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Brazil nut conservation through shifting cultivation

Paulo Marcelo Paiva[a,b,*], Marcelino Carneiro Guedes[a,b], Claudia Funi[a]

[a] Programa de Pós-Graduação em Biodiversidade Tropical, Universidade Federal do Amapá, Rodovia Juscelino Kubitscheck, km 02, Macapá, Amapá, Brazil
[b] Empresa Brasileira de Pesquisa Agropecuária – Embrapa Amapá, Rodovia Juscelino Kubitscheck km 05, Macapá, Amapá, Brazil

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ABSTRACT

The regeneration of Brazil nut trees depends on tree-fall gaps in the forest. However, shifting cultivation fallows also create comparable biotic and abiotic opportunities for the dispersion and establishment of this gap-loving species. At the same time, the ability of Brazil nut trees to resprout enables fallow individuals to survive successive slash-and-burn cycles. Recognizing the importance of shifting cultivation for the food security of forest dwellers, we investigated whether the high level of Brazil nut regeneration found in cultivation fallows could be explained by the resprouting capability of Brazil nut trees, the number of cultivation cycles, past agricultural use and distance to the nearest conspecific productive adults. We found that the Brazil nut tree population density increased from 8.86 trees ha^{-1} to 13.69 trees ha^{-1} and 27.09 trees ha^{-1} at sites after one, two and three or more shifting cultivation cycles, respectively. As a consequence of resprouting, after a certain number of shifting cultivation cycles, the fallows become dominated by Brazil nut trees, and the landholders may decide to preserve them and to exclude enriched sites from future agricultural use. Protected for their extractive value, the secondary forests spontaneously enriched with Brazil nut trees are allowed to develop into nut-producing forests that have reduced chances of conversion into crops or pastures, thus reversing the classical process of Amazon forest degradation.

1. Introduction

The Brazil nut (BN)[1] tree (*Bertholletia excelsa*, Bonpland, 1808) is currently classified as vulnerable to extinction (IUCN, 2010). Its conservation status is attributed to extensive seed gathering, which is said to compromise the regeneration of the over-exploited populations, and to deforestation, which reduces the species' biogeographical range. That harvest pressure may result in vulnerability is controversial. This issue continues to divide those who support (Wadt et al., 2008; Zuidema and Boot, 2002) the ecological sustainability of BN extraction from those who deny that such sustainability is possible (Peres et al., 2003). In contrast, BN vulnerability due to habitat loss is clearly a direct consequence of the conversion of Amazon forests into agricultural fields (Escobal and Aldana, 2003) and pastures (Clay, 1997).

Medium to large farms and cattle ranches are responsible for nearly 70% of total Amazon deforestation (Fearnside, 2005). Indigenous and extractive populations stand out as historical antagonists and as a force for political resistance against latifundium expansion (Allegretti, 1990; Campos and Nepstadt, 2006). However, the forest dwellers also depend on agriculture for their subsistence, and shifting cultivation (SC)[2] plays an important role that complements extractive seasonality (Escobal and Aldana, 2003). Conklin (1961) defined SC as any continuous agricultural system in which impermanent clearings are cultivated for shorter periods (in years) than they are left to lie fallow. In the Amazon, SC has been practiced by indigenous and traditional populations for centuries and has created a significant portion of the forests that many consider pristine (Balée, 1993; Denevan, 1992).

The effect of SC on BN regeneration is well known by extractivists, who consistently report greater BN regeneration levels in fallows than in nearby undisturbed forests (Wadt et al., 2005). The dispersal of this nut-producing tree depends on a highly specialized mutualism with scatter-hoarding agoutis (*Dasyprocta* sp.), for seeds that remain trapped inside unopened fruits suffer almost 100% mortality (Peres et al., 1997). Although they are prized as bush meat, agoutis are relatively resilient to hunting pressure and remain abundant even in areas having long histories of BN collection (Peres and Baider, 1997; Rumiz and Maglianesi, 2001). Agoutis frequently visit SC crops for food and may also bene-

* Corresponding author at: Empresa Brasileira de Pesquisa Agropecuária – Embrapa Amapá. Rodovia Juscelino Kubitscheck, km 05, n° 2600, CEP 68903-419, Caixa Postal 10, Macapá, Amapá, Brazil. Tel.: +55 96 4009 9508; fax: +55 96 4009 9531.
E-mail address: pmpaiva@yahoo.com (P.M. Paiva).

[1] BN is the abbreviation for *Brazil nut* throughout the article.

[2] SC is the abbreviation for *shifting cultivation* throughout the article.

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fit from the entangled vegetation and hollow trunks in fallows. These resources may offer shelter (Silvius and Fragoso, 2003) or visual cues for finding buried seed stocks (Smith and Reichman, 1984). Moreover, scatter-hoarding animals often transport nuts from late-successional, closed-canopy forests to hide them in early successional habitats such as old fields and disturbed areas. The animals thereby avoid pilferage from other nut-eaters that forage primarily in the forest (Vander Wall, 2001).

If the nuts transported to fallows survive and germinate, they have a higher probability of success due to reduced competition and a more favorable light environment. The luminosity is important because BN trees are light-demanding and depend on gaps in the forest to attain their reproductive size (Mori and Prance, 1990). Cotta et al. (2008) were first to outline an experiment to compare and explain the difference in BN regeneration density between fallows and mature nut-producing forests. They concluded that the higher density observed in fallows results from higher light availability. This conclusion for the fallow environment agrees with that established for forest tree-fall gaps, on which BN regeneration depends under closed canopy (Myers et al., 2000).

However, SC fallows are not tree-fall gaps (Janzen, 1990). Because of cyclical disturbances, SC creates gaps at a much higher frequency than do natural tree falls in the forest. In addition, every slash-and-burn cycle is a drastic intervention that eliminates all above-ground biomass before recreating the favorable biotic and abiotic conditions for the reestablishment of vegetation. Sprouters are favored over seeders when disturbance regimes are frequent and severe (Bond and Midgley, 2003), as in the dynamic environment of SC. Thus, to obtain a clear understanding of the effect of SC on BN regeneration, it is essential to consider the species' resprouting capability (Kainer et al., 1998).

Given the importance of SC to the economy and food security of BN-extractive communities, as well as the species' light-gap dependence and its ability to resprout from consecutive slash-and-burn events, we evaluated whether the high BN regeneration density observed in fallows near nut-producing areas could be explained by the (i) number of SC cycles, (ii) past agricultural use, (iii) resprouting capability, and (iv) distance to parent trees. Finally, we asked if the spontaneous enrichment of fallows influences landholders' decisions to protect them from further conversion into crop or pasture sites.

2. Materials

2.1. Study area

The study took place in the Reserva Extrativista do Rio Cajari, Amapá, Eastern Amazon, Brazil. The region contains a dense and open submontane rainforest with an Am Köppen climate (Peel et al., 2007). The annual average temperature is 25 °C with 2300 mm of average rainfall concentrated between December and June (Souza and Cunha, 2010). The relief is very hilly, and the predominant soil type is deep oxisols of Tertiary origin (RADAMBRASIL, 1974).

Our fieldwork was conducted from June to December, 2008, in the vicinity of two communities, *Martins* (52°17′30″W; 0°34′36″S) and *Marinho* (52°13′25″W; 0°34′40″S), both with a long BN-extractive tradition. These settlements followed the 19th- and 20th-century rubber-tapper migrations (tappers of *Hevea brasiliensis*). Following the decline in latex prices, these communities have subsisted chiefly on BN extraction and small-scale agriculture. For local dwellers, SC is more than a complementary activity to the seasonality of BN production. In those years when the market prices offered for the nuts do not even pay the costs of harvesting, agriculture guarantees a minimum income and food security. Currently, the landscape surrounding the two villages is a mosaic of mature forest with or without BN trees, active crops, pastures, and secondary forests in multiple seral stages.

2.2. Data collection

For the purposes of our study, BN regeneration refers to the individuals (seeders and resprouts) that we found colonizing agricultural sites following disturbances by cultivations. We related the BN regeneration density to a series of seven biotic and abiotic environmental variables measured at 40 sites with known agricultural past use and established near parent BN trees. For each site, we interviewed the responsible landholder about (1) past agricultural use and (2) the number of cultivation cycles, which were later confirmed by remote sensing techniques. We also recorded (3) current agricultural use, (4) fallow age, (5) site area, (6) distance to the nearest parent trees, and (7) landholder's decisions to preserve BN enriched fallows.

2.2.1. BN density, number of cycles and past agricultural use

We calculated BN regeneration density by dividing the number of BN seedlings ($10 \leq$ height < 150 cm), saplings (height $\geq$ 150 cm and dbh < 10 cm) and juvenile (non-mature) trees found in the census of the site by its respective area. All sites chosen had vegetation coverage adequate to localize BN plants of all sizes, including seedlings. We avoided recently abandoned crops because of their excessively dense and entangled vegetation. However, we sampled fallows older than ten years because they already show some stratification and, like the active crops, make the census easier to conduct. We also included some sites currently used as pastures. Pastures, an integral part of the local landscape, often succeed crops. The pastures are planted not only for cattle, but also as a grazing area for horses, donkeys, and mules, animals that represent a useful work force during the BN harvest and other daily activities.

The information obtained from the interviews about the number of cultivation cycles was later confirmed using a temporal sequence of Landst5 satellite images that were available with minimum cloud coverage above the studied sites. We used the multi-spectral TM sensor, comprising bands 5R4G3B of the 226/060 scene from 1985, 1991, 1996, 1997, 1998, 1999/2000, 2003, 2004, 2007 and 2008 images. The 2008 image was georeferenced with ground truth points collected during fieldwork (GPS Garmin 60 CS×), and the previous images were georeferenced based on the current one and adjusted using natural and man-made landscape features until a root-mean-square error lower than one pixel size was attained.

Our informers reported accurately about the last, penultimate and ante-penultimate agricultural use cycles on their fields. However, information prior to the ante-penultimate cycle occasionally sounded vague or divergent. At the same time, the limited temporal sequence of available images could not confirm cultivation patterns with certainty beyond the ante-penultimate cultivation cycle. For that reason, we restricted the number of cultivation cycles to those events of one, two and three or more cultivation cycles we were able to distinguish. Fallow sites were also classified according to the number of previous slash-and-burn cycles. We added one more cycle to the total for the site in cases of fallows having signs of prior disturbance verified in the oldest available image (light-green pixel sensor response in the 1985 scene).

We used a different counting method for pasture cycles. Because active pastures are burned repeatedly every two or three years, they never develop the vegetation coverage needed to support the natural disperser activity (Silvius and Fragoso, 2003). As chronically disturbed sites (Uhl et al., 1988), pastures were counted as a single continuous cycle from their establishment in the forest or as a second or third cycle if located in sites previously used for SC. In view of that adjustment, we sampled nine sites in a first-use cycle (established directly after clearance of mature forest), nine sites in