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**STRATEGIES FOR SUSTAINABLE AGRICULTURAL  
DEVELOPMENT IN THE ETHIOPIAN HIGHLANDS**

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## **ABSTRACT**

This paper investigates the impacts of population growth, market access, agricultural credit and technical assistance programs, land policies, livelihood strategies and other factors on changes in land management, natural resource conditions and human welfare indicators since 1991 in the northern Ethiopian highlands, based on a survey of 198 villages. We find that population growth has contributed significantly to land degradation, poverty and food insecurity in this region. In contrast, better market access and some credit and technical assistance programs were associated with improvement (or less decline) in land quality, wealth and food security; suggesting the possibility of “win-win-win” development outcomes with appropriate interventions. Land redistribution was associated with adoption of inorganic fertilizer, but also with declining use of fallow and declining soil fertility. We find also that different land management practices are adopted where different livelihood strategies are pursued, suggesting the importance of considering livelihood strategies in technical assistance programs. Development strategies should be tailored to the different comparative advantages of different locations; no “one-size-fits-all” strategy will work everywhere.

**KEYWORDS:** Land degradation, sustainable agriculture, population pressure, Ethiopian highlands

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## **STRATEGIES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN THE ETHIOPIAN HIGHLANDS**

John Pender, Berhanu Gebremedhin, Samuel Benin, and Simeon Ehui

Land degradation is a severe problem in the Ethiopian highlands. Soil erosion has been estimated to average 42 tons per hectare per year on cultivated land in the highlands (Hurni 1998), and Ethiopia has one of the highest rates of soil nutrient depletion in sub-Saharan Africa (Stoorvogel and Smaling 1990). Land degradation contributes to low agricultural productivity, which is reflected in cereal yields averaging less than one ton per hectare in most of the highlands, and milk yields only about one-fourth of the average for all developing countries. Such low productivity on farms generally less than two hectares in size, contributes to extreme poverty and food insecurity, as evidenced by recurrent problems of famine and incomes of less than one dollar per person per day.

Many hypotheses have been advanced concerning the causes of these problems and possible strategies for solving them. Echoing the dire predictions of Malthus, many observers see population pressure as the fundamental cause of land degradation in Ethiopia and other developing countries (e.g., WCED 1987; Grepperud 1996). However, others have argued, following Boserup, that population pressure induces households to intensify agricultural production, invest in land improvements and develop land-saving innovations, eventually resulting in improved resource conditions and possibly improved welfare (e.g., Tiffen et al.1994). Other factors that may be important in influencing land

management and its impacts on resources and human welfare include low and uncertain rainfall in much of the highlands, limited market access and market development, land tenure insecurity, credit constraints, farmers' limited education or limited awareness of technological opportunities, poverty, and government policies and programs affecting these factors (Bojo and Cassells 1995; Pender et al. 1999). Evidence on the impacts of such factors and possible strategies for overcoming land degradation and poverty in the Ethiopian highlands (and most other developing countries) is still sparse. In one recent study, Grepperud investigated impacts of population pressure on land degradation in the Ethiopian highlands, and found that population pressure contributed to land degradation. However, that study did not consider most of the other socioeconomic and policy factors mentioned above, and was based upon fairly aggregate level cross sectional data; so it may have been subject to serious problems of omitted variable bias. Neither did it consider impacts of such factors on land management practices or on human welfare.

This study addresses these issues using data on changes in land management and resource and poverty indicators collected in a large number of villages in the Ethiopian highlands. We investigate the impacts of policy factors such as land tenure policies, the presence of various programs and investments in infrastructure, as well as impacts of population pressure; and control for omitted variable bias caused by unobservable fixed factors. Like Grepperud, we find that population pressure contributes to land degradation in the Ethiopian highlands. We also find that population pressure contributes to increased poverty, while better market access and some credit and technical assistance programs have helped to reduce land degradation and poverty.

## DATA

This study is based upon a community-level survey conducted in 198 villages in the Tigray and Amhara regions of northern Ethiopia in 1999 and 2000. A stratified random sample of 99 Peasant Associations (PA's, usually 4 or 5 villages) was selected from highland areas of these regions (above 1500 meters above sea level). The stratification was based upon indicators of agricultural potential, market access and population density.<sup>1</sup> Two villages were randomly selected from each sample PA. Interviews with groups of about ten respondents from each PA and village collected information about changes in livelihood strategies, land management, causes of the changes, and resource and human welfare outcomes since 1991 (the year the current government assumed power); supplemented by secondary geographic information.

In general, mixed crop-livestock production is the dominant production system. Cereal crop production is the most important activity almost everywhere, while keeping cattle is usually the second most important. Other important occupations include raising other ruminant livestock (mainly sheep and goats), producing other storable annual crops (mainly pulses and oilseeds), off-farm activities (trading activities, salary employment,

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<sup>1</sup> For Amhara, the stratification was based on *woreda* (district) level secondary data, including whether the *woreda* is drought-prone (as classified by the Ethiopian Disaster Prevention and Preparedness Committee), access to an all-weather road, and 1994 rural population density (greater than or less than 100 per square kilometer). Two additional strata were defined for Peasant Associations (PA's) where an irrigation project is present (in drought-prone vs. higher rainfall areas), resulting in 10 strata. Five PA's were randomly selected from each stratum (except the irrigated drought-prone stratum, in which there were only four communities), and two villages randomly selected from each sample PA, for a total of 49 PA's and 98 villages. For Tigray, PA's were stratified by whether an irrigation project was present, and for those without irrigation, by distance to the *woreda* town (greater or less than 10 kilometer). This resulted in three strata for Tigray. 54 sample PA's were randomly selected from these strata; with oversampling of irrigated PA's and PA's close to towns to obtain adequate representation. Four PA's in the northern part of Tigray could not be studied because of the war with Eritrea. Thus 50 PA's and 100 villages were surveyed in Tigray. *Woredas* predominantly below 1500 meters above sea level were excluded from the sample frame.

or handicrafts), producing perishable annuals (mainly vegetables), and producing perennial crops (coffee, chat, and fruit trees). We thus classify six dominant livelihood strategies: 1) cereals-cattle, 2) cereals-small ruminants, 3) cereals-other storable annuals, 4) cereals-perishable annuals, 5) cereals-perennials, and 6) cereals-off-farm activities.<sup>2</sup>

There has been little change in these livelihood strategies since 1991 (Table 1).

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<sup>2</sup> In two of the sample communities, keeping cattle was the most important occupation and cereal production the second most important. These were classified as cereals/cattle communities. In six communities, other storable annual crops were the most important occupation. In one of these, cereal production was the second most important occupation; this was included with cereal/other storable annuals. In four of these, keeping cattle was the secondary occupation. Rather than create another category, these were included with cereals/cattle (technically the classification should be “cereals or other storable annuals/cattle”). In one community, other storable annuals were the primary occupation and off-farm activities were the second most important; this was included with cereals/off-farm activities (or “cereals or other storable annuals/off-farm activities”).



**Table 1--Summary Statistics (number of observations, means and standard errors)**

	Number of observations	1991	1998/99
Livelihood strategies (proportion of villages)			
- Cereals/cattle	196	0.648 (0.054)	0.614 (0.056)
- Cereals/other ruminants	196	0.157 (0.039)	0.173 (0.042)
- Cereals/other storable annual crops	196	0.070 (0.026)	0.077 (0.027)
- Cereals/perishable annuals	196	0.033 (0.018)	0.027 (0.016)
- Cereals/perennials	196	0.029 (0.023)	0.045 (0.028)
- Cereals/off-farm activities	196	0.064 (0.036)	0.064 (0.036)
Annual rainfall (1000 millimeters)	176	1.108 (0.030)	
Mean altitude (1000 meters above sea level)	178	2.120 (0.073)	
Distance to town (100 kilometers)	198	0.357 (0.046)	
Walking time to nearest all-weather road (1000 minutes)	187	0.311 (0.079)	0.293 (0.077)
Land redistributed since 1991	198	NA	0.413
Household density (100/square kilometer)	174	0.294 (0.032)	0.384 (0.042)
Percent of area irrigated	177	0.095 (0.044)	0.119 (0.046)
Tenure insecurity index <sup>a</sup>	196	2.704 (0.199)	1.704 (0.169)
Proportion of adults literate	198	0.354 (0.030)	0.530 (0.029)
Proportion of households using:			
- Credit from BOA	196	0.045 (0.026)	0.252 (0.052)
- Credit from REST	198	0.000 (0.000)	0.072 (0.007)
- Credit from ACSI	197	0.000 (0.000)	0.068 (0.025)
- Fallow	198	0.179 (0.036)	0.072 (0.017)
- Manure	198	0.367 (0.052)	0.411 (0.047)
- Compost	198	0.023 (0.012)	0.079 (0.025)
- Fertilizer	197	0.219 (0.047)	0.541 (0.051)
Proportion of households investing since 1991:			
- Stone terrace	198	NA	0.410 (0.052)
- Soil bund	198	NA	0.163 (0.040)
- Gully check	198	NA	0.295 (0.041)
- Tree planting	198	NA	0.173 (0.030)
- Live fence	198	NA	0.436 (0.058)
Perceived changes since 1991 <sup>b</sup>			
- Cropland quality	198	NA	-0.737 (0.148)
- Soil fertility	198	NA	-0.912 (0.101)
- Availability of grazing land	198	NA	-0.651 (0.173)
- Quality of grazing land	198	NA	-0.931 (0.112)
- Availability of forest	196	NA	0.506 (0.176)
- Quality of forest	195	NA	0.397 (0.184)
- Average wealth	198	NA	-1.026 (0.106)
- Availability of food	198	NA	-1.061 (0.119)
- Ability to cope with drought	198	NA	-1.197 (0.131)

<sup>a</sup> Measured as an ordinal index with 1 = very secure, 2 = moderately secure, 3 = moderately insecure, 4 = very insecure

<sup>b</sup> Measured as an ordinal index with -2 = major deterioration, -1 = minor deterioration, 0 = no significant change, +1 = minor improvement, +2 = major improvement.

In only four of the sample villages did the classification change between 1991 and 1998/1999. This suggests that the dominant livelihood strategies are determined mainly by fixed or relatively slowly changing factors and do not respond quickly to changes that have occurred since 1991. Agricultural and land management practices, natural resource and welfare outcomes may have been more responsive to such changes, however.

There have been many significant changes since 1991 in the northern Ethiopian highlands. The number of households in the highlands grew at an annual rate of over 3%, increasing landlessness and pressure on scarce resources. The Tigray region has stopped land redistributions since 1991; while the Amhara region implemented a major land redistribution in 1997 and 1998. Both regions have implemented other changes in land policy, including issuing registration certificates to land “owners”.<sup>3</sup> As a result, community respondents report substantial improvements in land tenure security, which they explain as due mainly to changes in land policy. Public investment has improved access of communities to roads, irrigation, bus service, credit, education, agricultural extension, and other infrastructure and services. Most communities still lack access or are far from basic services, however.

There have also been significant changes in land management practices since 1991. Fertilizer use has increased dramatically, promoted by the agricultural extension and credit program, as has use of other purchased inputs such as improved seeds and pesticides. Use of manure and compost has also increased somewhat, while the use of

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<sup>3</sup> According to the new Ethiopian constitution, all land is the property of the people, and may not be sold or mortgaged. This continues a prohibition on private land rights established by the former Marxist government, though some rights (e.g., rights to lease land) have been liberalized.

fallow has declined. Investments in soil and water conservation measures and land improvement have been relatively common. In general, land management has become more intensive in the northern Ethiopian highlands.

Despite widespread investments in land improvement, many indicators of land degradation have worsened in much of the region.<sup>4</sup> Problems of declining cropland quality resulting from soil nutrient mining and soil erosion, and declining grazing land availability and quality are perceived to be getting worse in most communities. On the other hand, the availability and quality of forests are improving in many areas, possibly because of policies to protect forests and promote establishment of community woodlots.

Several indicators of perceived changes in welfare conditions have worsened in most communities, including average wealth, availability of adequate food, nutrition of children and ability to cope with droughts. However, many other indicators have improved, including availability and quality of drinking water, health services, education, transportation and housing quality. In general, welfare indicators related to public services have improved more than those linked to agricultural performance.

## EMPIRICAL APPROACH

### *Land Management Practices*

We expect adoption of land management practices to be affected by factors that influence farmers' awareness of different practices; the costs, benefits and risks of such

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<sup>4</sup> Perceived changes in resource and human welfare conditions were measured as ordinal indexes of change classified as follows: -2 = major deterioration, -1 = minor deterioration, 0 = no significant change, +1=minor improvement, +2 = major improvement.

practices; or the availability of productive factors used for land management. Three factors—agricultural potential, market access and population density—are hypothesized to be particularly important in determining comparative advantages (Pender et al. 1999). Agricultural potential is measured by average annual rainfall and elevation, market access by distance to the nearest town and walking time to the nearest all-weather road, and population density by the number of households per square kilometer.

Land management may also be affected by the livelihood strategies being pursued. For example, labor-intensive practices may be less likely to be adopted in areas where more commercial livelihood strategies are being pursued, since the opportunity cost of labor may be higher and farmers may have greater ability to use purchased inputs.

Policies, programs and public investments are also expected to influence land management. These include investments in irrigation development (measured by change in proportion of area irrigated), education (change in proportion of literate adults), and extension and credit programs (change in proportion of households receiving credit and associated extension services from the regional Bureaus of Agriculture (BOA), the Relief Society of Tigray (REST), or the Amhara Credit and Savings Institution (ACSI). The effects of land redistribution (whether a land redistribution had occurred in the village since 1991) and other land policies affecting tenure security (change in an index of tenure insecurity, ranging from 1 (very secure) to 4 (very insecure) are also investigated.

The econometric model is given by:

$$1) \quad y_{v2} - y_{v1} = a_2 - a_1 + b(x_{v2} - x_{v1}) + (c_2 - c_1)z_v + e_{v2} - e_{v1}$$

where  $y_{vt}$  is the proportion of households in village  $v$  in year  $t$  that have adopted a particular practice,  $x_{vt}$  is a vector of observed time-varying factors affecting adoption,  $z_v$  is a vector of observed fixed factors affecting adoption, and  $e_{vt}$  are unobserved time-varying factors affecting adoption. This first-difference model eliminates unobservable

fixed factors as a source of omitted variable bias. In this model, observable fixed factors ( $z_v$ ) will have an effect only if the marginal impact of such factors has changed over time.

The land management practices considered in this analysis include changes in soil fertility management practices such as fallow, manure, compost, and inorganic fertilizer; and investments in land conservation and improvement such as stone terraces, soil bunds, gully checks, trees and live fences.<sup>5</sup>

There are two econometric problems to address with this model. One is that changes in many of the time-varying explanatory factors may be endogenous. Population growth, change in irrigated area, changes in tenure security, participation in extension and credit programs, and changes in literacy may respond to changing opportunities in agriculture and changing land management practices. We assume that change in walking time to the nearest all-weather road and whether there was land redistribution in a village (both determined by the regional government policies), are fixed factors and livelihood strategies (which change slowly) are exogenous to land management decisions.

We tested for exogeneity of the potentially endogenous variables by using a Hausman test.<sup>6</sup> Exogeneity of the explanatory variables is supported in all but one regression (investment in live fences). Nevertheless, we report below the robustness of the results to using predicted values of the potentially endogenous variables.

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<sup>5</sup> Other land management practices, such as contour plowing, crop rotation, improved fallow, mulching and use of green manures were also studied, but were not analyzed because they were either nearly universal (contour plowing and crop rotation) or used very little (improved fallow, mulching and green manures).

<sup>6</sup> The instrumental variables used to predict the potentially endogenous variables, in addition to the exogenous variables in the regressions, include the values of each of these variables in 1991, walking time to the nearest bus service in 1991 and change since 1991, walking time to the nearest grain mill in 1991 and change since 1991, and the proportion of households that were landless in 1991. The instruments predicted most of the potentially endogenous variables fairly well ( $R^2 = 0.81$  for prediction of change in household density, 0.72 for change in tenure insecurity index, 0.69 for change in proportion of households borrowing from REST, 0.43 for change in adult literacy, 0.42 for change in proportion of households borrowing from the BOA, 0.38 for change in proportion of households borrowing from ACSI, and 0.08 for change in proportion of area irrigated). The low explanatory power of the regression for irrigated area implies that it is difficult to identify the effect of irrigation when using predicted values.

The second econometric problem is that the dependent variables are censored. If the proportion of households adopting a practice by the latter year was either 0 or 1, the dependent variable was left or right censored. We estimate a maximum likelihood censored regression model, taking into account both lower and upper censoring. As is well known, such maximum likelihood models are sensitive to violations of distributional assumptions (Deaton 1997). We thus also estimate the models using the censored least absolute deviations (CLAD) estimator, which does not depend on distributional assumptions, using the approach of Buchinsky (1994). Below, we report which coefficients are statistically significant when the CLAD estimator is used.

#### *Resource and Human Welfare Outcomes*

Survey respondents provided their perceptions of change in a variety of indicators of natural resource conditions and human welfare. These perceptions were measured as an ordinal response with five possible levels: major deterioration, minor deterioration, no significant change, minor improvement, and major improvement. Ordered probit models were used to estimate the determinants of these changes. The models were estimated in reduced form, with the same explanatory factors used in these regressions as in the regressions explaining land management practices.<sup>7</sup> As above, we report the robustness of the results to using predicted values of potentially endogenous explanatory variables.

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<sup>7</sup> It is difficult to identify instrumental variables that would influence land management practices and not resource and welfare outcomes directly, as would be necessary to estimate a structural model showing the effects of changes in land management practices on such outcome indicators.

## RESULTS

### *Land Management Practices*

There are significant differences in land management practices among villages pursuing different livelihood strategies (Table 2). Land management is particularly different in cereals-perennials communities, where a greater proportion of households have increased use of manure and compost on their crops and have invested in live fences, but fewer households have invested in stone terraces and soil bunds than in other areas. Such physical conservation structures appear to yield lower returns in such higher potential cash crop areas. This may be because the water conservation benefits of such structures are less in these areas, while vegetative cover and vegetative conservation practices have greater potential and lower labor requirements. Consistent with this, we also find that stone terraces and gully checks are less common and live fences are more common in higher rainfall areas. These findings are consistent with other studies of adoption of soil and water conservation structures in the Ethiopian highlands (Herweg 1992; Gebremedhin 1998).

**Table 2--Determinants of Soil Fertility Management and Soil Conservation Practices (maximum likelihood censored regressions)<sup>a</sup>**

Variable	Fallow	Manure	Compost	Fertilizer	Stone Terrace	Soil Bund	Gully Check	Tree Planting	Live Fence
Livelihood strategies (secondary occupation of men)									
- Small ruminants	0.114	-0.128	-0.209 <sup>**R</sup>	-0.011 <sup>C</sup>	-0.124	0.167 <sup>C</sup>	-0.169	-0.356	0.121
- Pulses/oilseeds	0.081	0.141	0.205	-0.128	0.337	-4.764 <sup>***R</sup>	-0.046	-4.454 <sup>***R</sup>	-0.136
- Perishable annuals	0.079	0.100	-1.85 <sup>***R</sup>	0.151	0.463 <sup>*R</sup>	-4.515 <sup>***R</sup>	0.153	-0.565	0.440
- Perennials	0.083	0.619 <sup>*RC</sup>	1.51 <sup>***R</sup>	-0.076	-0.540 <sup>*RC</sup>	-4.915 <sup>***R</sup>	-0.224	-1.503	1.524 <sup>***RC</sup>
- Off-farm activities	-0.044	0.105	0.004	-0.228 <sup>**R</sup>	0.338	1.444 <sup>**R</sup>	-0.043	-0.170	-0.499 <sup>*</sup>
Annual rainfall (10 <sup>3</sup> mm)	-0.174	0.284	-0.238	-0.407 <sup>C</sup>	-1.649 <sup>***RC</sup>	-0.210	-1.129 <sup>***</sup>	-0.498 <sup>C</sup>	0.794 <sup>*RC</sup>
Mean altitude (10 <sup>3</sup> m.a.s.l.)	0.013	-0.015	0.105	0.038	0.157	0.206	0.277 <sup>*C</sup>	0.758 <sup>**R</sup>	-0.035
Distance to town (100 km)	0.169 <sup>**R</sup>	-0.204	-0.501 <sup>**C</sup>	-0.218	-0.036	-0.646 <sup>C</sup>	-0.509	-0.697	-0.054
Walking time to nearest all-weather road (10 <sup>3</sup> min.)	-0.179	-0.027 <sup>C</sup>	-0.082	0.423 <sup>***</sup>	-0.125	3.762 <sup>**</sup>	0.038	1.066	-0.281
Land redistributed since 1991	-0.752 <sup>***RC</sup>	-0.173	-0.025	0.493 <sup>***RC</sup>	0.031	0.656 <sup>C</sup>	-0.174	0.066	0.185
Household density (10 <sup>2</sup> /km <sup>2</sup> )	-0.789 <sup>**</sup>	-2.75 <sup>***R</sup>	-0.971	0.013	1.89	-1.24	1.776 <sup>*</sup>	1.392	-0.621
Percent of area irrigated	0.102	-0.061	0.022	-0.041	-0.162	0.177	-0.049	0.067	0.163
Tenure insecurity index	0.057 <sup>**</sup>	-0.050	0.028	-0.034	0.062 <sup>C</sup>	0.209 <sup>**</sup>	-0.022	-0.011	0.007
Proportion of households with									
- Credit from BOA	-0.190 <sup>**C</sup>	-0.425 <sup>**R</sup>	-0.204 <sup>**R</sup>	0.129	-0.130	0.603	-0.239	0.559 <sup>**R</sup>	-0.211
- Credit from REST	-0.027	-0.098	0.493 <sup>**R</sup>	0.170	-0.454	1.437 <sup>**</sup>	-0.417	1.091 <sup>**RC</sup>	0.687 <sup>*</sup>
- Credit from ACSI	-6.721 <sup>***RC</sup>	0.330	-1.686	0.348	0.056	1.837 <sup>*</sup>	0.680 <sup>C</sup>	-4.932 <sup>*</sup>	1.543 <sup>**R</sup>
Proportion of adults literate	0.165	0.709 <sup>**</sup>	0.110	0.377	-0.765 <sup>**</sup>	-0.331	-0.572	0.536	0.462
Intercept	-0.018	-0.057	0.371	0.552 <sup>***RC</sup>	1.771 <sup>***RC</sup>	-0.915	1.014 <sup>**R</sup>	-1.286	-0.621
Number of observations									
- Left censored	158	158	158	157	158	158	158	158	158
- Right censored	102	33	91	7	27	89	28	69	26
	9	24	1	25	17	12	18	20	25

\*, \*\*, \*\*\* indicate statistical significance at 10%, 5%, and 1% levels, respectively. <sup>R</sup> means coefficient of same sign and significant at 10% level when predicted values used for changes in household density, percent irrigated, tenure insecurity, credit use and literacy. <sup>C</sup> means coefficient of same sign and significant at 10% level in CLAD model.

<sup>a</sup> Dependent variables are changes in proportion of household using practices or proportion of households making investments since 1991. Coefficients and standard errors are adjusted for stratification, weighting and clustering of sample, and robust to heteroskedasticity.



Measures of market access have limited association with most land management practices. The decline in use of fallow is more common in villages closer to towns, probably because land is more valuable in such areas. Surprisingly, increases in use of fertilizer and construction of soil bunds have been less common where road access has improved more (though these results were not robust).

Population growth is not surprisingly associated with reduced use of fallow (though result not robust). It is robustly associated with reduced use of manure, probably because population pressure increases demand for manure as a fuel. There is weak evidence that population growth contributes to investment in gully checks (not robust).

Land redistribution is significantly and robustly associated with reduced use of fallow and increased use of fertilizer. It appears that land redistribution has promoted more intensive land use by allocating land to younger households with limited land who are less able to fallow and more prone to use modern inputs. Reduction in tenure insecurity is associated with declining use of fallow and with less investment in soil bunds (these results not robust). These results could be due to reverse causality; i.e., reduced use of fallow or investment in soil bunds may increase households' sense of tenure security. This would explain why the results were not robust when predicted rather than actual change in tenure insecurity was used in the regression.

We found no significant relationships between changes in irrigated area and adoption of any of the land management practices considered. Communities where investment in small-scale irrigation has occurred represent only a very small fraction of all communities in northern Ethiopia, and the proportion of area irrigated where such programs exist is relatively small. Thus it is not too surprising that irrigation has had limited impact on land management practices.

Access to credit and associated technical assistance has mixed effects on land management. Credit from the BOA is associated with reduced use of fallow and compost and increased tree planting. These findings are not surprising, since the BOA has promoted adoption of fertilizer and planting trees. Surprisingly, however, we find no significant relationship between the BOA or other credit programs and adoption of fertilizer, though the coefficient is positive in all cases. Multicollinearity among the explanatory variables is not likely the explanation. The maximum variance inflation factor for the explanatory variables is 3.6, and for these credit programs is only 2.1 (for REST); so multicollinearity is not a major problem. Other factors appear to play a stronger role in promoting demand for fertilizer.

REST credit is associated with increased use of compost and investments in soil bunds, trees and live fences. These associations likely reflect the influence of REST's technical assistance, which emphasizes such conservation practices, and are probably not simply the result of credit provision. ACSI credit is also associated with investments in soil bunds and live fences, but with less use of fallow and less tree planting (though only the effects on fallow and live fences are robust).

Improvement in education, as measured by increased adult literacy, is associated with greater use of manure but less investment in terraces, though neither effect is robust.

### *Resource and Human Welfare Outcomes*

There are significant differences in perceptions of resource and welfare outcomes across villages pursuing different livelihood strategies (Table 3).

**Table 3--Determinants of Perceived Changes in Resource Conditions and Welfare (ordered probit regressions)<sup>a</sup>**

Variable	Cropland quality	Soil fertility	Availability of grazing land	Quality of grazing land	Availability of forest	Quality of forest	Average wealth	Availability of food	Ability to cope with drought
- Small ruminants	0.681	0.293	-0.016	-0.394	-0.809 <sup>***R</sup>	-1.055 <sup>*K</sup>	0.833 <sup>**</sup>	-0.613	0.542
- Pulses/oilseeds	0.106	-0.767 <sup>*</sup>	0.285	-0.166	-1.123 <sup>**R</sup>	-1.296 <sup>***R</sup>	0.181	-0.310	-0.178
- Perishable annuals	2.269 <sup>***R</sup>	2.187 <sup>***R</sup>	-0.114	0.629	-1.068 <sup>***R</sup>	-0.063	1.471 <sup>***</sup>	0.385	0.807 <sup>*</sup>
- Perennials	0.066	0.447	-2.072 <sup>***R</sup>	-0.026	-0.804	-0.117	1.498 <sup>***R</sup>	1.683 <sup>***R</sup>	2.019 <sup>***R</sup>
- Off-farm activities	-0.536	0.058	-0.815	0.666	-0.068	0.142	0.411	-0.882	0.584
Annual rainfall (10 <sup>3</sup> mm)	-1.002 <sup>*</sup>	0.000	1.738 <sup>*R</sup>	1.246 <sup>*R</sup>	0.440	-0.061	-0.658	0.219	0.258
Mean altitude (10 <sup>3</sup> m.a.s.l.)	-0.831 <sup>***R</sup>	-0.579 <sup>*R</sup>	-0.502	-0.040	-0.138	0.588 <sup>*</sup>	-0.709 <sup>**</sup>	-0.278	-0.082
Distance to town (100 km)	-1.632 <sup>**</sup>	-1.905 <sup>***R</sup>	-0.288	-0.613	0.768	0.682	-1.663 <sup>***R</sup>	-1.346 <sup>**</sup>	-2.86 <sup>***R</sup>
Walking time to nearest all-weather road (10 <sup>3</sup> min.)	-1.184	-0.644	-0.156	-1.875 <sup>**</sup>	0.440	-0.280	-0.243	-1.295 <sup>*R</sup>	-0.229
Land redist. since 1991	-0.531	-1.261 <sup>***R</sup>	-0.102	-0.515	0.164	0.208	0.348	0.458	-0.167
Household density (10 <sup>2</sup> /km <sup>2</sup> )	-4.866 <sup>**</sup>	-5.774 <sup>***</sup>	-4.703 <sup>*R</sup>	-7.817 <sup>***R</sup>	4.258 <sup>*</sup>	0.405	-6.320 <sup>***</sup>	-5.995 <sup>**</sup>	-8.61 <sup>***R</sup>
Percent of area irrigated	-0.193	-0.023	-0.280	-0.201	0.383	0.120	-0.043	-0.108	-0.022
Tenure insecurity index	0.115	-0.126	-0.081	0.031	-0.222	-0.202 <sup>*</sup>	0.143	0.152	0.025
- Credit from BOA	1.165 <sup>***R</sup>	0.959 <sup>***R</sup>	-0.284	0.092	0.570	0.050	1.068 <sup>***R</sup>	0.703	0.036
- Credit from REST	2.815 <sup>***R</sup>	2.484 <sup>***R</sup>	1.750 <sup>***</sup>	2.239 <sup>***</sup>	1.100	1.452 <sup>**</sup>	0.866	1.816 <sup>***R</sup>	2.535 <sup>***</sup>
- Credit from ACSI	-0.429	-2.335 <sup>**</sup>	2.627 <sup>**</sup>	1.697 <sup>**</sup>	0.330	0.174	0.498	-0.219	-10.31 <sup>**</sup>
Prop. Of adults literate	-0.604	1.636	1.530 <sup>**</sup>	2.468 <sup>***R</sup>	2.151 <sup>*</sup>	1.985 <sup>*</sup>	1.141	1.041	0.447
Number of observations	158	158	158	158	157	156	158	158	158

<sup>\*</sup>, <sup>\*\*</sup>, <sup>\*\*\*</sup> indicate statistical significance at 10%, 5%, and 1% levels, respectively. <sup>R</sup> means coefficient of same sign and significant at 10% level when predicted values used for changes in household density, percent irrigated, tenure insecurity, credit use and literacy.<sup>a</sup> Dependent variables are ordinal indicators of perceived changes since 1991 (-2 = major deterioration, -1 = minor deterioration, 0 = no significant change, +1 = minor improvement, +2 = major improvement). Coefficients and standard errors are adjusted for stratification, weighting and clustering of sample, and robust to heteroskedasticity

Forest availability and quality are perceived to have declined more in villages where small ruminants or other annuals are important, perhaps as a result of deforestation to support these other sources of income. Improvements in cropland quality and soil conditions are most common in cereals/perishable annuals villages, possibly because land is more valuable there. Human welfare indicators have improved most in cereals/perennials and cereals/perishable annuals communities, probably because economic opportunities are greater in these areas, which have access to traditional sources of irrigation and tend to have higher rainfall and better access to markets (especially cereals/perennials communities).<sup>8</sup>

There are also differences in outcomes across areas of different agricultural potential. The availability and quality of grazing land is perceived to have improved more (or declined less) in higher rainfall areas. Cropland quality has declined more at higher elevations, perhaps because soils tend to be thinner at higher elevations. Average wealth is also perceived to have declined more (or increased less) at higher elevation, probably in part as a result of greater cropland degradation.

Several resource and welfare indicators have improved more in areas close to town or where road access has improved. Cropland quality, soil fertility, average wealth, food availability and ability to cope with drought have all improved more in villages closer to towns; while quality of grazing land and food availability have improved more where access to roads has improved.

Growth in population density is strongly associated with worsening of most resource and welfare indicators. Apparently population growth is not inducing sufficient investment in land improvement to overcome the negative effects of diminished fallow and increased pressure on degrading resources.

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<sup>8</sup> A multinomial logit regression for livelihood strategies show that cereal/perennial and cereals/perishable communities are much more likely than others to have traditional irrigation, and that cereals perennials villages have higher rainfall, are at lower elevation and closer to towns.

Land redistribution is associated with worsening soil conditions. Although we found that redistribution contributes to adoption of fertilizer, the negative impact of reduced fallow use appears to outweigh this. Changes in tenure security were not found to have significant impact on outcomes, perhaps because the policy changes promoting increased security were implemented fairly recently. Neither did changes in irrigation, consistent with the insignificant impact of irrigation on land management practices.

BOA and REST credit (and related technical assistance) programs have positive associations with several resource and welfare indicators. As with land management practices, ACSI has had more mixed associations, being associated with improved availability and quality of grazing land but with worsening soil fertility and ability to cope with drought. Unlike BOA and REST, ACSI does not provide technical assistance, which may explain its different impacts. Since ACSI credit is associated with reduced fallow use without substantial increase in fertilizer use, it is not surprising that it is associated with declining soil fertility. The association of ACSI credit with reduced ability to cope with drought may be a spurious relationship due to the fact that parts of the Amhara region have suffered from severe drought in recent years.

Improvement in literacy is associated with several indicators of improvement in resource conditions, including improved availability and quality of grazing lands and forest. This may be because educated people take better care of their resources, but it may also reflect impacts of education on people's outlook, making them generally more optimistic. Further research using more objective indicators of resource conditions will help to distinguish among these alternative explanations.

## CONCLUSIONS AND IMPLICATIONS

The evidence provided in this paper supports the Malthusian perspective of the negative impacts of population growth on natural resource conditions and human welfare; while population growth has had limited impact on investments in land improvement, contradicting the Boserupian perspective. By contrast, better market access and some credit and technical assistance programs have largely positive impacts on land improvement, resource and welfare conditions. These findings suggest the possibility of win-win development strategies that can reduce both land degradation and poverty, and that efforts to reduce population growth and improve market access should be priorities.

Land redistribution in the Amhara region appears to have promoted more intensive crop production, including increased use of fertilizer and fallowing. This appears to have reduced soil fertility, while the effects on welfare are not clear. Other land policies have contributed to greater tenure security, though their effects on land management and resource and welfare conditions are not yet clear. Further research at the household level is needed to identify these effects and to derive policy implications.

Different livelihood strategies favor different types of land management practices. For example, adoption of organic and vegetative practices is more common and physical conservation structures less common in areas of perennial crop production. Such differences in potentials for different technologies should be kept in mind by technical assistance programs designing intervention strategies for the Ethiopian highlands. There are also important differences in resource and welfare outcomes across different livelihood strategies. The cereals-perennials strategy and cereals-perishable annual crops strategies are associated with improvement in welfare conditions, but these strategies are more suited to higher potential irrigated areas with better market access. Other livelihood strategies are more suited to less-favored areas, though unfortunately few of these are shown to lead to a wide array of favorable outcomes. Perceived improvements in wealth are greater in areas where small ruminants are an

important activity than in other less-favored areas, though this strategy is also associated with worsening forest conditions.

No single strategy will solve the problems in all of the Ethiopian highlands. The key will be to identify the different comparative advantages of different locations, and to orient credit, technical assistance and other programs towards the activities and land management practices that are most suited to such comparative advantages.

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