



Using geoinformatics and cultural anthropology to identify links between land change, driving forces and actors in the Okavango catchment

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The recent acceleration of land use transformations, coupled with an increasing global population has manifested in an alteration of almost all terrestrial ecosystems (Millennium Ecosystem Assessment 2005). In particular, the extension and intensification of agricultural and pastoral uses has supported unprecedented rates of population growth (Ellis and Ramankutty 2008). However, this development stands opposed to increased greenhouse gas emissions, declining biodiversity, declining air quality and increasing soil degradation, being reflected in the general reduction in ecosystem services and functions (Sala, Chapin III et al. 2000; Butchart, Walpole et al. 2010; Banwart 2011; Lal 2013). Such global change processes are to a large degree driven by land-use transformations or modifications (Foley, Defries et al. 2005). These are in turn a result of the complex interaction of factors playing out at different scales, varying from global market dynamics through national policies to regional planning and local traditions (Hein, van Koppen et al. 2006). The Okavango Basin represents a highly complex social-ecological system, where the variation in physio-geographic characteristics is reflected by manifold livelihood strategies in the three adjacent countries Angola, Namibia and Botswana. In mostly rural areas, small-scale subsistence agriculture, livestock-keeping and the utilization of natural resources such as thatch grass, timber, fruits etc. have traditionally formed the basis for human well-being. These strategies are juxtaposed by recent urban and transportation infrastructure developments, the expansion of commodity markets, the creation of commercial irrigated farming schemes and dams for energy production, or the growing role of tourism, in particular in the Delta region, as a major source of income generation.

At present, the three countries bordering the river have individual legislations governing the use of natural resources, which usually originate at central institutions and are implemented in different ways at subordinate levels. Commonly, communities make their own decisions regarding the use of natural resources within the framework of statutory and traditional governance and national legislation. The Permanent Okavango River Basin Water Commission (OKACOM) has been created between Angola, Namibia and Botswana to deal with transboundary subjects and facilitate informed policies. Developing such informed policies is even more urgent given demographic and climatological predictions. The African population is expected to almost double by the end of this century (Haub 2012), while climate predictions indicate an overall increase in average temperatures, added to by an increase in dry spells during the wet season and overall decreases in precipitation (IPCC 2013). This will result in increasing demands for food, paralleled by less favorable production conditions.

The appropriation of resources in the wider region is therefore characterized by various, potentially conflicting demands that are likely to accumulate in space and time (Röder, Stellmes et al. 2013). A particular constraint draws from upstream-downstream issues, with a predicted increase in upstream water utilization for drinking and irrigation, while the Delta region relies on regular flood pulses of clean water to sustain its biodiversity, to which the tourist sector as a major source of national income is linked. This is threatened by the increasing concentrations of pesticides and herbicides used in the frame of irrigation schemes lowering water quality, and the change of flood pulse cycles through damming projects (Lindemann 2009).

Besides national policies and regional planning programs, an equally important element in understanding the utilization of natural resources is the individual perspective of actors that may range from the conservation of traditions and cultures to stronger market integration and consumerism (Pröpper, Falk et al. 2013) that result from rapidly changing social and environmental framework conditions (Weber, Krogman et al. 2012).

In this study, we integrated knowledge on determining factors at different levels with remote sensing techniques to understand which ecological, policy-, planning-, and human-related drivers and causes underlie the actors' decisions that have eventually shaped the present-day land use systems. These may in turn serve as a baseline for future integrated policies and sustainable local land management. A special focus is set on the unique cross-border situation in Northern Namibia and Southern Angola, which share physio-geographic properties on both sides of

the Cubango River, but vastly differ in respect to their recent history. While Namibia has experienced a period of stability since its independence in 1990, Angola is still recovering from the civil war that, with some interludes, lasted from 1975 until 2002.

We used a set of multi-temporal Landsat-5 TM and -7ETM+ data sets covering the period from 1989 to 2010 to assess the contrasting development of resource utilization on both sides of the Okavango River and to identify temporal trends. Reflecting the high spectral variability in surface types, support vector machine (SVM) classification was used to map major land use types. SVM uses kernel functions to map non-linear decision boundaries in the original data space into linear ones in a feature space of higher dimensionality (Huang, Davis et al. 2002) and is particularly useful when differentiating complex spectral classes with small numbers of training data. To further discriminate Savanna ecosystems, we used Iterative Spectral Mixture Analysis (ISMA) (Rogge, Rivard et al. 2006) that estimates the abundance of prevailing materials present in each pixel as an independent linear combination of reference spectra. To assess scale-dependencies of observable phenomena, MODIS and Quickbird data were employed. These provide context at a coarser scale (broad vegetation/ land use categories classified using phenology descriptors derived from 16-day EVI composites) (Jönsson and Eklundh 2004) and explanatory details (better understanding of mixed spectral signatures at Landsat resolution) at finer resolutions, respectively.

Census and household surveys as well as landscape value mapping were utilized to understand the local actors' perspectives, while literature reviews provide information on regional to national frameworks in terms of regulations and policies (Pröpfer, Falk et al. 2013; Rieprich 2013).

We found the conversion of woodland savannah to arable land to be by far the dominant land use change process during the observation period. Strong spatial change gradients occurred in relation to determining factors, such as accessibility, proximity to water, urban centers etc., while relations to settlements were less obvious (Röder et al., 2015). Assessing results by country illustrated the difference in land use intensity and resource consumption between Angola and Namibia, which relate directly to historical developments, with a long period of stability in Namibia standing opposed to the recent and ongoing recovery from civil war in Angola. These are added to by statutory and traditional policy frameworks, the national endowment with natural capital (e.g. oil, uranium, diamonds, and zinc) and the integration into global markets, which strongly affects national economies of both countries at large. Underlying land use decisions were found to be largely driven by individualized perspectives on growth ideologies, consumerism and wealth-aspirations connected to globalization processes. However, at present the result of these perspectives is still mainly a small-structured conversion to rainfed agriculture as a component of subsistence strategies of local livelihoods, and thus stands opposed to other regions of the world, where change processes are much more driven by large companies or follow national regulations and result in more intensive uses, although the same processes are likely to occur in parts of the Okavango region in the future.

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