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Spatial dynamics and quantification of deforestation in the central-plateau woodlands of Angola (1990–2009)

A.I.R. Cabral [a,*], M.J. Vasconcelos [a], D. Oom [a], R. Sardinha [b]

[a] *Tropical Research Institute, Travessa Conde da Ribeira, 9, 1300-142 Lisboa, Portugal*
[b] *Instituto Piaget, Av. João Paulo II, Lote 544-2, 1900-726, Lisboa, Portugal*

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A B S T R A C T

Some authors argue that deforestation in Africa is one of the highest among the world's continents. However, for several regions, historical data and observations obtained by remote sensing raise some controversy over the portrait accepted in international circles. This case study, located in the central plateau of Angola, highlights the importance of medium to high resolution multi-temporal observations of land cover by remote sensing as a means of obtaining objective information and illustrates the complexity of deforestation processes. Land cover change in the Huambo province (Angola) is analyzed using maps produced for three dates (in the period between 1990 and 2009) by classification of Landsat TM and ETM+ images. The results are a first stepping stone for the development of a forest monitoring baseline for REDD projects under the scope of post-Kioto agreements, and they indicate an overall recovery in the forest extent of Huambo (negative deforestation rate of −0.16%, contrasting with the +0.20% reported for the entire country). However, this apparent recovery hides an inversion in the dynamics of the more densely wooded vegetation types, the *miombo* woodlands, which show a very slight expansion in the first decade analyzed and a marked reduction in the second, while agriculture shows a consistent and constant expansion. The deforestation rate of 1.49% in *miombo* woodlands in the last decade is found to be seven times higher when compared with official figures reported for the entire country. These results are discussed in the context of the socio-economic factors that may have driven the observed dynamics.

Introduction

With the world's attention focused on climate change and on the reduction of global carbon emissions, forests became vital for managing global warming through their function as carbon sinks. Tropical deforestation contributes with approximately 12% of the world's carbon emissions (Van der Werf et al., 2009) and thus it is important to quantify and locate problematic areas in order to develop strategies that can reduce or avoid destruction. Deforestation estimates are a challenge, particularly in remote regions, where expensive and systematic ground measurements of biomass are difficult to obtain (Achard, Eva, Mayaux, Stibig, & Belward, 2004). In this context, remote sensing associated with digital analysis can be valuable for mapping forest area and monitoring spatial and temporal patterns of degradation in tropical forests, as well as, quantifying the rate of changes (Myers, 1988).

Even though satellite imagery is the best source of consistent and up-to-date spatial data for estimation of deforestation, low spatial resolution imagery (e.g. 1 km) may not be sufficient to detect changes in forest cover resulting from anthropogenic activities, like shifting cultivation. Several studies with low resolution imagery (Cabral, Vasconcelos, Pereira, Martins, & Bartholomé, 2006; Defries et al., 2002; Hansen & Defries, 2004; Tucker, Townshend, & Goff, 1985) have been conducted for the African continent. However, few exist using high to medium resolution information (e.g. Landsat TM, SPOT). Examples are the studies developed by Duveiller, Defourny, Desclée, and Mayaux (2008) and Zhang, Devers, Desch, Justice, & Townshend (2005) for Central Africa and Brink and Eva (2009) for sub-Sahara Africa. The first assesses land cover changes by combining a systematic regional sampling scheme with high spatial resolution imagery, and the second reports deforestation rates and patterns in relation to rural population density and forest accessibility. For sub-Sahara Africa, land cover change estimates were produced for the period 1975–2000. At a local scale, Kamusoko, Aniya, Adi, and Manjoro (2009) used

* Corresponding author. Tel.: +351 213616340x212; fax: +351 213640046.
E-mail addresses: anaicabral70@gmail.com (A.I.R. Cabral), maria.perestrelo@gmail.com (M.J. Vasconcelos), duarte.oom@gmail.com (D. Oom), rsardinha@lisboa.ipiaget.org (R. Sardinha).

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medium to high resolution land cover maps to simulate land use/cover changes (up to 2030) in two communal areas of the Bindura district, Zimbabwe, based on a combination of Markov chain analysis and cellular automata models. Vasconcelos, Biai, Araújo, and Diniz (2002) quantify and spatially characterized land cover changes in the regions of Cacheu and Orango protected areas in Guinea-Bissau using land cover maps co-registered and rasterized from 1956 to 1998 and a Landsat derived land cover map from 1998. Also, land cover change dynamics were analyzed in the Coastal zone of Egypt, by Shalaby and Tateishi (2007) between 1987 and 2001, as well as, in the Manica province (Mozambique) between 1990 and 2004 (Jansen, Bagnoli, & Focacci, 2008). Studies involving estimates of forest biomass, carbon stocks, and their relation with deforestation rates were also done using remote sensing data combined with ground measurements for tropical forests (Gibbs, Brown, Niles, & Foley, 2007; Oom et al., 2009). No work of this type that we know of has been developed for Angola.

Angola is extensively covered by forests, many of which are open-forest types, like the *miombo* (with its several sub-types shown in Barbosa (1970b)) that covers most of the central plateau of Angola; a remote region that was the stage of many war rides during civil unrest (which began before independence in 1975 and lasted until 2002). *Miombo* is one of the more ecologically relevant land cover types in Angola and consists of woodlands of very rich biodiversity, with about 8500 plant species – of which over 54% are endemic (Desanker, Frost, Frost, Justice, & Scholes, 1997). In addition to their ecological value, these woodlands provide food, fibre, medicinal plants, and cattle feed to local populations (Desanker et al., 1997). The use of *miombo* as a fuel source for domestic purposes, such as cooking and heating (AIE, 2006), or for commercial activities has been promoting degradation in the ecosystem. Often, the wood is collected in large quantities and converted to charcoal by professional charcoal makers working under contract, and eventually by the rural population, for supplying the cities.

The central plateau, where Huambo is located, includes one third of the rural population of Angola (WFP/VAM, 2005). The main ethnic group is the Ovimbundu. This group results from a mixture of other groups of diverse origin and varying size, and is the outcome of the historically high migration in the region (Birkeland, 2000; WFP/VAM, 2005). Until the independence of Angola in 1975, rural populations had adequate living conditions provided by extensive agriculture and commercial activities, as well as a good commercial network (Birkeland, 2000). The degradation of the road network and the impact of the war that followed independence affected rural livelihoods and drove a reshaping of land use patterns.

The civil unrest, which had its main focus in the Central Plateau, Moxico and Cuando Cubango provinces, forced people to leave their homes, moving from the countryside to urban areas and to central places in the provinces. In the Huambo province this displacement occurred to, and within, the government controlled areas along the Benguela railway corridor, with heavy concentrations in Caála and the Huambo municipality (Birkeland, 2000). This displacement occurred, also, to the coastal provinces, which had better security.

The main purpose of this work is to obtain an overview of land cover change tendencies in the province of Huambo, in the period 1990–2009 as a basis for the design and future development of a monitoring system that supports sustainable forest management. Such a system is envisioned as an essential tool for promoting the access of local organizations and communities to the investment mechanisms included in initiatives like REDD (http://unfccc.int/methods_science/redd/items/4531.php). Here, we use Landsat images and field observations to produce and validate land cover maps for three dates and to derive historical deforestation rates in Huambo. Additionally, we compare land cover change tendencies observed at this scale with those obtained from land cover maps of approximately the same dates but resulting from 1 km resolution images (IGBP[1], GLC2000[2], and MODIS[3] datasets). Deforestation is analyzed using both scales of analysis and discrepancies are discussed with a focus on the implications.

The results obtained in this study are intended to contribute to the establishment of a baseline and aid the development and planning of future actions to avoid deforestation and degradation processes, inducing certified forest management procedures. These will allow sustainable production of wood and fuel, while maintaining forest ecosystem services and the livelihood of local populations. This study was developed in the scope of the Natural Resources Development Project (CE-Food/2006/13044) being implemented by Marquês de Valle Flor Institute for the Ekunha Municipality in the Province of Huambo.

Study area and data

Location and biophysical characterization

The study area is the province of Huambo located in the central plateau of Angola (Fig. 1). With an area of about 34,270 km^2 and an estimated population of 1.9 million habitants, approximately 15% of the national total (USAID, 2008), it is divided into 11 municipalities: Huambo, Caála, Ekunha, Longonjo, Ukuma, Bailundo, Tchinjenje, Mungo, Katchiungo, Tchicala Tcholoanga and Londuimbali (USAID, 2008).

This region includes the higher elevation mountains and the highest peak in Angola – Môco Mountain (2620 m). Most rivers rise in these central mountains, many of which drain to the Atlantic Ocean, like the Cuanza and the Cunene. The climate is humid mesothermal with a dry winter and a warm summer, with an average annual maximum temperature of less than 20 °C. The wet season goes from October to April and the dry season is between May and September (MJIU, 1961).

The vegetation present in this region is mainly composed of *miombo* and savanna woodlands, with grasslands covering areas of lower drainage. The dominant tree genera in the *miombo* floristic formation are *Brachystegia* spp., *Combretum* spp., and *Julbernardia* spp., whereas in savannas the dominant grasses (*Graminae* family) are *Hyparrehenia* spp. and *Androgon* spp..

In poorly drained areas there are hydrophilic formations dominated by perennial grasses, while sedges (*Ciperaceae* family) are present in areas permanently under water. On the high plateau tops, generally above 1750 m, this same type of vegetation appears but the rhizomatous stratum is dominated by *Loudetia simplex*, and in valleys there are also trees, namely *Brachystegia russeliae* e *Criptosepalum curtisiorum*.

Landsat data

Landsat Thematic Mapper (TM) data are available for the study area, free of charge for the period 1990–2000 from the University of Maryland's Global Land Cover Facility (http://glcfapp.umiacs.umd.edu/) and Landsat satellite Enhanced Thematic Mapper Plus (ETM+) data are available for 2008/2009 from the U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center (EDC) (http://glovis.usgs.gov/). The details of the Landsat images used in this study are given in Table 1. The sensor ETM+ carried aboard the Landsat 7 has acquired images of the Earth since April 1999 with a 16-day repeat cycle (http://landsat.gsfc.nasa.gov/

[1] http://edc2.usgs.gov/glcc/tabgeo_globe.php
[2] http://bioval.jrc.ec.europa.eu/products/glc2000/products.php
[3] https://wist.echo.nasa.gov/