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Assessment of charcoal driven deforestation rates in a fragile rangeland environment in North Eastern Somalia using very high resolution imagery

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Multi-temporal very high resolution satellite images and field work have been used for quantifying the tree cutting rate over a 5 years period in a very arid tiger bush area of North Eastern Somalia with intensive charcoal production activities. By applying both a classical area frame sampling approach with visual interpretation of the samples and a semi-automatic tree detection algorithm, it was possible to create baseline tree density layers for the 2 years of observation and to quantify the tree cutting rates for the period from 2001 to 2006. An average annual tree loss of −2.8%, coupled with the total absence of regrowth during the 5 years study period, confirm the tremendous ecological impacts of charcoal driven tree cutting on tiger bush vegetation. Analysis of the results evidences spatial and temporal patterns in the cutting locations and poses the basis for a better understanding of the ecological and human dimensions of deforestation in the fragile rangeland environment of Northern Somalia.

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1. Introduction

1.1. Background

Tiger bush is a rare and vulnerable ecosystem occupying extremely dry climatic zones located mainly in Africa, Australia and Northern America. Human intervention and in particular a reduction of tree density in such areas can lead to rapid deterioration of the ecosystem, while accurate management of tree resources is crucial for long term sustainability especially in front of the threats of climate change (Valentin and d'Herbes, 1999).

The Sool Plateau in North Eastern Somalia, which includes the tiger bush ecosystem of this study, is one of the regions in Eastern Africa most frequently hit by drought. At the end of 2009 it was classified as "humanitarian emergency" area by the IPC (Integrated Food Security Phase Classification) as a consequence of 4 consecutive drought seasons (FSNAU, 2010). This fragile environment is particularly under pressure after the breakdown of governance in Somalia in 1991, and the following continuous decrease of civil security has opened the way to uncontrolled depredation of resources and often results in serious threats for sustainable resources management by local communities. Land degradation has been identified as a serious problem across the country, and actions to combat it are generally hindered by the enduring humanitarian and institutional crisis (Omuto et al., 2009). The progressive reduction of vegetation cover is one of the main types of land degradation in the whole country, due to different activities like livestock grazing and wood collection which cannot be sufficiently managed and controlled due to the lack of security (Omuto et al., 2009). The tree layer is well known as the main vegetation type used for fuel wood collection, fencing and construction materials. Charcoal, produced primarily from slow-growing acacia trees, is an important domestic energy source as in many African countries, but in Somalia its production is largely driven by foreign demand (UNEP, 2008). Trade in charcoal, known to many as "black gold", has developed into a very lucrative line of business (Bakonyi and Abdullahi, 2006). Every month, shiploads of charcoal are exported to the neighbouring Arab states and the profit made by well-organized armed groups makes it difficult for the local tribes

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to protect and manage their trees in a sustainable way. There have been several attempts in literature to quantify the production of charcoal (Fig. 1).

As per Fig. 1, the demand for charcoal increases in time and has clearly accelerated during the last 20 years and especially after the fall of the last stable government in Somalia in 1991. Large differences are visible in charcoal production estimates from different sources and very limited or no data at all are available on the tree density dynamics. As a result, sustainability of tree cutting, if any, is generally impossible to assess.

Using medium resolution remote sensing images and expert assessment, the tiger bush ecosystems of North Eastern Somalia were identified as areas in which tree cutting for charcoal burning is a common activity. However, it was not possible to come up with quantitative estimates of the tree-cutting rate (Oduori et al., 2009; Oroda et al., 2007).

The recognition of single trees is one of the main tasks when deriving forest information from very high resolution (VHR) remote sensing data and several image analysis approaches have been developed to tackle the issue (Fadaei et al., 2010; Hirschmugl et al., 2007; Karantzalos and Argialas, 2004; Leckie et al., 2005). The detectability of single trees has been shown to depend on a variety of factors with the most significant being the spatial resolution of image data in comparison with the size of the tree to be detected. Overlapping crowns especially for trees of different ages make detection more difficult (Hirschmugl et al., 2007; Leckie et al., 2005). Pansharpening has been found as a necessary processing step before applying any tree detection algorithms by Fadaei et al. (2010).

1.2. Objectives

The main objectives of this study are:

- to generate baseline data on tree density in the study area in Northern Somalia over two different periods (2001) and (2006) using very high resolution satellite imagery (IKONOS and QUICKBIRD);
- to apply a classical robust sampling procedure for tree counting and at the same time to test more complex automatic tree detection procedures to be applied in other woodlands in Somalia,.
- to detect tree cover changes and calculate the rate of tree cutting for the study period 2001–2006;

2. The study area

2.1. Study area location

The study area is located in the Sool–Sanag Plateau in Northern Somalia, on the border between the Sool and Sanag regions and is politically disputed between the two autonomous macro-regions of Somaliand and Puntland since 1998. The study area covers approximately 1929.5 km^2 of this extremely arid plateau with micro-dunes, sandy soils and very sparse vegetation. Rainfall typically ranges between 100 and 200 mm per year with a bimodal rainfall distribution, while mean annual temperatures vary between 24 °C and 28 °C. The first rainy season is called Gu and occurs between April and June. The dry season that follows the first rains is called Xagaa and lasts between July and September followed by the second rains called Deyr (October–November). The period between December and March is dry and is known as Jilaal. Rainfall is highly variable temporally and spatially and can be described as erratic.

2.2. The tiger bush ecosystem

The area is characterized by the rare tiger bush vegetation (Oroda et al., 2007), named according to it's classical pattern consisting of alternating bands of trees or shrubs, separated by bare ground or low herb cover, that run roughly parallel to contour lines of equal elevation. The patterns occur on low slopes in arid and semi-arid regions, such as in Australia, Sahelian West Africa, Somalia (Paron and Goudie, 2006) and the USA. The particular spatial vegetation pattern depends on two main factors: slope gradient and mean annual rainfall (d'Herbes et al., 2001; Valentin et al., 1999). Trees and shrubs are able to grow under extreme climatic conditions by either tapping soil moisture reserves laterally or by sending roots to deeper, wetter soil depths. By a combination of plant litter, root macropores, and increased surface roughness, infiltration into the soil around the base of these plants is enhanced. Surface runoff arriving at these plants will thus likely to become run-on, and infiltrate into the soil. Woody vegetation is made up of open shrubs covering 15–65% with sparse trees (1–15%). The woody plants here include *Acacia bussei*, *Acacia tortilis*, *Acacia nubica*, *Boscia minimifolia* and *Acacia melifera* while the herbaceous species include *Andropogon kelleri* and *Sporobolus spicatus*.

Tiger bush never develops on moderate to steep slopes, because in these cases surface runoff concentrates into narrow threads or rills instead of flowing over the surface as sheet flow. Sheet flow

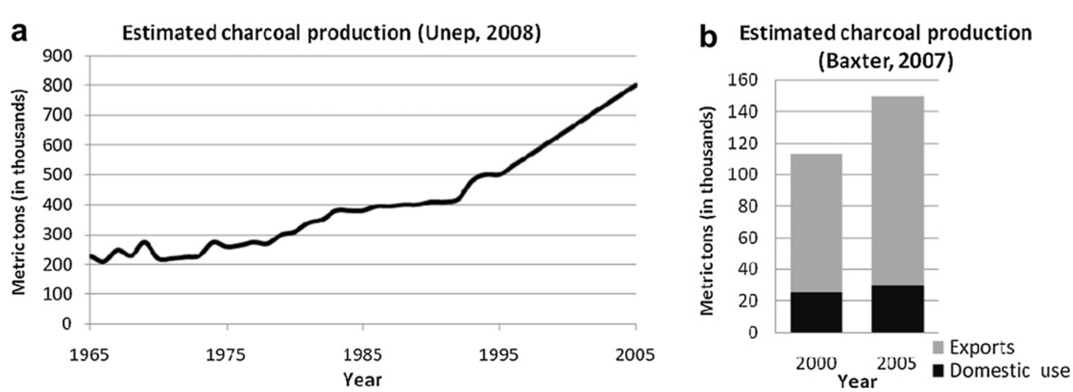

Fig. 1. Charcoal production in Somalia (Source: a) UNEP 2008; b) Baxter, 2007). The estimates vary significantly for different sources. However, it is interesting to observe that the slope of the continuous production increase becomes clearly steeper in 1992 which marks the end of political stability in Somalia (a). Lack of state control and civil insecurity favour the depredation of natural resources across the country and make charcoal export (b) a lucrative business.

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