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Food Policy 29 (2004) 369–392
FOOD POLICY
www.elsevier.com/locate/foodpol

Non-farm income, household welfare, and sustainable land management in a less-favoured area in the Ethiopian highlands

Stein Holden [a,*], Bekele Shiferaw [b], John Pender [c]

[a] Department of Economics and Social Sciences, Agricultural University of Norway, P.O. Box 5033, 1432 AS, Norway
[b] International Crops Research Institute for the Semi-Arid Tropics, 502 324 Patancheru, Andhra Pradesh, India
[c] International Food Policy Research Institute, Washington, DC, USA

Abstract

A bio-economic model has been calibrated to the socio-economic and biophysical characteristics of a less-favoured area in the Ethiopian highlands. Land degradation, population growth, stagnant technology, and drought necessitates development of non-farm employment opportunities in the area. The model has been used to assess the impact of improved access to non-farm income on household welfare, agricultural production, conservation investments and land degradation in form of soil erosion.

The model simulations indicate that access to low-wage off-farm income is restricted by lack of employment opportunities since households otherwise would have engaged in more off-farm wage employment than observed. The simulations show that better (unconstrained) access to low-wage non-farm income has a substantial positive effect on household income. Total agricultural production (crop and livestock production) and farm inputs used are reduced when access to non-farm employment is improved and thus increases the need to import food to the area. Access to non-farm income reduces farm households' incentives to invest in conservation and this leads to more overall soil erosion and more rapid land

* Corresponding author. Tel.: +47 64 94 86 03; fax: +47 64 94 30 12.
E-mail address: stein.holden@ior.nlh.no (S. Holden).

0306-9192/$ - see front matter
doi:10.1016/j.foodpol.2004.07.007

degradation even though intensity of production is reduced. Special policies are therefore needed to ensure land conservation and to sustain local food production.

Keywords: Nonfarm income; Market imperfections; Bioeconomic model; Ethiopia

Introduction

Little technological progress in agriculture, high population pressure and land degradation cause a need to develop the rural non-farm sector in the East African highlands (Block and Webb, 2001; Pender, 2000; Heyer and Campbell, 1999; ADE, 1996) to reduce poverty and improve food security. Land reform and land redistributions have until recently been used to avoid or minimize landlessness and reduce poverty in Ethiopia. Land scarcity and increasing fragmentation of already very small farms implies that the non-farm sector has to be developed to absorb more of the growing population. The policy to promote adoption of credit to stimulate adoption of high yielding varieties and fertilizer use has not been very successful in the fragile and drought prone Ethiopian highlands. The policy makers are therefore looking for alternative development strategies for these areas. Development of non-farm income opportunities may be an alternative development strategy.

The classical development economic models of Lewis (1954), Ranis and Fei (1961) presumed that agricultural labour could be shifted to the industrial sector without any reduction in total agricultural output. They called these economies "surplus labour economies", implying that the shadow wage in agriculture is nil and that labour is immobile. Sen (1966) developed a model that made it possible under certain conditions to have a positive marginal product of labour and still no loss in output when labourers are removed. We have developed a model that assesses the realism of these classical models in terms of the effect on the agricultural sector of providing non-agricultural employment opportunities.

There have been controversies over how well labour markets in developing countries function and whether it is a good approximation to represent them as perfectly competitive markets in economic models. Theoretical models with perfect labour markets and missing labour markets can give very different policy conclusions with respect to the impact of various policy instruments, technological change and exogenous shocks on land management decisions of farm households (Kaimowitz and Angelsen, 1998; Holden and Binswanger, 1998). The actual impact has therefore to be studied through empirical case studies and use of applied models. The empirical reality of labour markets is in most cases also somewhere between a perfect and a missing labour market.

Empirical studies in rural Africa (Reardon, 1997; Bryceson and Jamal, 1997; Little et al., 2001; Barrett et al., 2001) have revealed that non-farm sources may account as much as 40–45% of average household income and seem to be growing in importance. Non-farm activity has been found to be positively correlated with income and wealth and may offer a pathway out of poverty. The unequal distribution of non-farm income indicates, however, that there are substantial entry barriers and steep investment requirements to participation in non-farm activities capable of lifting them out of poverty (Barrett et al., 2001). Such entry barriers are particularly high for self-employment activities. The significance of the entry barriers in wage-employment is less clear and some studies indicate that "push factors" have a strong impact on the degree of involvement in wage-employment.

Improved access to non-farm sources of income is likely to be good for household welfare, including food security. However, we know little about the impact of labour market development or improved labour market access on the environment (management of natural resources). First, if agricultural production is liquidity constrained (for purchase of farm inputs), better access to non-farm income could relieve the liquidity constraint and result in more intensive agriculture (Reardon et al., 1994). Second, improved access to labour markets could reduce the labour use in agriculture and this could mean less pressure on the natural resource base and could be good (less of damaging use) or bad (less of conservation investment) for the environment. Theoretical models cannot provide the answer to what the overall effect of improved market access on the natural resource base is. Empirical studies and empirical models are necessary to answer this question for specific local environments. Such studies and models require a comprehensive treatment of biophysical as well as socio-economic conditions.

There is comprehensive evidence that improved market access, due to road building, can lead to more deforestation in land abundant areas (Kaimowitz and Angelsen, 1998). Evidence is less clear on the impact of improved market access in resource-poor land-scarce areas. As relevant panel data barely exist on this issue, one may use bio-economic models for such an analysis. The advantage of bio-economic models is that we can do with and without analysis with realistic specifications of market structures, the biophysical environment, and household preferences. They therefore represent a good tool for assessment of dynamic economy-environment linkages and policy effects (Barbier and Hazell, 2000; Okumu et al., 2002).

In this study, we have used dynamic bio-economic models of representative households to assess the impact of improved access to labour and credit markets on household welfare and the natural resource base in a less-favoured land-scarce economy in the Ethiopian highlands. We therefore, assess whether there may be win–win benefits from promotion of non-farm employment opportunities in the Ethiopian highlands and whether development of the non-farm sector has no negative effects on the agricultural sector like assumed in some of the classical models. We therefore assess how better access to non-farm income affects; (a) household welfare, (b) agricultural production (output and input use), (c) investment in land conservation, and (d) land degradation (soil erosion).

We find that better access to off-farm income reduces farm households' incentives to invest in conservation and that this leads to more overall soil erosion and more rapid land degradation. The first finding is consistent with some empirical studies in northern Ethiopia (Shiferaw and Holden, 1998; Hagos and Holden, 2003). The simulations also indicate that there is a lack of non-farm employment opportunities. Better (unlimited) access to off-farm income at the low seasonal wage rates that are typical in the study area had a considerable positive impact on household welfare but increased the need to import basic food grains to the area. Self-sufficiency in food seems not to be a viable option in the study area.

The rest of the paper is organized as follows. Section 2 presents an overview of some relevant studies. Section 3 provides basic data on the case study area. Section 4 presents the bio-economic model used for the simulations. Section 5 presents simulation results and discusses them. Section 6 concludes.

Review of relevant studies

Empirical studies in rural Africa show that there is a strong positive relation between non-farm income share and total household income (Reardon, 1997). Non-farm income was very unequally distributed, however, asset poverty appeared to inhibit entry into remunerative non-farm earnings, implying a vicious self reenforcing circle of unequal distribution of farm and non-farm earnings in areas with unequal distribution of land resources (Reardon et al., 2000). Many studies have revealed evidence of wealth- differentiated barriers to entry in non-farm activities in Burkina Faso, Côte d'Ivoire, Ethiopia, Kenya, Rwanda, South Africa, and Tanzania (Reardon et al., 1992; Dercon and Krishnan, 1996; Dercon, 1998; Carter and May, 1999; Barrett et al., 2000). It remains uncertain whether and how policies can be introduced to make non-farm income opportunities available for broad removal of rural poverty. Likewise, the feedback effects (growth linkages) to the agricultural sector are uncertain.

Reardon et al. (1994) provide evidence from Burkina Faso that non-farm activities can be an important source of cash that potentially can be used to improve farm productivity if it is used to finance farm input purchase or long-term capital investments. They conclude that sometimes non-farm activity draws resources away from farm activity and does not lead to reinvestment of profits on the farm, while in other cases non-farm profits are reinvested on the farm. Non-farm income activities are more likely to have a positive impact on farm productivity in cases where the rural credit market does not function. However, households have many other reasons for allocating time to non-farm activities than to generate capital for farming. Whether there are positive growth linkages from non-farm activity to farm activities is therefore uncertain. Labour market imperfections may cause the linkages to be negative while credit market imperfections may lead them to be positive.

Block and Webb (2001) found that wealthier Ethiopian households tended to have more diversified incomes and that those with initially more diversified incomes also had a greater increase in both income and calorie intake. This indicates that inequality may increase over time due to differential access to non-farm income.

Woldehanna and Oskam (2001) and Smith et al. (2001) found signs of labour market duality in their studies in Ethiopia and Uganda, where the skilled and educated enter high paid jobs or high return self-employment, while the unskilled and uneducated depend on low-pay casual employment opportunities. They found that off-farm low-wage employment was motivated by "push factors" such as low farm income and availability of surplus labour, while people enter into non-farm self-employment to earn an attractive return. Substantial entry barriers cause relatively wealthy farm households to dominate the lucrative self-employment activities. Non-farm unskilled wage employment was also limited, however, as they also found that farm households could have allocated substantially more labour in off-farm activities if there were enough jobs. They only worked (farm and off-farm) 47% of their available labour time. A low reservation wage increases the willingness to search for off-farm wage employment but does not guarantee that households succeed in finding employment. The significance of "push factors" is therefore not inconsistent with limited access to unskilled wage-employment. Other studies in Kenya (Carter and Wiebe, 1990) and Rwanda (Byiringiro and Reardon, 1996) also provide evidence of labour market failures and accumulation of household labour on the farm, with marginal returns below that in the local labour market. This empirical review illustrates that there is a need for a theory that can explain why wages do not adjust down so that the labour market clears. We will come back to this when we introduce the model.

Barrett et al. (2001) conclude that the poor have no other option but to diversify out of farming and into unskilled off-farm labour, whether in agriculture or not. This option is what we analyse the implications of for household welfare, production and natural resource management in this study.

Holden et al. (2001) found significant imperfections in land and labour markets in the case study area for which we have developed the bio-economic model. The econometric analysis of cross-section data revealed that households without off-farm employment were less likely to fallow land while higher off-farm income increased the probability of cropping. This may indicate that both labour and cash constraints are at work. Benin (2003) found that households further from a district town have higher crop productivity, especially in low rainfall areas in the Amhara region. This indicates that having more nonfarm income opportunities can reduce productivity in agriculture. Pender (unpublished) has found that households with less land have more nonfarm income and households in low potential areas have higher nonfarm income than households in high potential areas in the Amhara region.

Shiferaw and Holden (1998), analysing data from the case study area, found that off-farm income reduced incentives to keep (not remove) conservation structures that have been introduced through external projects.

Pender et al. (2002) found in an analysis of data from Tigray, Ethiopia, that households whose secondary income source was cereals (and had more non-farm income than most other households) invested more in stone terraces than other households. Ehui and Pender (2003) found that food-for-work (FFW) and cash-for-work (CFW) projects accounted for 40% of non-farm income in Tigray. Most FFW and CFW projects have targeted investment in soil and water conservation in Tigray (Hagos and Holden, 2003). Hagos and Holden (2003) found a positive impact of

FFW projects on private conservation investments in Tigray while access to off-farm work (other than FFW) had a negative impact on probability of investing on soil bunds.

The case study area: Andit Tid

Andit Tid is located approximately 60 km east of Debre Berhan, along the main road between Addis Ababa and the Tigray Region, in East Shewa in the Central Ethiopian Highlands. This implies that the market access is fairly good. The area is classified as belonging to the low potential cereal-livestock zone and is severely degraded. It is a high altitude area (>3000 m.a.s.l.). The land is located in two altitude zones; *dega* zone (<3200 m.a.s.l.) and *wurch* zone (>3200 m.a.s.l.). The average rainfall is 1336 mm per year distributed over two growing seasons, the *meher* season from June to November and the *belg* season from January to May. Droughts have not been common in the area till very lately when the *belg* rains have failed in two consecutive years (1999 and 2000), may be due to global climate change. Hailstorms and frost have, however, commonly damaged crops.

The two dominant soil types are *andosols* and *regosols*. Andosols dominate in the *wurch* zone while *regosols* dominate in the *dega* zone. Yohannes (1989) estimated 75% of the land to be on steep slopes (>25% slope). Soil erosion rates in the area are very high and a large share of the land is shallow, causing reduction of soil depth to affect crop rooting depth and thus yields (Shiferaw and Holden, 2001). Holden and Shiferaw (2000) estimated 21% of the land to be shallow (<30 cm soil depth) and 48% to be of medium depth (30–60 cm).

Various forms of conservation technologies are common in the area. They have partly been introduced through external food-for-work programs. Some of the exogenously introduced conservation structures have later been removed by the farmers. Shiferaw and Holden (1998) found that human population pressure (land scarcity) increased the probability that conservation structures were partly or fully removed. The reasons for this were thought to be that the conservation structures did not contribute to increased yields in the short run, the structures occupied some land and therefore reduced the effective planting area, and the structures collected fertile soils that could be used to increase short run production by dismantling the structures and spreading out the soil collected there. The structures could also harbour rats that may damage the crops. Or the removal was done in protest against the government and because the local people were not involved in the choice and design of conservation technologies.

The main crop in the area is barley, followed by wheat, horse bean, and field pea. Lentils and linseeds are also commonly grown. Most of the crop production takes place in the *dega* zone but barley is also grown in the *wurch* zone in the *belg* season.

Cattle and sheep are the dominant types of livestock but goats, equines and chicken are also common. The animal population density is very high in the area,

Table 1
Average income by source and household group in Andit Tid in 1999

Income source	0 oxen households	1 oxen households	2 or more oxen households
Wage income	111	63	76
Remittance income	44	12	48
Common property res. income	35	27	37
Business income	73	85	38
Food aid	495	517	565
Farm income[a]	394	330	55
Total income	1153	1028	1310

[a] This is cash income only. It does not include the value of crops or livestock products that were produced and consumed by the household during the year. The year (1999) was a drought year, causing total failure of crop production during the *belg* season.

Yohannes (1989) estimated it to be 1.48 TLU [1] per ha against 0.36 as the average for the Ethiopian highlands. We found this density to have increased to 2.03 TLU per ha in 1998 but it declined to 1.71 by the end of 1999 due to the drought (Holden and Shiferaw, 2000).

The human population density was estimated to be 145.5 persons per km^2 in 1986 against the average of 61 persons per km^2 for the Ethiopian highlands (Yohannes, 1989). The population density was 230 persons per km^2 cultivable land. The population growth rate was estimated to be 3.0% per year, indicating a high and increasing population pressure in the area.

The land resources (land of different qualities) are fairly evenly distributed in the area due to the land reform and frequent land redistributions in Ethiopia where land was allocated to households based on household size. Livestock wealth is therefore a better indicator of household wealth and wealth differentiation. Particularly oxen ownership signifies the farming capacity of households. It leads to the typical pattern, where households without oxen rent out land to households with two oxen or more, while households with one ox exchange oxen among themselves. Land renting typically takes place in form of share tenancy, where the share to the owner varies between 0.5 and 0.25 depending on land quality. Households may have access to credit in kind for purchase of fertilizers but are reluctant to take this kind of credit even though it appears profitable to do so. Risk and high aversion to this type of risk cause households to be reluctant to buy fertilizer on credit.

Households have limited access to off-farm income sources, and crop production is highly subsistence oriented. The trend during the last 20 years has been from households being net sellers of food grains to now being net buyers. The recent droughts have even transformed the area to dependency on food aid (Holden and Shiferaw, 2000). Observed seasonal wage rates (Birr per manday) in 1999 were as follows; January (5), February–May (3), June–July (8), August–November (4),

[1] TLU is tropical livestock units.

December (5). These were the rates used in the model, in combination with a price band, and households were assumed to have (constrained or unconstrained) access.

In Table 1 we present average income from different sources for the three categories of households for 1999. We have divided non-farm income in wage income, remittance income, common property resource, business income and food aid. Food aid was received for the first time in this community because 1999 was a drought year as the *belg* season rains failed totally, causing farm income to be very low in this year. FFW projects have not been used since the introduction of conservation technologies in the 1980s. Most of their food grain (barley) is usually produced in the *belg* season. The low levels of non-farm income from different sources indicate that access to these sources of income was constrained and this also made them very vulnerable to drought and this necessitated provision of food aid.

The bioeconomic model

Earlier versions of this model include Shiferaw et al. (2000, 2001), Holden and Shiferaw (2004) and Holden et al. (2002). The main expansion of the model presented here is that we have used the model to analyse the impact of better access to off-farm income on household welfare, production, investment and soil erosion.

Basic model structure

Households are maximizing their welfare (measured as discounted utility of certainty equivalent full income)

$$U = \int_0^T \rho^t u_t \mathrm{d}t = \sum_0^T \rho^t u_t, \tag{1}$$

through a time-separable utility function over the time horizon T. Utility in period t is discounted by the discount factor, $\rho^t = \left(\frac{1}{1+\delta}\right)^t$, where δ is the utility discount rate.

Utility in period t is represented by a constant partial relative risk aversion utility function [2]

$$u_t = (1-\mu)Y^{1-\mu} + \mu - 1, \tag{2}$$

where μ is the partial relative risk aversion or the absolute value of the elasticity of marginal utility of certainty equivalent full income, Y, which is equal to;

$$Y_t = E(I_t) - \psi_{1t} - \psi_{2t}, \tag{3}$$

where $E(I_t)$ is expected normalized full income in period t, ψ_{1t} is a downside risk premium related to obtaining formal credit and ψ_{2t} is a risk premium related to drought

[2] This type of utility function has been used by Binswanger (1981) and others in empirical studies of risk preferences of farm households. Its simple form makes it attractive also for modelling purposes as risk aversion is captured by a single parameter.

risk in the *belg* season. Full income was normalized by the poverty line full income (γ_t). This formulation gives utility equal to zero if the household has $Y_t = 1$, negative utility if Y_t is below the poverty line ($Y_t < 1$), and positive utility if $Y_t > 1$. Population growth affects the time endowment and poverty line income causing both to grow proportionally over time.

Market characteristics

The model incorporates the following market characteristics. We leave out the subscript for year to simplify notation.

Credit market: Formal credit in kind (for fertilizer) that is constrained from above (Eq. (10))

$$p_f Fe = C_f \leqslant \bar{C}_f. \tag{4}$$

This credit must be repaid after harvest. It may also be possible to obtain informal credit within the village at a higher rate of interest (Eq. (11))

$$C_i \leqslant \bar{C}_i. \tag{5}$$

This credit must also be paid back within the same year.

Labour market: Households are assumed to have constrained access to non-farm employment and the wage rate in the labour market varies across seasons. Households may also hire labour for work on the farm. Hired labour is not a perfect substitute to family labour, however, as there are search, screening and monitoring costs related to hiring labour (Sadoulet and de Janvry, 1995; Feder, 1985). Likewise, there are search costs related to finding off-farm employment. A transaction cost related to hiring labour of about 10–20% of the wage rate is added to capture this. The household shadow wage, w_p^*, should fall between the buying wage and the selling wage when households do not participate and are not rationed out of the labour market.

$$w_{sp} \leqslant w_p^* \leqslant w_{bp}. \tag{6}$$

Empirical evidence seems to indicate that there are limited off-farm employment opportunities and households may be rationed out of the labour market. This may cause the shadow wage in agriculture to fall below the market wage rate. This is a classical issue in development economics and goes back to the Lewis model (Lewis, 1954) and the efficiency wage theory (Leibenstein, 1957, 1958). There are nutrition based and learning based explanations for the failure of the market wage to fall sufficiently to clear the market. We think that the nutrition-based explanation is plausible in Ethiopia. Clark and Haswell (1970) (cited in Ray, 1998, p.273) provide estimates of energy requirements for agricultural work (from West Africa) in the range of 213–502 KCal per hour of work, showing a clear rationale for a minimum wage. This creates an equilibrium minimum wage where some are rationed out (involuntary unemployment) because they are not capable of supplying the labour at a lower wage (Ray, 1998, p.493). This is also consistent with the assumption that households are drudgery averse (Chayanov, 1966; Nakajima, 1986). Based on Nakajima (1986), we have assumed that the shadow wage (reservation wage) is an increasing function of the time worked and that there is a trade-off between income and leisure. Indifference curves between income and leisure will be upward sloping and convex in labour and income space. Household preferences for leisure in income-labour space are formulated as a reservation wage curve that is convex and upward sloping and calibrated to fit the observed seasonal labour supply/leisure demand and wage rates in the area, and does not fall below a minimum level

$$\begin{aligned} w_p^* &= \beta_1 + \beta_2 + \beta_3(D_p - \beta_4)^2, \\ D_p &= L_p^*/W, \\ L_p^* &\leqslant \bar{L}_p, \\ L_p^* &= L_{p\mathrm{F}} - L_{p\mathrm{H}} + L_{p\mathrm{O}}, \\ L_{p\mathrm{F}} &= L_{p\mathrm{C}} + L_{p\mathrm{L}}, \\ L_{p\mathrm{T}} &= L_p^* + L_{p\mathrm{E}} \end{aligned} \tag{7}$$

where β s are parameters, D_p is the seasonal family labour divided by the household labour force (W), $\bar{L}_p$ is the maximum time which is available for work [3], $L_{p\mathrm{C}}$ is seasonal labour in crop production, $L_{p\mathrm{L}}$ is seasonal labour in livestock production, $L_{p\mathrm{O}}$ is seasonal non-farm family labour [4], L_p^* is total seasonal family labour, $L_{p\mathrm{F}}$ is total seasonal on farm labour, and $L_{p\mathrm{H}}$ is hired labour, $L_{p\mathrm{T}}$ is the total seasonal time endowment, and $L_{p\mathrm{E}}$ is the seasonal leisure time. Labour for conservation (building of new structures, maintenance of structures, and removal of old structures) is included in $L_{p\mathrm{C}}$. Seasonal non-farm family labour may be constrained or unconstrained (alternative simulations) but when it is unconstrained, it can take place in any season of the year.

Land market: There is an informal rental market for land in the area. This market is interlinked with the output market as the rent is paid in the form of a share of the output (share tenancy).

Oxen rental market: There is an imperfect market for oxen renting in the model. Imperfections are due to moral hazard problems and seasonal timing constraints. Oxen can only be rented in exchange for labour.

Seed market: It is assumed that markets for seed function well but a price band is included making the price of purchased seeds 5% higher than the selling price. Households also have the option of storing seeds from their own harvest for the next season.

Output markets: Output markets are assumed to function well but a price band is included such that the purchase price is assumed to be 5% higher than the selling price.

Full income and cash constraints

Expected full income is the sum of expected crop and livestock production values less input costs, off farm income and the value of leisure

[3] Maximum time available for farm work is determined by subtracting religious holidays from the total number of days in the period. Work on the farm on religious holidays is not allowed.

[4] In this model no non-farm labour is allocated to land conservation (like FFW or CFW projects). The constraint on access is imposed on the total amount of time spent in non-farm employment.

$$E(I) = p_{\mathrm{C}}^{\mathrm{e}} yi_{\mathrm{Cr}A_q}^{\mathrm{e}} A_q - p_{q\mathrm{c}} Q_{\mathrm{c}} + p_{\mathrm{L}}^{\mathrm{e}} yi_{\mathrm{L}} \mathrm{LVP} - p_{q\mathrm{L}} Q_{\mathrm{L}} + w_{po} L_{p\mathrm{O}} + w_p^* Le, \tag{8}$$

where $p_{\mathrm{C}}^{\mathrm{e}}$ and $p_{\mathrm{L}}^{\mathrm{e}}$ are vectors of expected prices [5] for crop and livestock production, $p_{q\mathrm{c}}$ and $p_{q\mathrm{L}}$ are prices of inputs in crop and livestock production, Q_{C} and Q_{L} are vectors of non-labour input quantities in crop and livestock production, $w_{p\mathrm{O}}$ is a vector of seasonal wage rates in off-farm employment, and $L_{p\mathrm{O}}$ is a vector of seasonal participation in the labour market.

The cash constraint for farm input purchase is derived from an extended quadratic expenditure system. The quadratic term was insignificant and was therefore, omitted in the case of input expenditure. This implies that an increase in income through improved access to non-farm income also affects the cash constraint.

Land degradation and conservation

The main forms of land degradation in the model are soil erosion and nutrient depletion. For simplicity we only focus on soil erosion in this paper. Plot level soil erosion per unit of land (se_{A_q}) is a function of soil type, soil depth and slope (land type class, A_q), rainfall (ψ_{r}), crop choice (Cr), and use of conservation technology (Ψ)

$$se_{A_q} = se(A_q, \psi_{\mathrm{r}}, Cr, \Psi). \tag{9}$$

Soil erosion rates were determined based on field experiments carried out by the in the study area (Shiferaw and Holden, 2001). Farmers may influence soil erosion rates through their crop choice/land use or by building or removing conservation technologies on the different types of land. The model implicitly evaluates the profitability of erosion control on the different types of land (soil type, soil depth and land slope). Soil erosion affects soil depth (*sd*) through a transition equation

$$sd_t = sd_{t-1} - \tau se_t, \tag{10}$$

where τ is a conversion factor.

Households may decide to conserve their land by introducing conservation structures (graded soil/stone bunds). Only labour is needed as an input for this, 100–120 working days per ha, depending on the slope of the land. Maintenance of the structures requires an additional 15–20 working days per year and ha. Shiferaw and Holden (1998) found, based on econometric analysis of plot level data collected in 1994, that poor and land-scarce households were more likely to dismantle conservation structures introduced through food-for-work in the early 1980s. Therefore, in our model households may also decide to remove conservation structures and this is estimated to take only 25% of the time required for construction. The conservation structures may occupy some productive land, therefore reducing the effective cropping area and this may reduce initial crop yields.

[5] The expected prices depend on the probability of drought (weighted prices).

Crop production

Yields of different crops are functions of soil type, soil depth, slope, application of fertiliser and manure converted into nitrogen (N) and phosphorus (P), and conservation technology (Ψ). The intercept of the yield (yi_{int}) function, suppressing the crop type and year, is a function of soil type (A_q) and soil depth (sd)

$$yi_{\text{int}} = yi(A_q, sd). \tag{11}$$

The impact of soil depth on crop yield intercepts was estimated econometrically using farm level experimental data from the study area and testing alternative functional forms [6]. The final yields, including inputs, were also estimated econometrically [7]

$$yi_{A_q} = yi(yi_{\text{int}}, \Psi, \psi_{\text{r}}, \text{N}_{\text{F}}, \phi, \text{P}_{\text{F}}), \tag{12}$$

where ψ_{r} is rainfall (drought or normal year), N_{F} is fertiliser and manure nitrogen added, ϕ is the change in available mineralised nitrogen, and P_{F} is phosphorus added through fertilisers and manure. Yields may be influenced by conservation technologies (Ψ) as conservation structures take up some part of the land, the structures may harbor pests, they may reduce runoff and leaching and, of course, erosion. The short term effect on yields of the use of conservation technologies is therefore ambiguous but over time yields under conservation should decline less rapidly than without conservation.

This gives a brief overview of the essential parts of the model that have most relevance here.

Overall model characteristics and calibration

The model is non-linear in constraints and objective function. It has been programmed in GAMS. The current simulations were run for 10 years. The model had 79 000 variables and 46 000 equations. The model was calibrated to the biophysical and socio-economic characteristics of the case study area. Results are presented for the dominant household groups with two or more oxen. This group farms close to 70% of the land in the study area.

For the case study area we have unique availability of both biophysical and socio-economic data covering more than a 15 year period. Collection of biophysical data was started by the soil conservation research project (SCRP) when a field station was established in 1982. These data included soil erosion data at plot and watershed levels, yield measurements, conservation technology experiments, soil chemical and physical analyses, and meteorological data. Household survey data were collected in 1986, 1993/1994, 1997/1998 and 1999/2000. These surveys also included detailed

[6] See Shiferaw and Holden (2001) for details.

[7] Using data from FAO fertiliser demonstration plots for the Debre Berhan area, assessing alternative functional forms.

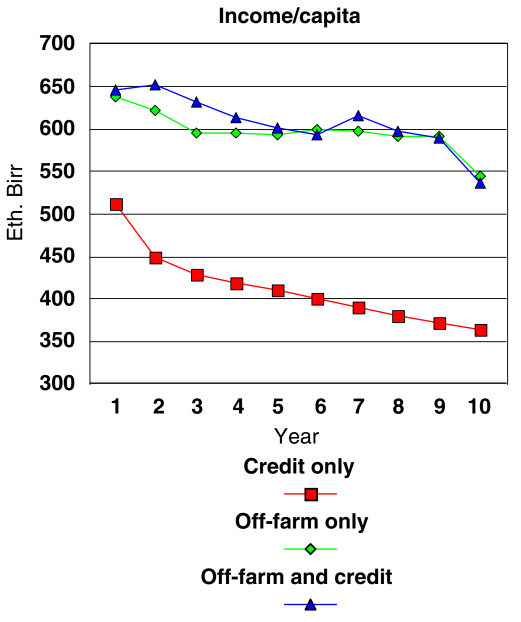

Fig. 1. Income per capita for households with unconstrained access to off-farm income only, credit only, and off-farm income and credit.

data collection at farm plot level. The data provided a unique opportunity to carefully analyse a number of policy-relevant issues.

We did not manage to make the bio-economic model solve for a 10 years period when access to both wage employment and credit are restricted at very low levels. We have therefore used the scenario with access to credit only as the baseline scenario. The income in case without credit and without wage employment would be lower than for the case of credit only (Fig. 1) and the decline over time is likely to be more rapid than in the case of credit only [8]. This illustrates the severity of the combined effects of land degradation, increasing population pressure, stagnant technology, and drought risk in the case study area. Households are becoming increasingly dependent on better market access or assistance from the outside.

[8] Holden and Shiferaw (2004) used five years versions of the model and found that unconstrained access to credit for purchase of fertilizer could increase income per capita of households by 8–20%. Due to population increase, land constraint and land degradation, income per capita would fall by 8% over a five year period when there is access to credit and by 16% when there is no access to credit.

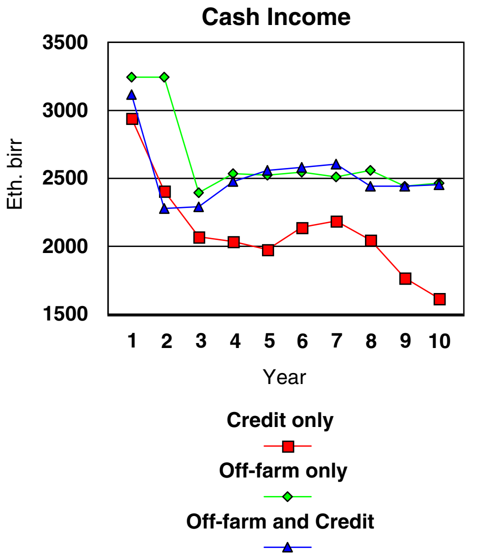

Fig. 2. Total cash income per household for households with access to off-farm income only, credit only, and off-farm income and credit.

Simulation results

Market access and household welfare

The impact of unconstrained access to low-wage non-farm wage employment (at 1999 wage rates), unconstrained access to credit, and combined unconstrained access to wage employment and credit on household income per capita are presented in Fig. 1. We see that unconstrained access to low-wage off-farm income yields a much higher income than provision of credit alone. Provision of credit in addition to unconstrained access to low-wage income had little additional effect on household income.

We see from Fig. 1 that unconstrained access to wage employment at the going wage rates in Andit Tid would have substantially improved household income in the area. The fact that households have low levels of non-farm income (Table 1) indicates that access to low-wage employment is constrained. Otherwise, households in the study area would have worked much more outside the farm given their small farms and the risk of agricultural production. Provision of better employment opportunities for unskilled labour (at low wages) may thus substantially improve household income in the study area.

Fig. 2 shows that unconstrained access to off-farm wage employment substantially improves household cash income and it also stabilizes income over time compared to provision of credit only. We will return to the reason for this later. Fig. 3 illustrates that unconstrained access to off-farm income reduces the demand for credit for purchase of farm inputs over time. This shows how the income-earned off-farm is being

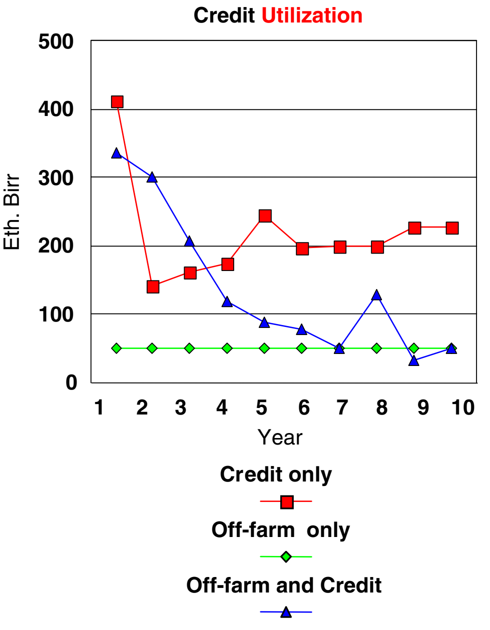

Fig. 3. Credit utilization by households with unconstrained access to off-farm income only, credit only and off-farm and credit.

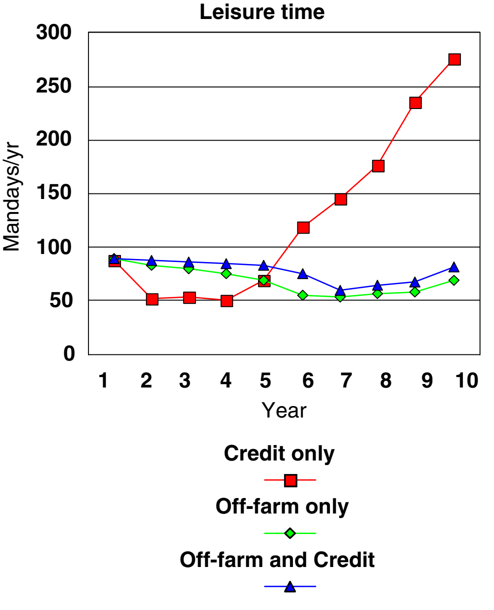

Fig. 4. Leisure time of households with unconstrained access to off-farm income only, credit only and off-farm and credit.

spent to finance purchase of fertilizer. Off-farm income complements fertilizer credit to purchase inputs. The straight line for off-farm employment access only shows the credit constraint.

We see from Fig. 4 that constrained access to non-farm wage employment and land constraints lead to a build-up of un-utilized household labour ("leisure" = surplus labour) due to limited intensification and extensification opportunities in farming. This is also because the work force grows over time due to population growth. The reservation wage in the model prevents the opportunity cost of labour from falling to zero.

Agricultural production and input use

We will now look at how different market access conditions affect the agricultural production over time. Fig. 5 shows that households with constrained access to off-farm wage employment cultivate more of their land. This is because they have a lower opportunity cost of labour. Unconstrained access to credit but not to non-farm employment creates more incentives for land cultivation than having access to both credit and non-farm employment. Agricultural production is continued on a larger area for a longer period of time when households have unconstrained access to credit only.

The effect on livestock capital of households under the different market access conditions is illustrated in Fig. 6. We see that households with access to credit only

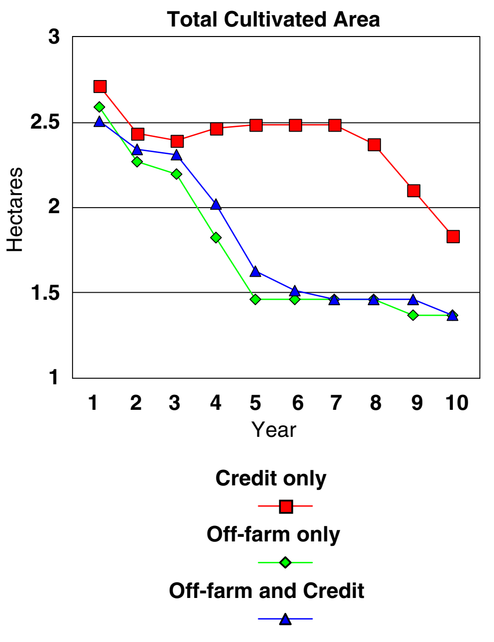

Fig. 5. Total cultivated area by households with unconstrained access to off-farm income only, credit only and off-farm and credit.

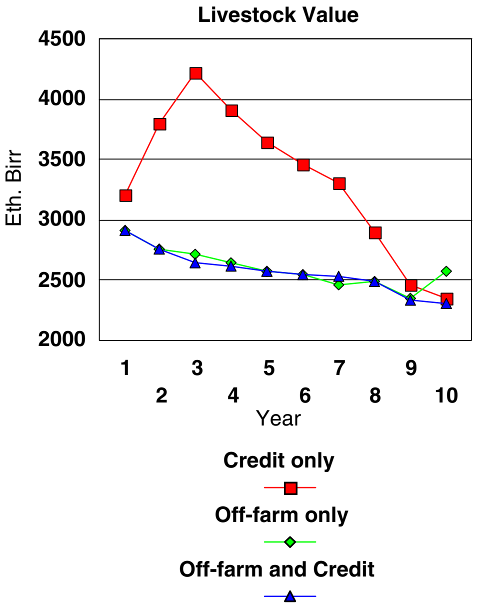

Fig. 6. Livestock capital of households with unconstrained access to off-farm income only, credit only and off-farm and credit.

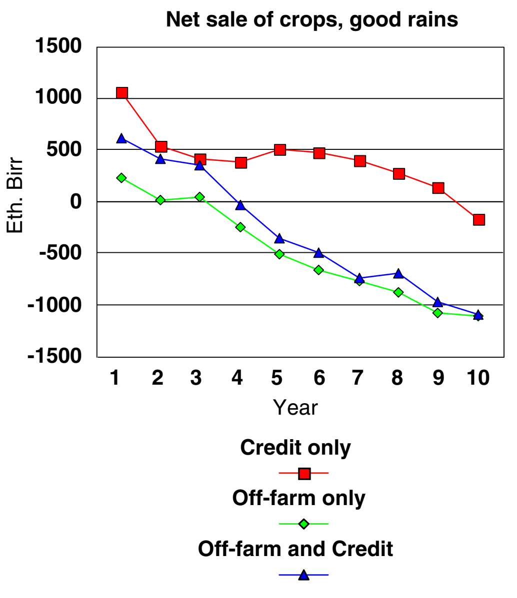

Fig. 7. Net sale of crops by households with unconstrained access to off-farm income only, credit only and off-farm and credit in years without drought.

build up and hold more livestock than households with access to non-farm employment (with or without credit constraint). There is a downward trend in livestock capital over the ten years period, however, probably as a result of a decline in fodder production due to land degradation.

Fig. 7 shows that households with unconstrained access to credit only remain net sellers of crops in years with good rains for most of the 10 year time period. The surplus declines over time, however, and turns into a net deficit in the last year. Households with access to non-farm income become deficit producers of food crops in years with good rainfall already after four years and the deficit grows to more than 1000 kg of grain per household by the 10th year. There are two reasons for this; first incentives for own food production are reduced due to the competition for labour and higher opportunity cost of time; secondly because off-farm income increases total income and consequently also demand for food since food is a normal good.

Households with unconstrained access to both credit and non-farm wage employment become deficit producers after 5 years already. They produce more food grain in the initial years than households with unconstrained access to non-farm wage employment only but they have a more rapid decline in food grain production and have after 10 years a deficit as large as those with unconstrained access to non-farm income only. Better access to non-farm income therefore reduces incentives to produce crops and produce a surplus or be self-sufficient in food grains. The pattern is very similar in drought years (Fig. 8, if the year was a drought year)

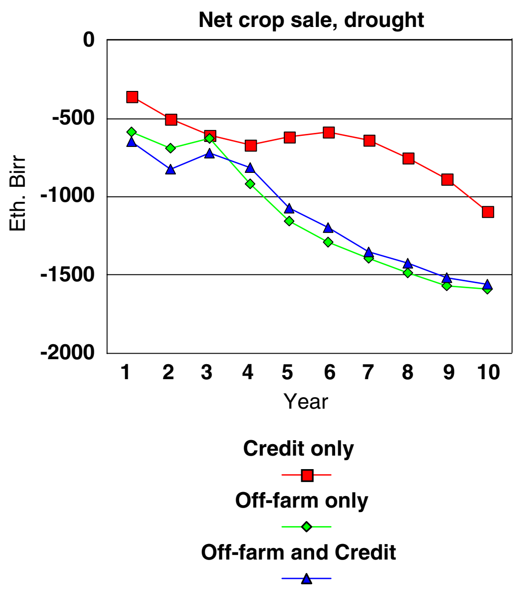

Fig. 8. Net sale of crops by households with unconstrained access to off-farm income only, credit only and off-farm and credit in years with drought.

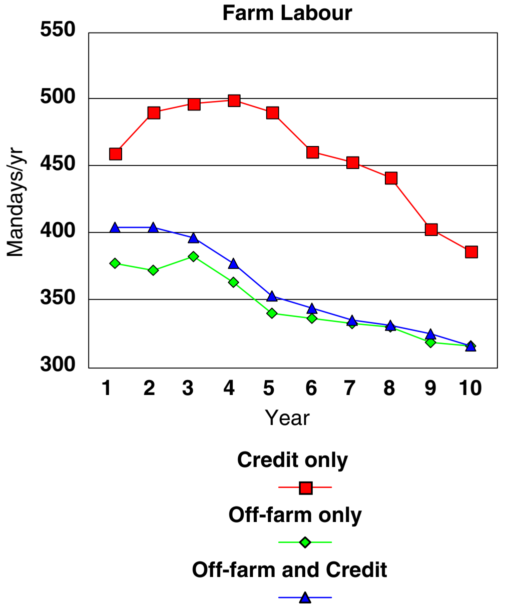

Fig. 9. Farm labour input of households with unconstrained access to off-farm income only, credit only and off-farm and credit.

but then all households are deficit producers. The deficit increases from about 400 to above 1000 kg of grains for households with unconstrained access to credit only over the 10 years period, while it increases from 600 to above 1500 kg for households with access to non-farm wage employment (with or without access to credit).

Farm labour input use is shown in Fig. 9. It can be seen that households with unconstrained access to credit only put much more labour into farming than households with unconstrained access to non-farm income. Access to credit does not help much for the incentives to work on the farm when there is unconstrained access to non-farm wage employment. Fig. 10 illustrates that the demand for non-farm employment (labour surplus) increases steadily due to the growth in the labour force (growing surplus labour). Land degradation and poor land quality also contributes (push factor) to the increasing demand for nonfarm activity.

Land degradation and conservation

We see from Fig. 11 that households with unconstrained access to credit only, had more incentives to conserve their land and conserved much more of it than households with unconstrained access to non-farm wage employment only. Households with unconstrained access to credit and non-farm wage employment conserved even a smaller share of their land than households with unconstrained access to non-farm wage employment only. In Fig. 12 we see the consequences of this for the total

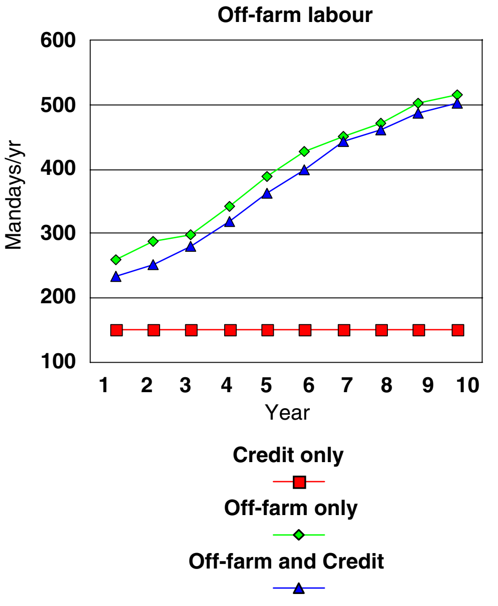

Fig. 10. Off-farm labour input of households with unconstrained access to off-farm income only, credit only and off-farm and credit.

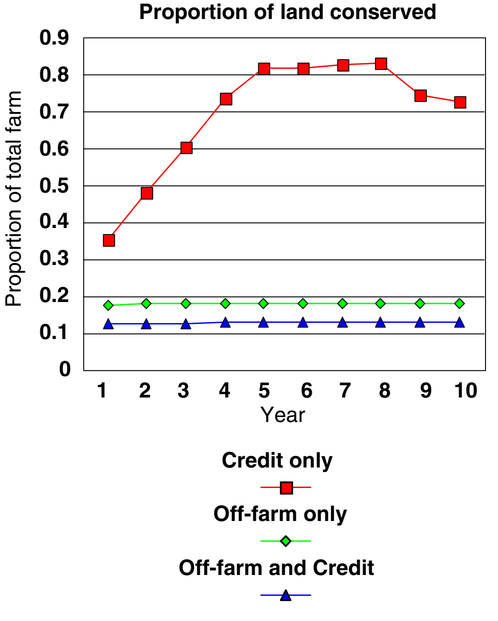

Fig. 11. Proportion of area conserved by households with unconstrained access to off-farm income only, credit only and off-farm and credit.

erosion on the typical farm. Even though households with unconstrained access to non-farm employment cultivate smaller land areas (have less intensive agricultural production), their activities cause more erosion than that of households with unconstrained access to credit only because they conserve a much smaller proportion of their farmland. This is because of the relatively lower returns to soil conservation compared to the low wage in off-farm employment. It appears therefore, that provision of better non-farm employment opportunities does not give win–win benefits as the natural resource base will suffer more due to neglect. Returns to labour in less sustainable agricultural practices are still high enough to be continued. Despite the increased availability of cash income it is not allocated to hiring of labour for land conservation (because of search, screening and monitoring costs related to hiring labour), and other purchased inputs are not used for land conservation. It is only when the shadow wage is very low due to lack of access to non-farm income that it pays to invest labour in conservation. Conservation activities are carried out outside the peak agricultural seasons when opportunity cost of time is low (when non-farm opportunities are very limited).

Leaving land fallow does not cause erosion to stop but erosion rates are lower on fallowed land than on cropped land and this is a one important reason for the reduction in erosion over time. Increasing use of conservation technologies is the other reason for reduced erosion rates over time in the baseline scenario with credit only.

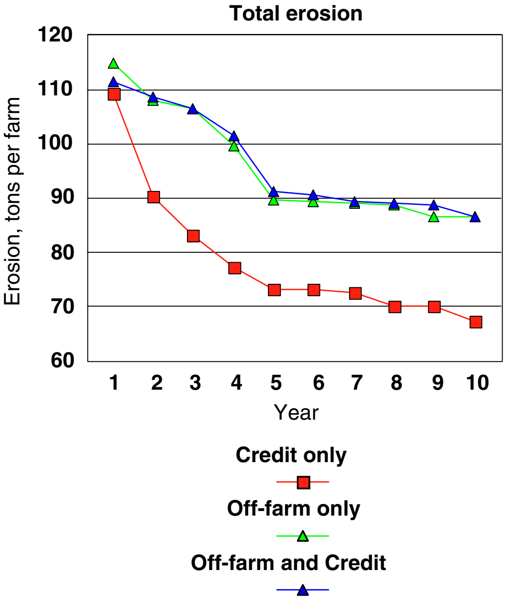

Fig. 12. Total erosion on farms of households with unconstrained access to off-farm income only, credit only and off-farm and credit.

Conclusion

We have used a calibrated dynamic bio-economic farm household model to assess the impact of improved access to off-farm income and farm credit on household welfare, agricultural production (output and input use), land degradation and conservation incentives in a severely degraded area in the Ethiopian highlands.

We found that unconstrained access to low-wage non-farm income could substantially improve the income of households in the case study area. It could improve income substantially more than did provision of unconstrained access to credit for purchase of farm inputs. Empirical data on non-farm incomes in the study area clearly indicate that access to such income is constrained.

Better access to non-farm income reduces incentives to do farming activities and this leads to lower agricultural production, including production of own food. Households therefore become net buyers of food. This shows that even thought there may be surplus labour in agriculture, the marginal return to labour is not zero and removal of labour has a negative effect on agricultural production because the marginal return to labour increases when it becomes more scarce.

The reduced pressure on the natural resource base due to improved access to non-farm income is not good for the environment, however. Because improved access to non-farm income undermines incentives to conserve land, the overall effect is increased land degradation in form of erosion. There appears therefore to be no win-win benefits from improving the access to non-farm income. Complementary policies are required to protect the natural resource base. FFW projects targeting land conservation may a useful approach that has demonstrated some success in the Tigray Region of Ethiopia (Hagos and Holden, 2002, 2003).

References

ADE s.a., 1996. European strategy to support food security in Ethiopia: Final Report. Sector Evaluation Report to the European Commission.

Barbier, B., Hazell, P., 2000. Implications of population growth and declining access to transhumant grazing areas for the sustainability of agropastoral systems in the semi-arid areas of Niger. In: McCarthy, N., Swallow, B., Kirk, M., Hazell, P. (Eds.), Property Rights, Risk, and Livestock Development in Africa. ILRI, IFPRI, Washington, DC, Nairobi.

Barrett, C.B., Bezuneh, M., Clay, D., Reardon, T., 2000. Heterogenous constraints, incentives and income diversification stragtegies in rural Africa. Mimeo.

Barrett, C.B., Reardon, T., Webb, P., 2001. Non-farm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. Food Policy 26 (4), 315–331.

Benin, S. (2003). Increasing land productivity in high versus low agricultural potential areas: The case of the Ethiopian highlands. Paper revised and resubmitted to Food Policy.

Binswanger, H.P., 1981. Attitudes towards Risk: Theoretical Implications of an Experiment in Rural India. The Economic Journal 91, 867–890.

Block, S., Webb, P., 2001. The dynamics of livelihood diversification in post-famine Ethiopia. Food Policy 26 (4), 333–350.

Bryceson, D.F., Jamal, V., 1997. Farewell to Farms: De-Agrarianisation and Employment in Africa. Ashgate, Aldershot, UK.

Byiringiro, F., Reardon, T., 1996. Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments. Agricultural Economics 15 (2), 127–136.

Carter, M.R., May, J., 1999. Poverty, livelihood adn class in Rural South Africa. World Development 27 (1), 1–20.

Carter, M.R., Wiebe, K.D., 1990. Access to capital and its impact on agrarian structure and productivity in Kenya. American Journal of Agricultural Economics, 1146–1150.

Chayanov, A.V., 1966. In: Thorner, D., Kerblay, B., Smith, R.E.F. (Eds.), The Theory of Peasant Economy. Irwin, Homewood, Illinios.

Clark, C., Haswell, M., 1970. The Economics and Subsistence Agriculture. St. Martin's Press, New York.

Dercon, S., 1998. Wealth, risk and activity choice: cattle in western Tanzania. Journal of Development Economics 55 (1), 1–42.

Dercon, S., Krishnan, P., 1996. Income portfolios in rural Ethiopia and Tanzania: choices and constraints. Journal of Development Studies 32 (6), 850–875.

Ehui, S., Pender, J., 2003. Resource degradation, low agricultural productivity and poverty in sub-Saharan Africa: Pathways out of the Spiral. Paper presented at the Twenty Fifth International Conference of Agricultural Economics, 16–23 August, Durban, South Africa.

Feder, G., 1985. The relationship between farm size and farm productivity: the role of family labour, supervision, and credit constraints. Journal of Development Economics 18, 297–313.

Hagos, F., Holden, S., 2002. Incentives for conservation in Tigray, Ethiopia: Findings from a Household Survey. Department of Economics and Social Sciences, Agricultural University of Norway, unpublished.

Hagos, F., Holden, S., 2003. Tenure security, resource poverty, risk aversion, public programs and household plot level conservation investment in the highlands of northern Ethiopia. In: F. Hagos (Ed.), Poverty, Institutions, Peasant Behaviour and Conservation Investment in Northern Ethiopia. Ph.D. Dissertation, Department of Economics and Social Sciences, Agricultural University of Norway, unpublished.

Heyer, J., Campbell, I., 1999. The effects of famine on capital assets in south west Ethiopia, 1984–1993. Report to the Department For International Development, Somerville College, University of Oxford, Oxford, UK.

Holden, S.T., Binswanger, H., 1998. Small-farmer decisionmaking, market imperfections, and natural resource management in developing countries. In: Lutz, E., Binswanger, H., Hazell, P., McCalla, A. (Eds.), Agriculture and the Environment. Perspectives on Sustainable Rural Development. The World Bank, Washington, DC.

Holden, S.T., Shiferaw, B., 2000. Development paths and policies for sustainable land mangement in Andit Tid, North Shewa. An Exploration of Policy Alternatives. Paper presented at the National Workshop on Policies for Sustainable Land Management in Addis Ababa, May 22–23, 2000.

Holden, S.T., Shiferaw, B., 2004. Land degradation, drought and food security: A bio-economic model with market imperfections. Agricultural Economics 30 (1), 31–49.

Holden, S.T., Shiferaw, B., Pender, J., 2001. Market imperfections and profitability of land use in the Ethiopian highlands: a comparison of selection models with heteroskedasticity. Journal of Agricultural Economics 52 (3), 53–70.

Holden, S.T., Shiferaw, B., Pender, J., 2002. Policy analysis for sustainable land management and food security: a bio-economic model with market imperfections. Paper presented at the Conference on Policies for Sustainable Land Management in the East African Highlands at the United Nations Economic Commission for Africa Conference Center, Addis Ababa, April 24–26, 2002.

Kaimowitz, D., Angelsen, A., 1998. Economic Models of Tropical Deforestation: A Review. Centre for International Forestry Research (CIFOR), Bogor, Indonesia.

Lewis, W.A., 1954. Economic development with unlimited supplies of labour. Manchester School of Economic and Social Studies 22, 139–191.

Little, P.D., Smith, K., Cellarius, B.A., Coppick, D.L., Barrett, C.B., 2001. Avoiding disaster: diversification and risk management among East African herders. Development and Change 32, 3.

Leibenstein, H., 1957. Underemployment in backward economies. Journal of Political Economy 65, 91–103.

Leibenstein, H., 1958. Underemployment in backward economies: some additional notes. Journal of Political Economy 66, 256–258.
Nakajima, C., 1986. Subjective Equilibrium Theory of the Farm Household. Elsevier, Amsterdam.
Okumu, B.N., Jabbar, M.A., Colman, D., Russell, N., 2002. A bio-economic model of integrated crop-livestock farming systems: the case of the Ginchi watershed in Ethiopia. In: Barrett, C.B., Place, F., Aboud, A.A. (Eds.), Natural Resource Management in African Agriculture. Understanding and Improving Current Practices. CABI Publishing, Wallingford, New York.
Pender, J., 2000. Development Strategies for the East African Highlands. 2020 Vision Focus No. 4. International Food Policy Research Institute, Washington, DC.
Pender, J., Gebremedhin, B., Haile, M., 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, 2002, Mimeo.
Ranis, G., Fei, J., 1961. A theory of economic development. American Economic Review 56, 533–558.
Ray, D., 1998. Development Economics. Princeton University Press, Princeton, NJ.
Reardon, T., 1997. Using evidence of household income diversification to inform study of the rural non-farm labour market in Africa. World Development 25 (5), 735–748.
Reardon, T., Crawford, E., Kelly, V., 1994. Links between non-farm income and farm investment in African households: adding the capital market perspective. American Journal of Agricultural Economics 76 (5), 1172–1176.
Reardon, T., Delgado, C., Matlon, P., 1992. Determinants and effects of income diversification amongst farm households in Burkina Faso. Journal of Development Studies 28, 264–296.
Reardon, T., Taylor, J.E., Stamoulis, K., Lanjouw, P., Balisacan, A., 2000. Effects of nonfarm employment on rural income inequality in developing countries: an investment perspective. Journal of Agricultural Economics 51 (2), 266–288.
Sadoulet, E., de Janvry, A., 1995. Quantitative Development Policy Analysis. John Hopkins University Press, New York.
Sen, A.K., 1966. Employment, Technology, and Development. International Institute for Labour Studies, Geneva.
Shiferaw, B., Holden, S.T., 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. Agricultural Economics 18, 233–247.
Shiferaw, B., Holden, S.T., 2001. Farm level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia. Environment and Development Economics 6, 335–358.
Shiferaw, B., Holden, S.T., Aune, J., 2000. Population pressure, poverty and incentives for soil conservation in ethiopia: a bio-economic modeling approach. Paper presented at the Second International Conference on Environment and Development, Stockholm, 6–8 September, 2000.
Shiferaw, B., Holden, S.T., Aune, J., 2001. Population pressure and land degradation in the Ethiopian highlands: a bio-economic model with endogenous soil degradation. In: Heerink, N., van Keulen, H., Kuiper, M. (Eds.), Economic Policy Reforms and Sustainable Land Use – Recent Advances in Quantitative Analysis for Developing Countries. Springer Verlag, Berlin.
Smith, K., Barrett, C.B., Box, P.W., 2001. Not necessarily in the same boat: heterogenous risk assessment among East African Pastoralists. Journal of Development Studies 37 (5), 1–30.
Woldehanna, T., Oskam, A., 2001. Income diversification and entry barriers: evidence from the Tigray region of northern Ethiopia. Food Policy 26 (4), 351–365.
Yohannes, G., 1989. Land-use, agricultural production and soil conservation methods in the Andit Tid Area, Shewa Region. Research Report 17. Soil Conservation Research Project, Ministry of Agriculture Soil and Water Conservation Development, Addis Ababa.