Ecosystem Services 23 (2017) 47–54

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia

Terefe Tolessa[a,b,*], Feyera Senbeta[a], Moges Kidane[b]

[a] Center for Environment and Development, College of Development Studies, Addis Ababa University, Ethiopia
[b] Department of Natural Resource Management, College of Agriculture and Veterinary Science, Ambo University, Ethiopia

ARTICLE INFO

Keywords:
Ecosystem service
Landscape change
Payment for ecosystem services
Land use/land cover
Chillimo
Livelihood

ABSTRACT

Ecosystems provide a wide range of services that are important for human-well being. Estimating the multiple services obtained from ecosystems is vital to support decision-making processes at different levels. This study analyzes land use/land cover (LU/LC) dynamics over four decades (i.e., 1973, 1986, 2001, 2015) to assess its impact on ecosystem services. Ecosystem Service Values (ESV) was determined using LU/LC analysis and established global data base. LU/LC analysis showed that forest cover reduced by 54.2% during study period; and settlement, bare land, shrub land and cultivated land increased considerably. The study indicates that due to forest cover change from 1973 to 2015, approximately US$ 3.69 million of ecosystem services values was lost. Among the ecosystem services reduced were: nutrient cycling, provision of raw material and erosion control. The use of LU/LC data along with established global ESV data sets reduce the costs of ground data collection, and help in tracking of past environmental changes and acquisition of quick and reliable results that can be used for decision making processes. We believe that the results obtained can be helpful in designing payment for environmental services and rural development policies.

1. Introduction

Ecosystems provide a wide range of multiple services that vary in quantity and quality depending on the type of ecosystems and their status (MA, 2005). For example, grass land was found to be quite different in service provision compared to tropical forests (Costanza et al., 1997, 2014; de Groot et al., 2012), but each one of them provides a unique service that cannot be replaced by others. Certain services are local specific (pollination of agricultural crops) and others are global in their nature (mitigation of global climatic change).

Many of these services are important for sustaining life on earth and maintaining the integrity of the ecosystem. These services are, nevertheless, currently under great pressure due to anthropogenic activities and climate change. Among the human activities that reduce ecosystem services include land use/land cover (LU/LC) change in a given area driven by agricultural activities, settlements, built up areas and mining (Li et al., 2007; de Groot et al., 2010; Haines-Young et al., 2012; Kindu et al., 2016). The impacts of LU/LC change on ecosystem services vary across space and time (Costanza et al., 1997, 2014; de Marko and Coelho, 2004; Hu et al., 2008; de Groot et al., 2012; Haines-Young et al., 2012; Bryan, 2013).

Expressing ecosystem services in monetary values is becoming a common practice to create awareness among users, provide evidence for decision/policy makers, help to know the opportunity costs of restoration and assist in payments for ecosystem service (Costanza et al., 1997; de Marko and Coelho, 2004; Nelson et al., 2009; de Groot et al., 2012; Alarcon et al., 2016). Since the completion of the Millennium Ecosystem Assessment (MA) (2005), research revealed the possibilities to quantify ecosystem services (Nelson et al., 2009; de Bello et al., 2010; de Groot et al., 2012; Ango et al., 2014; Kindu et al., 2016). However, quantification of ecosystem services has been a concern because of the debates surrounding the methodologies used, the type of service measured and the results obtained. In addition, ecosystem service valuation was limited to specific service and measurements are not comprehensive across the World (Costanza et al., 1997, 2014; Nelson et al., 2009; de Groot et al., 2012; Summers et al., 2012; Satz et al., 2013; Kindu et al., 2016). Despite these limitations attempts to estimate ecosystem service values are undertaking and improve our knowledge, experience and skills to refine the drawbacks. For the past two decades much effort has been made to come up with encouraging results, although much is needed for the future to incorporate wide ecological regions and services (de Bello et al., 2010; Satz et al., 2013; Tadesse et al., 2014b).

The highlands of Ethiopia (>1500 m above sea level (masl))

* Corresponding author at: Center for Environment and Development, College of Development Studies, Addis Ababa University, Ethiopia, P.O. Box 1176, Addis Ababa, Ethiopia.
E-mail address: tertol2000@yahoo.com (T. Tolessa).

http://dx.doi.org/10.1016/j.ecoser.2016.11.010
Received 12 June 2016; Received in revised form 7 November 2016; Accepted 22 November 2016
Available online 03 December 2016
2212-0416/

harbors some 88% of the population of the country, over 95% of the total cultivated land, about 75% of livestock population with an estimated area coverage of 44% of the land mass of the country (Hurni et al., 2005; Slaymaker, 2010). These highlands have been under intense pressure because of favorable climatic conditions for agriculture, human and animal health in comparison to the lowlands, leading to environmental resource degradation (Feoli et al., 2002; Nyssen et al., 2004; Lemenih and Teketay, 2005; Kidane et al., 2012). This environmental resource degradation causes the reduction in ecosystem services (Feoli et al., 2002; Slaymaker, 2010; Kindu et al., 2016). Our study forest, Chillimo, lies within the highlands of Ethiopia. The forest represents a vital ecological space for birds, mammal species, and water supply. It is the source of several large rivers, including Awash River, which is the major important water-way for irrigation of sugar plantations in the Rift Valley.

In Ethiopia, LU/LC changes are pervasive and common phenomenon where agricultural activities and settlements dominate rural landscapes affecting ecosystem services. Combining LU/LC and ecosystem service valuation data can help identify the area most vulnerable to changes in ecosystem services at landscape level and provide an entry point for land management opportunities in the future. Furthermore, studies conducted on LU/LC changes in Ethiopia focus on the dynamics of cover changes and their causes (Reid et al., 2000; Tsegaye et al., 2010; Meshesha et al., 2014) with little attention to address the impacts of such changes on ecosystem services aspect (Kindu et al., 2016; Tolessa et al., 2016).

In this study we hypothesize that LU/LC, especially forest cover change, is the reason for reducing ecosystem services valuation (ESV). Thus, we first assessed LU/LC dynamics in central highlands of Ethiopia and used global data base developed for different LU/LC as an input for ESV of different land use types to estimate the amount of services gained/ lost due to land cover changes over spatial and temporal scales in the study landscapes. We also carried out sensitivity analysis to explore the robustness of our results by 50% adjustment of value coefficients.

2. Study area and methods

2.1. Study area

The study was conducted in Chillimo Forest; which is located in Dendi district of Oromia National Regional State (Fig. 1). Its geographical location is 38°10'E and 9°05'N; with an altitudinal range between 2400 and 2900 m.a.s.l. (Tamrat, 1993). The forest is a typical dry Afromontane forest vegetation of the country with *Juniperus procera,* the most abundant and dominant tree species. The largest diameter classes dominate most of the forest structure with low regeneration capacity due to long years of exploitation and open access for livestock grazing (Ameha et al., 2014). Chillimo forest has been harvested for commercial timber production through selective cutting of matured trees for long period of time. The main rock type in the area is basalt, and some areas are covered with other volcanic rocks of more recent formation (Tesfaye et al., 2015). The soils are reddish brown, gravelly and shallow at higher altitudes, while at lower sites they tend to become dark-grey and deep. The soils in the surrounding low plains are vertisols, black soils with characteristic high clay content. The mean annual rainfall is 1264 mm, with a bimodal rainfall distribution of lower precipitation from November to January and there are five rainy months, May-September, with a peak in July. The mean annual temperature ranges between 15 and 20 °C (Tamrat, 1993; Mesfin, 1998).

Since 1996 the forest has been under a Participatory Forest Management (PFM) scheme to improve the empowerment the local community concerning management and use of the forest. After an agreement was made between community and government, the forest was handed over to forest user groups (FUGs). Currently there are

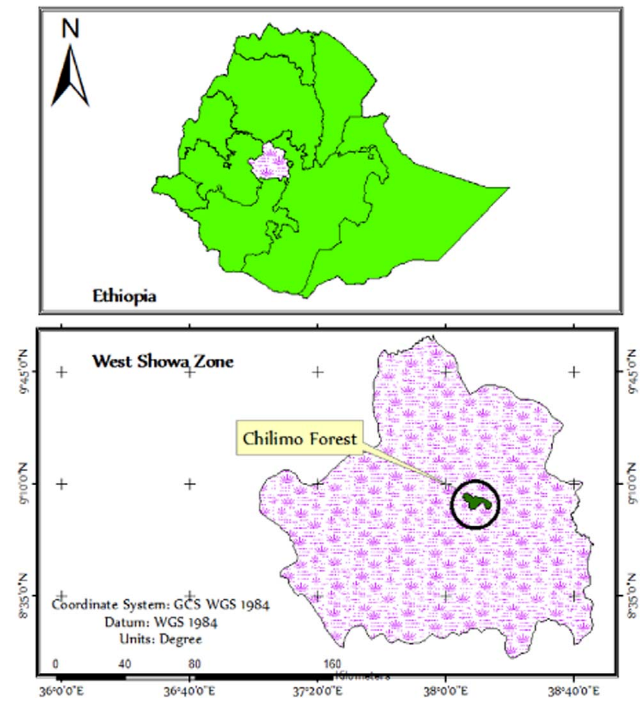

Fig. 1. Map of the study area.

about 12 FUGs who reside in and around the forest. On the base of the agreement set with the government, FUGs are currently extracting different forest products such firewood collection for subsistence and sell to the nearby town, harvesting of poles for sell and charcoal making. On behalf of the government, the Oromia Forest and Wildlife Enterprise is mandated to oversee and share the benefits that arise from forest product harvests. The enterprise regularly monitors forest condition in collaboration with the representatives of FUGs, including income distribution from forest income, as well as conduct training and renewing/giving licences.

2.2. Satellite data pre-processing and land use classification

In this study, time series data of LU/LC were produced from multi-spectral Landsat imagery (Land sat MSS, TM, ETM^+ and Land OLS), which were acquired on four separate dates: 1973, 1986, 2001, and 2015 (Table 1). All of the raw images were taken in the same season and nearly free of cloud since they were taken during the dry season. Prior to interpretation, atmospheric correction and geometrical rectification were performed including the resembling of a 1973 satellite image to match the pixel resolution. The dates selected for processing of LU/LC was mainly dependent on the availability of images, important dates in the change of government and policies related to land and land related resources.

Remote sensing image data were preprocessed and processed using ERDAS imagine.10 software by applying the basic image preprocessing techniques starting from image rectification, restoration, enhancement, image classification and accuracy assessment. To assist the supervised image classification, ground control points (GCPs) were collected from

Table 1
Description of imagery data used for land cover change study in Chillimo forest.

Imagery date	Imagery type	Resolution	Path and raw	Source
01/31/1973	Landsat MSS	57 * 57 m	181/54	USGS
02/07/1986	Landsat TM	30 * 30 m	169/54	USGS
01/31/2001	Landsat ETM^+	30 * 30 m	169/54	USGS
01/26/2015	Landsat OLS	30 * 30 m	169/54	USGS