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Brazil nut stock and harvesting at different spatial scales in southeastern Amazonia

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ABSTRACT

Evaluations of the effects of non-timber forest product (NTFP) extractive industries by traditional communities have focused on local effects, but effective conservation of species often requires evaluation at wider scales that can only be efficiently undertaken with the use of remote sensing. Brazil nut (*Bertholletia excelsa* seed) is one of the most important NTFP in the Amazon basin and has received considerable attention from researchers aiming to guarantee its sustainability. However, most studies evaluating the impacts of *B. excelsa* seed harvesting investigated only effects in harvested sites, and did not consider *B. excelsa* availability in the landscape, or patterns of harvesting at broader scales, which are critical to evaluate the viability of extraction and plan management practices. We used high-resolution satellite images associated with ground truthing, participative mapping with harvesters and harvest records, to evaluate abundance of *B. excelsa* in the territories of three Kayapó indigenous communities in southeastern Amazonia. This allowed us to obtain conservative estimates of the proportion of Brazil nut harvested by the Kayapó at scales appropriate to evaluate effects on stocks in the landscape and in harvested groves. *B. excelsa* groves are abundant in the Kayapó lands, but only about 30% of them are harvested. In recent years, the villagers have harvested from 7.2% to 43% of the seeds produced in harvested groves. These represent only 2.5–12.7% of total seeds estimated to have been produced within the Brazil nut-collection territories of those Kayapó villages. Our results show that the Kayapó have undertaken non-intensive Brazil nut harvesting at local and especially at landscape scales, which suggests that *B. excelsa* is currently not threatened by harvesting in the region and that there is still potential to expand commercial production in at least one of the sites. The application of similar multi-scale approaches in other sites and for other non-timber forest products would provide important information to evaluate their long term conservation, subsidize the development of management plans and help to guarantee the livelihoods of traditional communities.

1. Introduction

Non-timber forest products (NTFP)[1] have been considered one of the best alternatives for income generation by traditional people and for conservation of Amazonian forests (Anderson, 1990; Clay, 1997; Nepstad and Schwartman, 1992; Richards, 1993). However, together with the growing importance of NTFP as a conservation tool, concern over sustainability of their harvesting has increased, since overexploitation has been shown in many cases to cause ecological impacts for the harvested species (Gaoue and Ticktin, 2008, 2010; Nakazono et al., 2004; Peres et al., 2003; Scoles and Gribel, 2012; Ticktin, 2004; Ticktin et al., 2002). The availability of high-quality ecological information is critical to evaluate and plan sustainable harvesting of a NTFP, and estimates of resource distribution, abundance and productivity are considered to be the main inputs required for this evaluation (Peters, 1994). Information on spatial variation in environmental and harvesting conditions is also necessary to evaluate the impacts of harvesting (Gaoue and Ticktin, 2008; Ticktin, 2004).

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[1] NTFP is the abbreviation of non-timber forest product throughout the article.

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Brazil nut, the seed of *Bertholletia excelsa* Bonpl. (Lecythidaceae), is one the most important NTFP in the Amazon forest and is harvested almost exclusively from the wild (Clay, 1997; Mori, 1992; Ortiz, 2002). Brazil nuts have been harvested by indigenous people for thousands of years, and their commercialization is an important source of revenue for indigenous and riverine families in this region (Clement, 1999; Escobal and Aldana, 2003; Ortiz, 2002). Due to its importance for the Amazonian economy, *B. excelsa* has received considerable attention from scientists aiming to gather the ecological information necessary to increase commercial production and economic benefits for harvesters, as well as to guarantee its long-term use. Studies have been undertaken throughout the Amazon on the demography of *B. excelsa* (Peres and Baider, 1997, Scoles, 2010; Wadt et al., 2005; Zuidema and Boot, 2002), pollination (Maués, 2002), seed dispersal and predation (Baider, 2000; Jorge and Peres, 2005; Peres et al., 1997; Tuck Haugaasen et al., 2010), seed germination (Kainer et al., 1999), fruit production (Baider, 2000; Kainer et al., 2006, 2007) and seedling establishment (Cotta et al., 2008; Kainer et al., 1998; Myers et al., 2000; Paiva et al., 2011; Scoles, 2010), as well as the evaluation of impacts of harvesting (Peres et al., 2003; Scoles and Gribel, 2011; Wadt et al., 2008; Zuidema and Boot, 2002).

Although there is growing information about the ecology of *B. excelsa*, little is known about *B. excelsa* tree abundance and distribution, or harvesting patterns across the landscape. Except for the study of Scoles and Gribel (2011), evaluations of the effects of Brazil nut harvesting are usually based on one to three sites (Baider, 2000; Wadt et al., 2008; Zuidema and Boot, 2002). Even when those results are grouped for the whole Amazon (e.g., Peres et al., 2003), they still reflect the local effects of seed collection and do not consider impacts on the species throughout the landscapes around the studied localities. This is mainly due to the time-consuming and costly field work required to map *B. excelsa* trees in the forest and, consequently, reliable estimates of sizes of stocks of Brazil nut in larger landscapes are unavailable. Although these approaches are not necessarily incorrect, since they reflect the scale of interest of authors (Levin, 1992), inferences based on them about *B. excelsa* conservation status at wider scales may be unreliable. The lack of information about stocks across the landscape also limits the options for adaptive management in the case of overexploitation.

All ecological relationships depend on the scale evaluated (Peterson and Parker, 1998), and analysis of the effects of human harvesting on natural resources at scales different than those usually studied may provide valuable information to conserve and manage species where they are exploited (Levin, 1992). In this paper, we evaluate, through use of high-resolution satellite images, associated with ground truthing, participative mapping with harvesters and harvest records, how estimates of Brazil nut stocks and the proportion of seeds harvested vary depending on the scale evaluated, in three indigenous communities located in a reserve in southeastern Amazonia. Specifically, we asked the following questions: (1) What is the abundance of *B. excelsa* trees and seeds in the groves harvested by the Kayapó Indians and in the landscape (here considered the Brazil nut-collection territories of the villages)? (2) What is the proportion of *B. excelsa* groves in the landscape that is harvested by the Kayapó? (3) How does the proportion of Brazil nut harvested by the Kayapó vary at local (groves) and landscape scales?

2. Materials and methods

2.1. Study site and species

The study was undertaken in the territories of three Kayapó villages – A'Ukre (07°41′43″S, 51°52′53″W), Moikarakô (07°26′11″S, 51°48′57″W) and Kikretum (07°08′17″S, 51°39′26″W), located along the Riozinho and Fresco Rivers, which are second- and first-order tributaries of the Xingu River, respectively (Fig. 1). The three villages are located in the Kayapó Indigenous Land (hereafter Kayapó IL), a 3.284.005 ha reserve in southeastern Amazonia, in the transition zone between the Amazon forest and the savannas of central Brazil, where the dominant vegetation is seasonally-dry forest (Salm, 2004). The altitude of Kayapó IL varies between 200 and 500 m and the climate of the region is humid and hot, with a prominent dry season between May and August. The mean annual rainfall between 1996 and 2002 was 2100 mm and mean monthly maximum and minimum temperatures were 34.2 °C and 18.1 °C (Jerozolimski, 2005).

At the time the study was conducted, A'Ukre, Moikarakô and Kikretum had approximately 380, 380 and 840 inhabitants respectively. The distance between the most southern (A'Ukre) and the most northern village (Kikretum) is 65 km. The size and the boundaries of the territories of each Kayapó village are not clearly defined, but there are political agreements about the use of natural resources by each village. In the case of Brazil nut, harvesting territories are contained within a radius of approximately 15–20 km around each village. The Kayapó people traditionally harvest Brazil nuts for subsistence (Robert, 2009), and most families of the studied villages has been involved in Brazil nut harvest for subsistence or trade in the last decades. A'Ukre produced Brazil nut oil for a British cosmetics firm between 1991 and 2003, and has sporadically traded nuts on the local market. Moikarakô has traded nuts on the local market only in the last few years. Kikretum has constantly traded Brazil nuts on the local market due to its proximity to cities, except during the logging period between the late 1980s and 2002. Since 2005, all three communities have been engaged in an initiative of Brazil nut certification and fair trading lead by the Associação Floresta Protegida (AFP), a local indigenous non-profit organization.

B. excelsa occurs in *terra firme* forests of Brazil, Bolivia, Peru, Colombia, Venezuela and the Guianas (Mori and Prance, 1990; Peres et al., 2003; Shepard and Ramirez, 2011), and is among the tallest and most long-lived species of the Amazon forest (Mori and Prance, 1990; Vieira et al., 2005). Brazil nut trees normally occur in groves (clumps) of few to more than 300 individuals (Mori, 1992; Peres and Baider, 1997; Ribeiro, 2011), although individuals may be randomly distributed at relatively low densities in some areas (Wadt et al., 2005), and density of reproductive trees in these sites usually varies between 1 and 10 individuals ha^{-1} (Baider, 2000; DHV, 1993; Peres et al., 2003; Ribeiro, 2011; Scoles, 2010; Wadt et al., 2005). Fruit production usually varies from about 60–180 fruits per tree per year (Baider, 2000; Kainer et al., 2006, 2007; Zuidema and Boot, 2002). Fruits of *B. excelsa* are extremely hard, contain from 10 to 30 seeds and fall during the rainy season (Baider, 2000). Apart from humans, only a few species can open *B. excelsa* fruits, including agoutis, which are the main non-human Brazil nut predators and dispersers (Baider, 2000; Tuck Haugaasen et al., 2010). Recruitment of young *B. excelsa* trees in natural forest occurs mostly in gaps (Myers et al., 2000).

2.2. Data collection and analysis

2.2.1. Abundance and location of B. excelsa groves

Information on the abundance and location of *B. excelsa* groves in the territory of each Kayapó village was obtained from Kayapó villagers during participative mapping and interviews. We conducted three participative-mapping sessions, one in each Kayapó village. During a community meeting, satellite images with geographic and cultural references were presented to the Kayapó, who indicated the location and names of *B. excelsa* groves in the villages. Additionally, 98 interviews were conducted with individual villagers, 37 in A'Ukre, 32 in Moikarakô and 29 in Kikretum.