

# Revisiting the ‘cornerstone of Amazonian conservation’: a socioecological assessment of Brazil nut exploitation

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**Abstract** The Brazil nut (the seeds of the rainforest tree *Bertholletia excelsa*) is the only globally traded seed collected from the wild by forest-based harvesters across the Amazon basin. The large geographic scale of Brazil nut exploitation and the significant contributions to local livelihoods, national economies, and forest-based development over the last decades, merit a review of the “conservation-through-use” paradigm. We use Elinor Ostrom’s framework for assessing sustainability in socioecological systems: (1) resource unit, (2) users, (3) governance system, and (4) resource system, to determine how different contexts and external developments generate specific conservation and development outcomes. We find that the resource unit reacts robustly to the type and level of extraction currently practiced; that resource users have built on a self-organized system that had defined boundaries and access to the resource; that linked production chains, market networks and informal financing work to supply global markets; and that local harvesters have used supporting alliances with NGOs and conservationists to formalize and secure their endogenous governance system and make it more equitable. As a result, the Brazil nut model represents a socioecological system that may not require major changes to sustain productivity. Yet since long-term Brazil nut production seems inextricably tied to a continuous forest cover, and because planted Brazil nut trees currently provide a minimal contribution to total nut production basin-wide, we call to preserve, diversify and intensify production in Brazil nut-rich forests that will inevitably become ever more integrated within human-modified landscapes over time.

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## Introduction

One of the oddities of the NTFP category is that it excludes both the most structurally important components of the forest, and the ecological functions that bind it together (Lawrence 2003).

Non-timber forest products (NTFPs) are harvested across the tropics from diverse habitats and management systems, from cultivation on farms to wild harvest in forests. NTFPs reach both international and domestic markets and supply millions of rural households with significant income for their subsistence (Angelsen et al. 2014; Shanley et al. 2016). NTFPs gained prominence in the global forest agenda with the 1992 Rio Forest Principles, which promoted an integrated approach to livelihoods, the environment and forest management for a tropical forestry sector dominated by an industrial timber model (Rosendal 1995). An exemplary tropical NTFP is the Brazil nut (from the seeds of the Amazon rainforest tree *Bertholletia excelsa*). Over the last few decades, the harvesting of Brazil nuts has been a key resource, supporting the “conservation-through-use” of millions of hectares of Amazonian forest by tens of thousands of rural households (Ortiz 2002) and is an integral component of the extractivist culture of many indigenous and local communities (Clay and Clement 1993; Table 1). The large geographic scale of exploitation (Peres et al. 2003) and the significant contributions to local livelihoods and forest-based development prompted researchers to call the Brazil nut the cornerstone of Amazon forest conservation (Clay 1997). At present, the Brazil nut is the only globally traded seed crop collected from the wild by forest-based harvesters. Brazil nut extraction generates tens of millions of US dollars in annual export value in Brazil, Peru and Bolivia (Coslovsky 2014), the three countries which constitute the focus of this assessment.

In this paper, we reassess the role that Brazil nut extraction plays in Amazon rainforest conservation and evaluate the socioecological system of Brazil nut extraction to try to discern under which settings the “conservation-through-use” paradigm is applicable for this exemplary Amazonian tree in a changing environment. Since resource ecology and extraction are closely linked to socioeconomic development, we structure our review by adapting Ostrom’s (2009) framework for assessing sustainability in socioecological systems into four subsystems: (1) resource unit (i.e., the Brazil nut tree), (2) users (e.g., harvesters, middlemen, processors), (3) governance system (e.g., institutions, incentives, market and non-market instruments) and (4) resource system (i.e., Brazil nut-rich forests; defined here as those with at least 0.5–1 adult Brazil nut tree per hectare). We have chosen this structure because forests are an emblematic example of common-pool resources (Ostrom 1990), and Brazil nut production systems offer an illustrative case where a variety of stakeholders have self-organized to allocate property rights and to develop adaptable market networks that have persisted for the better part of a century (Ortiz 2002). In our assessment, we examine how different interventions and external developments both affect and interact across the four subsystems mentioned above, all of which generate specific conservation and development outcomes along with feedback loops. The wealth of information produced over recent years on this regionally prominent NTFP (its

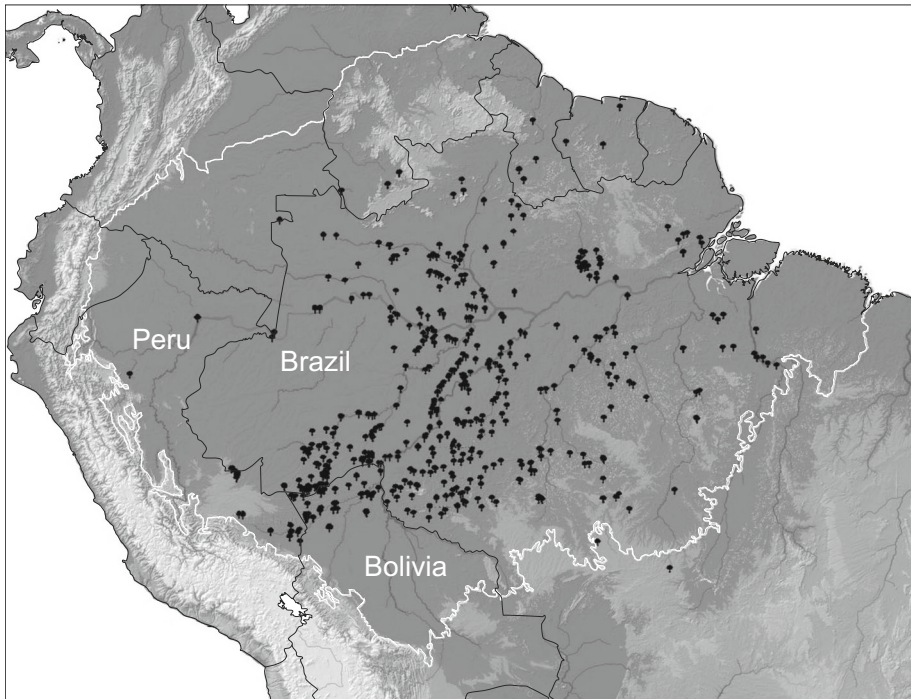
**Table 1** The percentage of total forest income derived from harvesting of Brazil nuts in selected Amazonian sites, from recently published literature

Location (country)	% of total household income from forest products	% of forest income derived from Brazil nuts	Sample type	Land use type	Source
Pando, Beni (Bolivia)	42	22	239 households	Colonist settlement	Zenteno et al. (2013)
Pando, Beni (Bolivia)	60	51	“Extractive” communities (27 % of 239 households)	Colonist settlement	Zenteno et al. (2013)
Pando, Beni (Bolivia)	36	20	“Multitasking” communities (33 % of 239 households)	Colonist settlement	Zenteno et al. (2013)
Pando, Beni (Bolivia)	53	27	Brazil nut and timber extraction (18 % of 239 households)	Colonist settlement	Zenteno et al. (2013)
Pando (Bolivia)	64	45	131 households	Protected area, nonprotected area	Duchelle et al. (2014a)
Acre (Brazil)	12	21	112 households	Extractive reserve, colonist settlements	Duchelle et al. (2014a)
Pará (Brazil)	33	17	23 households	Extractive reserve	Zeidemann et al. (2014)
Madre de Dios (Peru)	71	55–65	126 households	Brazil nut concessions	Garrish et al. (2014)
Pando, Beni (Bolivia)	59	74	24 households “Agroextractive communities”	Colonist settlement	Soriano et al. (2017)

geographical distribution shown in Fig. 1) provides an opportunity to offer a nuanced view on the biophysical, socioeconomic, institutional and governance aspects influencing the resource base in light of the current transformation of the Amazonian forest landscape (de Jong et al. 2010). Our review provides input to answer the following question: what set of key interventions may be needed to maintain the social, economic and environmental functions of Brazil nut-rich forests?

## The resource unit

Brazil nut trees can live for hundreds of years (Brienen and Zuidema 2006; Schöngart et al. 2015), attain heights of over 40 m (Mori and Prance 1990) and reach diameters (at breast height, Fig. 2a) of up to 5 m (de Salomão 1991; Peres et al. 2003; Brienen and Zuidema 2006; Kainer et al. 2007; Rockwell et al. 2015). They form high density groves (up to



**Fig. 1** The distribution of Brazil nut trees (*Bertholletia excelsa*) as evidenced by botanical records across the Amazon river basin (delineated in white). Modified from Clement et al. (2015)

15–20 adult individuals per ha; Mori and Prance 1990) probably due to the combined effects of anthropogenic activities (Shepard and Ramirez 2011; Scoles and Gribel 2012; Thomas et al. 2015) and short-distance seed dispersal by rodents (Peres and Baider 1997; Haugaasen et al. 2012). Cross-pollination (mediated primarily by non-social bees of the genus *Xylocopa*; Cavalcante et al. 2012) is necessary for fruit production and generates high levels of genetic diversity and low levels of inbreeding (Sujii et al. 2015). The seeds are contained within a globose, woody fruit (Fig. 2b, c).

It has been long hypothesized that a forested matrix (for hosting pollinators) is necessary for sustaining commercial Brazil nut yields and, therefore, that forest fragmentation and degradation could reduce tree fecundity (Ortiz 2002). Yet at present it is not known under which landscape configurations fruit yields are to decrease via potential disruption of inter-tree pollen transfer. In any case, at low timber harvesting intensities in closed-canopy forest, Brazil nut tree fecundity seems unaffected (Rockwell et al. 2015). Although promising efforts to intensify Brazil nut production through plantations do exist most prominently in central Brazil, yields are low (probably related to the specialized nature of their pollinators and type of planting material) thus making both market and volume shares currently insignificant basin-wide (Homma et al. 2014).

Current evidence suggests that the regeneration potential via seedlings and saplings of Brazil nut tree populations appears uncorrelated to the intensity of fruit harvest (Wadt et al. 2008; Scoles and Gribel 2012, 2015), although some areas that have experienced long and intensive harvesting pressure show evidence of a “demographic bottleneck” (i.e., absence of pre-reproductive trees; Peres et al. 2003). Yet if seed collection would cause



**Fig. 2** Graphic depiction of two out of the four subsystems that comprise the Brazil nut socioecological system (after Ostrom 2009). The “resource unit” (a) is the Brazil nut tree (individual shown is about 1.5 m in diameter at breast height and about 30 m tall; Madre de Dios, Peru). “Resource users” include harvesters (b, c; Madre de Dios, Peru), middlemen, and industry (d; Pando, Bolivia). Not shown (yet described in the text) are the “governance system” (i.e., institutions, rules and incentives) and the “resource system” (i.e. Brazil nut-rich forests)

regeneration bottlenecks, it would take several decades and probably up to a century to cause decline in Brazil nut productivity (Zuidema and Boot 2002). The abundance of naturally-regenerated, pre-reproductive Brazil nut trees is very low in shaded forest understories (Mori and Prance 1990; Myers et al. 2000; Rockwell et al. 2017) but high abundances are reported in young logging gaps (Soriano et al. 2012) and agricultural fallows close to old-growth forest (Cotta et al. 2008; Paiva et al. 2011). Seed harvesting is exclusively limited to collecting the fruits that fall to the ground during the rainy months, and opening them with a machete. Harvesting may extend beyond the end of the rainy season when export demand is very high, as happens in Bolivia (Duchelle et al. 2011).

## The resource users

The constellation of stakeholders that make up the Brazil nut sector participate in a production system that has extracted forest products for global markets since at least the seventeenth century while recent patterns and organizational systems are more closely rooted to the late nineteenth century extractive boom of wild rubber (*Hevea brasiliensis*).



Key aspects of that economic system for the extraction and global trade of wild NTFPs have persisted (Laird et al. 2010) yet shifting economic cycles and contested development trajectories have introduced new modes of control over the Brazil nut resource base. For example, although the harvesting of Brazil nuts has been catalogued as a “specialized natural strategy” (Belcher et al. 2005) optimizing both development and conservation outcomes (Kusters et al. 2006), and the activity has been characterized as one with a “high potential” for conservation-through-use (Newton 2008), these categorizations hide the large variation in socioecological and policy contexts across the Amazon basin (de Jong et al. 2010). Brazil nut resource users are spread across different tenure types: indigenous reserves (Ribeiro et al. 2014), extractive reserves (Zeidemann et al. 2014) and other government-sanctioned protected areas (Duchelle et al. 2014a), along with government-sanctioned concessions (Cossio-Solano et al. 2011), as well as communal and individual private property (Cronkleton and Pacheco 2010; Zenteno et al. 2013; Soriano et al. 2017).

As mentioned, the foundation of the Brazil nut economy emerged in the second half of the nineteenth century as early entrepreneurs moved across the Amazon to establish large forest estates to extract rubber (referred to as *seringais* in Portuguese and *barracas* or *fundos* in Spanish; Fifer 1970; Weinstein 1983; Coomes and Barham 1994). From the colonial period, estate owners in the Amazon had depended on coerced labor from indigenous people, but as the rubber boom accelerated, labor shortages required that they bring indentured workers from outside the region to settle in forests and extract rubber latex for global markets. During the boom, estate owners used debt peonage to control these workers, but as the rubber economy collapsed, the workers gained more autonomy and began exerting customary control over forest resources (Weinstein 1983; Bakx 1988; Ormachea and Fernández 1989; Pacheco 1992; Barham and Coomes 1996). While the estate owners maintained property claims, the forest workers expanded their livelihoods beyond rubber tapping and began extracting a wider range of forest products, particularly the Brazil nut. In Bolivia, for example, the Brazil nut had eclipsed rubber as the principal non-timber forest product by the 1950s (Stoian and Henkemans 2000).

As the economy changed, the forest estates provided external boundaries, which allowed resident extractivist populations to develop management institutions over these essentially common-pool resources. Within these properties, producers claimed customary private access to Brazil nut groves based on a form of ‘tree tenure’ (Fortmann 1985) in which individual families control economically valuable trees rather than the land itself. However, from the 1970s onward, economic change and shifts in development policies in each of the three countries further undercut the power of former estate owners and brought increased resource competition, thereby provoking social conflict and grassroots collective action in some cases. The conflict and unrest eventually pushed governments to introduce new property or resource access mechanisms that consolidated local control over the resource system. We briefly summarize below key parallels and differences as to how these changes played out in Brazil, Peru and Bolivia.

In Brazil, changing development incentives during the 1970s and 1980s encouraged forest estate owners to sell property claims (often to cattle ranchers), which sparked collective resistance by forest peoples (Schmink and Wood 1992). Rubber tappers, many of whom were also dependent on Brazil nut extraction, began forming a grassroots movement with assistance from the Catholic Church and environmental, non-governmental organizations (NGOs) (Schmink and Wood 1992; Assies 1997a), to pressure the government to recognize new property types, including conservation areas called extractive reserves (Allegretti 1990) and agro-extractive settlements (Cronkleton et al. 2008), both of which were communal areas intended to support customary livelihoods and patterns of forest use.

In Bolivia, *barraca* estate owners were not initially affected by waves of agrarian reform, but later had their rights challenged when the government granted logging contracts over extensive areas of Brazil nut production forests in 1995 (Pacheco 1998) and eventually converted these into timber concessions under the 1996 Forestry Law. In 2000, while the estate owners (*barraqueros*) lobbied the government to reestablish their control over remaining Brazil nut-rich forests, resistance from a coalition of Brazil nut gatherers supported by NGOs pressured the government to instead issue a series of presidential decrees that recognized communal properties for Brazil nut-dependent communities (Cronkleton and Pacheco 2010).

Peru's 1969 agrarian reform invalidated remaining property claims of forest estate owners and the 1975 Forestry Law recognized the rights of rural producers to continue gathering Brazil nuts and rubber through extraction contracts. This contract system continued until Peru's 2000 Forestry Law mandated their replacement by forest concessions. Initially, there was some uncertainty over how concession rights would be granted (Congreso del Perú 2002), but after a period of protests by Brazil nut gatherers and NGOs, the government agreed to honor their acquired rights held under preexisting Brazil nut extraction contracts.

This devolution of forest property rights resulted in a large transfer of Brazil nut-rich forests to local control by resource users. In Bolivia's Pando department alone, by 2010, over two million hectares of forest had been titled to 132 communities and two indigenous territories (Cronkleton and Pacheco 2010), with the remainder held in timber concessions or still claimed by *barraqueros*. In Peru's department of Madre de Dios, as of 2015 there were 1174 Brazil nut concessions and 6 indigenous communities controlling approximately one million hectares of forested land (Perales and Guariguata 2015). In Brazil, the 2011 national plan for supporting community forest management of NTFPs (which prioritized Brazil nuts) identified 22 conservation units (including extractive reserves) and 15 agro-extractive settlements covering more than 12 million hectares and almost 20,000 families (SFB 2010). While these shifts in property rights favored Brazil nut gatherer households, there are still large areas of Brazil nut-rich forests on private properties in Brazil and Bolivia, in timber concessions in Bolivia (Guariguata et al. 2009) and Peru (Chavez et al. 2012), and in public forest areas in all three countries. Given the overall (yet dynamic) importance of Brazil nut-rich forests as sources of a significant proportion of local household income (Table 1), it is crucial to understand how a mix of domestic policies, supply chains and incentives come together in Brazil, Peru and Bolivia, either to support or threaten the future of this socioecological system.

## The governance system

### Policy frameworks

The policy frameworks in each country establish co-management NTFPs where government partially transferred rights over forest resources to local users, but retained key oversight authority. In co-management schemes, governments need to provide secure property rights that define who has rights and responsibilities to manage, and to establish guidelines or frameworks that encourage sustainable management practices (Cronkleton et al. 2012a). An important step in securing resource rights is apparent in the multiple types of property institutions created to grant to indigenous peoples and extractivist populations

rights over Brazil nut-rich forests. In extractive reserves in Brazil, for example, the external reserve boundaries allowed the exclusion of outsiders but accommodated the residents' forest-based livelihoods by tacitly recognizing existing customary patterns of resource access and internal control (Ankersen and Barnes 2004). In contrast, in Pando, Bolivia, the formalization of customary rights through the government's 500-ha-per-family decree created confusion in the sense that local norms and rules for managing Brazil nut-rich forests would be rearranged internally (Cronkleton et al. 2010). Such differences in the process of formally recognizing customary rights can have implications for resource management, as evidenced by an increase in conflicts over Brazil nuts in Pando (that did not happen across the border in Acre, Brazil) when nut prices increased (Duchelle et al. 2011).

Policy makers in all three countries have taken legal steps to conserve the Brazil nut resource base. Peru's government banned the felling or burning of Brazil nut trees in 1981 and in 1997 prohibited the titling of lands with Brazil nut trees (Cossio-Solano et al. 2011). The original Brazilian Forest Code of 1965, along with subsequent legislation banned the cutting of Brazil nut trees (Homma 2001). Bolivia, on the other hand, did not prohibit the felling of Brazil nut trees until 2004 (Cronkleton and Pacheco 2010). Although these policies have largely stopped the exploitation of Brazil nut trees for timber, they do not guarantee the conservation of surrounding forest. "Brazil nut cemeteries", where standing Brazil nut trees in pastures are either dead or hardly set any fruit, perhaps due to fire damage and reproductive isolation from conspecific individuals, are common across deforested Amazonian landscapes (Silva Bentes et al. 1988; Peña 2010).

In Peru, with the creation of the Brazil nut concession system in 2000, the government established the most elaborate administrative compliance systems for Brazil nut harvesting and transport of the three countries examined here. As mentioned, Brazil nut gatherers who held harvest contracts prior to 2000 were required to document their preexisting rights to qualify for a concession and then needed to work with forestry professionals to develop management plans to gain approval. Once approved, the technical norms require concession holders to prepare annual operating plans that estimate the total volume of seeds to be harvested a priori. Yet due to strong inter-annual variation in fruit production at the tree level (Kainer et al. 2007), it is virtually impossible to predict harvestable yields (essential information for approving operating plans). While the administrative and financial burden of these requirements for complying with these regulations are high, the information these plans provide for supporting management decisions at the concessionaire and central government levels is of little use (Perales and Guariguata 2015).

In Bolivia, the technical norms for timber management under the 1996 Forestry Law allowed the inclusion of Brazil nut harvesting (MDS 1998). However, the requirements were vague and thus generally ignored (Cronkleton et al. 2012b). In 2005, while Bolivia ratified technical norms only for Brazil nut management (MDS 2005), these were modeled on timber harvesting plans rather than specifically addressing the management behavior of Brazil nut extractors. The norms required the delineation of a 'no-take' zone intended to enhance Brazil nut regeneration via seed germination (which would add substantial opportunity costs to harvesters and also likely to be ineffective, as Brazil nut tree establishment is severely limited under a closed canopy as mentioned above). Government-sanctioned, Brazil nut 'management' plans prepared under these norms have also been disregarded and have had little impact on changing the *status quo* (Cronkleton et al. 2012b).



## Supply chains, cooperatives and certification

While the Brazil nut sector has been tied to global markets from its inception, the role played by different stakeholders in the supply chain has evolved over time. The Brazil nut value chain originates with nut gatherers who, during the harvest season, live in rural homesteads linked to trails leading to the Brazil nut trees where they collect the fruits from the forest floor. With the recognition of forest property rights, many of these families have gained more autonomy through managing the resources they control, often within communal properties, or with individual rights as in Peruvian Brazil nut concessions. In the remaining large tracts of Brazil nut-rich forest claimed as private property or granted as timber concessions, contract labor is still used. For such cases, substantial numbers of families continue to supply migrant labor (especially in Bolivia). Although machinery to shell Brazil nuts was brought to the Amazon in the early twentieth century (Fifer 1970), it was not until the 1990s that processing plants became more prominent, particularly in Bolivia (Fig. 2d; Cronkleton and Pacheco 2010). The export market of shelled nuts began in the Brazilian municipality of Marabá in the state of Pará in the Eastern Amazon, and was dominated for decades by the oligarchic Mutran family in the mid-1900s. In 1998, European importers raised their quality standards for Brazil nuts and Brazilian exporters' access to the European market was impeded (Newing and Harrop 2000; Coslovsky 2014). Other reasons given for the decline of Brazil nut production in Brazil include less productive trees in the Eastern Amazon, deficient infrastructure for transport and storage, and the lack of policies and programs to incentivize production (Toledo et al. 2016). In Bolivia, processing industries, with support from government regulators effectively met food safety standards and did not lose access to the important European markets (Cronkleton and Pacheco 2010). At present, Bolivia dominates the global Brazil nut processing and export market (Coslovsky 2014). As of 2013, Bolivia produced 52 %, Brazil 42 % and Peru 6 %, according to FAOSTAT (<http://www.fao.org/faostat/en/#home>).<sup>1</sup>

Historically, gatherers used nuts to repay the estate owner for incurred debts; however, today's autonomous gatherers deal with competing intermediaries who are attempting to secure nuts for resale and processing. With more secure property rights, competition among buyers and higher prices, gatherers now have more leverage in negotiating terms of sale than in the past. Many processing plants establish trade networks, extending credit to secure access to sufficient supply to fulfill their contracts with international buyers. As Brazil nut gatherers in the region were struggling to defend their rights to forests and gain a higher profile, a common strategy of NGOs and bilateral donors was to support the formation of cooperatives and in some cases assist them to establish producer-owned processing plants. In Acre, Brazil, the rubber tapper's union set up *Cooperativa Agro-extrativista de Xapuri* (CAEX) in 1988 (Assies 1997b), and in Bolivia, the producer-owned *Cooperativa Agrícola Integral Campesino Ltda* (CAIC) established its own processing plant in 1994. The Bolivian producers' *Cooperativa Integral Agroextractivista Campesinos de Pando* (COINACAPA), formed in 2001, adopted the innovative strategy of contracting third-party processing plants, which allowed the cooperative to sell shelled nuts to international buyers and thus capture a greater share of value for members without the risk and overhead costs associated with managing an industrial plant themselves (Cronkleton and Albornoz 2009). Some governments have directly supported producer organizations, as can be seen with the government-

<sup>1</sup> FAOSTAT lists Cote d'Ivoire as the source of 15 % of the global Brazil nut production in 2013 making it the fourth largest producer (on top of Perú). As *Bertholletia excelsa* is a strictly Amazonian tree species we believe this is an error and suspect FAOSTAT refers, in the case of Cote d'Ivoire, to cashew nuts.

run *Cooperativa Central de Comercialização Extrativista do Estado do Acre Ltda* (COOPERACRE), which, since 2001, has been tied to the State of Acre's Forest Secretariat, and provides an official umbrella organization for local cooperatives across the state and serves as a market outlet for thousands of Brazil nut harvesters (Silva 2010). Although the growth of these cooperatives has been fundamental for linking Brazil nut harvesters to global markets, Peruvian harvesters on the contrary largely suffer from lack of social cohesiveness and knowledge exchange among various producers' associations thus hampering progress toward equity and enhanced market access (Quaedvlieg et al. 2014). And, as for most Amazonian rural populations (Mathews and Schmink 2015), informal financing in the Brazil nut sector is the norm since access to formal microcredit is largely nonexistent (Cronkleton and Pacheco 2010; Perales and Guariguata 2015) as well as for Amazonian smallholder forestry operations as a whole (Pacheco et al. 2016).

A related innovation in the Brazil nut supply chain came with the emergence of three certification schemes: (i) organic certification; (ii) Fairtrade certification; and (iii) Forest Stewardship Council (FSC) certification (Duchelle et al. 2014b). Organic certification has been the most relevant and useful. Since Brazil nuts are a wild product, production is essentially organic, so standards focus primarily on post-harvest handling (to ensure they do not become contaminated with aflatoxins while in storage, or with petrochemical pesticides during transport). Fairtrade certification, which requires producers to be organized in cooperatives and verify that they are small producers, not intermediaries, provides access to niche markets offering price premiums. However, the most important advantage that Fairtrade arrangements offer is that small producer groups are able to sell directly to buyers in foreign markets.

There are multiple benefits of these individual certification schemes (and combinations thereof). Among Brazil nut producers in southwestern Amazonia, a combination of organic and Fairtrade certification was associated with better post-harvest practices and higher prices, while FSC certification was related to pre-harvest planning (Duchelle et al. 2014b). Of the three above mentioned schemes, organic certification has gained the most traction due in part to European Union legislation that tolerates only limited amounts of fungus-produced aflatoxins (up to 10 parts per billion) in imported Brazil nuts. Since the fungus thrives when nuts remain on the forest floor for extended periods of time (Hudler 1998), Brazil nut producers are encouraged to dry nuts post-harvest to avoid contamination. The construction of drying structures became part of a series of 'best management practices' outlined in the extension literature (Cardó 2000; Wadt et al. 2005; APIZ 2008). While FSC standards for Brazil nuts have been developed in Brazil, Peru and Bolivia, there are few experiences of FSC certification on the ground, since it is perceived as costly as it attempts to cover too many forest management dimensions for what is considered a non-destructive harvesting activity (Duchelle et al. 2014b).

## The resource system

Relatively high Brazil nut prices over the past decade have generated incentives for gatherers to defend the Brazil nut resource system; however, there are continued threats to these resources and a need for more government attention to support forest conservation. For example, new economic opportunities for forest-dependent people are inducing a transition from traditional extractive activities to greater investment in cattle ranching (Salisbury and Schmink 2007; Gomes 2009; Coomes et al. 2016). In addition, trans-

boundary road connectivity through the southwestern Amazon, although relatively recent, is already leading to forest conversion in this key Brazil nut-producing region (Southworth et al. 2011; Perz et al. 2013). Moreover, market fluctuations in Brazil nut prices (which remove incentives for producers to maintain production) and policy failures (such as when governments do not defend extractivist property rights or introduce regulations that undercut harvesters; e.g., Perales and Guariguata 2015), are worrisome. In addition, the social implications for the permanence of the resource system due to an aging extractivist population are not insubstantial, especially when the many harvesters are elderly, as is the case in Madre de Dios, Peru. Likewise, and in spite of earlier concerns regarding the lack of the regenerative potential of Brazil nut-rich forests in some locations across the Amazon basin due to fruit overharvesting (Peres et al. 2003), which can be tackled by adaptive management, these seem small compared with the threats of deforestation on the continued provision of Brazil nuts. We discuss below what we consider key strategic entry points that could help to maintain the resource base over the long term.

### Understanding livelihood strategies and drivers of population exodus

Remote sensing studies suggest that at present, Brazil nut-rich forests can be robust to conversion to non-forest uses such as in southwestern Amazonia (Perz et al. 2013). However, on-the-ground assessments indicate that forest permanence is contingent on a variety of current and historical factors that generate particular livelihood outcomes. In locations where access to main roads and infrastructure development is limited and opportunities for livelihood diversification remain constrained, a higher degree of forest cover at the household level is linked to a high economic dependency on the Brazil nut harvest (Zenteno et al. 2013; Duchelle et al. 2014a; Zeidemann et al. 2014; Soriano et al. 2017). When household economies start to diversify through the acquisition of more material assets, income from Brazil nut sales are typically reinvested into non-forest activities (Duchelle et al. 2014a). Thus, the ‘cornerstone’ role of the Brazil nut in forest conservation seems contingent on a unique livelihood strategy, which may not necessarily be the most profitable (Zenteno et al. 2013) nor permanent in a changing landscape. Yet in Brazil, smallholders living in extractive reserves rely on both Brazil nut harvesting as well as on non-forest uses while maintaining forest cover in settings where deforestation pressure can be high (Duchelle et al. 2014a). Importantly, even within these reserves, household characteristics such as age, amount of accumulated forest knowledge and proximity to the resource influence the overall reliance on Brazil nuts as a proportion of total cash income (Zeidemann et al. 2014).

Based on the above, and as recently demonstrated by Zenteno et al. (2013) and Soriano et al. (2017) in Bolivia, and Scullion et al. (2016) in Peru, explicit consideration of differentiated local livelihood strategies and resource use perspectives are essential for designing specific interventions to conserve the Brazil nut resource system while meeting development needs. For example, smallholders protect their forest fallows from further conversion when they detect a sufficient number of Brazil nut trees worth keeping (Paiva et al. 2011). Specific considerations that promote secondary forest conservation-through-use may help to achieve this end. In particular, recognizing that secondary forests serve both agricultural and environmental functions is key for fostering inclusive policies that incorporate the views of production and conservation actors (Vieira et al. 2014, Chazdon and Guariguata 2016) while moving away from technocratic forest management approaches applied to this particular forest resource (Cronkleton et al. 2013). In addition, understanding the drivers of rural-to-urban migration can help in the design of effective

policies and incentive structures. The decline in rubber prices played a major, historical role in promoting migration from forests into cities in Amazonia (see Parry et al. 2010). Recently, migration from remote areas (once almost entirely dependent on forest extractivism) to local urban centers in the Brazilian state of Amazonas appears to have been primarily driven by lack of access to education (Parry et al. 2010). Thus, providing educational facilities as well as other key services and programs could help motivate people to stay in forested areas.

Hunting becomes the main source of protein during the Brazil nut harvest season particularly in locations away from permanent settlements (Rumiz and Maglianesi 2001). Besides promoting local depletion of vertebrate fauna, exacerbated hunting pressure limits the dispersal of mammal-consumed tree seeds of commercial importance (Forget and Jansen 2007), including the Brazil nut tree (Haugaasen et al. 2012). Vertebrate defaunation also impairs tree regeneration which may lead to loss of aboveground forest biomass as evidenced in Amazonia (Peres et al. 2016). In Peru, hunting is prohibited by law in Brazil nut concessions (SERFOR 2016) and in Bolivia, hunting is also legally banned country-wide although particular species can be hunted for subsistence (Gaceta Oficial de Bolivia, Decreto Supremo nos. 22641 and 25458). Yet because of the (often) remote nature of Brazil nut harvesting, enforcement and monitoring is virtually impossible. As most Amazon basin countries lack clear policy frameworks for allowing subsistence consumption of bushmeat by rural populations (see e.g. van Vliet et al. 2015), designing participatory schemes for promoting sustainable hunting are warranted (e.g. Sandrin et al. 2016).

### Curbing deforestation

The collapse of the Brazil nut sector in the eastern Brazilian Amazon from its peak in the 1950s can provide policy lessons on what to avoid in promoting sustainability in other parts of the Amazon basin. The construction of multiple highways and dams in the region, national support for mining projects, and the conflictual land occupation that followed, all contributed to the massive devastation of Brazil nut-rich forests along with a major decline in Brazil nut production at the national level (Homma 2001; Coslovsky 2014). Thus, key to promoting the long-term sustainability of Brazil nut-rich forests are domestic efforts to curb deforestation. Brazil and Peru have both included measures to reduce deforestation and forest degradation in their Nationally Determined Contributions (NDCs) toward keeping the global temperature rise below 2.0 °C. Furthermore, subnational government members of the Governors' Climate and Forests (GCF) Task Force have pledged to reduce deforestation in their states and provinces by 80 % by 2020 through the Rio Branco Declaration (GCF 2014). The members of the GCF include the Brazil nut-producing states of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia in Brazil, along with the department of Madre de Dios in Peru. Brazil's success in reducing Amazonian deforestation (INPE 2015) is largely attributed to increased regulatory efforts, including monitoring and enforcement by the Brazilian Institute of Environment (IBAMA), along with a slowdown in the growth of commodity prices that curbed investments in forest clearing (Assunção et al. 2012). Yet, such trends are not sustainable if protection measures are weakened and landholders do not receive incentives for conserving forests, as seen from the recent increase in deforestation in the Brazilian Amazon (Tollefson 2016). Identifying the main drivers of deforestation within Brazil nut-rich forests in local and/or subnational contexts is also necessary to inform decision-makers on sound policy and practical alternatives. For example, in Brazil nut-rich forests of Pando, Bolivia, cattle-

ranching is currently the main driver of deforestation (Müller et al. 2013), while in Madre de Dios, Peru, illegal yet highly profitable gold mining is steadily encroaching into Brazil nut concessions (Scullion et al. 2014). To the extent that forest and agricultural policies are harmonized, integrated production systems are promoted, and cross sectorial land use planning is effectively implemented, deforestation pressures can be minimized.

The designation of extractive reserves and indigenous reserves, such as through Brazil's Amazon Protected Areas Program, can have positive implications for the Brazil nut socioecological system. These areas have played a fundamental role in mitigating deforestation (Nepstad et al. 2006; Pfaff et al. 2014), and many shelter Brazil nut-rich forests and human populations that partially depend on this species for their livelihoods. Opportunities exist to bolster conservation of Brazil nut-rich forests through incentives associated with Reducing Emissions from Deforestation and Forest Degradation (REDD+). In Peru, Brazil nut concessions store, as a land use type, the largest above-ground carbon densities across the country (110 Mg C ha<sup>-1</sup>; Asner et al. 2014). And basin-wide, Brazil nut trees rank third among the dominant top 20 tree species in terms of above-ground biomass (Fauset et al. 2015) while being an "hyperdominant" element of the tree flora (ter Steege et al. 2013). At the national level, Perú's National Forest Conservation Program (<http://www.bosques.gob.pe/grants>) grants subsidies per hectare to native and indigenous communities holding large tracts of forest in exchange for avoiding deforestation and degradation (Börner et al. 2016). This intervention could be emulated in the country's Brazil nut concessions.

There are also nearly 80 subnational REDD+ programs and projects throughout the Amazon (Simonet et al. 2015), including one that focuses specifically on Brazil nut producers. The REDD+ project in Brazil nut concessions in Madre de Dios, Peru, is a contractual partnership between the company Bosques Amazonicos (BAM) and the local federation of nut producers. BAM provides financial and technical support to Brazil nut concessionaires, including a share of profits from carbon offset sales on the voluntary market and access to a local nut processing plant to enhance the product's value, in exchange for forest carbon rights (Garrish et al. 2014). Despite the potential for REDD+ to bolster income gleaned from Brazil nuts in Madre de Dios (Nunes et al. 2012), challenges do exist. For example, in Bolivia, the titled areas for Brazil nut communities are frequently irregularly shaped, noncontiguous, and do not include all stands claimed by the community, which makes the resources difficult for residents to defend (Cronkleton et al. 2009). In Peru, lack of coordination between governmental agencies has resulted in overlapping property rights and land allocation in areas set aside for Brazil nut concessions (Chavez et al. 2012). Yet there is hope, as Norway and Germany's recent USD 240 million pledge to Peru for REDD+ (<https://www.regjeringen.no/contentassets/b324ccc0cf88419fab88f2f4c7101f20/declarationofintentperu.pdf>) includes, for example, regularization of indigenous lands, along with assigning undesignated forestland to indigenous areas, protected areas, and timber and non-timber production areas.

### **Promoting integrated management approaches and sustainable value chains**

Multiple use forest management, while riddled at times with acute development and ecological trade-offs (García-Fernández et al. 2008; Guariguata et al. 2010), has the potential to generate a financial edge over mono-productive options (Ashton et al. 2001; Wang and Wilson 2007). In Peru, harvesting of Brazil nut is both a financially attractive and complementary activity in ecotourism forest concessions (Kirby et al. 2010) and biophysically compatible with low intensity timber harvesting (Rockwell et al. 2015). Across its vast



geographical range, the Brazil nut tree coexists with dozens of timber species (ter Steege et al. 2013; Fauset et al. 2015). And although integrated timber–Brazil nut management can be hampered due to policy, economic and technical constraints (Guariguata et al. 2009; Cronkleton et al. 2012b; Duchelle et al. 2012; Rockwell et al. 2015), many of these trade-offs are not insurmountable. To this end, such integrated management approaches need further development from a technical, regulatory and educational standpoint (Guariguata et al. 2012). In addition to timber regulations, Brazil nut harvesters in Peru, for example, are separately mandated to comply with complex procedures for harvesting, transporting and selling the nuts (Perales and Guariguata 2015) from within the same forest location. That said, Bolivia’s success in dominating the global Brazil nut export market (Coslovsky 2014) has relied less on harvesters following government-led regulations and norms, and more on adapting to international market and trade forces.

Minimizing international price volatility in Brazil nuts is also warranted since a few factors interact in generating price fluctuations. First, “good” and “bad” export years are the combined outcome of inter-annual variation in tree fecundity (Kainer et al. 2007; Rockwell et al. 2015), coupled to weather events such as extended dry seasons that impair river transport and/or floods that damage largely unpaved roads, hindering both access to, and exit from, the forest. Second, because Brazil nuts travel large trans-oceanic distances from producer to importing countries, shipment delays are unavoidable thus affecting the size and storage quality of Brazil nut stocks and therefore the capacity of suppliers and buyers to satisfy demand at any given time. Positive feedbacks can also play a role since low motivation for harvesters to enter the forest in a given year may arise due to low prices the preceding year. Fourth, Brazil nut prices are known to shift as a function of other internationally traded nuts. In addition, the Brazil nut market is subject to heavy speculation since future prices are not negotiated in advance. Hence, state-led and private sector interventions may need to be adapted to locally relevant market approaches and value chains from traditional Amazonian extractivists to global commodity markets (Pokorny and Pacheco 2014). Evidence from Brazil and Bolivia highlights how partnerships between local communities and companies in NTFP commercialization may enhance their well-being (Morsello et al. 2012). Increasing national and international consumer awareness is also key. Although Brazil nuts are a well-known export NTFP for decades, broadening their use by showcasing the nutritional and health benefits is paramount for improving supply chain value and helping to buffer price fluctuations. Brazil nuts are a natural source of selenium (Chang et al. 1995), a mineral with antioxidant properties. They are also a good source of (unsaturated) fatty acids that help reduce coronary heart disease, while also being an alternative for those with gluten intolerance (Yang 2009). The Brazilian national market has a wider array of finished products derived from Brazil nuts (Homma et al. 2014), compared to Peru and Bolivia both of which export most of the shelled and unshelled nuts they produce (although incipient product diversification is emerging). This is probably because the market share of Brazil’s production is larger internal than externally (74 vs. 26 %, respectively; Toledo et al. 2016).

## Conclusions

Returning to our organizing framework, we find through this review that the resource unit (i.e., the Brazil nut tree) reacts robustly to the type and level of extraction currently practiced. Its longevity buffers the impact of repeated harvesting episodes on population

regeneration (Zuidema and Boot 2002; Brienen and Zuidema 2006). Likewise, the diverse resource users have developed a self-organized system that allocates access to the resource base, links to, and supplies global markets, and provides informal financing. Further, resource users have developed endogenous management systems that do not require major change to sustain productivity. In addition, the governance system has, either formally or informally, been supportive to Brazil nut gatherers and the sector as a whole. Yet as more roads dissect Amazonian forests and income from agricultural expansion in the Amazon region transforms local economies, the extraction of forest products may eventually play a lesser role (Ruiz-Pérez et al. 2004; Coomes et al. 2016). Since long-term Brazil nut production seems inextricably tied to a continuous forest cover, one key intervention is clearly to preserve large expanses of productive Brazil nut-rich forests functionally integrated within human-modified landscapes (Sayer et al. 2013; Reed et al. 2016).

Efforts may also be needed to enrich forests in a cost-effective manner to enhance the abundance of pre-reproductive Brazil nut trees. For example, despite the fact that in Peru many Brazil nut concessionaires extract timber as supplementary income (Garrish et al. 2014), historical harvesting intensities have been insufficient in opening up the canopy to the point of significantly enhancing natural regeneration of Brazil nut trees which average only one pre-reproductive individual (10–40 cm in diameter) per every 10 ha (Rockwell et al. 2017). And although timber will keep providing a substantial proportion of forest-based income in Brazil nut-rich forests (Zenteno et al. 2013; Garrish et al. 2014), there is still a notable lack of technical support for managing Brazil nut–timber systems, incorporating local knowledge, focusing less on top-down regulations and more on promoting good practice (Cronkleton et al. 2012b; Duchelle et al. 2012). To this end, the design and implementation of flexible and integrated frameworks adapted to the realities of smallholders, along with suitable extension and financial services are paramount. Peru seems to rely more on command-and-control policies and regulations for smallholder forestry compared, for example, to Bolivia (Pacheco et al. 2016).

Fostering dialogue between different stakeholders—including buyers at the very end of the value chain in developed countries—is also paramount for enhancing equity and benefit sharing. Taking a broader view, it is important to note that certification organizations, such as the FSC, are rethinking their hitherto timber-oriented philosophy and moving to holistic and cross-sectorial approaches that incorporate forest-based ecosystem goods and services (FSC 2015). Expanding Brazil nut harvesting into a “good practice” landscape approach that explicitly includes other ecosystem services and biodiversity conservation benefits could potentially be achieved in the future (Tscharntke et al. 2014). Explicit integration and recognition of Brazil nut harvesting into other productive activities that are also usually carried out by extractivists, such as farming and hunting (as mentioned above), will be needed.

Finally, while granting property rights has been a very important benefit that goes a long way towards maintaining the resource system, national and local governments still need to monitor who continues to hold these rights and ensure the involvement of smallholder extractivists. It is also critical for governments to make sure that devolved rights to Brazil nut harvesters are not transferred to third parties intent on forest conversion. Our own experience in the region suggests that, at present, governments are not doing enough to monitor what happens to Brazil nut harvesters’ rights once they are granted. As described here, the overall resource system does face threats, and continued follow up is needed to support all the key four components described in this paper so they can be adapted to interact in a positive manner in rapidly changing conditions. And as shown above, the role of Brazil nut as the cornerstone of Amazon forest conservation is at present highly

contextual and modulated by both internal and external factors. Tailored interventions that are adapted to the local context may contribute to maintaining the resource base in the long-term.

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