

Wood biomass availability for smallholder charcoal production in dry forest and savannah ecosystems of south-western Madagascar



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ABSTRACT

Deforestation has accelerated over the last decades in south-western Madagascar due to overutilization of natural resources, slash and burn agriculture and charcoal production. To provide information for sustainable forest management, we assessed the biomass availability of woody species frequently used for charcoal production. Semi-structured household interviews ($N = 63$) were conducted to collect information on charcoal production activities and identify the species used for this activity. A cluster sampling approach was applied to inventory woody species and measure DBH, total height and crown diameter. Allometric equations for wood biomass and wood volume estimation were established for *Acacia bellula* ($N = 20$), *Acacia royumae* ($N = 18$), *Albizia polyphylla* ($N = 17$), *Cedrelopsis* spp. ($N = 13$) and mixed species ($N = 43$).

Altogether, 68 species were found to be used for charcoal production. High correlations between DBH, total height and wood biomass were observed (R^2 varied between 0.78 and 0.99). Wood biomass increased with distance to settlements and significantly differed between land cover types with highest values in the dry forest. Overall, tree biomass near villages was lower than biomass inside the National Park and in other semi-arid regions, mainly due to anthropogenic activities such as charcoal production.

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1. Introduction

Forests and savannah ecosystems are known to deliver ecosystem services such as erosion control (Zhaoa et al., 2009), desertification control (Carucci, 2000; Malagnoux et al., 2007), watershed protection (Malagnoux et al., 2007), biodiversity conservation (Wu et al., 2010) and carbon sequestration (Sedjo, 2001). Moreover, they often contribute directly to the livelihoods of indigenous populations in tropical countries (Chidumayo and Gumbo, 2010; Shackleton et al., 2007). In many rural areas, people largely depend on tree-based resources such as wood for house construction, wood carvings, fuelwood and non-timber forest products (NTFPs) including food, medicinal plants and animal fodder (Paré et al., 2010; Shackleton and Shackleton, 2004).

In the semi-arid region of south-western (SW) Madagascar, forests and trees are crucial for human nutrition and health care particularly during the lean period, providing fruits, tubers and medicinal plants (Andriamparany et al., 2014, 2015). The forest

contains multiple medicinal plants that are frequently used by local people (Andriamparany et al., 2014). Moreover, it provides wood for houses (*Cedrelopsis* spp.), fuelwood (mainly dead wood) and coffin construction (*Albizia tullearensis* R.Vig., Ratvonamana, 2016). It is also a source of animal fodder such as *Euphorbia stenoclada* Baill. (a succulent) widely used as supplementary feed for Zebu cattle (Feldt and Schlecht, 2016; Kaufmann and Tsiarahamba, 2006; Rabesandratana, 1999). Finally, the forest provides social services in this region: sacred groves and trees are believed to be intermediaries between the spirits of ancestors and living people, who visit these sites to pray for blessings (Ranaivoson et al., 2015; Tengö et al., 2007).

During the last decades heavy forest losses were observed in the Mahafaly region leading to high deforestation rates (Brinkmann et al., 2014) which can be attributed mainly to slash and burn agriculture and charcoal production activities (Casse et al., 2004). Okello et al. (2001) reported that selective extraction of woody species for charcoal production can lead to fundamental changes in forest composition and structure. As in many other African countries, charcoal is the most important energy source for heating and cooking, especially in urban areas due to its high energy density yet

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affordable price (Bailis et al., 2005; Ellegård, 1996; Girard, 2002). It burns more cleanly than wood and thus causes less respiratory illnesses (Ezzati and Kammen, 2002). Additionally, charcoal production provides income for rural population, transporters, collectors and urban sellers (Brouwer and Falcao, 2004; Coomes and Burt, 2001; Ruuska, 2013), and can contribute to a viable livelihood strategy if forest resources are managed sustainably and suitable settings for production are in place (Coomes and Burt, 2001; Ruuska, 2013). Charcoal production in the Mahafaly region reportedly started in the early 1970s near important market places (Sussman et al., 1994). Although rural people in SW Madagascar mostly use fuelwood and dead wood material for cooking, charcoal is produced in large amounts and sold along major roads and on markets to satisfy the energy demands of urban people in nearby Tuléar, the capital of the Atsimo-Andrefana region. The charcoal demand of the urban population of Tuléar is almost fully covered by the nearby dry forests of SW Madagascar (Waeber et al., 2015). During the past two decades population growth in this town has boosted demand for charcoal and increased its production in rural areas, which has tripled from 2000 to 2012 (Waeber et al., 2015; WWF, 2012). However, it has been predicted that the supply will not be able to satisfy demand by 2030 (WWF, 2012).

In view of the increasing pressure of charcoal production on forest and savannah ecosystems in SW Madagascar and its importance for local livelihoods, knowledge on the preferred woody species, their current stock, distribution and wood biomass is urgently needed for the development of more sustainable land management strategies to slow down the overutilization of natural

resources (Okello et al., 2001).

Using semi structured interviews, field inventory data, allometric equations and spatial geographic data, this study aims to provide information on woody species used in charcoal production activities and the availability of wood biomass in different land cover types of the Mahafaly region. We hypothesize that wood biomass in forests increases with increasing distance from villages and roads.

2. Material and methods

2.1. Description of the study site

The Mahafaly region is located 90 km south of Tuléar, and constitutes one of the poorest regions of Madagascar. It is characterized by an altitude of < 400 m (Fig. 1), a semi-arid climate with a dry period lasting eight to nine months and very irregular rainfall with a long term annual average < 500 mm and a mean temperature of 24 °C (Hanisch et al., 2015). The region comprises different habitats from a coastal plain to a vast limestone plateau including the dry spiny forests and shrublands of the Tsimanampesotse National Park. The coastal plain is characterized by coastal shrubland dominated by *Euphorbia stenoclada* Baill. (Razanaka, 1996) on unconsolidated sands and saline soils (Besaire, 1946) with an annual average rainfall < 350 mm. The plateau area east of the National Park is dominated by limestone and siliceous red soils, covered by savannah grasslands with *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult. (Morat, 1973), interspersed with dry spiny forest

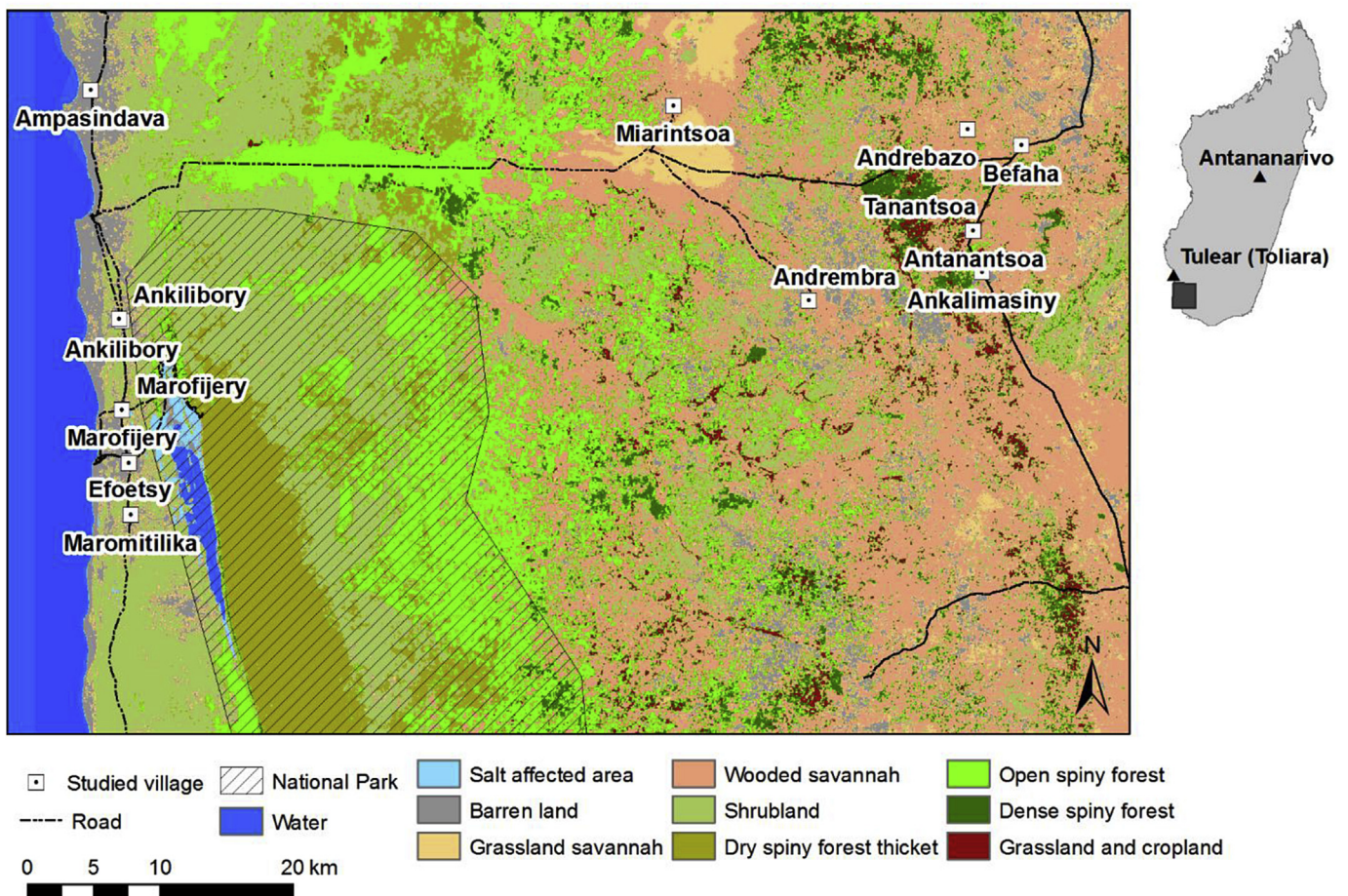


Fig. 1. Location of the studied villages in the Mahafaly region, SW Madagascar.

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