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Effects of goat grazing and woody charcoal production on xerophytic thickets of southwestern Madagascar

Josoa R. Randriamalala [a], Heriniaina O. Radosy [a], Samuel Razanaka [b], Herizo Randriambanona [b], Dominique Hervé [c, *, 1]

[a] Département des Eaux et Forêts, École Supérieure des Sciences Agronomiques, Université d'Antananarivo, BP 175, Ankatso, Antananarivo 101, Madagascar
[b] Centre National de Recherches sur l'Environnement (CNRE), BP 1739, Antananarivo 101, Madagascar
[c] Institut de Recherche pour le Développement (IRD), UMR GRED (IRD-UPV), BP 64501, 34394 Montpellier Cedex 5, France

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ABSTRACT

The effects of goat grazing and woody charcoal production are analysed on the diversity, structure, production and regeneration of the xerophytic thickets in southwestern Madagascar. Twenty (20 × 20) m^2 plots were sampled according to soil type (yellow sand and calcareous) and disturbance intensities (low: ungrazed and no woody charcoal production; high: grazed and with woody charcoal production). Woody charcoal production reduced shrub density and biomass and affected species composition on yellow sand soil. In contrast, goat grazing alone did not significantly affect the diversity, mean height, stem and leaf biomass or species composition of xerophytic thickets on calcareous soil. However, shrub regeneration rate was low on both grazed and ungrazed sites. Rainfall variability may be the reason for this low regeneration. Goat grazing at a moderate stocking rate (~1 head per ha) does not affect xerophytic thickets communities (plant diversity, biomass, regeneration rate). This finding indicates a need to (i) emphasize individual case studies that help to manage shrub pasture in semi arid regions, and (ii) avoid broad generalisations about the negative effects of goats on dry vegetation. Furthermore, goat breeding may be a viable alternative to woody charcoal production in these xerophytic thickets.

1. Introduction

With very few resources available in semi-arid environments, populations living in such areas make extensive use of forest resources. Forests provide goods and services such as arable land, food, fodder for livestock (especially small ruminants), timber and fuelwood (Pote et al., 2006; Abule et al., 2007; Songer et al., 2009).

Small ruminants, especially goats, dominate the breeding sector in semi-arid areas and are the main source of meat (Landau et al., 2000). Breeding small ruminants helps to improve the livelihoods of local populations and contributes to regional economies (Mahieu et al., 2008; Schlecht et al., 2011). Many studies have analysed the effects of goat grazing on semi-arid vegetation. Heavy goat grazing reduces shrub cover (Severson and Debano, 1991; Mellado et al., 2003; Jauregui et al., 2008; Bermejo et al., 2012), impairs the potential regeneration of fodder species (Moser-Norgaard and Denich, 2011; Säumel et al., 2011), and, to a lesser extent, species richness (Arévalo et al., 2007). Goat grazing can also negatively affect seed production (Sigwela et al., 2009). The characteristic variability in precipitation in many semi-arid climates usually leads to frequent and prolonged droughts that increase the negative effects of goat grazing on biomass production and plant diversity (Archer, 2004; Bermejo et al., 2012; DeMalach et al., 2014). However, when stocking density is moderate, goat herbivory can stimulate shrub shoot growth (Oba, 1998) and twig biomass production (Oba and Post, 1999). Furthermore, and again under moderate stocking conditions, goats can play a role in seed dispersion in semi-arid ecosystems (Baraza and Valiente-Benuet, 2008; Rosa Garcia et al., 2012). The effects of goat grazing on vegetation thus depend on goat stocking density (Rosa García et al., 2012) and pasture management. Appropriate pasture management, such as one including grazing rotation, can considerably reduce livestock

* Corresponding author. Present address: CNRE, BP1739, Antananarivo 101, Madagascar.
E-mail addresses: rramarolanonana@yahoo.fr (J.R. Randriamalala), vonenina@gmail.com (H.O. Radosy), samuel.razanaka@gmail.com (S. Razanaka), zombanona@yahoo.fr (H. Randriambanona), dominique.herve@ird.fr (D. Hervé).
[1] Permanent address: IRD, UMR GRED (IRD-UPV), BP 64501, 911 avenue Agropolis, 34394, Montpellier Cedex 5, France.

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pressure on pasture vegetation and contribute to biodiversity conservation.

Woody charcoal is the main source of domestic energy in many developing countries, particularly in Africa (Mahiri and Howorth, 2001; Oduori et al., 2011). The cutting and harvesting of trees for charcoal production, and, to a lesser extent, for fuelwood, are important causes of land degradation in semi-arid areas (Wezel and Bender, 2004; Masezamana et al., 2013). However, studies of woody charcoal production practices mainly focus on socio-economic questions (Pote et al., 2006; Naughton-Treves et al., 2007). Assessments of the impact of this activity on forest ecosystem diversity, structure and biomass production are scarce (Naughton-Treves and Chapman, 2002;Kouami et al., 2009). The cutting of trees and shrubs for charcoal production can reduce forest density (Wezel and Bender, 2004; Oduori et al., 2011) and wood carbonisation can be a source of uncontrolled forest fire (Wezel and Bender, 2004).

Although the xerophytic thickets of southwestern Madagascar contain many endemic species and are hot-spots of biodiversity (Moat and Smith, 2007), they are grazed by goats and are a source of woody biomass for charcoal production and fuelwood (Raoliarivelo et al., 2010). However, little is known about the effects of goat grazing and woody charcoal production on Madagascar's dry vegetation, which currently is undergoing degradation and deforestation (Seddon et al., 2000; Masezamana et al., 2013). This paper analyses the impacts of goat grazing and woody charcoal production on xerophytic thickets vegetation. Two working hypothesis were tested: (i) goat grazing alone inhibits the regeneration of xerophytic thickets and reduces the leafy biomass (twigs $\leq$3 cm diameter; stems and leaves) that can be browsed by goats, and (ii) the combination of woody charcoal production and goat grazing reduces the diversity (species richness and evenness) and biomass production of xerophytic thickets.

2. Methods

2.1. Study site

The study site is located in Soalara-Sud commune, Toliara II District, in southwestern Madagascar (Fig. 1). The climate is semi-arid with a mean annual rainfall of about 400 mm (Radosy, 2013). Over 67% of annual precipitation falls between December and February (80–90 mm per month), and the remaining 9 months are mostly dry. The natural vegetation of the study site is composed of xerophytic thickets (XT), characterised by species from the *Didieraceae* and *Euphorbiaceae* families (Cornet and Guillaumet, 1976). The two main soil types are rocky calcareous and yellow sand soils. The local population belongs mainly to the *Tanalana* ethnic group. Small ruminant breeding and woody charcoal (WC) production are the most important sources of income (Raoliarivelo et al., 2010). These two activities are carried out by almost every household in the study site (Rabeniala et al., 2009). Those who possess few small ruminants tend to devote comparatively more time to woody charcoal production (Raoliarivelo et al., 2010).

2.2. Small ruminant breeding in the study site

The breeding of small ruminants (goat, *Capra hircus* and sheep, *Ovis aries*) is the main activity of the local population and is conducted extensively in the study area. Breeders aim to possess as many heads as possible. The density of small ruminants in the study site is about one animal per hectare (Rabeniala et al., 2009). As goats constitute over 85% of the herd (Rabeniala et al., 2009), only goat pastoral practices are considered in this study. Rabeniala et al. (2009) estimated the mean number of goats per household to be 60 (2–180 goats). Goat breeding is oriented first to meat and second to milk production. In the study area, Randriamalala (2014) observed that goat diets are essentially formed by shrub leaves, shoots and twigs and identified the species most consumed by goats to be *Commiphora* sp., *Rhigozum madagascariense* Drake, *Talinella boiviniana* Baillon, *Dicoma incana* (Baker) O. Hoffm, *Diospyros latispathulata* H. Perrier, *Solanum bumeliaefolium* Dunal and *Chadsia flammea* Bojer. Goat pastureland lies on both calcareous and yellow sand soils.

Goatherds release goats from their night pens around 6 or 7 am and lead them first to a nearby water point located less than 1 km from the village (less than a 30 mn walk away) before continuing on to distant pastures. Goatherds leave the herds alone in these pastures during the day, returning around 3–4 pm to lead the herds back to their pens. Goats thus graze pasture for 10–12 h a day (Randriamalala, 2014). Goat pens are located near villages (<2 km) and goat pasture sites lie within a 3 km radius around the pens (Randriamalala, 2014). The distance from villages consequently can be used as a proxy for grazing intensity: xerophytic thickets within a 5 km radius of a village are grazed by goats while those located outside this radius are not.

2.3. Woody charcoal production in the study site

Woody charcoal (WC) production is an important source of income for the population living in the study site. All of the production is concentrated in Soalara commune and exported by pirogue from Soalara to the town of Toliara, located about 25 km away by sea (Ramaroson, 2014). WC production is initiated by cutting the trunks and main stems of trees and shrubs with hard wood and drying them for 1–7 days. The wood is then carbonised in a furnace consisting of a hole about 0.8 m deep, 3 m long and 2 m wide. The wood is put into the hole, with bigger trunks placed on top of smaller ones to make it easier to light the fire, forming a pile rising about 1 m above the ground. Once the fire is lit, the pile of wood is covered first by branches and then by soil. The carbonisation process takes 7–10 days. WC is produced exclusively on yellow sand soils because rocks in calcareous soils make it difficult to dig WC furnaces (Radosy, 2013).

WC production sites currently are located less than 4 km from the villages of Soalara commune and lie in the eastern part of the commune. The villages are located in the western part near the Mozambique Channel (Fig. 1). WC producers hire carts pulled by zebus to transport the charcoal from the production sites to Soalara harbour for export. To remain profitable for the producer, the round trip journey must be made within a day (Raoliarivelo et al., 2010). Therefore, distance from villages can again be considered as a proxy for the intensity of disturbance caused by WC production: it decreases when distance from a village increases. Distance from villages consequently is a proxy for both grazing intensity and intensity of disturbance caused by WC production.

As goat grazing activity, fuelwood for cooking is also collected on sites near the villages of the commune, both on yellow sand and calcareous soils. However, the corresponding woody biomass was not estimated in this study, which focuses only on woody charcoal. We assumed that the quantities of wood collected in this framework, mainly dead trunks, are limited by the family needs, compared to the biomass collected for WC production, which is exported to the nearest town.

2.4. Vegetation survey

Twenty (20×20) m^2 plots were randomly sampled according to soil types and disturbance intensities combining goat grazing and woody charcoal production. The most disturbed sites are located