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Earth observation based multi-scale assessment of logging activities in the Democratic Republic of the Congo

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ABSTRACT

The Congo rainforest, known for its high biodiversity and valuable resources, is the second largest area of rainforest in the world. Two thirds of the forest cover of the basin is located in the Democratic Republic of the Congo (DRC). Despite the importance, deforestation continues recognizing a connection between forests, logging and conflict. Increasing demand for resources, population growth and environmental stresses including climate change, will likely compound these problems. At the same time, conflicts cause serious environmental impacts, which need to be addressed to protect health and livelihoods. The risk that armed groups become involved in timber and mineral trades, that revenues be misappropriated and that forest-dependent communities are being pushed off their land also presents considerable threats to the peacebuilding process.

The present study investigates the applicability of a multi-scale approach combining pixel- and object-based images analysis methods for the assessment of different logging activities in the context of conflict in the DRC. Optical high and very high resolution satellite imagery from 2000 to 2014 are analyzed within three different districts characterizing specific logging activities. As a major result one can clearly distinguish these activities and link them to the specific situation in the respective region. In the case of Ituri district logging is directly related to the conflict situation and increasing population pressure. While the slash-and-burn activities in Tshopo seems to be stable and show only minor decrease of *primary forest*, industrial-scale logging in the Mongala district has degraded a significant amount of *primary forest* into *secondary forest* or *bare soil*.

1. Introduction

This study presents a multi-scale assessment focusing on the loss of *primary forest* attributed to different logging activities in three districts within the Democratic Republic of the Congo (DRC). The objective is to demonstrate the capabilities of satellite Earth observation (EO), applied at two distinct scale levels, (1) an overview, regional scale, for high-frequent, quasi continuous monitoring and (2) specific change analysis on dedicated areas in a detailed scale.

1.1. Natural resources and conflict in the Democratic Republic of the Congo

The Congo Basin, of which the DRC has by far the largest share, is a region of tremendous wealth with respect to biodiversity, timber, non-timber forest, mineral and hydrocarbon resources (Doetinchem et al., 2013; Global Witness, 2012; Zhang et al., 2005; Duveiller et al., 2008). The country's economy still highly depends on agriculture and forestry and rank among the poorest countries in the world (Burnley, 2011). Instead of fueling economic development, minerals and forest resources have been engines for sustaining mismanagement and conflict (Katunga, 2007; UNEP, 2009; Nellemann et al., 2010; Seyler et al., 2010; Laudati, 2013).

Forest cover declined by more than 2.5% between 1990 and 2010 in the DRC (Potapov et al., 2012; FAO, 2010). Despite several activities for the facilitation of a legal and sustainable forest management regime, amongst others by the "Central African Regional Program for the Environment (CARPE)", large forest areas are logged illegally and in an industrial, unsustainable way.

Over millennia, sedentary communities also have farmed small portions of the land in environment-sustaining, rotational ways, known as shifting cultivation. In addition, the forests play an important role in the retention and regulation of local and regional water supply and the

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climate at large. Local and international governmental and non-governmental organizations have developed approaches to preserve natural, old-grown forests through the establishment of ecotourism and conservation areas. Yet, resources such as wood, minerals and petrol found in and under their soils are also of high interest for private, profit-driven companies and the governments who aspire to get revenues from their extraction. These competing interests often create conflicts between the concerned "stakeholders", with local communities who mostly lack any statutory rights on the land they are living in and from usually losing out.

The fragmentation of rainforests by logging roads and skidding tracks results in well-analyzed secondary effects, such as encroaching agricultural land use alongside logging roads (UNEP, 2006), charcoal production, poaching as well as mining activities (Potapov et al., 2012).

1.2. Specifics of logging in the Democratic Republic of the Congo

Logging in the DRC can be subdivided into two economic categories: Firstly, an export-oriented formal sector dominated by large industrial companies contributing rather insignificantly to the national GDP, and secondly, an informal sector which has been growing rapidly in importance in order to meet local timber demands (Doetinchem et al., 2013) and in search of income. The latter can be broken down to (a) small-scale artisanal logging and (b) fuelwood and charcoal production. In addition, the opening-up of forests by logging companies facilitates expansion of slash-and-burn agriculture as a market-oriented economic activity, and as such also enters the informal economy.

With respect to all logging activities in the DRC, about 90% is done illegally (Lawson, 2014), driven by varying reasons of the above indicated different stakeholders in both logging sub-sectors.

1.2.1. Industrial logging (selective logging of the industrial sector)

The export-oriented industrial sector of the timber industry provides contributions to the GDP to various degrees in all countries of the Congo Basin. In the DRC, 149,000 km^2 of the 1.02 Mio. km^2 total forest area (de Wasseige et al., 2012) are assigned as concessions, primarily to European enterprises (Global Witness, 2013b). In contrast to other tropical regions, the extensive logging in African countries is mainly focused on selective harvesting of only a few most economically rewarding species (Doetinchem et al., 2013). While this does not endanger the forests in the Congo Basin by a complete deforestation, it strongly contributes to forest degradation and loss of biodiversity. Although by law Forest Management Plans of logging concessions limit the volume of single tree species that can be logged in annual operation cycles, experiences by Global Witness in Cameroon and the DRC show that these restrictions can be exceeded, with impunity, by up to 30% on average for much demanded, high value species. These illegal acts are facilitated by corruption and the lack of law enforcement inspections (Hillman-Smith, 2002; Greenpeace Africa, 2013; Doetinchem et al., 2013; Global Witness, 2013a). The legality of harvested and traded timber derived from industrial logging in the DRC is to 90% not verified independently, and confusing regulations make it almost impossible to implement independent verification (Lawson, 2014).

1.2.2. Small-scale artisanal logging

The importance of the informal logging sector has long been underestimated although the contribution to the domestic market demand, and moreover the creation of jobs and income nowadays exceeds that of the industrial sector (Doetinchem et al., 2013; Lescuyer and Cerutti, 2013). By definition artisanal logging means small-scale logging by usually local individuals having contracts with local landowners and logging permits obtained locally by regional/provincial administration. Alongside these practices and in the absence of any non-timber energy supply, the informal sector satisfies the increasing demand for wood as primary energy source (fire, charcoal) for local population (Spittaels and Hilgert, 2008). Today, some artisanal loggers are operating in a "semi-industrial" way, working with heavy machinery and establishing logging roads for removing timber, which simultaneously serve as entrance for hunters and farmers into the inner forests. These operators also facilitate migration of forestry workers into the region (Brown and Makana, 2010).

Another important stimulator for internal migration is conflict, with a significant increase in population in the North-eastern Ituri district – in the villages and in newly established IDP camps. The concentration of these migrants further facilitates the pressure on forest resources (Nellemann et al., 2010) as an important source for food (bush meat, establishment of fields) and energy (firewood, charcoal).

During both Congo wars (1996–2003) logging in North-eastern DRC increased significantly, facilitated by military as well as politicians (Nackoney et al., 2014; Brown and Makana, 2010). Illegal and unregulated artisanal logging continued after the 2nd Congo war ended, with major activities along the roads between Mambasa and Beni as well as Komanda and Mambasa. Along these roads our VHR study areas Biakutu and Lolwa are located.

1.2.3. Slash and burn agriculture

Slash and burn agriculture – also named shifting cultivation or swidden farming – is a traditional agricultural practice in tropical regions in which small parts of forest (3000–10,000 m^2) are cleared in order to establish new cultivations. In the DRC this is the dominant type of agriculture (Tollens, 2010) that was practiced over millennia in central Africa as the most appropriate method to regenerate the poor tropical forest soils through fallow periods to land fertile enough for planting new crops. In regions with low population pressure and subsequent rotation cycles that are long enough for soil fertility regeneration small-scale agriculture, with low productivity rates but acceptable yields (Nellemann et al., 2010; Molinario et al., 2015), is not the major driver for deforestation (Duveiller et al., 2008; Tollens, 2010). The resulting pattern in land cover is a characteristic mosaic of *secondary forest*, fallow land and *bare soil* surrounded by *primary forest* which can be found along major transport routes and in the vicinity of small villages (Molinario et al., 2015; Duveiller et al., 2008; Mayaux et al., 2000). Thus, limited population pressure provides the basis for traditional, sustainable shifting cultivation with low rates of *primary forest* loss (Molinario et al., 2015; de Wasseige et al., 2012).

This sustainable system gets out of balance in regions with high and even increasing population densities, often aggravated by migration caused by land grab or violent conflicts, such as in eastern DRC, creating in turn new conflicts.

1.2.4. Fuelwood and charcoal production

In areas with no alternative energies accessible, fuelwood serves as cooking energy (Daurella and Foster, 2009). This also applies to the Congo Basin, as well (Marien, 2009). Thereby, forests in the vicinity of urban areas are most important for the collection of fuelwood resulting in a high rate of deforestation (de Wasseige et al., 2012). According to the Food and Agriculture Organization of the United Nations (FAO) 90% of all wood removal from forests in Africa is assigned to fuelwood and charcoal which points to the negative impact, namely deforestation and forest degradation (FAO, 2011). Growing population which is fostered by conflict-induced migration results in increasing demands for fuelwood and charcoal. Additionally, raising demand for new cropland and forest resources as source of income needs to be balanced with the conservation of tropical forest (Sigler, 2012). Solving the problems of increasing population pressure and local concentration of population seems to be one of the major tasks combined with an overall strategy for sustainable resource management. With respect to the eastern DRC this means stabilization and long-term peace-building.

1.3. The benefit of Earth observation

Technological sensor developments and analytical capabilities