Science of the Total Environment 622–623 (2018) 534–546

Contents lists available at ScienceDirect

Science of the Total Environment

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

Scenario modelling of land use/land cover changes in Munessa-Shashemene landscape of the Ethiopian highlands

Mengistie Kindu [a,*], Thomas Schneider [a], Martin Döllerer [a], Demel Teketay [b], Thomas Knoke [a]

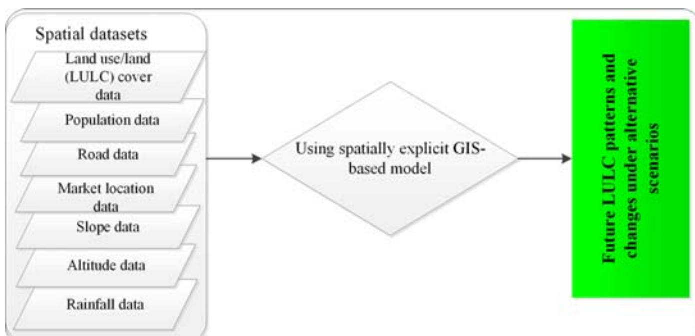
[a] Institute of Forest Management, Department of Ecology and Ecosystem Management, TUM School of Life Sciences Weihenstephan, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, D-85354 Freising, Germany

[b] Department of Crop Science and Production, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana

HIGHLIGHTS

- Future land use/land cover changes under sets of scenarios are examined using model.
- Areas of croplands will expand to the forests under Business As Usual scenario.
- Strict implementation of current policies will bring competition among land uses.
- Sustainable Intensification scenario ensure expected production while safeguarding the environment.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 2 October 2017
Received in revised form 28 November 2017
Accepted 29 November 2017
Available online xxxx

Editor: Ouyang Wei

Keywords:
GIS
Scenario
Regression
Remote sensing
Model
Resource management

ABSTRACT

Models under a set of scenarios are used to simulate and improve our understanding of land use/land cover (LULC) changes, which is central for sustainable management of a given natural resource. In this study, we simulated and examined the possible future LULC patterns and changes in Munessa-Shashemene landscape of the Ethiopian highlands covering four decades (2012–2050) using a spatially explicit GIS-based model. Both primary and secondary sources were utilized to identify relevant explanatory variables (drivers) and LULC datasets for the model. Three alternative scenarios, namely Business As Usual (BAU), Forest Conservation and Water Protection (FCWP) and Sustainable Intensification (SI) were used. The simulated LULC map of 2012 was compared with the actual for model validation and showed a good consistency. The results revealed that areas of croplands will increase widely under the BAU scenario and would expand to the remaining woodlands, natural forests and grasslands, reflecting vulnerability of these LULC types and potential loss of associated ecosystem service values (ESVs). FCWP scenario would bring competition among other LULC types, particularly more pressure to the grassland ecosystem. Hence, the two scenarios will result in severe LULC dynamics that lead to serious environmental crisis. The SI scenario, with holistic approach, demonstrated that expansion of croplands could vigorously be reduced, remaining forests better conserved and degraded land recovered, resulting in gains of the associated total ESVs. We conclude that a holistic landscape management, i.e. SI, is the best approach to ensure expected production while safeguarding the environment of the studied landscape and elsewhere with similar geographic settings. Further study is suggested to practically test our framework through a research for

* Corresponding author.
E-mail addresses: mengistie@tum.de, mengistiek@yahoo.com (M. Kindu), tomi.schneider@tum.de (T. Schneider), doellerer@tum.de (M. Döllerer), dteketay@bca.bw (D. Teketay), knoke@forst.wzw.tum.de (T. Knoke).

https://doi.org/10.1016/j.scitotenv.2017.11.338
0048-9697/© 2017 Elsevier B.V. All rights reserved.

development approach in a test site so that it can be used as a model area for effective use and conservation of our natural resources.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Natural resources, particularly land use/land cover (LULC) types and their associated changes, were central to all related sustainable development issues (Turner, 1997) and, yet, today, they are also important concerns in many regions of the world (Sleeter et al., 2013; Niedertscheider et al., 2014; Belward and Skøien, 2015; Taelman et al., 2016). It is recognized that dramatic changes in LULC can significantly modify regional climate (Fairman et al., 2011), and water balance (Davis et al., 2015), silt-up streams (Zaimes and Schultz, 2015), affect biodiversity (Dayamba et al., 2016) and ecosystems stability (Paz-Kagan et al., 2014), and disrupt socio-cultural practices (Raynaut, 2001). As pressure on LULC types increases everywhere, understanding future LULC patterns and changes is critical (Schaldach et al., 2011; Grinblat et al., 2015). These call for global attention for scientific research (Teixeira et al., 2009; Kamusoko et al., 2011; Hansen and Loveland, 2012; Belward and Skøien, 2015; Qiang and Lam, 2015).

In Ethiopia, several studies were devoted to investigate historical LULC changes and drivers behind the dynamics (Zeleke and Hurni, 2001; Tegene, 2002; Hurni et al., 2005; Dessie and Kleman, 2007; Kindu et al., 2013, 2015; Temesgen et al., 2013) and their associated consequences (Daye and Healey, 2015; Kindu et al., 2016). Most of the results of these studies revealed a worrying trend of LULC changes and illustrated the complexity of the conversion process as well as the strong location dependence of the drivers in order of importance (Bewket, 2002; Kindu et al., 2015). For instance, Zeleke and Hurni (2001) reported a sharp decrease of forest cover by 99% and increase of cultivated lands by 38% in 38 years (1957–1995) in the Dembecha area of northwestern Ethiopia. Dessie and Kleman (2007) also reported >82% of high forest conversion in the south-central Rift Valley of Ethiopia in about 28 years (1972–2000). Recently, Kindu et al. (2013) revealed that about 95% of woodlands and 59% of natural forests that existed in 1973 have been converted to other LULC types in the past four decades in Munessa-Shashemene landscape of the Ethiopian highlands. The drivers of these changes may be well defined depending on their location, such as population growth, expansion of cultivated lands and settlements, livestock ranching, cutting of woody species for fuelwood and charcoal making (Bewket, 2002; Tegene, 2002; Kindu et al., 2015). The problem is more severe in the highlands (altitude > 1500 m) that cover nearly 44% of the total landmass of the country (Hurni et al., 2005). Steep and very steep sloppy areas of these highlands are under crop cultivation (Zeleke and Hurni, 2001; Tegene, 2002; Kindu et al., 2013). These cultivated lands have suffered from loss of top soil as a result of soil erosion. The severity of such soil erosion is visible from the thick mass of soil taken away by major rivers, such as Abay (the Blue Nile - the longest river in the world), Awash, Omo and Baro (Adimassu et al., 2013). These rivers are nowadays colored into chocolates or dirty brown during the main rain season due to soil erosion from their catchment areas. However, future situations and potential consequences of this trend is not yet investigated.

One way of exploring the potential future situation of land resource is through the use of modelling. Simulation models have been used by a large number of research groups to explore when and where future LULC changes would occur based on the goals of a particular study (Wu et al., 2006; Schaldach et al., 2011; Grinblat et al., 2015; Nourqolipour et al., 2015). There are differences in modelling approaches of these studies, which often relate to differences in the purpose of the study. For example, Wu et al. (2006) predicted land use change in Beijing. Grinblat et al. (2015) developed and simulated dynamics of agricultural land use in Mali, West Africa. Nourqolipour et al. (2015) employed a GIS-based model to analyse spatial and temporal development of oil palm. These results showed wide variety of information about future LULC types in each of the studied area. Since the drivers of LULC change differ from place to place, it is important to understand their location-specific interaction and reasonably predict the future demand of land, which is a key in land use planning and management specific to the areas under investigation (Wardell et al., 2003; Kindu et al., 2015; Nourqolipour et al., 2015). Otherwise, making generalization of the results to other areas might lead to erroneous conclusions.

Modelling approach to future LULC dynamics under sets of scenarios from multidisciplinary perspective provides good information on how various courses of action may affect the future of a resource in question in which today's decision might be played out (Sun et al., 2012; Martinuzzi et al., 2015). Additionally, it gives a chance to estimate the changes of ecosystem service values (ESV) in response to LULC dynamics (Hu et al., 2008; Dallimer et al., 2015; Kindu et al., 2016). In this case, it can enrich our understanding of human activities about resource use and conservation (Bachelet et al., 2003). In particular, knowing the potential outcomes of alternative scenarios can be a powerful tool when making and implementing difficult policy decisions (Sun et al., 2012). Thus, it significantly contributes to the understanding of the potential constraints and opportunities associated with various course of actions and enhances early decision making process to minimize consequences.

Although numerous spatial scenario simulation models have provided valuable insights into the LULC, particularly in the tropical region (Hall et al., 1995; Messina and Walsh, 2001; Pontius et al., 2001; Soares-Filho et al., 2006; Grinblat et al., 2015; Nourqolipour et al., 2015), future LULC patterns and changes are still poorly understood in the Ethiopian landscapes, especially in areas under extensive agricultural systems (Kindu et al., 2013; Temesgen et al., 2013). In this regard, flexible spatial simulation models with the capacity to develop insights into LULC dynamics as well as explore "what if" scenarios are required. GIS can provide such extensive opportunities to model LULC dynamics in a spatially explicit manner (Nourqolipour et al., 2015; Qiang and Lam, 2015). Owning to the complex dynamics to the LULC types in a given landscape, simulating the entire landscape is also advisable for inclusive recommendations, instead of working on models that only examine a specific part of LULC types, such as modelling crop or grassland ecosystems independently (Sabatier et al., 2010; E. Wang et al. 2014).

The present study, thus, takes a different and novel approach, simulating the spatial LULC patterns and changes for the entire Munessa-Shashemene landscape of the Ethiopian Highlands in the next four decades. We employed GIS-based simulation modelling approach to compose datasets mainly generated from our own research (Kindu et al., 2013, 2015, 2016) and assumptions as followed by previous studies (Messina and Walsh, 2001; Grinblat et al., 2015) under three scenarios. Thus, the approach developed for this study directly integrates major LULC types of the studied landscape, their associated drivers and assumptions for the considered scenarios. The objective was to simulate and examine the future LULC patterns and changes under each considered scenario likely to prevail in affecting their sustainable use and conservation in the studied landscape of the Ethiopian highlands. We also estimated changes in ESVs in response to future LULC dynamics and explored opportunities and constraints under each of the considered scenarios. Ultimately, findings of this study are intended to serve as early warning system for understanding the future effects of LULC dynamics

Download English Version:

https://daneshyari.com/en/article/8861609

Download Persian Version:

https://daneshyari.com/article/8861609

Daneshyari.com