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Estimating Land Use and Land Cover Trends in the Context of Socio-Economic and Climate Change in Ethiopian Watershed

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Abstract
For decades the world has experienced extensive tropical deforestation. In some countries there are now signs of a forest transition whereby loss of natural forest continues while land previously used for agriculture or grazing is being converted into tree plantations and cash crops. This watershed study explores drivers and impacts of such developments to socio-economy and carbon storage and its policy relevance. The study was based on satellite image analysis, field data and interviews regarding land use and forest cover, socio-economic situation and policy over 14 years. It found that intensified land management and drivers of market, infrastructure and household tenure security, have contributed to increased production of food and tree crops and increased forest cover. This forest transition is partly related to policy and driven by the households' response to a changing market and socio-economic situation. Understanding drivers of change can contribute to sustainable climate and resource management policies.
Keywords: Carbon sequestration, Driving forces, Forest transition, Policy, Woodlot plantation

INTRODUCTION

There are nearly 1.6 billion people globally who rely on forests and other natural systems for their livelihoods (http://www.un.org/sustainabledevelopment/biodiversity/).However, the livelihood of these people is at risk due to environmental and climatic changes which increases the risk of crop failures and thereby also the pressure on the forests. Intensification of crop production in agricultural landscapes contributes to increased food production, but not necessarily to significantly reduced poverty and vulnerability among rural people (Tcharntke*et al*, 2012). Dynamics in the processes of land use change, food production and land management in forest landscapes, especially in the context of forest transition, have huge implications to the livelihoods, biodiversity and food security. While local people take the final decisions on land use, the frames and conditions for making those decisions are often set by policies.

Forest transition in an area is experienced when decline in forest cover cease and recovery in forest cover begins (Mather, 1992). Although forest transition rarely helps conserving biodiversity it often contributes to soil conservation and carbon sequestration and is therefore of interest for policy makers in the area of forest and climate change (Rudel*et al*, 2005). In a number of developing countries there is currently a trend of forest transition as a result of institutional policies and market reforms promoting natural forest restoration and tree plantation by smallholders (Mather, 2007; Sandewall *et al*, 2015). Different regional paths and trajectories have led towards transition through expansion of tree plantations, and in parts of Asia as well as parts of Southern and Eastern Africa the presence of millions of smallholders on the land combined with active policy reforms has created that effect (Rudel, 2009).

In Ethiopia, there has been a continuous conversion of forests to crop land since the 1970's, although periods of rapid deforestation were also reported before the 1970s (Bekele, 2003; Eshetu, 2013). According to FAO (2015), about 11% of Ethiopia's land area is forested and the country lost 105 000 ha yr^{-1} during 1990-2015 corresponding to an annual deforestation rate of 0.8%. Deforestation for agricultural land, forest degradation due to fuel wood consumption and formal and informal logging are the major proximate drivers of deforestation and forest degradation and they respectively contribute 50%, 46% and 4% of carbon dioxide emissions from the forestry sector in Ethiopia (FDRE, 2011). In the Ethiopian highlands there are signs that expansion of crop lands through cultivation of marginal lands has reached its upper limit (Moges and Holden, 2009).

In some parts of Ethiopia, farmers are now increasingly planting trees being stimulated by scarcity of forest products from natural sources, market and policy environment. Accordingly, conversion of former crop land into woodlots is widely observed in several rural areas of the country (Lemenih and Kassa, 2014).The trend is particularly strong in Amhara Regional State, one among the nine regional states of Ethiopia, where 640 000 ha of non-industrial small scale private plantations have been planted (Bekele, 2011) although the farm size has been shrinking at the same time. Sixty percent of the 15 million landholders in the Ethiopian highlands possess

one hectare of land or less and a third of them own less than 0.5 hectare (Central Statistics Agency, 2012). As tree growing mostly requires less labor than annual crop production, the observed shift from annual crops to tree growing may facilitate diversification of livelihood options and enhance farmers' adaptive capacity to climate change effects.

At federal level, a "forest development, conservation and utilization proclamation" was issued in 2007 and private forest is recognized in this proclamation. The country's Climate Resilient Green Economy (CRGE) strategy emphasizes land use management and enhancement of forest through afforestation and reforestation for reducing Greenhouse Gas Emission (FDRE, 2011). The second national Growth and Transformation Plan (2015-2020) targets expansion of afforestation and management of lands with natural forests. These policies and strategies recognize both state and private ownership, encourage non-state actors to become involved in forest management and state that 'any person who develops forest on his land holding or in a state forest area given to him on concession shall be given assurance to his ownership of the forest' (MARD, 2007). In addition, the CRGE stipulates forestry as one of its four pillars and envisages building on the forest-energy link by improving availability of (cheap) hydroelectricity and improving efficiency in use of biomass energy (FDRE, 2011). Afforestation and reforestation are expected to increase availability of biomass energy while sequestrating additional carbon. Thus, tree plantation has obtained an increased focus also for its link with climate change.

A range of factors including the rapidly changing land use situation in Ethiopia, the driving forces of demographic and climatic change, economic growth, changing energy needs and society´s dependency on agriculture and forest production accentuate the need for far sighted economic, institutional, agricultural and forest policies. Developing and implementing those policies requires interaction and a common understanding among authorities, central and local level actors, market and stakeholders. The implication of forest transition and land use/land cover change on socio-economy and climate change, specifically carbon storage, is largely unknown given related emerging policies and political commitments in Ethiopia.

The aim of this paper is presenting a case that could illustrate past and ongoing changes of land use and forest cover in Ethiopia for the purpose of discussing how a forest transition is influencing carbon storage, rural livelihoods and potential resource management policies.

MATERIALS AND METHODS

Description of Study area

Birr watershed in the Amhara Regional State was selected for the study[1]. The purpose was identifying an area with an emerging forest cover transition and subjected to the impact of the broader economic change in Ethiopia. A previous study (Gebrehiwot *et al*, 2010; 2014) was used as a base for the choice of study area and for providing some historical reference data. It revealed that between 1957 and year 2000 the natural forest in Birr decreased from 29% to 13% while 9% of Eucalyptus plantation was exhibited in 2000. The watershed covers an area of 971.4 km^2 and is a tributary river basin of the Upper Nile River located in the North-western Ethiopian Highlands (Figure. 1). It is situated 375 km north of Addis Abeba. With a population of 197 000 (2015)[2] and divided on 4 administrative districts (woredas), the population density has surpassed 200 persons per km^2.

[1]The underlying data of this paper have been derived from an MSc thesis by one of the authors (Senamaw et al, 2016).
[2]Source Degadamot Woreda Finance Economic Development Office

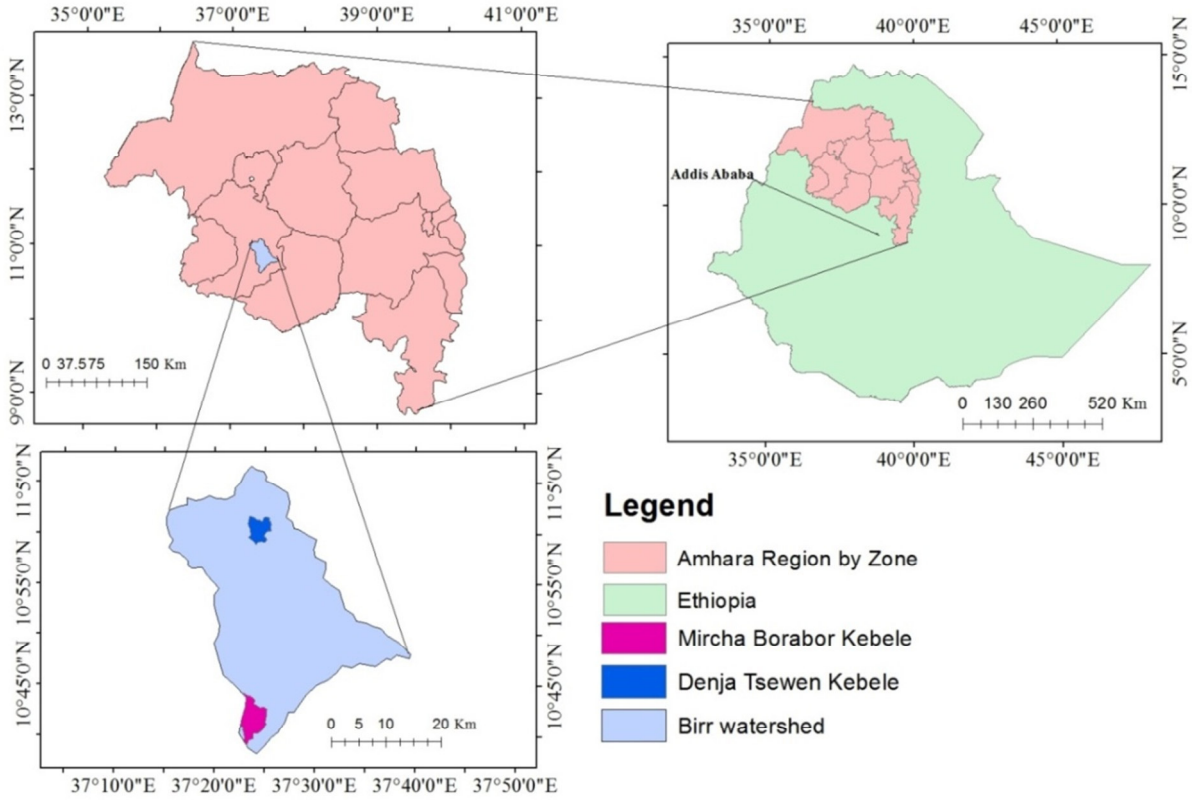

Figure 1. The location of the study area in Ethiopia including the position of the two sampled Kebeles.

The field studies and interviews were concentrated to two Kebeles[1] (one in the upper part of the watershed (DenjaTsewen), one in the lower (Mircha Borabor). They were selected in order to cover the upstream and the downstream part of the watershed including its different characteristics related to local climate, natural vegetation, agricultural practices and infrastructure. The occupation of the farmers sampled for interviews was predominantly crop production mixed with animal rearing (80-87%), and crop production only (11-19%). Some 1.5 - 3% of the farmers were occupied with small scale trade or other activities.

Classification and analysis of images and biophysical data

The study combined a multidisciplinary, multi-temporal analysis of satellite imagery and field data on land use and forest cover, socio-economic characteristics, policies and external developments with regard to situation and trends. For the purpose of verifying and explaining changes and enabling understanding of driving forces, the analysis of remote sensing and socio-economic data involved various forms of interaction with communities, farmers and administrative staff.

Predominantly cloud free satellite image data from three occasions, 2001 (Landsat ETM$^+$), 2009 (Landsat ETM$^+$) and 2015 (OLI /TIR Operational Land Imager/Thermal Infrared Radiation) were selected and used for the land use land cover classification, and various software IDRISI SELVA 17, ERDAS imagine 9.1, ARC-GIS 9.3 and SPPSS20 were used in the analysis. The image classification was based on predefined LULC class categories (Table 1). During field observations complementary ground truth and other biophysical data were collected.

[1]Kebele is the the lowest administrative unit in the Ethiopian government structure

Table 1 Description of LULC class categories considered in image classification[1]

LULC class	General description
Natural forest	Areas covered with forest of both natural indigenous tree and riverine vegetation species.
Bush/Shrub land	Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests
Grazing land	Land covered by grasses and currently used for domestic grazing, as well as bare land that has little grass or no grass cover.
Cultivated/settlement land	Areas allotted to rain fed and irrigated cultivation for crop production and scattered rural settlement usually associated with cultivated lands.
Forest tree plantations	*Eucalyptus* woodlots grown on small individual farm plots or plantations dominated by *Eucalyptus* spp.

Socio-economic data and analysis

Collection of socio-economic data was initiated by a reconnaissance survey for obtaining a general understanding of the study area and for work planning. A household survey based on questionnaire was conducted in 124 households randomly sampled from the two studied Kebeles, which had a total of 1222 households. Among the respondents 23 were female headed households. Two (2) focus group discussions in each Kebele were held for the purpose of generating qualitative information that could complement data from questionnaire and remote sensing. Further, twelve (12) key informants having lived long time in study area were interviewed. Those included natural resource management experts, local elders, environmental and land management experts and administration staff at Kebele and woreda level and both from the upstream and downstream sites. The selection of key informants was made with the help of district and Kebele officers. The purpose was to triangulate information and obtaining an in-depth understanding of drivers of land use change in the study area.

Review of policy documents and secondary data

Several research documents provide a good review of policy issues related to forest plantation and re-greening in Ethiopia in recent years (e.g. Bekele 2011; Lemenih and Kassa, 2014). As a complement to an initial literature review, documents were collected from the local government offices for obtaining complementary information on relevant local and national policies and other data on the socio-economic and demographic situation.

RESULTS

Land Use/Land Cover trends of Birr watershed

The result from the image analysis shows that cultivated/settlement land and grazing land are the two most dominant land use/land cover type in the study watershed (Table 2 and Figure. 2).

Table 2 Land use/ land cover class and the corresponding area cover over the study period

Land use/land cover class	2001	2009	2015
	Area (%)	Area (%)	Area (%)
Cultivated/ settlement land	64.18	66.13	67.88
Grazing land	15.62	13.65	12.66
Bush/shrub land	9.18	8.44	7.58
Plantation (*Eucalyptus* spp.)	8.16	9.63	10.16
Natural forest	2.85	2.15	1.82
Total area, percent	100	100	100
Total land area, ha	97 137	97137	97 137

[1]Adopted from Getachew *et al.* (2011) and Amare (2013)

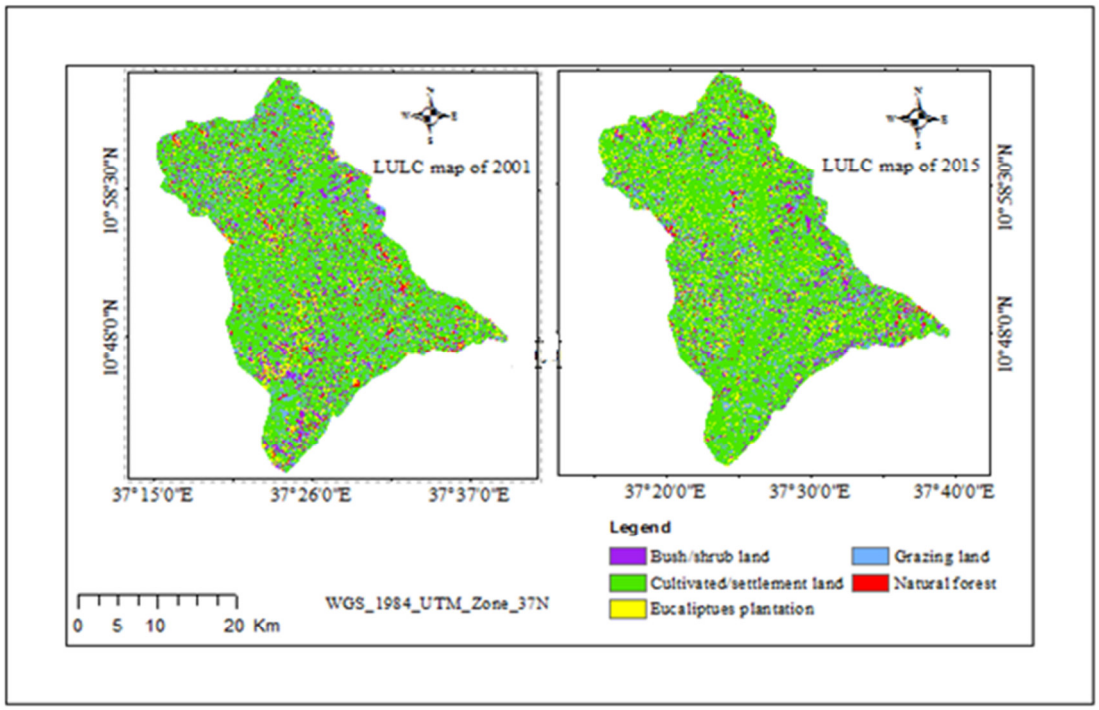

Figure 2. Land use/ land cover map dated 2001 and 2015 of Birr watershed.

Based on the various complementary methods the major land use and livelihoods changes during 2001-2015 were analysed and summarised as follows:

The total cultivated land area (agriculture and tree plantation) has increased by 5439 ha during 14 years (388 ha per annum) at the expense of natural forest, bush/shrub and grazing land. The data for 2009 show that no significant change of this trend was observed within the 14 year period.

The deforestation of the natural forest area was 71 ha per annum, meaning that 0.25% of the natural forest cover was lost annually. However the total forest area had increased, because the area of Eucalyptus plantation alone increased by 138 ha annually over 14 years. The increase of plantation area slowed down within the 14 year-period (from 178 ha/year 2001-2009 to 85 ha/year 2009-2015).

Tree planting among households has increased while average the land holding size has decreased. Only 21% of the households (upper watershed) and 17% (lower watershed) now have less than 50 trees. In comparison 74% (lower watershed) and 69% (upper) had less than 50 trees 14 years ago. As confirmed by households improved infrastructure and market situation has made it more attractive for farmers to plant trees. The land holdings of the households were bigger in the upper part of the watershed than in the lower (Figure. 3). 40.1% of the households reported that their land holdings had decreased during the period, primarily as a result of land fragmentation during transfer of land to the younger generation, while 16.1% reported that their land holding had increased. For the remaining households the holdings had not changed.

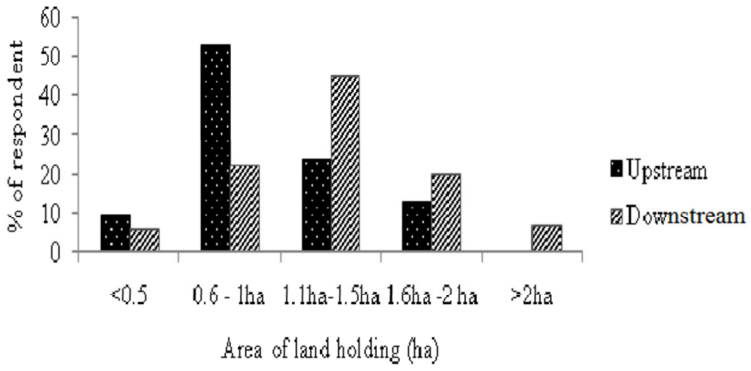

Figure 3. Size of the land holdings of interviewed households in the two villages studied.

A contingency matrix can help to improve understanding of the dynamics in land-use change over time. (Table 3). The matrix as derived from remote sensing data shows that *Eucalyptus* spp. was planted predominantly on cultivated and settlement land. After the plantation was cut, part of it went back to that category while another part was replanted or left idle.

Grazing lands was the major contributor for expansion of cultivated/settlement land (Table 3). This finding was also confirmed during field observation, and by the local inhabitants, that there was continuous expansion of cultivated/settlement land to marginal areas like grazing lands.

Table 3. Contingency matrix showing gain and loss in different LULC during 2001-2015 (km^2 of land in various categories) in Birr watershed.

Land use Land cover 2001	Land use Land cover 2015						
	Cult/settl	Grazing	BushShrub	Eucalyptus	NatForest	Total	Loss
Cult/settl	**452**	69	35	60	8	624	172
Grazing	100	**23**	12	14	2	151	128
BushShrub	49	18	**9**	10	2	88	79
Eucalyptus	47	9	10	**11**	3	80	69
NatForest	10	3	8	5	**2**	28	26
TOTAL	658	122	74	100	17	**971**	474
GAIN	206	99	65	89	15	474	

A process of land registration and title certification started in Amhara Region in 2002 with the aim to improve and sustain land management and promote farmers' investment in their land. The ultimate objective of certification is to ensure that holders have long-term holding rights (Adgo et al., 2014; ANRS, 2000).In the present study, 93.4% of the households had acquired a land certification card and 92% had a "green book" (book of holding). There has been an increased market access and demand for Eucalyptus products such as timber, poles and fuel wood within the area and from nearby urban areas.

Impacts of the changes to communities

Consumption of fuel wood, which is the primary source of household energy in the study area, is high but has decreased from 92% to 82% over the 14 years while the use of cow dung and crop residues has increased (Figure. 4). Farmers explained the result by the increased shortage of natural forest which has also encouraged farmers to plant Eucalyptus and use it partly as a fuel energy source.

Most farmers claimed that yields have increased over 14 years (56-85% depending on crop type) for the various crops grown in the area (teff, maize, wheat, barley, millet, chickpea, niger seed, potato and pepper). Improved seeds, fertilizers, pesticides and improved farming practices were mentioned as the major causes.

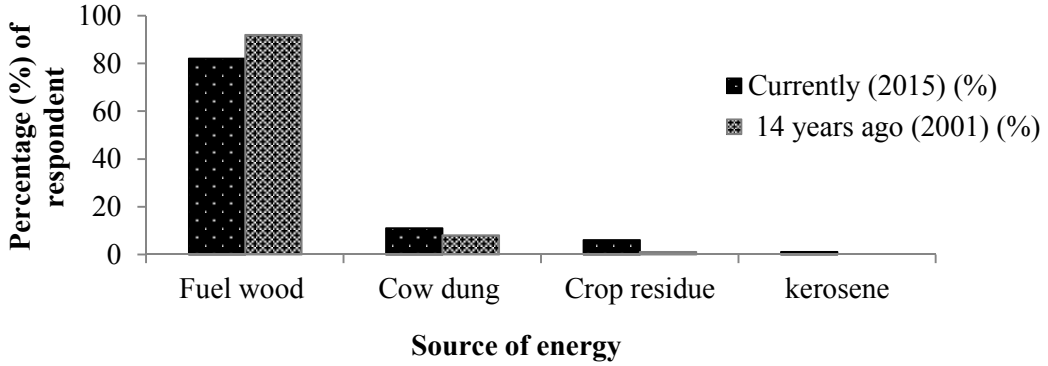

Figure 4 .Source of households' energy and its change from 2001 to 2015 in the two villages

On the other hand, livestock production has declined, primarily as a result of increasing feed shortage. The total livestock number among sampled households has dropped by 13% over the 14 years period. All types of livestock, except donkeys, have decreased in number. Nobody has private grazing land and all villagers' livestock browse on a limited area of land which is causing land degradation.

DISCUSSION

Land use land cover change in the study area

Assessment of transitions and dynamics in land use and land cover, their drivers and impacts are often based on multi-disciplinary and multi-temporal approaches. Those usually involve image interpretation, sampling based field observations, participatory socio-economic studies and use of historical records (e.g. Garedew *et al,* 2009*;* Kibret*et al*, 2015; Liu *et al*, 2016).For a policy relevant analysis that not only quantifies and statistically verifies the observed changes and trends, but also enables understanding of its drivers and current and potential impacts, the different quantitative and qualitative methods need to be combined (Sandewall and Gebrehiwot, 2015)

The image interpretation reveals a significant net increase of cultivated land and tree plantation while the area of other land use categories has decreased. Similar trends in Ethiopia over the last 40 years have been observed by other authors (Kibret et al, 2015). The increase of cultivated land in the study area is relatively

modest (about 0.4% per annum). It is less than the population growth of 0.7% per year but changes in crop yields, increased cash economy with displacement of some agriculture production (Meyfroidt et al, 2010), and other developments during the study period would explain the difference from a food production perspective.

Increased small-scale farming by resource poor farmers in the study area is held accountable for decreased areas of grassland, natural forest and bush/shrub land. Numerous studies in Ethiopia and other countries (e.g. Zhao *et al*. 2006; Dessie and Kleman 2007; Paré *et al*. 2008) have reported expansion of croplands and *Eucalyptus* plantations at the expense of grasslands.

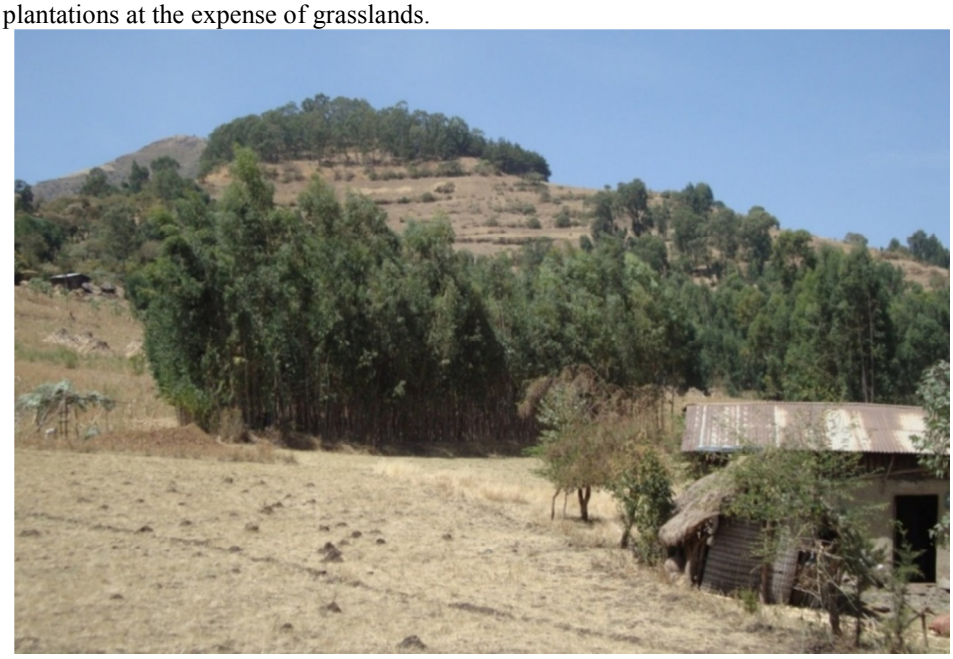

Figure 5. The tree density in wood lot plantations has increased in recent years.

The increase of forest plantation area was about 1.4% per year. Compared to the expansion in the 1980s and 1990s (Gebrehiwot et al, 2014) the annual increase has slowed down but is still significant. Previous period included both the establishment of public protection forest plantations and farmers Eucalyptus plantation woodlots while the forest plantation in recent years relies predominantly on wood lots (Figure.5 and 6). Another interesting development is that the number of planted trees per household has increased. It should imply that plantation management has become more intensive so that farmers plant a higher number of trees per area unit than in the past. We may speculate that the land shortage in the area has made it difficult to expand the tree plantation area as before, while the needs for marketable wood and fuel wood are increasingly being satisfied through denser wood lot plantations. It may also be related to policy and tax incentives (Bekele, 2011).

Figure 6. Landscape view in the upper part of Birr watershed.

Data from the contingency analysis (table 2) indicates that many new areas were planted but also that some former plantations were reconverted to crop land, including settlements, or left idle after cutting. Farmers confirmed that such reconversion is occurring although the results indicate a magnitude bigger than would be expected. About 70% of the cropland area in 2001 was classified as crop land in 2015 while the corresponding Figure for tree plantations was 10-15% only. From a methodological aspect it is a challenge separating real changes from other discrepancies caused in the process of classifying land use in a fragmented landscape on temporal images. A conservative approach while evaluating the dynamics based upon the image data only is therefore advocated, but it could well be used as a base for discussions with the local farmers.

The increased area of croplands and trees was claimed by the households to be the outcome of increasing population, land tenure security policy, and economic factors (market accessibility, infrastructure, market prices). Those claims were also supported by the other data sources.

In accordance with similar approaches applied in a number of other countries, e.g. China and Vietnam (Clement and Amezaga, 2011), a process of land certification and land registration for the purpose of increased land tenure security was started in Amhara Region in 2002 (Sida and BEPLAU, 2010; Bezabih et al, 2011). In the present study, over 90% of the households had acquired a land certification card and a "green book" (book of holding) confirming their rights as a land users and to invest efforts and resources in their own (individual) land without worries of losing it. How effective the reform has been or will be to actually achieve that has sometimes been disputed (in Ethiopia as well as in other countries). It has depended on the way the reform has been implemented locally and farmers trust in the authorities, but in the study area the findings indicate that the reform has had a positive effect.

The tropical landscape transition and expansion of forest plantations varies regionally. In parts of Asia and Africa it is seen as an outcome of changed market forces caused by high population pressure, rural to urban migration, economic growth and increased demands for forest products as a result of that (Rudel et al, 2009). Institutional changes including tenure arrangements and forest policies promoting plantation has also played a role in many countries (Sandewall et al, 2015). Increased agriculture crop yields through technical means and more intensive management systems has changed the situation and potentially released land for other use in many Asian countries (Cassman, 1999, Meyfroidt et al. 2010).

It seems that there are similar transitional trends and drivers in Birr although the pace appears slower than in e.g. Vietnam or China. On the other hand the government promotion of forest plantation is strong in those countries while in Birr the interest to plant trees seems to be primarily driven by the farmers, market demands and the changing frames and opportunities of their lives.

Land use change and carbon stock change

The nature of land use change has a significant impact on soil carbon stocks. A meta-analysis based on 74 publications indicated that soil carbon stocks decline after land use changes from pasture to plantation (−10%), native forest to plantation (−13%), native forest to crop (−42%), and pasture to crop (−59%) (Guo and Gifford, 2002).Wherever one of the land use changes decreased soil carbon, the reverse process usually increased soil carbon and vice versa. By favouring those processes that increase biomass the carbon stock will be built up. This is also reflected in climate related policies and programs worldwide.

However, there is little point in increasing carbon storage in one forest landscape if it is at the expense of substantially increased use of non-renewable energy over time in other areas. The needs of society to produce food, commodities and energy sometimes contradict the requirements to sequester carbon for countering global warming. The situation is complex as it involves both short-term and long-term needs and trends. Policies do not only have to consider carbon sequestration and change of forest cover but also socio-economic needs and expectations, conservation aspects (e.g. bio-diversity), management of conflicts and disasters and local vs global demands and politics. Considering those aspects while minimizing unsustainability in land management is a major policy issue.

Driving forces and forest policy options

The increase of cultivated land in the study area is modest but intensified land management and other developments have ensured food production, tree production and a slightly increased forest cover in the area. Those "developments" are investments and improvements in crop yields, improved infrastructure and market access and increased cash based economy with displacement of some agriculture production to other areas. The land change is at the expense of lost biodiversity, potential overuse of some land, reduced livestock production and a strained livelihood for resource poor farmers.

The increased area cover and density of the tree plantations in Birr watershed broadly coincides with national trends and indicates an increased contribution of smallholder woodlots (Bekele, 2011). The driving forces of change provide a crucial base for forest and land use policies. Although it is the farmers who make the decision to plant, current policies provide an important incentives framework. In the study the drivers of land use

and land cover trends were related to demographic changes, institutional changes such as tenure security, economic changes including improved yields and practices, infrastructure and market signals.

Policies and developments that provide economic incentives such as land certification and an improved local market for wood tend to have a strong impact on promoting the reforestation of farmers by tree planting (Lemenih and Kassa, 2014). In the study area the shortage of fuel wood has also had an impact on plantation establishment. Other changes such as the increased land shortage and the reduced size of holdings may have influenced farmers to plant trees more densely. The strong focus on Eucalyptus should be seen from the perspective that it is a popular species with extensive local use and a good record regarding diseases. The current restrictions preventing farmers to cut trees of indigenous species (Lemenih and Kassa, 2014) may possibly have had an impact on farmers' decisions *not* to plant other potentially useful tree species although it could not be derived from the results of the interviews.

As reflected in the study, the policy issue is much broader than increasing tree cover. If the increase of trees is at the expense of reduced food production, land productivity, biodiversity, resilience to irregular weather patterns or other negative effects there is a need to address the local society and environment accordingly.

CONCLUSION

Land use change in Ethiopia involves agriculture intensification, deforestation, reforestation, new forms of agriculture and socio-economic change. As an outcome of expanding agriculture and tree plantation the land use is becoming increasingly intensified at the expense of natural and extensively used forest and grazing land. The situation is changing rapidly as a result of external and internal developments. Its impact on weather patterns, carbon sequestration, environment, biodiversity and livelihoods is a political and societal concern. Identifying policies that can contribute to influencing social behaviors in a way that counters climate change is crucial.

CONFLICT OF INTEREST

The authors declare that there is no conflicts' of interest regarding the publication of this paper.

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