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Exploring Drivers of Forest Degradation and Fragmentation in Sudan: The Case of Erawashda Forest and its Surrounding Community

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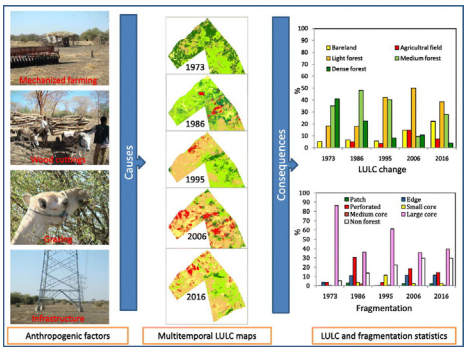
HIGHLIGHTS

- Assessment of impact of land use and land cover (LULC) changes on forest degradation and fragmentation
- Trajectory analysis showed that LULC changes are very dynamic.
- Forest fragmentation indices computed are patch, edge, perforated and core.
- Anthropogenic stressors are mechanized agriculture, wood extraction, grazing and constructions.
- The findings provided spatio-temporal information that support rehabilitation programs.

GRAPHICAL ABSTRACT



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ABSTRACT

Sudan is a hot spot for forest degradation. Efforts to maintain what remains of its forests should be of the highest priority. However, precise information on its forests' current state is very limited. Therefore, in order to effectively intervene in support of existing resources, it is important to have a better understanding of processes taking place in the country and impacting those resources. The objectives of this study are to quantify the consequences of land use and land cover (LULC) changes on forest degradation and fragmentation and to analyze the anthropogenic factors causing it, taking Erawashda Forest, eastern Sudan, as an example. The study utilized a series of Landsat imageries, field surveys and interviews with informants to analyze the decrease in forest cover. The years between 1973 and 2015 saw a 16.9% and 5.4% increase in bare land and large-scale mechanized agriculture respectively. During the same period there was a 37% decrease in dense forest cover and a 20% increase in light forest cover. The trajectory analysis showed that all LULC categories are subjected to very rapid changes from one class to another throughout the period of the study and the most dynamic class is light forest cover. Computed fragmentation indices showed that large core is the dominant category. Key informants identified the main factors of degradation and fragmentation as the expansion of mechanized rain-fed agriculture, felling of trees and wood cutting, bad grazing activities, and construction of infrastructure. Information garnered from this study can provide a good basis for forest rehabilitation programs and can also be used for developing proper management plans that take into account the needs of the communities utilizing the forest.

1. Introduction

Forest degradation poses a great threat to the stability of global climate, because forests store more carbon than any other terrestrial ecosystem (Skole and Tucker, 1993; Gibbs et al., 2007). Even though

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globally the rate of forest loss has decreased (FAO, 2015), changes in forest cover continue to represent one of the most important topics in global environmental discussions and negotiations. Therefore, reliable and up-to-date information on the state of forest resources is still crucial.

Drivers of forest degradation such as extraction of resources, conversion to agriculture, human settlements and their associated infrastructure are leading to forest fragmentation (Crooks et al., 2011; Uddin et al., 2015). According to Hobbs et al. (2008), fragmentation is one of the most pervasive effects of humans on the environment and has emerged as a primary component of global change. Forest fragmentation refers to any process that result in the conversion of formerly continuous forest into patches of forest separated by non-forested lands (FAO, 2007). It is a complex process resulting from dynamic interactions between the natural landscape and the ever-increasing demands of its surrounding populations, generating a mosaic of natural and human-transformed environments (ibid.). Forest fragmentation is occurring mostly as a result of human interventions, in many cases in the name of development. Among the marked consequences of forest fragmentation are detrimental impacts on biodiversity loss and on species distribution (Bogaert et al., 2011; Sharma et al., 2016), loss of area, increase of isolation (Pereira et al., 2010; Haddad et al. 2015), and ultimately ecosystem services (Fremier et al., 2013). Under severe appropriation by humans, fragmentation may threaten forests functionally as ecosystems (Laurance et al., 2002; Castelletta et al., 2005).

Accurate mapping and quantification of land use and land cover (LULC) using space-borne imagery, has become a prerequisite for effective fragmentation analysis. Lambin et al. (2003) state that impact on forest fragmentation requires accurate measurements of LULC conversions. Such measurements reveal how human activities are transforming natural ecosystems. Most of these observations take place in forest areas due to the fact that the contrast between forest and human-induced LULC is high (Haddad et al., 2015). Understanding the complexity of landscapes requires mapping the landscape through time and tracing the evolution of LULC transformations (Narumalani et al., 2004; Kamusoko and Aniya, 2007). Thus, the combination of remote sensing data, Geographical Information System (GIS) and landscape metrics can provide more spatially consistent findings, which in turn will facilitate the recognition of the social and biophysical processes driving landscape fragmentation (Sader et al., 2001; Brown et al., 2000; FAO, 2007; Sharma et al., 2016).

In fact, fragmentation of a habitat into smaller parcels can negatively impact ecosystem processes and the flow of ecosystem services, which in turn affects communities relying on forests to secure their livelihood (Wade et al., 2003; Shapiro et al., 2016). In the context of Africa, forests are essential for the survival and the welfare of millions of people, especially in the rural areas. According to Somorin (2010), over two-thirds of people are rely directly and indirectly on forests to secure their livelihoods. Because of the ongoing forest degradation caused by factors such as droughts, agricultural expansion, or an increasing demand for charcoal and firewood in rural areas and urban centers, the contribution of forest resources to the livelihood strategies of the rural poor may not continue for long (Kandji et al., 2006; Vincke et al., 2010). Over-exploitation of forest resources in Sudan has caused one of the highest deforestation and degradation rates in Africa (FAO, 2011). Like many African countries, the majority of the population in Sudan relies on land resources to secure its livelihood. The people derive their income from various combinations of farming, livestock rearing and forest exploitation. Additionally, the horizontal expansion of agriculture, rather than vertical improvement in productivity, is resulting in drastic clearance of forests in Sudan (Sulieman and Elagib, 2012). About 95% of forests in eastern Sudan were cleared to make way for agricultural expansion (Suliman, 1992). Sulieman and Ahmed (2016) report that land for large-scale mechanized agriculture in Gadarif State increased from 500 ha in the 1940s to about 4 million ha today. Elnagheeb and Bromley (1994) argued that agricultural expansion is one of the major factors contributing to the destruction of forests in Africa and in Sudan.

Gadarif State, eastern Sudan, is one of the hot spots of forest degradation in Africa. Understanding the ongoing processes impacting the remaining forest is of the utmost importance. This study uses the example of Erawashda Forest and its surrounding community to quantify the consequences of LULC changes on forest degradation and fragmentation and to identify main anthropogenic factors driving these changes.

2. The study area

2.1. The Erawashda Forest reserve

The Erawashda Forest reserve (officially Erawashda and Wed Kabo) (Fig. 1) represents one of the few remaining forests in Gadarif State. It is located approximately 25 km northeast of the city of Gadarif, the capital of the state. It covers an area of about 50,400 ha and is the largest forest in Gadarif State. It lies in a semi-arid zone with an average annual rainfall of 500 mm, mainly from July to September. The average temperature during the hottest months (April or May) is around 40 °C and the mean minimum temperature during the coolest month (January) is 13–17 °C. The soil type is heavy cracking vertisol. It has a good holding capacity and it is reasonably fertile. Ecologically, the forest lies in the semi-arid zone of the south central clay plains where there is a transition from *Acacia mellifera* to the *Acacia seyal - Balanites* savannah woodland (Vink, 1987). Main tree species are *Acacia seyal* var. *seyal*, *Acacia mellifera*, *Balanites aegyptiaca* and *Acacia nubica*, with *Acacia senegal* and *Ziziphus spina-christi* and *Acacia seyal* var. *fistula* also present.

Erawashda Forest is situated between two major cities, Gadarif and Showak, and is surrounded by seven villages (Fig. 1). The highway that connects East Sudan and Khartoum crosses the forest. The forest is surrounded by agricultural land. It is the main firewood and charcoal source in the area. Moreover, it is a major fodder resource for livestock owned by the community settled around it and the transhumant pastoralists crossing the forest in their annual cycle of movement. According to Harris (2000), Erawashda Forest resources have been subjected to increasing pressure from people and livestock. Much of this pressure is attributable to the reduction of grazing lands in the vicinity of the forest as a result of the expansion of large-scale mechanized agriculture. Whilst the outer boundaries of the forest are to a certain extent protected by law as a reserve area, degradation and fragmentation are taking place in many areas inside the forest. However, Erawashda Forest still represents the original natural cover, which once prevailed in the area, and is the last existing forested area in the dry savannah. From an environmental and biodiversity point of view, it is a very important resource (El-Dool, 1994).

2.2. Communities surrounding the forest

As shown in Fig. 1, Erawashda Forest is surrounded by a good number of settlements consisting of seven villages and two former refugee camps, which are somewhat farther away to the northeast of the forest. Some communities have been in the area for centuries, such as the villages of Wed Elnair and Wed Kabo. Most of the other settlements were founded in the early 1900s. Kurkora and Um Gargour were established in the mid-1970s as refugee camps to host Eritreans displaced from their home country during the civil war. Farming is the main activity. However, farming is normally combined with livestock rearing. Collecting and trading of forest products and charcoal are other economic activities. Due to the rapid expansion of large-scale mechanized agriculture, local farmers have no way to continue practicing the traditional shifting cultivation and are forced to farm the same piece of land without fallow periods or even crop rotation. Sorghum and sesame are the main crops. Glover (2005) notes that, due to the expansion of large-scale mechanized farming, traditional shifting cultivation is no longer practiced in the area and that, with the growing population, a group of landless peasants emerged in the process.