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Delineating the drivers of waning wildlife habitat: The predominance of cotton farming on the fringe of protected areas in the Mid-Zambezi Valley, Zimbabwe

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ABSTRACT

Zimbabwe's Mid-Zambezi Valley is of global importance for the emblematic mega-fauna of Africa. Over the past 30 years rapid land use change in this area has substantially reduced wildlife habitat. Tsetse control operations are often blamed for this. In this study, we quantify this change for the Dande Communal Area, Mbire District, of the Mid-Zambezi Valley and analyse the contribution of three major potential drivers: (1) increase in human population; (2) increase in cattle population (and the expansion of associated plough-based agriculture), and; (3) expansion of cotton farming. Although direct effects of land use change on wildlife densities could not be proven, our study suggests that the consequences for elephant and buffalo numbers are negative. All three of the above drivers have contributed to the observed land use change. However, we found farmland to have expanded faster than the human population, and to have followed a similar rate of expansion in cattle sparse, tsetse infested areas as in tsetse free areas where cattle-drawn plough agriculture dominates. This implies the existence of a paramount driver, which we demonstrate to be cotton farming. Contrary to common belief, we argue that tsetse control was not the major trigger behind the dramatic land use change observed, but merely alleviated a constraint to cattle accumulation. We argue that without the presence of a cash crop (cotton), land use change would have been neither as extensive nor as rapid as has been observed. Therefore, conservation agencies should be as concerned by the way people farm as they are by population increase. Conserving biodiversity without jeopardising agricultural production will require the development of innovative technological and institutional options in association with policy and market interventions.

1. Introduction

Globally, agricultural expansion represents the most significant threat to biodiversity (Vitousek et al., 1997), which is affected directly through biotic additions and removals, and indirectly through modifications of the biogeochemical cycles. Conversion to agriculture disturbs flows of energy, material and organisms within a wider ecological unit and may reduce, through isolation, the capacity of a protected area to support biodiversity (DeFries et al., 2007). The consequences of fragmentation on wildlife populations can take several generations to be fully manifested, and land use change may represent an "extinction debt" for the future (Tilman et al., 1994; Cowlishaw, 1999).

Today, agricultural expansion occurs mostly in the developing world (Gibbs et al., 2010): whereas cropland area shrank in the developed world, the total area of cropland in the developing world increased by more than 20% between 1961 and 1999 (Green et al., 2005). Population growth is an important driver of this expansion, but often neither the only nor the main one (Lambin et al., 2001). Policy and markets increasingly shape farming practices, (Mattison and Norris, 2005), rendering a Malthusian framework – stressing population growth and assuming subsistence-oriented agricultural production – too limited for the understanding of the drivers of land use change (Angelsen, 1999; Madhusudan, 2005).

Agricultural policies are often at odds with conservation objectives. For instance, policies which improved market access, subsidised farm gate prices, and provided extension services in Zimbabwe in the early 1980s, contributed to an expansion of land cultivated to maize and, to a lesser extent, cotton (Chipika and Kowero, 2000). Interventions in urban centres may also have

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important consequences for land use change, due to rural–urban ties (Jones and O'Neill, 1994). Finally, macro-economic policy may indirectly increase the pressure on wildlife habitats, as has been noticed in the case of several developing countries after policy reforms included in economic liberalisation and adjustment programmes (Angelsen and Kaimowitz, 1999). Land use change is thus driven by a wide range of factors which have locally specific impacts (Scrieciu, 2007). Conservation practices and strategies, therefore, should be based on an intimate understanding of the dynamics, and the drivers of these dynamics, within the area they target.

In this study, we illustrate this complexity with the particular case of the Dande Communal Land in the Mid-Zambezi Valley. As in many areas of sub-Saharan Africa, operations of tsetse control enabled the expansion of human settlements, reinforcing the common perception that tsetse fly is an ally of conservation (Happold, 1995). The Mid-Zambezi Valley is shared between Mozambique, Zambia and Zimbabwe. It is home to all the emblematic African mega-fauna, with the notable exception of the Black Rhinoceros (*Diceros bicornis* Linnaeus) which became locally extinct due to extensive poaching between 1989 and 1991 (Cumming and Lynam, 1997). It is a priority area for conservation, as demonstrated by its inclusion in various regional landscape conservation initiatives, such as the "Zambezi Heartland" of the African Wildlife Foundation (Muruthi, 2005) and the "Mid-Zambezi Valley Area of Biological Significance" of the World Wide Fund for conservation of nature (WWF Ecoregion Conservation Programme, 2003). At the heart of the Mid-Zambezi Valley, wildlife is well-preserved in a complex of protected areas formed by Mana Pools National Park, Sapi Safari Area and Chewore Safari Area – a world heritage site since 1984. However, smallholder farming areas adjacent to these protected areas, such as the Dande Communal Area in Mbire District, also sustain significant wildlife populations (Gaidet et al., 2003). This landscape shared between people and wildlife, was one of the first sites in which the world-renowned Communal Area Management Programme for Indigenous Resources (CAMPFIRE) was initiated in 1989. CAMPFIRE aims to finance rural development through the sustainable use of wildlife and other natural resources (Taylor, 2009). Around 90% of CAMPFIRE revenues in the study area are derived from elephant and buffalo (Gaidet et al., 2006).

Wildlife abundance in the Mbire District is at least partially the result of the area being part of the so-called "common fly-belt" extending from Zimbabwe into Mozambique, Zambia and Malawi. Until the late 1980s, it remained infested by tsetse flies (*Glossina morsitans morsitans* Westwood and *G. pallipides* Austen), vectors of trypanosomiasis. Of low risk to humans, this disease is lethal for cattle (Pollock, 1991). After Zimbabwe's independence in 1980, the new government sought to stimulate smallholder agricultural development. As tsetse fly was perceived as the major limiting factor to such development in the then sparsely populated Mid-Zambezi Valley, large-scale operations of aerial and ground spraying of insecticides were conducted in the mid-1980s, and gradually replaced by the more environmental-friendly method of deploying target traps (RTTCP, 1995). Tsetse eradication has often been presented as the single most important factor causing the dramatic decrease of prime wildlife area in Dande Communal Area since the 1980s, threatening a remarkable biodiversity and eroding the revenues generated by CAMPFIRE (Aubin, 1997; Cumming and Lynam, 1997; Biodiversity Project, 2002).

The objectives of this study were to quantify land use changes that occurred since independence in a pilot zone of the Dande Communal Area neighbouring the Mana Pools–Sapi–Chewore complex and to review three possible drivers: population growth (including state-planned resettlement), the expansion of plough-based agriculture (made possible by tsetse eradication), and the expansion of cotton farming.

2. Materials and methods

2.1. Site description

The study focused on the Mid-Zambezi Valley, Northern Zimbabwe, between 30°00 and 31°45 longitude east and 16°00 and 16°30 latitude south. It is designated Communal Area (Dande Communal Area), which is state-owned land that may be used for small-scale farming and residential purposes by individual households whose access is regulated by customary arrangements. The area studied is comprised of three wards (Wards 2, 3 and 9), which are administrative sub-divisions of districts that, in the case of Mbire district, comprise some 10–15 villages (Fig. 1). In this paper, we define "West Ward 2" as the part of Ward 2 West of the Angwa river, "East Ward 2" as the area of Ward 2 East of the Angwa river, and "Wards 3 and 9" as the area formed by Ward 3 and Ward 9. Angwa growth point lies at the centre of Ward 2 and Mushumbi Pools at the heart of Wards 3 and 9. The area lies in the former floodplains of the Zambezi River, at an average altitude of 400 m above sea level, and is drained by two main rivers: the Angwa and the Manyame. It has a dry tropical climate, with low and very variable annual rainfall (on average between 450 and 650 mm $year^{-1}$) and a mean annual temperature of 25 °C. Two seasons are clearly defined: a rainy season from December to March and a long dry season from April to November.

The natural land cover is deciduous dry savannah, dominated by Mopane trees (*Colophospermum mopane* (J.Kirk ex J.Léonard)). The local biodiversity is relatively intact, with more than 40 large mammal, 200 bird and 700 plant species (Biodiversity Project, 2002). In 2002, a total of 71,000 people lived in this area of 4100 km^2, but population densities vary considerably: 5.7, 29.2 and 42.9 inhab km^{-2} in Wards 2, 3 and 9 respectively (Central Statistic Office, 2002). Settlements occur predominantly along the main rivers and the major activity is dryland farming of cotton, maize and sorghum.

2.2. Development of a land use data base

Land use change was assessed in terms of conversion of natural vegetation to agriculture for the period 1980–2007. For this, expansion of farmland, which was defined as any surface that has been cleared for cultivation or residential purpose (i.e. homesteads, cultivated fields and fallows) was analysed through remote sensing.

We used Landsat Thematic Mapper (Landsat) of 2007, "Système Pour l'Observation de la Terre" (SPOT) Multispectral (XS) satellite images of 1990, 1997 and 2001, as well as aerial photographs of 1980, all taken during the dry season between July and September, to estimate farmland areas. Landsat has a spatial resolution of 30 m, while SPOT XS has a 20 m spatial resolution. Aerial photographs that we used have a spatial resolution of 5 m. Aerial photographs and SPOT (XS) satellite images were re-sampled to 30 m to be compatible with the Landsat images and all images were geo-referenced.

Farmland was determined through on-screen visual interpretation and digitization in a Geographical Information System: fields, fallows and homesteads can clearly be delineated when images are displayed in pseudo-natural colours, as they appear near regular, light toned and relatively smooth. We assessed the accuracy of the visual interpretations of the 1990 and 1997 SPOT (XS) images using farmland classifications from aerial photographs of 1990 and 1997. We use SPOT images in Google earth of 2007 to assess the accuracy of the 2007 Landsat image visual interpretation (as in Knorn et al., 2009). The Kappa statistics obtained were 0.93 for 1990 with 88 samples, 0.87 for 1997 with 108 samples, 0.77 in