FRAMEWORK, AND HYPOTHESES

One of the rural development strategies of Ethiopia's current government is decentralizing natural resource management. This policy is in sharp contrast to the heavily centralized socialist regime (the Derg) that ruled Ethiopia until 1991. Between 1974 and the late 1980s, the military regime of Mingistu Haile Mariam undertook an aggressive agrarian reform that included the nationalization of private commercial farms; land tenure reforms that abolished tenancy and the use of hired labor; large-scale environmental reclamation programs; and other measures. Unpaid labor was requisitioned to support tree planting and other land reclamation efforts fueled by a Malthusian environmental degradation narrative – more people leads to more erosion (Hoben 1996).

Since the toppling of the Derg in 1991, the People's Revolutionary Democratic Front (EPRDF) has maintained a commitment to addressing environmental problems (Hoben 1996). Rather than maintaining centralized control, woodlots have been devolved to varying degrees. Old and newly established woodlots have been placed under the management of communities, villages, and sub-villages. In addition, a quasi-privatization of community hillsides is taking place as degraded hillsides are parceled out to individual households for tree planting. However, in Tigray, the tradition of mass mobilization has prevailed. Smallholders are required to devote 20 days of uncompensated labor annually to various land reclamation and tree planting initiatives.

Investment in tree planting is hypothesized to be a potential development pathway out of poverty in the low potential areas of Tigray, particularly in areas with relatively good market access (Hagos, Pender and Gebreselassie 1999).[1] Ethiopian smallholders are heavily focused on cereal production. Data from a 1998 survey of households throughout the region indicate that cereal production was the primary occupational strategy for men in all villages studied, and after household maintenance, the most important occupational strategy for most women (Pender, Jagger, and Gebremedhin 2001). However, returns from cereal production in the highlands of Tigray are low, relative to returns from activities such as bee keeping and livestock production (Pender, Gebremedhin, and Haile 2002). Estimates of the potential benefits from the sustainable harvest of eucalyptus poles from household managed woodlots in Tigray suggest an annual average return of approximately 370 EB per capita, approximately half of the per capita Gross Domestic Product in Ethiopia in 1998 (Jagger and Pender 2003).

Woodlots are an increasingly important source of woody biomass, as well as a critical soil and water conservation investment as deforestation and land degradation worsen. Ethiopia's remaining natural forest is estimated to be diminishing at a rate of 50,000 to 200,000 hectares per year; by 2015 Ethiopia's indigenous forests may be completely exhausted (Stiles, Pohjonen, and Weber 1991). Demand for woody biomass, as an alternative to burning dung and crop residues is very high in Ethiopia. In Tigray, dung and crop residues account for as much as 81 percent of total household energy consumption, leaving little organic matter for fertilizing crops (Bekele-Tesemma 1997).

[1] The concept of "development pathways" relates to common patterns of change in livelihood strategies over a fairly long period of time. The concept of development pathways is similar to livelihood strategies, but focuses on changes over time (Pender, Place and Ehui 1999).

The burning of dung and crop residues represents an estimated loss in crop production equivalent to approximately 700,000 tons of grain per annum (EFAP 1993).

Estimates of soil erosion in the Ethiopian highlands indicate that 2 million hectares of land have been severely degraded, and that if management practices are not changed, as much as an additional 7.6 million hectares will be degraded to the same status by 2010 (FAO 1998). Annual economic losses attributable to soil erosion are estimated to be EB 10-12 million per annum (calculated at 1994 prices) (Sutcliffe 1993; Bojo and Cassells 1995). The potential for afforestation as a soil and water conservation tool to halt land degradation may be significant.

Whether the shift away from centralized management of woodlot resources enables resource users to have greater decision-making power over woodlot management, greater income generation opportunities, and a positive impact on biodiversity preservation and environmental sustainability are important questions. Evidence from community surveys carried out in the late 1990s indicated that though woodlots have been devolved to varying degrees, there were still significant institutional barriers with respect to decision-making power over the establishment, management, and harvest of products from woodlots (Gebremedhin, Pender and Tesfay 2003; Jagger and Pender 2003).

THEORETICAL FRAMEWORK AND HYPOTHESES

Central to the goal of poverty alleviation in rural areas are strengthening the rights, capabilities, and governance of local peoples (empowerment); improving the ability to capture emerging opportunities for income generation (opportunity); and the maintenance of biodiversity, soils and other natural resource conditions (sustainability).[2] Ethiopian smallholders currently face significant challenges with respect to each of these aspects of poverty alleviation. Our central hypothesis is that in Tigray, community woodlots are a more effective mechanism for promoting sustainable land management and biodiversity preservation, whereas household managed woodlots are more effective for improving smallholder incomes. We also hypothesize that community managed woodlots promote the most equitable distribution of benefits, thus empowering the greatest number of people, whereas household managed woodlots empower a select number of people, while excluding others.

The devolution of woodlots to community, village and sub-village, and household management has the potential to empower rural communities and smallholders by increasing their decision-making power, and providing mechanisms to develop local governance structures. Development practitioners generally accept that local communities can play a central role in the effective management of natural resources (Johnson and Forsyth 2002).

However, numerous conditions have been identified in the literature as being essential to the effective management of common property resources. For example, communities must possess the knowledge, information and incentives to manage and conserve the resource on which they depend, should share a strong sense of historical presence and a clear sense of identity, and should be granted at least "minimal recognition" by the state (Agrawal and Gibson 1999; Ostrom 1990).

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[2] Reducing vulnerability to shocks is also central to poverty alleviation. However, beyond the contribution woodlots make to diversifying income sources, we do not address the potential role for woodlot devolution to contribute to risk management in this paper.

Table 1 – Framework for characterizing devolution of woodlot management

MANAGEMENT CATEGORY	HYPOTHESES
COMMUNITY MANAGEMENT[A]	
Empowerment	All community members have access to the resource – most equitable management category, but due to large group size the poorest of the resource users may have less of a voice in decision-making than less poor resource users who have greater social capital, education, and information; decisions about harvest of woodlot products requires the consensus of a large group; external agencies may have greater input regarding management and harvesting of woodlot products limiting empowerment of community members
Income generation	Income generally derived from low value, intensively harvested products; some households may rely on the harvest of woodlot products to diversify income sources; relationship between benefits and costs of production less easily understood by all resource users
Biodiversity and environmental sustainability	May be stronger focus on land reclamation and biodiversity benefits for the community; harvest of high demand woodlot products such as fuelwood may not be sustainable unless rules and regulations regarding access are well defined and enforced
PARTIAL DEVOLUTION (VILLAGE OR SUB-VILLAGE MANAGEMENT)	
Empowerment	Some community members may be excluded from having access to the resource; smaller groups make it easier to reach consensus about woodlot management and harvesting decisions; less reliance on external agencies
Income generation	Incomes likely to be diversified by access to woodlot products as smaller group size may facilitate decreased transactions costs in making harvesting decisions; clearer relationship between benefits and costs of production
Biodiversity and environmental sustainability	Larger proportion of woodlot may be planted to exotics; increased access to higher value woodlot products may result in unsustainable harvesting of trees, though rules and regulation of harvesting may be easier to enforce
HOUSEHOLD MANAGEMENT	
Empowerment	Landless households greatly empowered by right to privately manage woodlot, but some households in the community will be excluded from access to woodlot resources; limited input from external agencies regarding management and harvesting
Income generation	Households may derive large share of income from woodlot products, but may be limited by market access; relationship between benefits and costs of production clear
Biodiversity and environmental sustainability	Emphasis on fast growing exotics (due to high discount rates); woodlot products may not be sustainably harvested, may result in unsustainable land management

A. We define a community as a *tabia,* the lowest administrative unit in Tigray, usually consisting of four or five villages.

Devolving woodlots from community management to smaller groups including villages and sub-villages may lead to more effective resource management and greater decision-making power. When groups are smaller in size and more homogeneous in nature, decision-making regarding the management and use of the resource is generally easier and more efficient (Agrawal 2002). However, multiple user situations that formalize rights of access may leave out or disadvantage those that previously had de facto rights of access (Arnold 1998).

We hypothesize that community managed woodlots offer a lesser degree of decision-making power by the membership than village, sub-village or household managed woodlots. Large and heterogeneous groups are likely to have higher transaction costs associated with determining the distribution of benefits to resource users, and increase potential conflicts of interest (Baland and Platteau 1996; Ostrom 1990; Sandler 1992; Olson 1965). In addition, external agencies may be more involved in decision making about establishment, management and harvesting woodlot products. Household managed woodlots are likely the most empowered with respect to deciding what to plant, when to plant, how much to harvest, and determining labor inputs.

It is generally assumed that local resource users will have more incentives to invest in and sustainably manage forest, woodland, and planted woodlots than centralized administrations (Lemessa and Perault 2001). However, the role that devolution of woodlot management plays in generating income may vary. Community managed woodlots may be better suited to meeting subsistence demands for woodlot products rather than production for the market (Baland and Platteau 1996). However, as woodlots are devolved to village, sub-village and household management, a stronger correlation between inputs, labor, and outputs is understood, with the strongest correlation being at the household level (Gregersen, Draper and Elz 1989). In other words, households have more incentive to apply inputs on household-managed woodlots, since they receive the full marginal benefit of any inputs applied. More devolved woodlots are more likely to be managed with a stronger focus on generating positive economic returns.

We hypothesize that community managed woodlots are more focused on subsistence production for community members; while household managed woodlots are likely to yield the greatest income earning opportunities. When landless households are the recipients of community land for private tree planting, woodlots may provide the primary source of income for the household. However, income generation opportunities will be largely influenced by access to markets for woodlot products.

The environmental externalities associated with woodlots are expected to be correlated with the land area the woodlot covers, the variety of tree species planted in the woodlot, the age of the woodlot, previous land uses, biophysical factors such as soil type and slope, and how sustainably woodlot products are harvested. Larger, sustainably managed woodlots, and woodlots planted to a variety of tree species are more likely to have a higher level of positive environmental externalities associated with them. However, the rules and regulations of harvesting may be more difficult to enforce for large heterogeneous user groups. Conversely, smaller woodlots planted to a single species are likely to have a smaller impact on reversing land degradation and promoting biodiversity, particularly if that species is non-leguminous and/or exotic.

We hypothesize that the land reclamation and biodiversity functions of woodlots will be greatest for community-managed woodlots. Because these functions are perceived as positive externalities – potentially accruing to numerous members of the community – the incentive to maintain and sustainably manage these resources is highest for large groups. We also hypothesize that as woodlots are devolved, a stronger emphasis will be placed on establishing woodlots of fast growing exotics such as eucalyptus, which in many settings can have implications for biodiversity and general environmental conditions (Jagger and Pender 2003). For household managed woodlots the planting of fast growing exotics is motivated by the need for immediate returns on investment (due to high discount rates of poor people) (Mink 1993; Pender 1996; Holden Shiferaw and Wik 1998).

3. METHODS

This study is based upon data from two surveys conducted in Tigray between December 2000 and mid 2001. The first survey focused on collectively managed woodlots and included woodlots managed at the *tabia* level (community), *kushet* level (village), or at the *sub-kushet* level (by a sub-group within a village). Woodlots were selected from an inventory established during a survey of *tabias* and *kushets* in Tigray in 1998.[3] We surveyed up to three woodlots per community, and when there were more than three woodlots per community, three woodlots were randomly selected. Where possible, survey respondents for the community level survey included a representative from the *tabia* or *kushet baito* (administrative council), a community member from the agricultural cadre, the woodlot guard, one woman, and one community member with no office. In total 120 groups were surveyed about their collectively managed woodlots.

The second survey focused on households that are beneficiaries of a pilot project in Tigray to devolve management of degraded community hillsides to households for the purpose of tree planting. Based upon information provided by the Bureau of Agriculture on the households that have received land distributions for private tree planting by *tabia*, three households were randomly selected from each *tabia* where land was distributed for private tree planting. Sixty-six households with privately managed woodlots were surveyed. Both questionnaires were administered in *Tigrigna* by local enumerators.

We consider the factors influencing empowerment, income generation, and environmental sustainability for woodlots under varying degrees of devolution. The main research question is: What contribution can woodlot devolution make to the general goals of poverty alleviation? More specifically, we explore empowerment, the determinants of

[3] The International Food Policy Research Institute (IFPRI), the International Livestock Research Institute (ILRI), and Mekelle University as part of the project "Policies for Sustainable Land Management in the Ethiopian highlands" collaboratively undertook the community (*tabia*) and village (*kushet*) surveys.

returns on investment, and perceived changes in environmental conditions for woodlots that have been devolved to varying degrees.

Analysis of descriptive information from the survey was used to identify current decision-making power and rights of access to various woodlot products, the benefits and costs of woodlot management, and the perceived effects of woodlots on environmental externalities both within woodlots, and on plots adjacent to woodlots. Determinants of changes in environmental conditions in woodlots were econometrically investigated using an ordered probit model, since the dependent variables are ordinal (Maddala 1983). In all regressions, explanatory variables were transformed if they were more normally distributed in an alternative functional form, and tested for multicollinearity using the variance inflation factor test (VIF) (Mukerjee et al. 1998).

4. ANALYSIS

GENERAL WOODLOT CHARACTERISTICS

We present information characterizing woodlots under varying levels of management (Table 2). Community managed woodlots are the largest, averaging over 12 hectares in size. Village and sub-village managed woodlots are roughly half the size of community managed woodlots, and do not differ significantly in area. Sub-village managed woodlots are the oldest. It is likely that these woodlots have been devolved from larger community woodlots as village or sub-village managed woodlots were not common in Ethiopia in the early 1990s.

Data on the average number of seedlings planted per hectare, in the year the woodlot was established, indicate that village managed woodlots have significantly lower seedling planting densities than other woodlots. Seedling survival rates are highest for sub-village and household managed woodlots, indicating that more devolved woodlots may be investing more labor in important activities like weeding and watering to ensure seedling survival.[4] (Table 2)

We note that seedling survival rates are relatively low, averaging 48 percent for all woodlots surveyed.[5] High seedling mortality may be an indication that seedlings are being planted too close together. Tree species diversity is clearly greater in community and village managed woodlots than in sub-village and household managed woodlots. In addition, the percentage of seedlings planted that are eucalyptus species is very high for household managed woodlots.[6] These findings support our hypothesis that sustainability and biodiversity considerations are greater for less devolved woodlots.

[4]The highest intensity of weeding and watering was undertaken by sub-village managed woodlots. Households weeded less than collectively managed woodlots, and were as likely to water their seedlings as collectively managed woodlots.

[5] These figures are comparable to those found in Jagger and Pender (2003) for village managed woodlots, but significantly lower than survival rates for community *(tabia*) managed woodlots reported there.

[6] We assume that higher proportions of fast growing exotics such eucalyptus do not favor biodiversity. For a discussion of the ecological impacts of eucalyptus species see Jagger and Pender (2000).

Table 2 – Woodlot characteristics[A, B]

Item	Collectively Managed Woodlots			Household Managed Woodlots (N=66)
	Community (N=34)	Village (N=75)	Sub-village (N=11)	
Area (hectares)	12.5	6.3	7.6	0.2
	(2.4)	(0.8)	(1.3)	(0.03)
Age in 2000 (years)	6.2	5.5	8.7	1.0
	(1.6)	(0.4)	(1.6)	(0.1)
Seedlings planted in year woodlot was established (seedlings/ha)	4472.1	1984.9	3848.6	4159.4
	(1460.0)	(402.9)	(2343.3)	(741.9)
Seedling survival rate (percent)	45.3	49.3	52.7	52.4
	(5.4)	(3.0)	(4.8)	(3.3)
Number of different tree species represented in woodlot	3.9	3.6	2.7	2.7
	(0.3)	(0.2)	(0.3)	(0.2)
Percentage of seedlings planted that are eucalyptus species	24.8	31.3	18.27	77.5
	(6.8)	(5.2)	(9.2)	(3.2)
Woodlots promoted by external organization (percent)	41.5	67.7	73.3	74.2
	(10.6)	(6.9)	(9.5)	(0.1)
Promoted by BoANRD	100.0	97.9	100.0	100.0
Woodlots that received extension advice (percent)	93.8	100.0	100.0	25.8
	(3.8)	(0.0)	(0.0)	(0.3)
Seedling planting and tending to trees	73.5	82.4	40.0	25.8
Semi-moon terrace construction	5.3	17.0	0.0	3.0
Gully stabilization	0.0	6.1	0.0	0.0
Woodlot management	48.8	33.8	77.3	7.6
Soil and water conservation	36.8	51.6	22.7	19.7

A. Values in parentheses indicate standard error
B. Means and standard errors are corrected for sampling stratification and weights.

Less than half of community-managed woodlots have been promoted by external organizations.[7] A higher proportion of village and sub-village managed woodlots have been promoted by external organizations. Almost all community, village and sub-village managed woodlots received extension advice during the 1990s. Advice on a variety of topics was given; seedling planting and tending to seedlings, woodlot management, and soil and water conservation techniques were emphasized.

Household managed woodlots are very small – averaging only 0.20 hectares per household. These small plots are indicative of the goal of the pilot program to partition

[7] Woodlots that were not promoted by external organizations were motivated by local administrations including *woreda (district), tabia* and *kushet baitos.*

community lands for private tree planting in such a way that as many households as possible will benefit. Given the newness of the pilot program to plant trees under private management at the time of the survey, household managed woodlots are very young.

Approximately 75 percent of household managed woodlots were externally promoted. It is interesting to note that external organizations such as the Bureau of Agriculture and Natural Resources Development (BoANRD) are generally the main promoter of more devolved woodlots, indicating that external forces are driving their formation rather than grass roots initiatives. Household managed woodlots that were not externally promoted were established primarily by *tabia baitos*, and to a lesser extent *kushet baitos*. The majority of households were selected for the pilot program because they were landless, indicating that the BoANRD and local administrations are using the pilot program as a mechanism for distributing land to very poor households. In contrast with community, village, and sub-village managed woodlots, extension advice to households managing woodlots has been limited, with only 25 percent of households receiving advice. Seedling planting and soil and water conservation techniques have been the main focus of extension to household managed woodlots.

EMPOWERMENT

The ability to harvest woodlot products without permission is an indicator of how autonomous communities and households managing woodlots are from the external organizations or local administrations that have promoted the woodlots and oversee community resources. When permission to harvest woodlot products is required, it is generally obtained from the Bureau of Agriculture, *tabia baito* (community administration), or *kushet baito* (village administration). Having to seek permission from the Bureau of Agriculture to harvest woodlot products indicates that woodlots have a lower degree of autonomy than if permission is needed only from local administrations.

The proportion of communities requiring permission to harvest woodlot products is relatively high for each level of collective woodlot management (Table 3). For timber related woodlot products (poles, fuelwood and tree fodder), fewer village and sub-village managed woodlots than community woodlots are required to obtain permission for harvesting. However, a higher proportion of sub-village managed woodlots are required to obtain permission to harvest grass and non-timber forest products (NTFPs).[8]

[8] Traditional medicines and prickly pear cactus were the non-timber forest products identified by communities and households managing woodlots.

Table 3 – Communities/households that require permission to harvest, and who they obtain permission from, percent[A, B]

Woodlot Product	Collectively Managed Woodlots Community (N=34)	Village (N=75)	Sub-village (N=11)	Household Managed Woodlots (N=66)
Poles	90.0 (4.1)	80.4 (7.1)	81.3 (14.0)	50.0 (0.1)
BoARND[C]	51.8	43.1	51.2	48.5
Tabia Baito[C]	48.2	34.9	0.0	36.4
Kushet Baito[C]	0.0	21.9	48.8	9.1
Other[C]	0.0	0.0	0.0	6.1
Fuelwood	93.4 (3.2)	81.0 (7.0)	81.3 (14.0)	52.4 (0.1)
BoARND[C]	59.0	41.3	51.2	48.5
Tabia Baito[C]	41.0	34.7	0.0	36.4
Kushet Baito[C]	0.0	21.8	48.8	9.1
Other[C]	0.0	2.3	0.0	6.1
Tree Fodder	90.0 (4.1)	79.2 (7.1)	69.7 (12.6)	42.9 (0.1)
BoARND[C]	51.8	45.7	57.0	59.3
Tabia Baito[C]	48.2	33.3	0.0	33.3
Kushet Baito[C]	0.0	20.9	40.3	0.0
Other[C, D]	0.0	0.0	0.0	7.4
Grass	97.1 (2.0)	89.5 (5.8)	100.0 (0)	22.7 (0.1)
BoARND[C]	50.7	34.6	47.4	60.0
Tabia Baito[C]	48.1	36.3	0.0	33.3
Kushet Baito[C]	0.0	20.6	45.1	0.0
Other[C, D]	1.1	8.6	7.6	6.7
NTFPs	79.4 (10.3)	75.5 (7.2)	87.0 (12.8)	36.4 (0.1)
BoARND[C]	56.1	39.3	54.4	62.5
Tabia Baito[C]	43.9	35.7	0.0	37.5
Kushet Baito[C]	0.0	22.5	45.6	0.0
Other[C, D]	0.0	2.4	0.0	0.0

A. Values in parentheses indicate standard error.
B. Means and standard errors are corrected for sampling stratification and weights.
C. Percentages are conditional upon permission being required.
D. Other includes *woreda baitos* (administrations), marketing coops, woodlot guards, and village churches.

Household managed woodlots have the greatest degree of autonomy with respect to the harvesting of all types of woodlot products. Approximately 50 percent of households managing woodlots were required to obtain permission to harvest poles, fuelwood and tree fodder. Fewer households are required to get permission to harvest grass and other non-timber forest products. Of the households that are required to get permission to harvest woodlot products approximately 50 to 60 percent get permission for the Bureau of Agriculture, rather than the local administration.

The data in Table 3 indicate that household level woodlot management is more autonomous regarding the harvesting of both timber and non-timber woodlot products. We also note that devolving collectively managed woodlots from communities to village and sub-village groups does not have a significant effect on the ability of the resource users to make decisions about harvesting woodlot products. Recall that all of the woodlots in our study are planted on community land. Making the leap from collective management to household management appears to significantly affect the ability of resource users to make harvesting decisions. The decision to harvest woodlot products still remains with external agencies for many collectively and household managed woodlots, suggesting that opportunities for further empowerment of local resource users and administrations exists.

INCOME POTENTIAL

Table 4 provides a summary of the percentage of communities and households that harvested woodlot products, as well as the average annual harvest of woodlot products between 1997 and 2000. There has been very limited harvesting of poles in community woodlots, and no reported harvesting of fuelwood or tree fodder in any woodlots. This is surprising given that demand for fuelwood in Tigray is very high. Three factors may be contributing to the very limited harvesting of woodlot products. First, obtaining permission to harvest woodlot products can be time consuming, particularly if permission is to be obtained from the local BoARND office, which may be distant from the user group. Second, almost all woodlots in our sample were guarded 365 days a year, and respondents indicated that cash penalties, and in some cases imprisonment are imposed for harvesting woodlot products without permission. Finally, both fuelwood and tree fodder are generally obtained from deadwood in woodlots and area enclosures, rather than from the harvest of live trees.[9]

[9] Collection of deadwood was not considered "harvesting" by survey respondents.

Table 4 – Harvest of woodlot products 1997 to 2000[A, B]

Woodlot Product	Collectively Managed Woodlots Community	Village	Sub-village	Household Managed Woodlots
Percent of woodlots that harvested product				
Woodlot 0-4 years	**N=19**	**N=32**	**N=4**	**N=66**
Poles	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.5 (1.5)
Thatching grass	51.5 (15.9)	66.0 (10.5)	31.3 (28.9)	7.6 (3.3)
Fodder grass	47.9 (16.4)	74.9 (9.3)	45.2 (29.6)	19.7 (4.9)
Handicraft grass	0.0 (0.0)	4.0 (3.7)	0.0 (0.0)	3.0 (2.1)
NTFPs	1.2 (2.1)	1.7 (1.3)	0.0 (0.0)	1.5 (1.5)
Woodlot 5-10 years	**N=12**	**N=37**	**N=3**	N/A
Poles	11.8 (8.7)	10.3 (6.3)	50.5 (37.5)	
Thatching grass	59.4 (18.6)	64.7 (10.3)	50.5 (37.5)	
Fodder grass	61.8 (18.1)	68.6 (10.0)	25.2 (28.8)	
Handicraft grass	5.9 (6.1)	6.3 (5.6)	0.0 (0.0)	N/A
NTFPs	0.0 (0.0)	4.6 (3.2)	0.0 (0.0)	
Woodlots 11-25 years	**N=2**	**N=6**	**N-4**	
Poles	100.0 (0.0)	17.8 (13.9)	0.0 (0.0)	
Thatching grass	100.0 (0.0)	31.3 (21.2)	63.6 (30.9)	
Fodder grass	0.0 (0.0)	33.4 (26.4)	0.0 (0.0)	
Handicraft grass	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
NTFPs	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
If harvested, Average quantity of product harvested per hectare per year				
Woodlot 0-4 years	**N=19**	**N=32**	**N=4**	**N=66**
Poles (number)[D]	No obs	No obs	No obs	N/A[C]
Thatching grass (headload)[D]	23.0 (20.2)	10.0 (2.4)	1.6 (.)	2.2 (1.2)
Fodder grass (headload)[D]	7.4 (3.4)	7.3 (1.6)	0.2 (0.5)	13.0 (11.5)
Handicraft grass (headload)[D]	No obs	0.3 (0.2)	No obs	2.0 (0.3)
NTFPs (handful)[D]	N/A[C]	4.2 (2.6)	No obs	N/A[C]
Woodlot 5-10 years	**N=12**	**N=37**	**N=3**	N/A
Poles (number)[D]	1.2 (0.7)	3.2 (1.6)	12.0 (3.0)	
Thatching grass (headload)[D]	13.8 (6.1)	10.0 (1.6)	3.7 (0.3)	
Fodder grass (headload)[D]	19.4 (4.2)	31.2 (10.5)	7.5 (.)	
Handicraft grass (headload)[D]	0.3 (.)	0.9 (0.1)	No obs	
NTFPs (handful)[D]	No obs	0.4 (0.4)	No obs	N/A
Woodlots 11-25 years	**N=2**	**N=6**	**N-4**	
Poles (number)[D]	N/A[C]	3.9 (1.4)	No obs	
Thatching grass (headload)[D]	13.1 (5.0)	14.6 (9.2)	5.3 (1.0)	
Fodder grass (headload)[D]	No obs	12.7 (3.0)	No obs	
Handicraft grass (headload)[D]	No obs	No obs	No obs	
NTFPs (handful)[D]	No obs	No obs	No obs	

A. Values in parentheses indicate standard error.
B. Means and standard errors are corrected for sampling stratification and weights.
C. Respondents were unable to provide information on quantities of poles and NTFPs harvested.
D. Values are conditional upon respondents indicating that they had had harvested woodlot products at some point between 1997 and 2000.
N/A = not applicable

Grass is the most commonly harvested woodlot product. Approximately 50 percent of community and village managed woodlots harvested grass for thatching and for fodder. Village managed woodlots had the highest rates of harvest of grass for thatching, fodder and handicrafts. The quantities of grass harvested by collectively managed woodlots generally remained relatively constant or increased as woodlots got older. Grass harvesting is relatively limited for household managed woodlots – perhaps due to the fact that these woodlots were only recently established on degraded hillsides. The harvest of other non-timber forest products is limited to community, village, and to a lesser degree household managed woodlots. Quantities of NTFPs harvested from woodlots are generally very low and unlikely to significantly contribute to incomes. Poles were harvested by approximately 10 percent of community and village households in the 5 to 10 year age category. A large share of sub-village managed woodlots of that age harvested poles, though this finding is based upon very few observations.

As we have already noted, community managed woodlots rely on a variety of types of labor for undertaking various woodlot management activities, including mass mobilization (i.e. non-voluntary uncompensated labor), voluntary uncompensated labor, and voluntary compensated labor. Household managed woodlots rely largely on household labor – though activities such as guarding the woodlot are often undertaken collectively in cases where many household managed woodlots are located in close proximity. Table 5 provides a summary of total labor inputs per hectare per year between 1997 and 2000. There is a clear trend in the average number of person days per hectare in devolved woodlot management for woodlots below 5 years, and woodlots between 5 and 10 years of age. As woodlots are devolved, labor days per hectare decrease. This is largely due to very large inputs of labor to community woodlots through community mass mobilization campaigns and food-for-work projects (voluntary compensated labor).

Table 5 – Total labor inputs 1997 to 2000, person days per hectare per year[A, B, C]

Age of woodlot	Collectively Managed Woodlots			Household Managed Woodlots
	Community	Village	Sub-village	
Woodlot 0-4 years	N=19	N=32	N=4	N=66
Mass mobilization	501.9 (199.8)	281.4 (94.5)	158.8 (102.1)	N/A
Voluntary uncompensated labor	7.5 (3.7)	4.9 (1.2)	0.3 (0.3)	N/A
Voluntary compensated labor	270.8 (142.6)	191.2 (143.0)	102.0 (73.6)	N/A
Household labor	N/A	N/A	N/A	56.5 (11.2)
Hired labor	N/A	N/A	N/A	3.4 (1.9)
Total	**780.2 (339.8)**	**477.8 (223.2)**	**261.0 (174.6)**	**58.9 (13.0)**
Woodlot 5-10 years	N=12	N=37	N=3	
Mass mobilization	1710.4 (1296.9)	192.6 (52.4)	85.2 (12.9)	
Voluntary uncompensated labor	6.8 (2.8)	24.6 (6.1)	4.8 (3.7)	
Voluntary compensated labor	1445.2 (1469.3)	19.5 (9.2)	0.0	
Total	**3162.3 (2762.3)**	**236.8 (52.5)**	**90.0 (9.4)**	
Woodlots 11-25 years	N=3	N=6	N-4	
Mass mobilization	245.6 (77.0)	140.3 (88.0)	176.5 (93.1)	
Voluntary uncompensated labor	16.3 (4.0)	4.7 (3.1)	22.4 (11.0)	
Voluntary compensated labor	35.0 (14.0)	49.4 (19.2)	0.0	
Total	**296.9 (95.0)**	**194.3 (104.9)**	**198.9 (103.8)**	

A. Values in parentheses indicate standard error.
B. Means and standard errors are corrected for sampling stratification and weights.
C. Estimates include labor for digging fire breaks; digging holes and planting seedlings; weeding and cultivating seedlings; removing stones; clearing land, building and maintaining soil and water conservation structures; building a fence around the woodlot; watering seedlings; pruning and thinning trees; and labor for harvesting grass, non-timber forest products and poles. Payments for woodlot guards and time spent receiving extension advice are excluded from the labor estimates in the above table.

To further understand the flow of costs and benefits by age and type of woodlot we estimate the value of the various components of woodlot production between 1997 and 2000 (Table 6). Estimates of the value of both average annual benefits and costs further validate the findings in Tables 4 and 5. The average annual value of benefits between 1997 and 2000 was very low, even for older woodlots. Though grass is the major benefit – when considering the number of resource users that harvested these quantities, grass is a relatively minor contributor to smallholder incomes. For example, for household managed woodlots (assuming all grass is utilized by the managing household), grass is contributing approximately 60 EB (less than 8 U.S. dollars) per year to household incomes.

As expected, the cost of labor is the most significant cost associated with woodlot management. Labor costs decline with devolution, indicating that more devolved woodlots are more efficient. Average annual net benefits for all types of woodlots are negative, though for woodlots under 11 years of age, average annual net benefits improve with devolution, indicating greater potential for income diversification when smaller groups or households manage woodlots. Furthermore, the household woodlots in the sample were too young for poles to be harvested. The net benefits of such woodlots are likely to be much greater once poles are harvested.

The contrast of high costs and very low economic benefits in a region where demand for woodlot products is very high is troubling. The need to improve access to woodlot products, both for subsistence use and for income generation is essential. However, issues of sustainability also need to be carefully considered. Recall that a very low proportion of household managed woodlots received extension advice on woodlot management, which includes training on sustainable woodlot management to ensure a constant and positive stream of benefits over time.

Table 6 – Estimated value of total benefits and costs, 1997-2000, per hectare per year (EB)[A, B, C]

Age of woodlot	Collectively Managed Woodlots: Community	Village	Sub-village	Household Managed Woodlots
Woodlot 0-4 years	N=19	N=32	N=4	N=66
Benefits				
Poles[D]	N/A	N/A	N/A	N/A
Grass[E]	138.0 (98.7)	83.4 (14.5)	6.5 (3.6)	60.1 (26.4)
Costs[I]				
Mass mobilization labor[F]	3513.6 (1398.5)	1969.9 (661.6)	1111.5 (714.6)	
Voluntary uncompensated labor[F]	74.7 (29.9)	50.0 (10.5)	6.2 (2.4)	
Voluntary compensated labor[G]	864.2 (435.5)	201.3 (90.6)	353.3 (263.8)	
Household labor[F]				402.1 (78.9)
Hired labor[G]				121.3 (49.0)
Seedlings[H]	163.1 (95.7)	56.4 (17.6)	179.8 (134.3)	161.9 (21.7)
Average Annual Net Benefit	-4534.6 (1915.8)	-2211.5 (725.5)	-1647.8 (918.4)	-670.8 (123.8)
Woodlot 5-10 years	N=12	N=37	N=3	
Benefits				
Poles[D]	12.6 (5.7)	34.7 (17.6)	132.0 (33.0)	
Grass[E]	145.1 (25.2)	171.3 (45.7)	40.8 (24.2)	
Costs[I]				
Mass mobilization labor[F]	11972.5 (9078.2)	1348.5 (366.6)	596.3 (90.4)	
Voluntary uncompensated labor[F]	66.5 (19.3)	208.1 (43.3)	74.0 (12.1)	
Voluntary compensated labor[G]	2062.1 (1969.9)	217.8 (75.2)	90.3 (41.9)	
Seedlings[H]	33.7 (20.0)	8.2 (2.7)	56.1 (19.5)	
Average Annual Net Benefit	-14020.2 (11031.0)	-1614.0 (395.8)	-453.6 (36.3)	
Woodlots 11-25 years	N=3	N=6	N-4	
Benefits				
Poles[D]	N/A	42.4 (15.6)	N/A	
Grass[E]	65.5 (25.2)	80.6 (24.0)	26.3 (5.1)	
Costs[I]				
Mass mobilization labor[F]	1719.4 (539.00)	982.0 (616.3)	1235.4 (651.4)	
Voluntary uncompensated labor[F]	125.4 (29.0)	47.1 (21.5)	188.2 (90.0)	
Voluntary compensated labor[G]	427.5 (156.0)	590.7 (337.5)	20.5 (14.0)	
Seedlings[H]	29.4 (11.8)	4.3 (3.7)	24.8 (16.3)	
Average Annual Net Benefit	-459.8 (0)	-523.8 (89.9)	-1451.9 (749.3)	

A. Values in parentheses indicate standard error.
B. Means and standard errors are corrected for sampling stratification and weights.
C. At the time of surveying $1 US=8.2 Ethiopian Birr.
D. Value of poles estimated using average value of 11 EB per pole, the average price of poles sold. Conditional mean, value when number of poles harvested was greater than 0.
E. Value of grass estimated using average values of 5, 6 and 60 EB per headload for thatching, fodder and handicraft grass respectively, average prices of grass sold. Conditional mean, value when headloads of grass harvested was greater than 0.
F. Value of labor based upon average wage rate for adult labor in Tigray of 7 EB per person day. Voluntary uncompensated labor includes value of time spent receiving extension advice.
G. Values of hired and compensated labor are based upon value of actual payment. Includes guard payment.
H. Value of seedlings estimated using average value of seedlings purchased of 0.15 EB per seedling.
I. Opportunity cost of land omitted. Former land use of many woodlots was community area enclosure or wasteland.

ENVIRONMENTAL SUSTAINABILITY

As we have already discussed, the maintenance of biodiversity and the sustainability of use of natural resources is an important component of poverty alleviation. The contribution that afforestation efforts make to environmental sustainability is perceived to be significant, particularly in highly degraded areas such as the highlands of Tigray. How woodlots at varying levels of devolution affect soil conditions, gully formation, local water resources and biodiversity is an important question. Table 7 provides information on perceived changes in environmental conditions in woodlots since the year they were established.[10] The general trend observed for all types of collectively managed woodlots is that perceived soil erosion and gully formation within the woodlot has decreased since woodlots were established. Village managed woodlots indicate a slightly greater decline in soil erosion. Household managed woodlots reported greater decreases in soil erosion than sub-village managed woodlots. In general, the biodiversity impacts of collectively managed woodlots were perceived as positive, with the presence of wild animals and birds increasing in all types of collective woodlots. However, these increases were accompanied by an increase in animals and birds that are considered pests. Household managed woodlots reported very minor increases in the presence of animals and birds, including those that are considered to be pests, probably because these woodlots are very young.

[10] We acknowledge that perceived changes in environmental conditions for household managed woodlots should be very limited given that the average household managed woodlot has been established for only one year.

Table 7 – Perceived Changes in Soil, Water and Biodiversity Conditions in the Woodlot, mean rank[A, B, C]

Indicator	Collectively Managed Woodlots			Household Managed Woodlots (N=66)
	Community (N=34)	Village (N=75)	Sub-village (N=11)	
Soil erosion	-1.47 (0.19)	-1.73 (0.10)	-0.75 (0.20)	-1.20 (0.08)
Gully formation	-1.23 (0.20)	-1.59 (0.12)	-0.75 (0.17)	-0.86 (0.10)
Flow of springs	0.13 (0.06)	0.15 (0.08)	0.23 (0.13)	0.02 (0.02)
Number of springs	0.05 (0.04)	0.15 (0.08)	0.08 (0.08)	0.02 (0.02)
Presence of wild animals	1.30 (0.13)	1.38 (0.12)	1.09 (0.20)	0.15 (0.05)
Presence of birds	1.55 (0.12)	1.49 (0.10)	1.35 (0.16)	0.38 (0.07)
Presence of pests	1.41 (0.13)	1.41 (0.12)	1.41 (0.16)	0.40 (0.06)

A. Rank (-2=Major decrease, -1=Minor decrease, 0=No change, 1=Minor increase, 2=Major increase)
B. Values in parentheses indicate standard errors.
C. Means and standard errors are corrected for sampling stratification and weights.

Communities and households managing woodlots were also asked about perceived environmental impacts on sites downstream, upstream and adjacent to woodlots (Table 8).

Perceptions of environmental externalities on sites surrounding woodlots were generally positive. Soil depth and soil moisture retention were perceived to be improving; whereas run off, flooding, and gully width were perceived to be decreasing. Woodlot managers perceived very limited influence of woodlots on water availability in springs and wells on adjacent sites. Environmental benefits were perceived to be greatest on sites downhill from woodlots, suggesting that the planting of woodlots on hillsides may be having a positive impact on farmlands located downhill from woodlots.[11]

[11] Externalities were also considered for woodlots where greater than 75 percent of seedlings planted were eucalyptus species. Similar positive environmental impacts were perceived by woodlot managers for this subset of woodlots, suggesting that a bias towards fast growing non-leguminous tree species may still provide environmental benefits.

Table 8 – Perceived effect of the woodlot on soil, water and biodiversity on adjacent sites, mean rank[A,B,C]

Indicator	Collectively Managed Woodlots (N=120)				Household Managed Woodlots (N=66)			
	Downhill	Uphill	Lateral 1	Lateral 2	Downhill	Uphill	Lateral 1	Lateral 2
Soil depth	0.82	0.37	0.58	0.42	0.63	0.26	0.28	0.28
	(0.09)	(0.08)	(0.10)	(0.09)	(0.08)	(0.08)	(0.08)	(0.08)
Moisture	0.65	0.32	0.42	0.32	0.39	0.26	0.28	0.30
retention	(0.09)	(0.06)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Water	0.22	0.09	0.12	0.02	0.02	0.00	0.00	0.00
availability in springs/wells	(0.06)	(0.05)	(0.04)	(0.02)	(0.02)	(0.0)	(0.0)	(0.0)
Runoff/flooding	-0.49	-0.15	-0.10	-0.04	-0.50	-0.07	-0.09	-0.13
	(0.10)	(0.06)	(0.06)	(0.04)	(0.08)	(0.05)	(0.04)	(0.05)
Width of gullies	-0.69	-0.26	-0.17	-0.08	-0.69	-0.26	-0.25	-0.27
	(0.12)	(0.10)	(0.11)	(0.10)	(0.09)	(0.07)	(0.08)	(0.08)

A. Rank (-2=Major decrease, -1=Minor decrease, 0=No change, 1=Minor increase, 2=Major increase)
B. Values in parentheses indicate standard errors.
C. Means and standard errors are corrected for sampling stratification and weights.

We explore the determinants of changes in environmental conditions in woodlots econometrically (Table 9).[12] Our dependent variables are perceived changes in soil erosion, gully formation, and in the presence of wild bird and animals in the woodlot since it was established. The factors used to explain variation in changes in environmental conditions within the woodlot are population density; access to markets; who manages the woodlot; general characteristics of the woodlot including age, area, number of seedlings originally planted per hectares, seedling survival rate, whether or not the land area was wasteland prior to woodlot establishment, soil and water conservation structures present in the woodlot, whether or not tree root exposure is a problem, whether grazing is permitted in the woodlot, the number of different tree species planted in the woodlot, and biophysical characteristics such as annual average rainfall, slope, and soil color.[13]

[12] Summary statistics for the variables used in this set of regressions are found in Appendix A.
[13] We take the natural log or square root of the explanatory variables when the variable is more normally distributed in this alternative functional form. Doing so generally improved the specification of our model (Mukherjee et al. 1998).

Table 9–Ordered probit regressions - Determinants of changes in environmental conditions since woodlot was established[A, B]

Explanatory variables	Change in soil erosion within woodlot	Change in gully formation within woodlot	Change in presence of wild birds and animals within woodlots[C]
	Coef.	Coef.	Coef.
Central zone (c.f. Southern zone)	-0.6744 (0.4314)	-1.2032*** (0.3843)	0.3822 (0.3638)
Eastern zone (c.f. Southern zone)	-1.9468*** (0.5712)	-1.5482*** (0.5064)	-0.3669 (0.4988)
Northern zone (c.f. Southern zone)	-1.0162** (0.5048)	-1.8030*** (0.4975)	0.0264 (0.4588)
(ln) Population density (persons/square km, 1994)	-1.0345*** (0.2919)	-0.5716** (0.2614)	-0.3256 (0.2502)
(sqrt) Distance to woreda town (kms)	-0.0822 (0.0825)	-0.0284 (0.0654)	0.0702 (0.2502)
Managed by village (c.f. community managed)	0.1793 (0.4011)	0.0080 (0.3527)	-0.0374 (0.0619)
Managed by sub-village (c.f. community managed)	1.4291*** (0.5450)	1.1710** (0.5022)	-0.5854 (0.4698)
Managed by household (c.f. community managed)	0.6039 (0.7386)	0.1560 (0.6587)	-1.8637*** (0.6456)
(sqrt) Woodlot age in 2000 (years)	-0.4702** (0.1878)	-0.3507** (0.1554)	0.2429 (0.1511)
(ln) Area of woodlot (hectares)	0.1001 (0.1486)	-0.0202 (0.1281)	0.1742 (0.1253)
(sqrt) Seedlings planted in year woodlot was established (number/ha)	0.0010 (0.0038)	-0.0012 (0.0035)	0.0049 (0.0034)
Seedling survival rate (percent)	-1.4903*** (0.5424)	-1.4751*** (0.5047)	1.0071* (0.5268)
Wasteland prior to woodlot establishment	-0.7271 (0.4465)	-1.0818*** (0.4463)	0.4489 (0.4308)
Stone terrace in woodlot (meters)	0.0000 (0.0001)	0.0000 (0.0001)	0.0000 (0.0000)
Soil bunds in woodlot (meters)	0.0001 (0.0002)	-0.0001 (0.0002)	-0.0004*** (0.0001)
Trenches in woodlot (meters)	-0.0010** (0.0005)	-0.0001 (0.0001)	0.0000 (0.0000)
Check dams in woodlot (meters)	0.0006* (0.0004)	0.0003 (0.0002)	0.0028** (0.0014)
Microdams in woodlots (number)	-0.0001 (0.0001)	0.0000 (0.0000)	-0.0001** (0.0000)
(sqrt) Altitude (m.a.s.l.)	-0.0012 (0.0552)	-0.0792 (0.0484)	0.0442 (0.0455)
Annual precipitation	-0.0036** (0.0017)	-0.0013 (0.00158)	-0.0038** (0.0017)
Slope moderately steep (c.f. flat)	-1.3419*** (0.4811)	-1.4980*** (0.4441)	0.8507* (0.4537)
Slope steep (c.f. flat)	-1.4180*** (0.4961)	-1.5059*** (0.4554)	0.7490 (0.4587)
Slope very steep (c.f. flat)	-2.1435*** (0.5557)	-1.8353*** (0.4819)	0.8376* (0.4762)
Brown soil (c.f. black)	0.1413 (0.6210)	0.4535 (0.5937)	-0.7173 (0.6047)
Grey soil (c.f. black)	-0.2019 (0.4190)	0.0824 (0.3827)	-0.6817* (0.4055)
Red soil (c.f. black)	-0.6589 (0.4980)	-0.2915 (0.4380)	-0.8098* (0.4475)
Tree root exposure	1.5750* (0.8873)	0.8848 (0.8035)	0.7119 (0.7456)
Grazing allowed in woodlot	-0.2333 (0.4339)	-0.1699 (0.3886)	-0.1744 (0.4085)
Tree species represented in woodlot (number)	-0.1376* (0.0861)	-0.1770** (0.0760)	0.1557** (0.0698)
Pseudo R-squared	0.2781	0.2348	0.3632
Number of observations	167	167	165

A. *, **, *** coefficient statistically significant at 10%, 5% and 1% levels respectively
B. Independent variables had an average variance inflation factor of 3.25 indicating that multicollinearity is not a significant problem in our model.
C. Excludes animals and birds that are considered pests.

We have several hypotheses regarding the variables in our model, some of which build from the discussion in Section 2. We expect population density and market access to be negatively associated with improvements in environmental conditions. Population pressure and related demand for fuelwood and other woodlot products are likely to lead to unsustainable harvests and degraded conditions within the woodlot. Lower levels of devolution are likely related to declining resource conditions, as smallholders with more control over woodlots are more likely to plant fast growing exotics and to be more focused on the woodlot as a source of income. Both age and area of the woodlot are expected to be positively related to improvements in environmental conditions. The longer the trees are present in the woodlot and the more area covered; the greater the magnitude of the environmental benefits.

The effect of the woodlot being established on wasteland is expected to be positive relative to the prior land use. The number of seedlings planted and survival rate are expected to be positively related to improvements in environmental conditions. Density of tree cover should serve to slow erosion, improve biodiversity etc. We expect the presence of soil and water conservation investments in the woodlot to be positively associated with improvements in environmental conditions within the woodlot. Tree root exposure and allowing grazing in the woodlot are expected to be negatively correlated with improvements in environmental conditions. We expect the number of tree species present in the woodlot to be positively associated with improvements in biodiversity.

We find that increases in soil erosion and gully formation are positively associated with sub-village managed woodlots. We also find that household managed woodlots are negatively associated with improvements in biodiversity conditions. These findings suggest that more devolved woodlots may not be contributing as much to reducing land degradation and improving biodiversity. We find a negative association between woodlot age and increases in soil erosion and gully formation. As expected young woodlots are not contributing as much to improving environmental conditions as older woodlots. Increased erosion and gully formation are associated with low seedling survival rates, whereas improvements in biodiversity are associated with higher survival rates. The number of different species found in woodlots also influences environmental conditions; improved biodiversity and reduced gully formation are positively associated with woodlots that have a greater number of tree species planted. As expected, increased erosion is associated with tree root exposure in the woodlot. We find mixed effects regarding the influence of soil and water conservation investments on environmental conditions in woodlots.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

Our study indicates that there are trade-offs between the goals of empowering local communities, generating income diversification opportunities, and environmental sustainability when considering the devolution of woodlot management in Tigray. In general, devolution favors the objectives of empowerment and income generation, while environmental sustainability is more favored by community management of woodlots.

We hypothesized that community managed woodlots would promote the most equitable distribution of benefits and empower the greatest number of people whereas household managed woodlots would empower a select number of people. We found that most collectively managed woodlots, and about half of household woodlots require permission from either the BoARND or local administrations to harvest woodlot products. That household managed woodlots have more control over decisions about the harvest of woodlot products indicates a greater degree of decision making power at more devolved levels of woodlot management. Our hypothesis that a select number of people will have greater decision-making power over woodlot resources is confirmed by our findings.

We also hypothesized that community woodlots would be a more effective mechanism for promoting sustainable land management and biodiversity preservation, whereas household managed woodlots are more appropriate for improving smallholder incomes. Our analysis of the benefits, costs, and average net annual returns per hectare per year indicates that woodlots in Tigray were not profitable between 1997 and 2000.[14] Though average annual net benefits were negative for all categories of woodlots, more devolved woodlots were more efficient. Two factors are limiting the potential for woodlots to yield positive returns in Tigray. First, restrictions on the harvesting of high value woodlot products, especially poles, are a significant barrier to income generation. A strong emphasis on the land reclamation and biodiversity benefits of woodlots by the BoARND, which maintains control over the allocation of harvesting rights for most collectively managed woodlots, is limiting the economic potential of woodlots. Second, labor investments, particularly those associated with mass mobilization, are not efficient. More devolved woodlots have far fewer labor days devoted to various woodlot management activities, yet maintain higher survival rates for trees.

With respect to environmental sustainability we found that more devolved woodlots are less likely to contribute to reducing land degradation and improving biodiversity. Several factors contribute to the fact that community managed woodlots are better suited to sustainability, including the longer period community woodlots since most were established, and the wider range of tree species present in community woodlots. Our findings confirm our hypothesis that income diversification and environmental sustainability are competing management goals for woodlots in Tigray.

[14] We note however, that our analysis of benefits and costs does not include an assessment of the value of the timber stock or the environmental benefits from woodlots, which may be high, particularly in the case of community and village woodlots.

Strategies for income generation and poverty alleviation in Tigray are extremely limited. We have shown that more devolved woodlots have greater potential for empowering local peoples as well as providing a source of income. However, significant barriers exist with respect to realizing the income generation potential of these woodlots. The potential economic benefits of allowing the sustainable harvest of woodlots in the region are large, particularly in the context of the very limited supply of woody biomass in the region. Our finding that community management of woodlots favors environmental sustainability and biodiversity should be considered in the broader context of the short to medium term poverty alleviation and development goals of the region. Helping smallholders move out of poverty by allowing new sources of income and promoting empowerment may better enable them to invest in improved resource management in the medium to long-term.

REFERENCES

Agrawal, Arun. 2002. Common property institutions and sustainable governance of resources. *World Development*.

Agrawal, A., and C. Gibson. 1999. Enchantment and disenchantment: The role of community in natural resource conservation. *World Development* 27(4): 629-649.

Arnold, J.E.M. 1998. Devolution of control of common pool resources to local communities: Experiences in forestry. Prepared for the meeting of the UNU/WIDER Project on "Land Reform Revisited: Access to Land, Rural Poverty, and Public Action," Santiago Chile. April 26-28.

Baland, J.M., and J.P. Platteau. 1996. *Halting degradation of natural resources: Is there a role for rural communities.* Oxford: Clarendon Press.

Bekele – Tesemma, A. 1997. *A participatory approach for soil and water conservation in Ethiopia.* Tropical Resource Management Papers No. 17. Wageningen, the Netherlands: Wageningen Agricultural University.

Böjo, J. and D. Cassells. 1995. *Land degradation and rehabilitation in Ethiopia: A reassessment*. AFTES Working Paper No.17. Washington, D.C.: World Bank.

EFAP. 1993. *Ethiopian forestry action programme*: Final report. Addis Ababa: Ministry of Natural Resource Development and Environmental Protection.

FAO (Food and Agriculture Organization of the United Nations). 1998. Ethiopia: Soil fertility initiative—Concept paper. Rome.

Gebremedhin, B, J. Pender, and G. Tesfay. 2003. Community resource management: The case of woodlots in northern Ethiopia. *Environment and Development Economics* 8 (1): 129-148.

Gregersen, Hans, Sydney Draper and Dieter Elz eds. 1989. *People and trees: The role of social forestry in sustainable development.* Washington, D.C.: The World Bank.

Hagos, Fitsum, J. Pender, and Nega Gebreselassie. 1999. *Land degradation in the highlands of Tigray and strategies for sustainable land management.* Socio-economics and Policy Research Working Paper 25. Nairobi: International Livestock Research Institute (ILRI).

Holden, S.T., B. Shiferaw, and M. Wik. 1998. Poverty, market imperfections and time preferences: Of relevance for environmental policy? *Environment and Development Economics* 3:105-130.

Hoben, Allan. 1996. The cultural construction of environmental policy: Paradigms and politics in Ethiopia. In *The lie of the land: Challenging received wisdom on the African environment*, M. Leach and R. Mearns, ed. London: Villiers Publications.

Jagger, P. and J. Pender. 2000. *The role of trees for sustainable management of less favored lands: The case of eucalyptus in Ethiopia.* Environment and Production Technology Discussion Paper No. 65. Washington, DC: International Food Policy Research Institute.

Jagger, P. and J. Pender. 2003. The role of trees for sustainable management of less-favored lands: The case of eucalyptus in Ethiopia. *Forest Policy and Economics* 5:83-95.

Johnson, C. and Timothy Forsyth. 2002. In the eyes of the state: Negotiating a "rights-based approach" to forest conservation in Thailand. *World Development* 30(9): 1591-1605.

Lemessa, Dechasssa and Mathew Perault. 2001. Forests fire in Ethiopia: Reflections on socio-economic and environmental effects of the fires in 2000. Assessment Study June-September. Addis Ababa and Providence, RI, USA: UNDP Emergencies Unit for Ethiopia and Brown University.

Lind, Jeremy and Jan Cappon. 2001. *Realities or Rhetoric? Revisiting the decentralization of natural resources management in Uganda and Zambia.* Nairobi, Kenya: ACTS (African Center for Technology Studies) Press.

Maddala, G. 1983. *Limited dependent and qualitative variables in econometrics.* Cambridge: Cambridge University Press.

Mink, S. 1993. Poverty and the environment. *Finance and Development* (December).

Mukherjee, C., H. White and M. Wuyts. 1998. *Econometrics and Data Analysis for Developing Countries.* London: Routledge.

Olson, M. 1965. *The logic of collective action: Public goods and the theory of groups*. Cambridge: Harvard University Press.

Ostrom, E. 1990. *Governing the commons: The evolution of institutions for collective action.* Cambridge: Cambridge University Press.

Pender, J. 1996. Discount rates and credit markets: Theory and evidence from rural India. *Journal of Development Economics* 50: 257-296.

Pender, J., B. Gebremedhin and M. Haile. 2002. Livelihood strategies and land management practices in the highlands of Tigray. Paper presented at the Conference on Policies for Sustainable Land Management in the East African Highlands, UNECA, Addis Ababa, April 24-26. Mimeo.

Pender, J., P. Jagger, and B. Gebremedhin. 2001. Agricultural change and land management in the highlands of Tigray: Causes and Implications. Environment and Production Technology Division. Washington, DC: International Food Policy Research Institute. Mimeo.

Pender, John, Frank Place and Simeon Ehui. 1999. *Strategies for sustainable agricultural development in the east African highlands*. Environment and Production Technology Division Discussion Paper No. 41. Washington, D.C.: International Food Policy Research Institute.

Ribot, J. 1999. Accountable representation and power in participatory and decentralized environmental management. *Unasylva* 50(3): 18-22.

Sandler, Todd. 1992. *Collective action: Theory and Applications.* Ann Arbor: University of Michigan Press.

Stiles, D. V.M. Pohjonen, and F. Weber. 1991. *Reforestation: The Ethiopian experience, 1984-1989.* Technical Support Division of UNSO (United Nations Sudano-Sahelian Office). New York: UNSO.

Sutcliffe, J.P. 1993. *Economic assessment of land degradation in the Ethiopian highlands: A case study.* Addis Ababa: National Conservation Strategy Secretariat, Ministry of Planning and Economic Development, Transitional Government of Ethiopia.

APPENDIX A - Summary statistics of variables used in regressions

Variable	Number of observations	Mean	Standard error	Minimum	Maximum
Change in soil erosion in woodlot	186	-1.28	0.08	-2.00	2.00
Change in gully formation in woodlot	186	-1.07	0.09	-2.00	2.00
Change in presence of wild birds and animals in woodlot	184	0.97	0.06	0.00	2.00
Southern zone	186.00	0.30	0.03	0.23	0.37
Central zone	186.00	0.32	0.03	0.25	0.38
Eastern zone	186.00	0.31	0.03	0.24	0.37
Northern zone	186.00	0.08	0.02	0.04	0.11
Population density (persons/square km, 1994)	183.00	147.29	4.71	39.49	302.56
Distance to *woreda* town (kms)	186.00	18.72	1.30	0.00	87.00
Woodlot managed by community	186.00	0.18	0.03	0.13	0.24
Woodlot managed by village	186.00	0.40	0.04	0.33	0.47
Woodlot managed by sub-village	186.00	0.06	0.02	0.02	0.09
Woodlot managed by household	186.00	0.35	0.04	0.29	0.42
Woodlot age in 2000 (years)	185.00	4.26	0.32	0.00	25.00
Area of woodlot (hectares)	186.00	5.97	0.61	0.00	50.00
Seedlings planted in year woodlot was established (seedlings/ha)	186.00	3541.50	423.36	2706.26	4376.74
Seedling survival rate (percent)	178.00	0.48	0.02	0.45	0.52
Wasteland prior to woodlot establishment	186.00	0.07	0.02	0.00	1.00
Stone terrace in woolot (meters)	185.00	2370.20	1087.21	0.00	195000.00
Soil bunds in woodlot (meters)	185.00	546.49	389.90	0.00	71000.00
Trenches in woodlot (meters)	185.00	1231.46	616.93	0.00	87000.00
Check dams in woodlot (meters)	186.00	114.13	46.14	0.00	7500.00
Microdams in woodlots (number)	184.00	508.37	224.37	0.00	25000.00
Altitude (m.a.s.l.)	183.00	2325.49	23.00	1502.00	3100.00
Annual precipitation	180.00	636.39	8.79	619.05	653.73
Slope flat	186.00	0.08	0.02	0.04	0.11
Slope moderately steep	186.00	0.21	0.03	0.15	0.27
Slope steep	186.00	0.51	0.04	0.43	0.58
Slope very steep	186.00	0.21	0.03	0.15	0.27
Black soil	186.00	0.12	0.02	0.08	0.17
Brown soil	186.00	0.04	0.01	0.01	0.07
Grey soil	186.00	0.53	0.04	0.46	0.60
Red soil	186.00	0.30	0.03	0.23	0.37
Tree root exposure	186.00	0.027	0.12	0.00	1.00
Grazing allowed in woodlot	186.00	0.10	0.22	0.00	1.00
Number of tree species in woodlot	186.00	3.44	0.14	1.00	9.00

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