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Three decades of forest cover change in Uganda's Northern Albertine Rift Landscape

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ABSTRACT

Deforestation within and outside protected areas is widespread in Western Uganda, but quantification of such forest changes is rare. In this study, spatio- temporal forest cover patterns in the Northern Albertine Rift Landscape were reconstructed for the period 1985–2014, over a range extending from Bugoma forest in the South of the region to as far as Murchison Falls National Park in the North, an area approximately 225 km North-South by 63 km East–West. We examine both the spatial and temporal heterogeneity of the land cover changes. Seven 30 × 30 m resolution, ortho-rectified, cloud-free Landsat images obtained from the USGS archive were analysed at the landscape- and three smaller scales. Forest classification using Landsat imagery appears robust; similar amounts are obtained from a UK-DMCii image (22 m resolution) taken a day before the Landsat scene in Dec, 2010. Our results show that larger-scale aggregate measures of total change can obscure more local patterns, in which protected areas and the national park maintain or grow forest cover, whilst the forest corridor areas that are not protected suffer drastic losses. Time-series show that the loss continues nearly linearly into the present around Bugoma, but seems to level off around Budongo Forest after 2010, apparently because almost all forested corridor areas have been cleared. At the landscape scale, between 1985 and 2014, the data suggest approximately 0.4% of initial cover was lost per year. However, this was mostly a result of the large protected forest blocks remaining relatively stable; deforestation was mostly situated in the corridor and riverine areas. Local-scale losses were most prominent in unprotected forests around Budongo and Bugoma, with annual losses at a much higher average rate about of 3.3% per year in each case. The annual rates of loss are higher than Uganda's average (1–3%). Forest cover in the protected zones expanded only marginally, with annual average increases of order 0.03% and 0.5% in Budongo and Bugoma reserves, respectively. Our results suggest that forest protection in the gazetted areas is successful, and the protection policy is working, but these forests are being isolated by large losses immediately outside the protected zones, in the forest corridors. This may have severe social and ecological consequences—both within and outside protected forests.

1. Introduction

Deforestation threatens biodiversity, climate and livelihoods (Bala et al., 2007). Deforestation rates in the African Tropics are some of the highest in the world (Achard et al., 2002), and accounted for over 23% of global forest loss between 1990 and 2009 (Houghton, 2012). Deforestation is reported to have increased in several parts of Uganda in the last half-century. Examples include conversion for coffee production around Mt. Elgon in Eastern Uganda (Sassen et al., 2013). Forest loss on protected and private land around Kibale National Park in South- western Uganda is attributed to charcoal production (with preference for old-growth hardwood tropical species), high fuelwood demand by the tea industry, settlement and agricultural expansion (Naughton-Treves et al., 2007). Forest cover has been lost around Bwindi impenetrable forest in South-western Uganda, as a result of agricultural expansion and ambiguous forest boundaries (Twongyirwe et al., 2011). Recently, Ryan et al. (2014) found that population changes are correlated with forest loss along the whole Albertine Rift, but they sampled the region sparsely, excluding protected areas, and only looked at two time points.

There is however evidence of successful forest protection in some National Parks and Forest Reserves by Uganda's designated forest authorities (e.g., Bwindi impenetrable forest, see Hamilton et al., 2000; Budongo, Wambabya and Bugoma forests—this paper).

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There are some regions of forest stability and recovery/gain in various parts of the country between 2000 and 2010, according to recent global forest cover change mapping (Hansen et al., 2013).

The Northern Albertine Rift Landscape in Western Uganda is an iconic landscape endowed with the largest natural forests in Uganda (Budongo and Bugoma), with rich biodiversity (Plumptre et al., 2007), and yet it has suffered extensive deforestation. While discourses in local media highlight the prevalence of this deforestation (e.g., Mugerwa, 2011; Namutebi, 2013; Tenywa, 2014), the only published work found is fragmented and limited to Budongo forest (Nangendo, 2005; Nangendo et al., 2007; Mwavu and Witkowski, 2008). Forest loss around Budongo has been reported on private landholdings, and attributed to agricultural expansion, population growth, illegal timber harvesting, unclear land tenure systems and weak forest protection enforcement (Mwavu and Witkowski, 2008). There is however a dearth of information on Bugoma (another large forest in the landscape), and forest corridors in the region. Some studies exist by the Wildlife Conservation Society (WCS) and other NGOs working on forest loss in the Albertine Rift region, but only in unpublished reports and the methods used in the estimation are not rigorous.

The extent of forest cover change particularly at the landscape- and local-scales around Bugoma and Budongo forests in the last 30 years is not thoroughly understood. Providing unambiguous extents of historical vegetation cover changes could provide the impetus to address local, regional and national needs, and may prove critical for future planning. Efforts on Reducing Emissions from Deforestation and Forest Degradation (REDD) in the region will be enhanced by establishing the baseline deforestation rates. The focus here is mainly on identifying deforestation rates, and less on its drivers. Contrary to many studies we attempt to recover the time–series of change, rather than just looking at start and end points of the period: this helps to distinguish the deforestation signal from other temporal fluctuations. However, in order to get an unambiguous result it is also necessary to look at spatial patterns.

The issue of the spatial scale of analysis has received limited attention in forest cover change literature. A large-scale analysis (which in the current case is 4–5 times the size of the largest protected forest area – we refer to this as the "landscape" scale below – see Fig. 1) could provide insights into the connectivity of the forest cover mosaics, essential for biodiversity conservation, where, for instance, allowing free wildlife movement in a well-connected landscape is important for breeding; while a more localised investigation unearths intricacies in anthropogenic-related selection and exploitation biases, which could impact on the larger-scale processes. To understand the spatio-temporal complexity of forest cover change, our investigation explored the landscape scale, and three more local areas. The landscape scale covers the entire study area while each of the local-scale studies first exclude the national park region in the North, but include the forest corridors and riverine regions, and then focus in on the Budongo region, where the southern part has been less thoroughly studied, and the Bugoma forest which has been least studied of all. The objective of this paper was to understand the spatial distribution and patterns of the connecting forest patches influenced by anthropogenic activities within and between the main protected forests; namely Budongo, and Bugoma (and the smaller Wambabya forest) between 1985 and 2014.

2. Study area, data, materials and methods

2.1. Description of study area

The Northern Albertine Rift Landscape in Western Uganda lies approximately between 1°18′–2°11′N and 30°40′–31°52′E with an estimated area of 14,098.9 km^2. This is the delineated area for this study in Fig. 1; the full extent of the Albertine Rift covers many countries (see e.g., Ryan et al., 2014). The Albertine Rift is one of the most important conservation regions in Africa with extensive areas of both protected and unprotected forest (Owiunji & Plumptre 1998; McLennan & Hill, 2012), abundant bird species, high plant and tree species diversity (Eilu et al., 2004), and an unmatched animal species diversity, most of which are endemic to this ecosystem (Plumptre et al., 2007).

The landscape has a characteristically gently sloping terrain, and a tropical climate with two rainfall peaks, March to May and September to November (Eilu et al., 2004). The region's ecosystem is threatened by widespread deforestation (Mwavu & Witkowski, 2008) partially due to a dense population of approximately 123 people km^{-2} (the majority living below the poverty line, on less than a dollar per day), and a population growth rate of about 3.2% per annum (UBOS, 2002), exacerbated by a large influx of refugees (Mwavu & Witkowski, 2008). Small-scale agriculture is the main way of life, although with limited commercial farming to provide raw materials for sugar, tea and tobacco industries in the region (Nangendo et al., 2007).

The landscape has attracted many government and non-government conservation and development organisations. Oil was discovered in the Albertine Rift in the mid 2000s and construction of an oil industry is underway. It is not clear how development goals and conservation will work simultaneously in this landscape.

2.2. Remote sensing data used in the analysis

Two remote sensing data sources are used in this study: (1) Landsat (30m resolution) and (2) UK-Disaster Monitoring Constellation International Imaging (UK- DMCii, 22 m resolution). Landsat images were the main data source, obtained from the USGS archive via the Earth Explorer web-link (http://earthexplorer.usgs.gov/). The archive has a large database from the 1970s which is now freely accessible to the public from the USGS web portal (Wulder et al., 2012). Good quality scenes for the study were available from January, 1985 to March, 2014 (to include the period of fieldwork). In total, a time–series of 80 scenes was downloaded.

Clouds obscure vegetation cover; the surface of the Earth can still be seen through haze, but the spectral characteristics are often changed and this can render imagery unusable (Mitchard, 2012). We screened images for those with more than 50% haze and cloud cover, especially in core case study areas. We excluded images that were not totally cloud-free, and those affected by Scan line Corrector (SLC)-error over the region of study. At both scales only 7 scenes were considered suitable (Table 1); essentially, only 8.8% of those downloaded. One cloud-free scene obtained and donated by UK-DMCii was also included to compare with estimates of forest quantities obtained using Landsat imagery.

The study area lies in a single Landsat Path and Row (172/059), and therefore a mosaic of multiple scenes was not required. Unsurprisingly, the useable imagery at the landscape and local scales proved to lie in the dry season, which is more likely to be cloud and haze free. This helps to control for seasonal variability that could confuse the overall change signal due to phenological effects on the classification.

2.2.1. Image processing

Image processing was undertaken using Erdas Imagine 2013 and ArcGIS 10.0 in three phases: (1) Pre–classification processing, (2) classification and (3) post-classification change detection as summarised in Fig. 2. These are described in turn.

2.2.1.1. Pre-classification processing. Band selection: After some preliminary trials with other band combinations, we settled on the