Remote Sensing of Environment 194 (2017) 278–286

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Analysing land cover and land use change in the Matobo National Park and surroundings in Zimbabwe

Valeska Scharsich[a,b,f,*], Kupakwashe Mtata[c,f], Michael Hauhs[a,d], Holger Lange[d,e], Christina Bogner[a,d]

[a] Ecological Modelling, University of Bayreuth, Germany
[b] Soil Physics Group, University of Bayreuth, Germany
[c] Bayreuth International Graduate School of African Studies, University of Bayreuth, Germany
[d] BayCEER, University of Bayreuth, Germany
[e] Norwegian Institute of Bioeconomy Research, Ås, Norway
[f] Bayreuth Academy of Advanced African Studies, University of Bayreuth, Germany

ARTICLE INFO

Article history:
Received 3 October 2016
Received in revised form 17 March 2017
Accepted 29 March 2017
Available online xxxx

Keywords:
Land use and land cover
Remote sensing
Change detection
Change vector analysis
Matobo National Park
Fast Track Reform of Zimbabwe

ABSTRACT

National parks are established to reduce human influence on nature and contribute to species conservation, biodiversity and ecological services. Other states of protection like the UNESCO world heritage sites, for example, are created for maintaining culturally important places or lifestyles. In the Matobo Hills (Zimbabwe) both states of protection are present, a national park and a world heritage site. In addition, the land outside the National Park belongs to two different systems of ownership, namely "common" (i.e. community-owned) and "not-common" (privately or governmentally owned) land.

In this paper, we investigated how the state of protection and the ownership affected the land use and land cover. We derived maps using Landsat images from 1989, 1998 and 2014 by supervised classification with Random Forests. To compensate for the lack of ground data we inferred past land use and land cover from recent observations combining photographs, Google Earth images and change detection. We could identify four classes, namely *shrub land*, *forest*, *patchy vegetation* and *agricultural area*.

The Matobo National Park showed a stable composition of land cover during the study period and the main changes were observable in the surroundings. Outside the national park, *forest* increased by about 7%. The common lands have changed substantially and their agricultural area decreased. We attribute this development to the Fast Track Land Reform, which took place in the early 2000s. Our approach shows that combining information on recent land cover with change detection allows to study the temporal development of protected areas.

1. Introduction

National parks and protected areas in general play an important role in maintaining biodiversity, preserving endangered species and providing ecosystem services, such as water filtration or air cleaning (Gaston et al., 2008; Belgacem et al., 2013). Today, protected areas cover over 15% of the global terrestrial and inland water areas and the goal for 2020 is to increase them to 17% (Juffe-Bignoli et al., 2014). Much effort is done to reach this goal. However, the official declaration of land as a protected area is often not sufficient and protection measures have to be implemented. In some cases the local inhabitants are resettled to establish a national park. As a consequence pastures might become inaccessible and game hunting is prohibited. This can decrease the acceptance of the park by local people and could result in disregarded boundaries by illegal hunting, illegal grazing of livestock or illegal farming, for example. Thus, protected areas are seldom isolated from their surroundings. Actually, changes in land use and land cover (LULC) around protected areas could influence their natural resources and ecological functioning (Jones et al., 2009). According to DeFries et al. (2007) an appropriate balance between conservation goals in protected areas and development of surrounding areas to improve human well-being is a core societal issue. Therefore, monitoring of LULC in protected areas need to include their surroundings.

To decide whether the state of protection or management of surrounding areas have a quantifiable effect on LULC, remote sensing provides a valuable data source. Particularly in order to observe large, heterogeneous or poorly accessible regions, remote sensing data are a good choice. Satellite images constitute the main tool to infer LULC all over the world and are used to detect changes and developments

* Corresponding author.
E-mail address: valeska.scharsich@uni-bayreuth.de (V. Scharsich).

http://dx.doi.org/10.1016/j.rse.2017.03.037
0034-4257/

in various landscapes. Today, a broad range of satellite images and other remote sensing data are freely available and some data even date back to the middle of the last century. Therefore, it is possible to monitor and analyse the development of almost any region in the world and possibly assess anthropogenic impacts. In protected areas like national parks, the aim is to minimize these impacts.

In order to detect the effect of protection measures on LULC, two general approaches are possible. On the one hand, one can compare areas with similar environmental conditions but with different states of protection. In most cases, this approach is based on a comparison of the protected area with its surroundings (Wasiolka and Blaum, 2011; Belgacem et al., 2013). On the other hand, it is possible to observe the temporal development of a protected area. For the latter purpose, time series of aerial photographs or of satellite images can be used for change detection, a wide field of research with many different methods (cf. Tewkesbury et al., 2015; Lu et al., 2004) for an overview).

The most popular procedure for change detection is the post-classification comparison, in which separately classified satellite images are compared with regard to their respective LULC classes (e.g. Bayarsaikhan et al., 2009). The main advantages of a post-classification comparison is its capability to provide complete information on LULC class changes and to reduce the influence of atmospheric and environmental differences between mutli-temporal images (Lu et al., 2004). The latter is particularly important when working with different satellite sensors like Landsat imagery, for example. However, the accuracy of a post-classification comparison depends on the quality of classification of every single image. One of the most widely used classifiers in remote sensing is Random Forests (Breiman, 2001). They show one of the best overall accuracies for a wide range of different data sets in comparison with over a hundred other classifiers (Fernández-Delgado et al., 2014).

The main challenge for the classification is the availability of training data, in particularly for historical images. To deal with this issue we combine unsupervised clustering to identify spectrally similar pixels and change-vector analysis (Bovolo et al., 2012) to find pixels that remained unchanged over time. We use Google Earth images and recent ground photographs to identify LULC classes and train the classifier on unchanged pixels (Chen et al., 2012). To our knowledge, this approach to analyse LULC class changes in protected areas has rarely been used (Sieber et al., 2013; Gaveau et al., 2012), although it can be applied even when access to the region, for the reasons of local politics or difficult terrain, is not possible.

The aim of this study is to analyse changes of LULC in the Matobo National Park and its surrounding area in Zimbabwe. The study area has a long history of conflicts regarding the land use and land ownership. Our focus is to investigate the effectiveness of the state of protection of the national park and the effect of land ownership in its surroundings.

2. Material and methods

2.1. Study area

The Matobo National Park (20° 27'S–20° 39'S and 28° 20'E–28° 44'E) is located in the Matobo Hills in the southern part of Zimbabwe and covers an area of 425 km^2 (Ranger, 1989) (Fig. 1). The Matobo Hills are characterised by a rolling countryside with granite inselbergs. The land cover ranges from fields and grazed areas, present mainly outside the national park, to shrub land and forest covering the park. The area surrounding the Matobo Hills is dominated by flat dry savannah and agricultural land.

Established in 1926, the Matobo National Park is the oldest national park of Zimbabwe with a long history of conflicts concerning the usage of the area. In its core area it remained continuously under protection. However, two parts in the south and in the east of the park were reattributed to common lands in 1953, a compromise for the local people. In 1982 the national park gained area in the north and remained unchanged since then.

A part of the Matobo Hills outside the national park is declared common land. This might have an effect on the land cover since the farming practice between these areas and the not-common land differs. The common land belongs to the community, in contrast to the privately or governmentally owned land. Chiefs, custodians of the land, allocate a field to each family of the community. This field remains under control of the family for all generations until it is abandoned. This land is mostly cultivated by hand aided by livestock. In the literature the term common land is also referred to as communal land (Anderson et al., 1993).

The national park is surrounded by villages all along its boundaries apart in the North. In the Northwest, commercial farms run some camps for tourists. The forests outside the park are free to use for the villagers. Inside the park it is periodically allowed to harvest grass for one's own use or for selling. This strategy replaced in 1962 the periodical burning of the long grass in the national park. Outside the park fire is seldom used for bush control.

In the early 2000s, the Fast Track land reform changed the land ownership in large parts of Zimbabwe. As described by Alexander (2006) the reform started with the occupation of commercial farm land, which was mostly in possession of white farmers. The occupations were later legalized and at the end of 2001, 9 million hectares of land were acquired. In the following years 5 of the 9 million hectares, assigned for small-holder farming, were claimed mostly by households from communal areas. The remaining 4 million hectares were assigned for medium and large-scale commercial farming, yet in August 2003 merely 50% had been occupied (Alexander, 2006). We suppose that this reform might be a driver of LULC change in the surroundings of the national park.

In 2003, most of the Matobo Hills comprising the Matobo National Park were declared a UNESCO World Heritage Cultural Site because of its natural and cultural importance. This category includes World Heritage Sites which are characterized as an anthropogenically influenced landscape, where culture and nature have an entangled history. This decision was justified inter alia by the high concentration of rock art and archaeological findings, representing the life during the Stone Age and later agricultural societies. Moreover, the interplay between surrounding landscape and the religious belief in the creator Mwari, a powerful oracular tradition in southern Africa, is present in the Matobo Hills (Fowler, 2002).

Our study area comprises 1.4 times the extent of the World Heritage Site (Fig. 1). For further analysis of the effectiveness of protection, we divided the study area into three parts with different states of protection (Fig. 1), namely the Matobo National Park (NP), the Matobo Hills World Heritage Site (WH) and the residual area (R, no protection). Because the fence along the boundary of the National Park has been pulled down occasionally and livestock grazes inside the park, we further subdivided the National Park into two zones, the core zone and a 500 m margin along the boundary to evaluate a possible effect of grazing. The information about the extension of the common lands east of 29° 03'23" is missing, therefore, any results concerning the common lands refer to the land west of that longitude.

2.2. Landsat images

We analysed three Landsat surface reflectance images (downloaded from http://earthexplorer.usgs.gov on 11 March 2015) (spatial resolution 30 m × 30 m). They were acquired by L5 TM on 19th May 1989 and 10th May 1998 and by L8 OLI/TIRS on 15th May 2014. We used comparable bands in the images, namely 1–5 and 7 in L5 TM and 2–7 in L8 OLI/TIRS. To guarantee good comparability, we selected the images in three steps. First, we chose