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An upland farming system under transformation: Proximate causes of land use change in Bela-Welleh catchment (Wag, Northern Ethiopian Highlands)

J. Nyssen [a,b,*], Getachew Simegn [a,c], Nurhussen Taha [a]

[a] Department of Land Resources Management and Environmental Protection, Mekelle University, P.O. Box 231, Mekelle, Ethiopia
[b] Department of Geography, Ghent University, Krijgslaan 281 S8, B-9000 Gent, Belgium
[c] Wag Trade and Industry Office, Sekota, Wag-Hemra, Amhara Region, Ethiopia

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ABSTRACT

A possible way out of the 'low-level equilibrium trap' in the Ethiopian Highlands is agricultural intensification. To characterise and quantify current transformations in these permanent upland cultivation systems, a detailed study on land use changes and its proximate causes was carried out in the 41 km^2 Bela-Welleh catchment (2050–3682 m a.s.l.) in the Wag zone of Amhara Region, Northern Ethiopia. Land use maps were obtained through aerial photo interpretation (1965 and 1986) and detailed field mapping (2005–2006). Interpretation of topographic maps and field mapping gave knowledge of the spatial distribution of possible explanatory factors. Major land use changes are (1) a gradual abandonment of mountain agriculture which was replaced by woody vegetation (now covering 70% of the upper catchment) and (2) the widespread introduction of irrigation agriculture, wherever water is available (from 0% in 1982 to 5% of the catchment in 2006). Whereas both changes are favoured by government policies, they have now at least partially been taken up by the farming communities. The study demonstrates these land use changes and their influencing factors. Changes of crop- and rangeland into forest occur on the steeper slopes in higher topographical position. Changes from rain fed cropland into irrigated cropland (two harvests) depend obviously on the availability of water, but also on population density, and inversely on distance to Sekota town. We are here in presence of an almost classical example of the mutation of a "permanent upland cultivation system" into a system with irrigated agriculture.

1. Introduction

The sustainability of traditional agricultural systems in Ethiopia is threatened, not only by soil degradation but also by a decline in the natural vegetation (Gryseels, 1988; Zeleke et al., 1999). Limited agricultural intensification combined with a population growth rate of 2.7% $year^{-1}$ for the period 1975–2004 (UNDP, 2006) has resulted in increased pressure on the natural resources of the Ethiopian Highlands, leading to land degradation.

The declining soil fertility in the Ethiopian Highlands, where permanent upland farming dominates and where population factors have led to land scarcity, induces a conflict in land use for forestry, agriculture and livestock (Zeleke et al., 1999).

Historically, livestock has played a critical role in the process of agricultural intensification and provided energy and capital for farm operations (Steinfeld et al., 1998). In the rural Ethiopian context, livestock population increases with human population to support the farming activity and overall rural life (Befekadu and Berhanu, 2000). The integration of livestock and crop operations is still the main avenue for sustainable intensification of agriculture in many regions of the developing world (Steinfeld et al., 1998; Ehui et al., 1998). However, traditional, low-intensity livestock production methods remain all over the Ethiopian Highlands. A huge livestock population pressure can push the traditional systems to produce beyond their capacity. This can bring them into conflict with the environment. The deteriorating environmental conditions have adversely affected availability of feed resources, leaving the country's herds poorly nourished and prone to diseases.

The increase of human population has resulted in an increase in cropland at the expense of traditional grazing areas such as bush lands, rangeland and forests (Hoekstra et al., 1990). The simultaneous increase in both human and livestock population brings about the depletion of biological resources. This has induced overgrazing and soil erosion, which eventually led to land degradation.

* Corresponding author at: Geography Department, Ghent University, Krijgslaan 281 S8, B-9000 Gent, Belgium.
E-mail address: jan.nyssen@ugent.be (J. Nyssen).

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The smallholdings in this permanent upland farming system are caught in a low-level equilibrium trap. The suggested way out is to attain high returns per ha by diversification and introduction of yield-increasing innovations (Nyssen et al., 2008a).

By analogy to what has been observed in Ethiopia and neighbouring countries (see for instance Bilsborrow and DeLargy, 1990; Reid et al., 2000; Serneels and Lambin, 2001; Gete and Hurni, 2001) it might be expected that such agricultural intensification in the Ethiopian Highlands would lead to additional expansion of cropped area and hence additional degradation.

In addition, in most areas including Ethiopia an improvement in accessibility is mentioned to be one of the causes in land use/land cover change (LUCC). Muluneh (1994) for instance, has evidenced the change of cropping pattern of Sebeta-Bet-Gurage from enset (*Ensete ventricosum*) and cereals to cash crop due to the improvement of motorized transport and proximity to Addis Ababa. The impact of such factors is not equally distributed across space: each individual community "conditions" the impact of these prime factors through its particular set of endowments; namely its biophysical characteristics, infrastructural resources, and social capital (local institutions and culture of production). These conditioning variables filter the pressures for change, by affecting the constraints and opportunities at the local level (Bergeron and Pender, 1999).

Once filtered by local variables, macro-level factors affect land use through their effect on local micro economic conditions. For example, national policies may promote the development of local credit markets, making it possible for farmers to invest in some plots and convert them to the production of cash crops. An agricultural extension policy that results in local yield increases may allow farmers to redirect some of their lands towards other purposes (Bergeron and Pender, 1999).

The study area constitutes one of the oldest settlement and cultivation zones in Ethiopia. To understand the linkages between LUCC and its resulting effects, it will be necessary to document the rates and causes of changes. Therefore, this research addressed relevant issues on LUCC in relation to the socio-economic and biophysical set up of the study area and tries to provide recommendations, which may contribute to the sustainability of highland environments and hence the betterment of the livelihoods of farming communities in the study area and beyond.

Concerns about LUCC emerged in the research agenda on global environmental change several decades ago with the realization that land surface processes influence climate (Lambin et al., 2003). In the mid-1970s, it was recognized that LUCC modifies surface albedo and thus energy exchanges with the atmosphere, which have an impact on regional climate (Sagan et al., 1979). In the early 1980s, terrestrial ecosystems as sources and sinks of carbon were highlighted; this underscored the impact of LUCC on the global climate through the carbon cycle (Houghton et al., 1985). Later, the important contribution of local evapotranspiration to the water cycle has been related to LUCC (Eltahir and Bras, 1996; Lambin et al., 2003). A much broader range of impacts of LUCC on the ecosystem was further identified: impacts on biotic diversity, on soil degradation, and on the ability of biological systems to support human needs (Sala et al., 2000). LUCC determine, in part, the vulnerability of land and people to climatic, economic or socio-political perturbations (Lambin et al., 2003). LUCC are also considered to create, particularly in the developing countries, both short and long-term losses in agricultural productivity (Kurukulasuriya and Rosenthal, 2003).

To characterise and quantify current transformations in these permanent upland farming systems, a detailed study on LUCC and its proximate causes was carried out in the 41 km^2 Bela-Welleh catchment in the Wag-Hemra zone of Amhara Region, Northern Ethiopia (Fig. 1). Underlying hypothesis was that LUCC in the different altitudinal belts of Bela-Welleh catchment is not homogenous but induced by various socio-economic and biophysical factors.

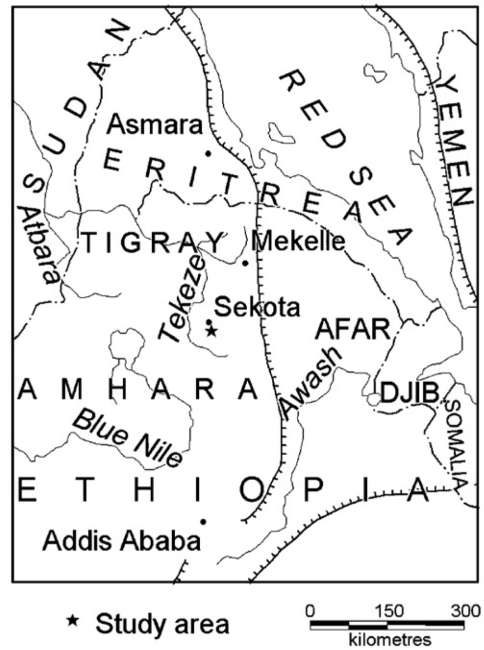

Fig. 1. Location map of Bela-Welleh catchment, in the headwaters of Tekeze river.

2. Methodology

2.1. Study area

2.1.1. Context

The Bela-Welleh catchment covers about 33 km^2; it is located at 12°30'N and 39°E, on the Northern slope of Bela mountain, some 20 km south of Sekota town. The altitude ranges between 2050 and 3682 m a.s.l. (Figs. 2 and 3).

The selected catchment is typical for the Northern Ethiopian Highlands, where cultivation has a long history and drought and famine are recurrent. The mountainous topography, the contrasted climate, the extensive cultivation and the dense population (both human and livestock) make the study area vulnerable to environmental degradation. The study area represents mountain degradation in most parts of the Ethiopian Highlands, with the following outstanding features:

Fig. 2. Partial view of Bela-Welleh catchment (backslopes, zones E, F and G).

Fig. 3. Lower part of the catchment (zones A and B, essentially on alluvio-colluvial deposits).

1. Rapid population growth has forced farming families to expand their fields onto the steeper slopes. Current population density of the study area is around 85 km^{-2} (DPPC and USAID, 2000).
2. Accelerated soil erosion which is attributed to slope steepness, loss of vegetation cover, a long history of agricultural settlement, stagnating farm technology and little tradition of land resources conservation (Nyssen et al., 2004).
3. The shortage of fuel wood leads to the use of dung as a fuel instead of being left in the fields to replenish the fertility status of the soils.
4. High vulnerability to drought and famine, growing population pressure and land degradation, amongst others, have resulted in reduced yield per capita. In 1984, for instance, early warning reports indicated that 80% of the 225,000 people residing in Wag-Hemra were in immediate need of food/relief assistance. During this period about 100–150 people died daily for lack of food and medicine. In addition to the serious food shortage, 70% of the cattle had died or had been sold due to lack of feed resources. Ten years later, in 1994, these people faced the same problem and almost 300,000 people were in immediate need of food/relief assistance. However, there were no losses of life, as NGOs and governmental organisations could encounter basic needs (DPPC and USAID, 2000; Amhara State, 2002). Food aid distribution supplement 50% of the total population and indicate the structural deficit in the study area.

2.1.2. Geology, topography and soils

The Bela mountain is composed of Oligocene flood basalt. The rocks are tilted, folded and cut by numerous normal faults with dip up to 40° (Kieffer et al., 2004). The study area includes the peak of the mountain and its Northern footslope, which are characterised by mountainous and rugged topography with gorges and valleys. The soils of cultivated areas are predominantly located on (alluvio-)colluvial deposits. The general slope ranges on which these soils occur is at 0 to 8%. Steeper slopes under rangeland or forest bear (remnants of) the original Phaeozems (Descheemaeker et al., 2006a).

2.1.3. Climate

Rainfall in the study area is unimodal; most rain occurs in June, July and August. Rainfall shows large seasonal and interannual variability. The long-term (1971–2004) mean annual rainfall in Sekota is 575.4 mm. The highest rainfall was recorded in 1974, where the annual rainfall was 1110 mm. Generally, clouds are formed at the end of the morning, as a result of evaporation and convective cloud formation due to daytime heating of the land, and it rains in the afternoon. This convective nature of rain explains why individual showers have a very local distribution (Nyssen et al., 2005). Air temperature in Sekota station (2266 m a.s.l.) fluctuates between 10 and 30 °C, with a mean annual temperature of 22.5 °C; obviously, temperatures are lower at higher elevations.

2.1.4. Vegetation

The mountain slopes were covered with indigenous *Juniperus procera* and *Olea europaea* ssp. *africana*. According to elders large parts of the steeper slopes were cultivated by hoe during the monarchy period (pre-1974). Wildfires were used to clear the land. The most recent big fire, sparked in 1961, burned off most of the vegetation. Since 1965 the government and people decided to stop cultivation and grazing on the steepest slopes. Consequently a secondary vegetation dominated by *Erica arborea* emerged. A recent regeneration of *Olea* and *Juniperus* can be observed. Getachew (2006) surveyed the indigenous trees and other common bush and shrub species that are present on the mountain and its footslopes.

Cutting (for firewood and construction material) and fire are common phenomena that threaten the forest cover. In early 2000, a forest area was set into fire (information provided by local farmers and Sekota Woreda Agriculture office).

2.1.5. Farming system

Agriculture in Bela-Welleh consists exclusively of small-scale family farms. Since the 1980s a land tenure regime has been introduced which has led to broad equality in size of landholdings. On average, the families in the study area use two or three parcels of cropland, with a combined area of 0.5–1 ha (field measurements). Grass land, rangeland and forest are communally owned.

The cultivated crops include common cereals like barley (*Hordeum vulgare*) and wheat (*Triticum* sp.), as well as tef (*Eragrostis tef*), a cereal with very fine grains endemic to Ethiopia. Horse beans (*Vicia faba*) are also important crops. In the lower parts of the study area, sorghum is common (*Sorghum bicolor*). Livestock are mainly cattle, especially oxen, sheep, goats, donkeys and mules. "Livestock keeping is part of the permanent upland system" (Ruthenberg, 1980). Traditionally, cattle are allowed to graze in all places where it is not explicitly forbidden to do so, including fallow land and harvested cropland. Other facts that indicate the high land pressure are the ploughing of lynchets (Nyssen et al., 2000) and the exploitation of marginal fields on steep slopes. Long-term land degradation contributes to the present low productivity status of the soil, to dwindling food reserves, and to economic deterioration over generations. In a bid to protect the most endangered areas such as steep slopes, they are increasingly converted into exclosures, i.e. land under strict management, often by the community, where grazing is prohibited, woodcutting sometimes allowed under strict regulations, and yearly grass cutting organised (Descheemaeker et al., 2006a).

2.1.6. Water resources

The study area is the source of perennial rivers and streams that spring out from the Bela mountain and drain to Tekeze river and Nile. In the mountain and hilly parts of the catchment however, water for both human and livestock consumption is not easily available. In most instances the water sources are unclean running water, shared by human and livestock. In few cases, especially in the alluvial plain, farmers use water from deep hand-dug wells (Collick, 2008).

On the perennial rivers diversions are used to irrigate about 205 ha of land (field measurements). In addition to diversions built with traditional technology in the hilly areas, a cemented diversion

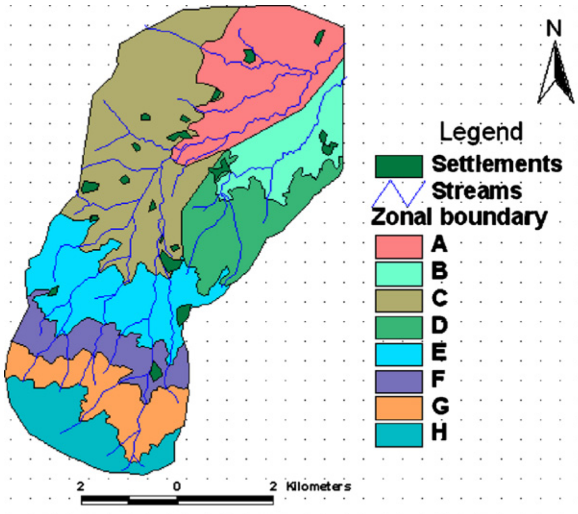

Fig. 4. Zonation of the study catchment; see details in Table 1.

Table 2
Post-classification of land cover changes in Bela-Welleh catchment between 1965 and 2006

Land cover changes	Regrouping
From forest land to shrub land	Deforestation
From forest land to settlement	
From forest land to bare land	
From forest land to rain fed farm	
From forest land to grass land	
From shrub land to farm land	
From shrub land to grass land	
From shrub land to settlement	
From shrub land to bare land	
From forest land to rain fed farm	Expansion of farm land
From shrub land to rain fed farm	
From grass land to rain fed farm	
From bare land to rain fed farm	
From settlement to rain fed farm	
From rain fed farm to shrub land	Tree regrowth
From grass land to shrub land	
From settlement to shrub land	
From bare land to shrub land	
From shrub land to forest land	
From settlement to forest land	
From bare land to forest land	
From grass land to forest land	
From rain fed farm to irrigated land	Development of irrigation
From shrub land to irrigated land	

was built on the lower course of Welleh river. Onion, sugarcane, chickpea and other vegetables are commonly grown using this source. Both in the traditional and modern irrigation system chickpea is the preferred crop, as it can be grown with little moisture and can get a good price in the market. In addition, nitrogen fixation in the soil plays an important role as the small size of land holdings in the study area does not allow fallowing. This irrigated agriculture is a relatively recent phenomenon, some 10–15 years old. According to elders, "in previous times the rain fed crop production was sufficient to feed everybody", pointing thereby to current high population density as well as to increased need for cash to pay schools and clothes.

2.2. LUCC mapping

The catchment was divided in eight zones, based on elevation and geographical proximity (Fig. 4, Table 1). Land use maps (Fig. 5) were obtained through aerial photo interpretation (1965 and 1986) and detailed field mapping (2005–2006).

Table 1
Zonation of the study area

Zone	Altitude (m a.s.l.)	Brief description	Area (ha)	(%)
A	2050–2200	North-western part of Welleh plain including Adiaro and Zawola villages	671.1	20.4
B	2050–2200	South-eastern part of Welleh plain including Adisan and Shibaban villages	352.0	10.7
C	2200–2400	North-western hill land including Shilshiman, Abidedu and Cheimatiku villages	496.0	15.1
D	2200–2400	South-eastern hill land, including Adikishinu village	213.0	6.5
E	2400–2600	Footslopes including Maymeder and Mekenzeba villages	583.1	17.7
F	2600–2800	Upper footslopes with Adiss Mender and Mezedigura villages	289.0	8.8
G	2800–3200	Bela slopes	364.0	11.1
H	3200–3682	Upper slopes and Bela plateau	319.0	9.7

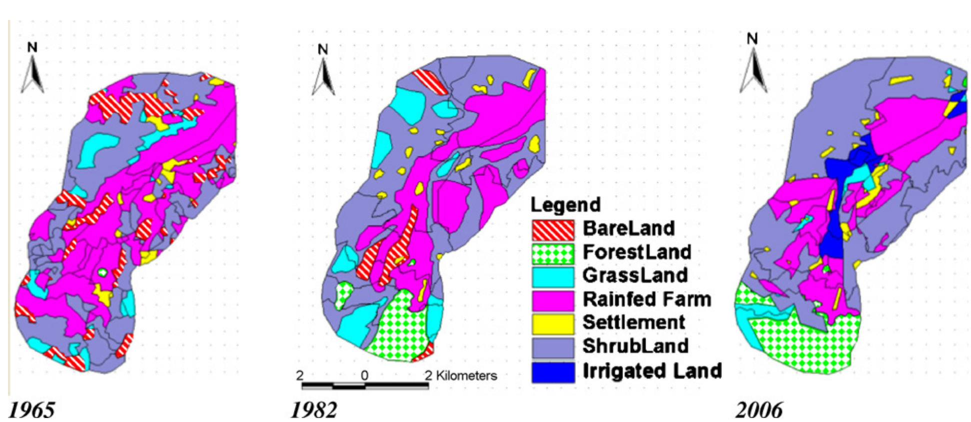

Fig. 5. Land cover maps of Bela-Welleh catchment – note the expansion of forested and irrigated land.

Table 3
Potential explanatory factors for the magnitude of land cover changes in Bela-Welleh catchment

Variable	Unit	Methodology
Average elevation	m a.s.l.	Map
Average slope gradient	%	Map/GIS
Drainage density	km/km^2	Mapping
Distance to permanent water	m	Mapping
Lithology	% Covered by alluvio-colluvial deposits	Field mapping
Rural population density (1965 and 1982)	Inhabitants/km^2	House counting from aerial photographs
Rural population density (2006)	Inhabitants/km^2	Field mapping of houses
Distance to school (2006)	m	Mapping
Livestock density (2006)	TLU[a]/km^2	Field interview and counts
Distance to Sekota	m	Map/field survey
Distance to the road	m	Map/field survey
Land holding size	ha	Field interview and count

[a] TLU or Tropical Livestock Unit is a means of accounting for different livestock species in a common unit, using conversion factors: sheep and goats 0.1, horses 0.8, mules 0.7, donkeys 0.5, all cattle 0.7 (Jahnke, 1982).

In this study, considerable dynamics were observed in the land use system of the different zones. LUCC analysis by post-classification method revealed 26 types of change, which were regrouped into four LUCC categories, i.e. tree regrowth, expansion of farm land, deforestation and development of irrigated land (see Table 2).

2.3. Explanatory factors

Discussions with key informants among the community, topomap interpretation and field mapping gave knowledge of the spatial distribution of possible explanatory factors for LUCC, such as topography, parent material, access to permanent water and infrastructure (schools, roads, towns, ...), population density and its evolution (Table 3). The field survey lasted for 2 months in December 2005 and January 2006.

3. Results and discussion

3.1. Land use changes

Four important changes were consistent in both periods (1965–1986 and 1986–2006): there was tree regrowth in all zones but especially on the upper slopes; deforestation to a lesser extent, farm expansion and irrigation development in the lower part of the catchment (Fig. 6). Major changes are (1) a gradual recovery of mountain forests from 0.4% in 1965 to 12.7% in 2006 (Fig. 7) and (2) expansion of irrigation agriculture from 0% to 5% between 1982 and 2006 (Fig. 8).

3.2. Expansion of mountain forests

Changes of crop- and rangeland into forest occur on the steeper slopes in higher topographical position (up to 70% of those areas) (Table 4, Fig. 6). Most of the deforestation during the two periods occurs in the lower area (especially zone "C") and is generally explainable by the close distance to settlements and more easily accessible terrain. The area affected by deforestation decreased during the second period (13% versus 10%) and the area with tree regrowth increased (13% to 27%). This is presumably due to management effects including the development since 1991 of the exclosure policy (Descheemaeker et al., 2006a). Moreover implementation of the government policy known as hill side distribution to interested landless people, implemented during 1994–1996 (Amhara State, 2002) is deemed to have contributed to tree regrowth, as strict management conditions are linked to the attribution of hillside plots. In essence, despite locally observed deforestation, the study shows a continuous increase in forest regrowth, and overall decline in deforestation. This indicates that factors responsible for forest

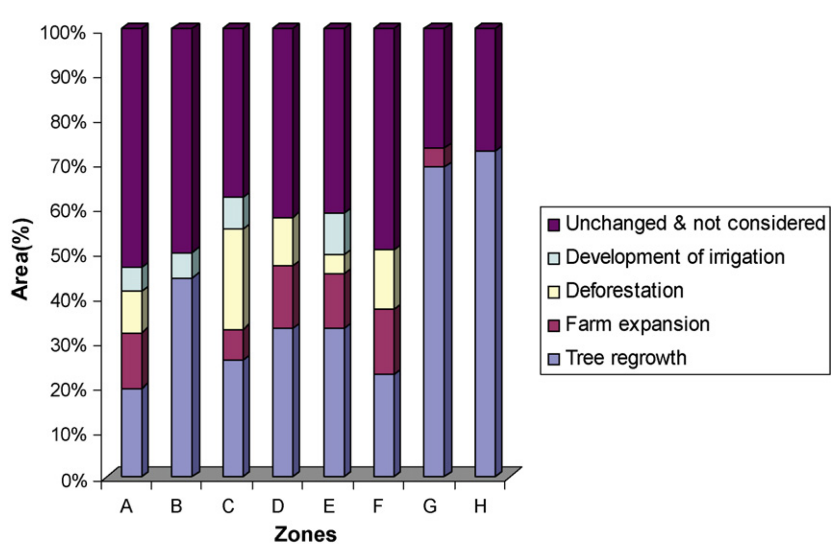

Fig. 6. Land cover changes by zone (1965–2006); area of the zones ranges between 213 and 671 ha (see Table 1).

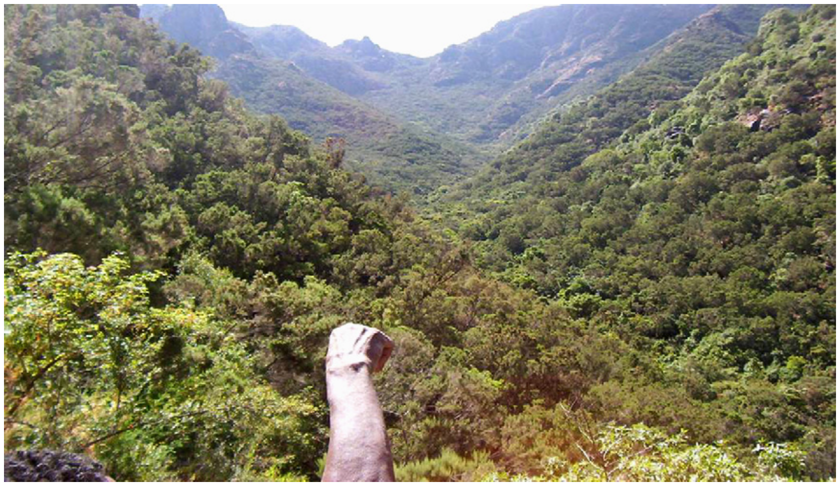

Fig. 7. Though impressive it looks, this forest is less than 40 years old. According to aerial photo interpretation, and to informants, large parts of these slopes were farmed until the 1970s. The current secondary vegetation, composed mainly of *Erica arborea*, enhances infiltration. A spontaneous regeneration of *Juniperus* and *Olea* was noted.

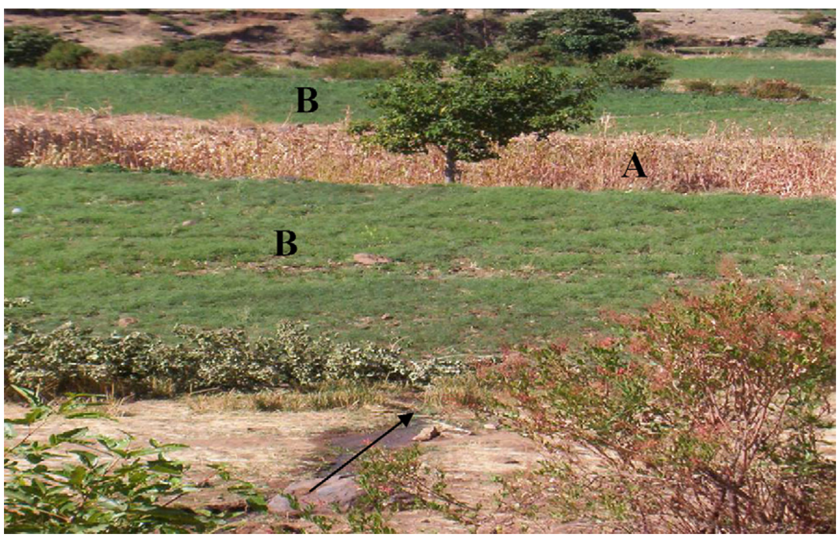

Fig. 8. Zone "E": enhanced hydrological conditions, and increased population density contributed to a change from rain fed agriculture (see sorghum stover on rain fed land – A) to irrigated agriculture (under chickpea – B). The irrigation canal is on the foreground (arrow).

recovery be more important than those that cause forest loss. However, this study is just limited to examining the coverage of forest. To have a better insight of forest quality a more profound study is required.

3.3. Irrigated agriculture

Changes from rain fed cropland to irrigated cropland with two harvests depend obviously on the availability of water and suitable

Table 4
Pairwise correlations between land cover changes per zone (1965–2006) and explanatory factors ($n = 8$)

	Tree regrowth (ha)	Farm expansion (ha)	Deforestation (ha)	Irrigation development (ha)	Unchanged (ha)
Lithology (% of alluvio-colluvial parent material)	−0.21	0.07	−0.06	0.46	0.31
Altitude (m a.s.l.)	0.59	−0.59	−0.36	−0.44	−0.65
Slope gradient (%)	0.62	−0.64	−0.40	−0.50	−0.68
Distance to permanent water (m) 2006	0.26	−0.29	0.16	−0.63	−0.08
Distance to potable water (m) 2006	0.57	−0.62	−0.47	−0.38	−0.76
Drainage density (m/km^2) 1994	−0.60	0.17	0.05	−0.09	0.20
Distance to Sekota (m)	0.47	−0.53	−0.43	−0.35	−0.72
Distance to road (m) 2006	0.45	−0.46	−0.33	−0.36	−0.65
Distance to school (m) 2006	−0.85	0.44	0.45	0.05	0.46
Livestock density (TLU/km^2) 2006	−0.47	0.63	0.15	0.56	0.32
Land holding size (ha) 1965	0.38	−0.30	−0.00	−0.56	−0.42
Land holding size (ha) 2006	0.63	−0.58	−0.09	−0.60	−0.50
Population density (person/km^2) 1965	−0.84	0.44	0.33	0.01	0.27
Population density (person/km^2) 2006	−0.80	0.16	0.05	0.13	0.10

(level) land, but also and inversely on land holding size ($r = -0.6$), as well as on distance to the road ($r = -0.36$) and to Sekota town ($r = -0.35$) (Table 4, Fig. 5). As inputs and outputs have to be transported between the irrigation sites and market area, it is understandable that priority is given to easily accessible areas. Only a few small patches of irrigated land are found in the hilly backslopes of the upper catchment. The possible explanation of the negative relation between land holding size and irrigation development is that smaller land holding sizes induce the farmers to start intensive farming with the help of traditional and improved irrigation schemes. Similarly, high livestock densities will motivate farmers to go into irrigation agriculture, as straw is badly needed for fodder and manure is readily available for amending the irrigated lands.

Importantly, studies elsewhere in Northern Ethiopia show that permanent water becomes increasingly available in the lower catchment when regrowing vegetation upslope in the landscape acts as buffers for runoff and enhances infiltration (Descheemaeker, 2006; Descheemaeker et al., 2006b).

More in general, the only way out of the low-level equilibrium trap in which smallholders of the permanent upland farming system are trapped, except through migration, is to attain high returns per ha by introducing yield-increasing or value-added innovations. Where water is available, "permanent upland systems" are most likely to develop into systems with irrigated agriculture (Ruthenberg, 1980). The evolution towards irrigation farming starts with the use of valley bottoms, as is the case in Wag. These developments can only be appreciated if they are compared to the situation less than two decades ago, which was described as follows: "irrigated agriculture in Ethiopia (. . .) is still unimportant in the densely populated highlands. The government-sponsored small-scale irrigation programme, although resulting in increased production in some producer cooperatives, has been plagued by civil war, the villagisation and resettlement programmes, insecure land tenure, absence of adequate water-use legislation and, above all, lack of peasant interest in government-sponsored projects" (Kloos, 1991).

Current agricultural intensification also involves terracing on slopes (Nyssen et al., 2007) and storage of runoff water in small ponds and leading it into the cropped fields in case of dry spells during the rainy season, as it is now done in the nearby Tigray Highlands (Fekadu et al., 2007).

3.4. Positive impact of recent LUCC

It is commonly assumed that LUCC in developing countries consists generally in the conversion of forests to agricultural uses (deforestation) or the destruction of natural vegetation by overgrazing, which leads to desertification. The growth of human and livestock population and its increase in consumption are often thought to drive to deteriorated land conditions (see for instance Serneels and Lambin, 2001). However, our study area shows that LUCC processes may be much more complex and intricate, whereby overall impacts are not negative, as LUCC are here associated with increases in food and biomass production, in resource use efficiency, and in wealth and well-being (Lambin et al., 2003). Photo-monitoring over 30 years' interval in nearby Tigray has shown improved SWC, vegetation cover and decreased soil loss rate while population has more than doubled (Nyssen et al., 2008b; Munro et al., 2008).

4. Conclusion

The study catchment shows significant and consistent LUCC over the last four decades. The changes were largely induced by increased population pressure. The major changes in the Bela-Welleh catchment were the emergence and growth of irrigated land development and forest regrowth in the uplands. These positive changes are in accordance with Boserup's (1981) thesis. Before 1965, there was only rain fed farmland, grass land, rural settlements, shrub land and a single small church forest. In Bela-Welleh catchment the optimistic views of Boserup are in place since the irrigation development is growing and comes with yield-increasing and value-added innovations that improve the standard of living of the people by way of economic diversification, improving basic infrastructure and market opportunities which ultimately leads to intensification and improves productivity. The LUCC in the uplands are not spontaneous but due to government intervention. However, whereas changes are favoured by government policies, they have now at least partially been taken up by the farming communities. Changes of crop- and rangeland into forest occur on the steeper slopes in higher topographical position.

Though forest quality merits a more profound study, the regeneration of forest in the upland leads to spring development at the back- and footslopes. Rivers are used as sources of drinking water for humans and livestock as well as for irrigation (currently about 205 ha). This development of irrigated agriculture is often initiated by the farmers themselves, but governmental authorities give strong support in terms of infrastructure development and agricultural extension.

Despite high livestock density, available feed resources are limited and as a result livestock suffers from lack of feed. Among the feed resources available, crop residues have a reasonably good share because of conversion of grazing land into forest or cropland. Hence, crop and livestock production systems are becoming more integrated because crop residue is becoming the major source of feed for livestock in the study area.

We are here in presence of an almost classical example of the mutation of a permanent upland farming system into a mixed system with irrigated agriculture (Ruthenberg, 1980). Faced with a deteriorating environment, society frequently reacts in order to improve environmental management and agricultural production, often leading to qualitative changes in the production system (Boserup, 1981).

Blaikie and Brookfield (1987) and Ståhl (1990) insist on the necessity that modern science be involved in this innovative process. The present-day rise in food production in Ethiopia can, besides re-established climatic conditions, also be attributed to a variety of human interventions at different levels (Nyssen et al., 2004), similar to the one that can be observed in Bela-Welleh. Abandonment of the free grazing system is a key issue for agricultural intensification in as much as free roaming livestock are an obstacle for farmers to select the best management options for their land, especially with regard to crop management, agroforestry, biological SWC measures and stubble management. Conservation agriculture (Nyssen et al., 2006) seems another promising way out of the low equilibrium trap in the Northern Ethiopian Highlands. A challenge to be met is that environmental investments take place in the uplands (via exclosures) and benefits (irrigation agriculture) in the lowlands – this would justify public investment in the hilly backslopes, particularly in terms of drinking water adduction and irrigation development.

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