Geoinformatik

Mengistie Kindu

Landscape Level Modelling of the Ethiopian Highland Resources

A geo-informatics application to their sustainable management, use and conservation

SHAKER VERLAG

TECHNISCHE UNIVERSITÄT MÜNCHEN

Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt

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Mengistie Kindu Mengesha

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Abstract

Monitoring of land use/land cover (LULC) changes provides critical inputs to evaluate complex causes and responses in order to project future trends better, and it is a prerequisite for making effective development plans. This thesis aims to develop a new methodological framework using geo-informatics for sustainable natural resource management, use and conservation in the Ethiopian highlands from a novel multidisciplinary perspective by taking Munessa-Shashemene landscape as a case study site. Satellite images of Landsat MSS (1973), TM (1986), ETM+ (2000) and RapidEye (2012) were used to derive nine LULC types using object-based image classification. Other datasets required for the study were generated from both primary and secondary sources. Combination of techniques, including post classification comparison, GIS-based processing, descriptive statistics and logistic regression were employed for data analyses of LULC changes of the past four decades (1973-2012) and their drivers. Estimation and change analyses of ecosystem service values (ESVs) were conducted, mainly, by employing GIS using LULC datasets of each reference year with their corresponding global value coefficients developed earlier and own modified conservative value coefficients for the studied landscape. Possible future LULC patterns and changes covering the next four decades (2012-2050) were simulated and examined by using a spatially explicit GIS-based model. Three alternative scenarios, namely Business As Usual (BAU), Forest Conservation and Water Protection (FCWP) and Sustainable Intensification (SI) were used. The classification result revealed that grasslands (42.3%), natural forests (21%), and woodlands (11.4%) were dominant LULC types in 1973. In 2012, croplands (48.5%) were the major LULC types followed by others. The change results showed that about 60% of the land had experienced changes in LULC over the past four decades. Specifically, about 95% of woodlands, 74% of grasslands and 59% of natural forests that existed in 1973 have been converted to other LULCs types. On the other hand, croplands showed rapid expansion of about 272% during the study years. The LULC changes were triggered by the interplay between more than twelve drivers related to social, economic, environmental, policy/institutional and technological factors. Six of them were the top important drivers as viewed by the local people and confirmed by quantitative analyses. As a result of the changes, the study revealed a total loss of ESVs ranging from US$ 19.3 million per year when using own modified value coefficients to US$ 45.9 million per year when employing global value coefficients. The simulation results also showed 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 ESVs. FCWP scenario would bring competition among other LULC types, particularly more pressure on the grassland ecosystem. The SI scenario, with holistic landscape management approach, demonstrated that expansion of croplands could vigorously be reduced, remaining forests would be better conserved and degraded land would be recovered, resulting in gains of the associated total ESVs. The approach framed in this study is an important tool for supporting appropriate management options of natural resources at the landscape level.

Zusammenfassung

Die Beobachtung von Veränderungen der Landnutzung/Landbedeckung (LN/LB) hilft, die komplexen Zusammenhänge aus Ursache und Wirkung zu verstehen. Dies ist wichtig, um die zukünftigen Entwicklungen besser prognostizieren zu können. Die Beobachtungen sind eine notwendige Voraussetzung für eine erfolgreiche Entwicklungsplanung. Ziel der vorliegenden Arbeit war es, Geoinformatik in einem neuartigen multidisziplinären Ansatz zu verwenden, um damit ein neues methodisches Rahmenwerk für eine nachhaltige Bewirtschaftung der natürlichen Ressourcen – deren Nutzung sowie Schutz – im äthiopischen Hochland zu erstellen. Als Untersuchungsgebiet diente die Munessa-Shashemene-Region. Als Datengrundlage dienten unter anderem Satellitenaufnahmen von Landsat MSS (1973), TM (1986), ETM+ (2000) und RapidEye (2012), wobei unter Verwendung des objekt-basierten Bildklassifikationsansatzes neun verschiedene LULC-Klassen ausgewiesen wurden. Weitere Primär- und Sekundärquellen dienten als Grundlage für zusätzlich benötigte Datensätze. Für die Erfassung und Untersuchung der LN/LB-Veränderungen in den letzten vier Jahrzehnten (1973-2012) sowie deren Ursachen kam eine Kombination unterschiedlicher Methoden zum Einsatz – unter anderem post-classification-comparison, GIS-basierte Analysen, deskriptive Statistik und logistische Regression. Für die Bewertung von Ökosystemdienstleistungen sowie die Beurteilung der Veränderungen wurden mittels GIS-Analysen sogenannte Ecosystem Service Values (ESVs) ermittelt. Als Eingangsdaten wurden hier die LN/LB-Datensätze der jeweiligen Bezugsjahre in Kombination mit zuvor entwickelten Wertkoeffizienten verwendet – sowohl passende globale Koeffizienten als auch eigens an das Untersuchungsgebiet angepasste konservative Koeffizienten. Mögliche LN/LB -Muster und -Veränderungen über die kommenden vier Jahrzehnten (2012-2050) wurden anhand eines räumlich expliziten, GIS-basierten Modells simuliert. Untersucht wurden drei unterschiedliche Szenarien: „Weiter wie bisher“ („Business as usual“ (BAU)), „Vorrang für Wald- und Wasserschutz“ („Forest Conservation and Water Protection“ (FCWP)) und „Nachhaltige Intensivierung“ („Sustainable Intensification“ (SI)). Das Klassifikationsergebnis zeigt, dass 1973 v.a. Grasland (42,3%), natürlicher Wald (21%) und Akazienwälder (11,4%) die vorherrschenden LN/LB-Klassen waren. Im Jahr 2012 war hingegen Ackerland (48,5%) die dominierende LN/LB-Klasse, gefolgt von anderen. Die Untersuchungsergebnisse zeigten, dass sich die vorherrschende LN/LB-Klasse auf ca. 60% der Untersuchungsfläche in den letzten vier Jahrzehnten verändert hat. Von den 1973 existierenden LN/LB-Klassen waren die Klassen natürlicher Wald, Grasland und Akazienwälder am stärksten von den Veränderungen

betroffen, wobei ca. 95%, 74% und 59% der Fläche in andere LN/LB-Klassen umgewandelt wurden. Im Gegensatz dazu erweiterte sich der Anteil an Ackerflächen im Untersuchungszeitraum rapide um etwa 272%. Unterschiedlichste soziale, wirtschaftliche, ökologische, politische und technologische Faktoren sowie deren Interaktionen können als Triebfedern für die beobachteten LN/LB-Veränderungen ausgemacht werden. Die einheimische Bevölkerung benannte sechs Faktoren als die wichtigsten Ursachen der Veränderung, was durch eine quantitative Analyse bestätigt werden konnte. Die LN/LB-Veränderungen während des Untersuchungszeitraums bedingten einen enormen Verlust der vorhandenen Ökosystemdienstleistungen, der unter Verwendung der globalen bzw. der modifizierten konservativen Wertkoeffizienten auf 45,9 bzw. 19,3 Millionen US-Dollar pro Jahr beziffert werden kann. Die Simulation mit unterschiedlichen Szenarios zeigte Folgendes: Im BAU-Szenario nimmt die Ackerfläche weiter stark zu und verdrängt verbleibende Wald- und Urwaldflächen sowie Grasland. Das verdeutlicht die Vulnerabilität dieser LN/LB-Klassen und den damit verbundenen potentiellen Verlust an ESV. Unter einem FCWP-Szenario würde der Druck auf die Flächen mit nicht explizit geschützten LN/LB-Klassen, insbesondere das Grasland, weiter steigen. Wird das SI-Szenario – mit einem ganzheitlich integrierten Ansatz für das Landschaftsmanagement – für die Simulation herangezogen, kann die weitere Ausdehnung der Ackerflächen deutlich reduziert werden. Verbleibende Waldgebiete können besser geschützt werden und aktuell degradiertes Land kann sich regenerieren, was zu einem Anstieg der damit verbundenen ESVs führt. Der in dieser Arbeit umrissene Ansatz ist ein wichtiges Werkzeug, um geeignete Maßnahmen für das Management natürlicher Ressourcen auf Landschaftsebene zu unterstützen.

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