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From conflict of use to multiple use: Forest management innovations by small holders in Amazonian logging frontiers

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ABSTRACT

The Brazilian Amazon is a significant source of timber as well as a rich source of non-timber forest products (NTFPs) such as medicinal barks, oils and fruits. Lack of quantity, quality, uniformity and price as well as a lack understanding of NTFPs socioeconomic, cultural or spiritual value and function in societies relegates them to a marginal economic status eclipsed by timber. The data vacuum for most NTFPs is contrasted by the large amount of timber-specific data available for many logged species. Such data sources can offer insights into the extraction level and locations of a subset of species that are valued for both timber and NTFPs. These are referred to as 'conflict-of-use' species. In this article we examine three such species, focusing on the Amazonian state of Pará. Pará is situated in the Brazilian "arc of deforestation" and the state accounts for 47% of all timber produced in the Legal Amazon. We describe three highly-utilized Amazonian NTFPs currently logged commercially: (1) Cumuru, *Dipteryx odorata*, which bears a seed yielding an essential oil employed in the perfume industry and providing income and medicine to rural families; (2) Amapá amargoso, *Parahancornia fasciculata*, which produces a powerful exudate used as a treatment of respiratory diseases; and (3) Uxi, *Endopleura uchi*, which produces a nutritious fruit consumed by humans and wildlife. We analyze data from the timber industry indicating the rate of extraction of these species, as well as data regarding their use and value as NTFPs. Results indicate that extraction of these species in logging frontiers contributes to declining access. However, in communities with links to markets, undocumented management systems supply the increasing demand for NTFPs in urban areas. While there are no formal management plans for these species and few scientific attempts made to manage them, small holders have developed local knowledge and innovative techniques to improve productivity, increase density and create multiple-use systems in the face of growing land use pressures.

1. Introduction

Globally 400–500 million people are estimated to be directly dependent on forest resources (WRI, 2005) and non-timber forest products (NTFPs) are estimated to account for as much as 25% of the income of close to one billion people (Molnar et al., 2004). Forest dependent people utilize a large suite of the forest resources available (Ballée, 1994; Bennett and Bradley, 2002). For example in the high-diversity Amazonian forests, an estimated 3000 of some 14,000 species of vascular plants are used by people (Lleras Pérez and Mariante, 2009). These species are well-known locally and can be intrinsic to livelihoods, particularly as a buffer in times of hardship. This insurance is lost and household vulnerability increases once the landscape is degraded or useful species are over-harvested (Pattanayak and Sills, 2001). Outside of the local sphere, little is known about the ecology, trade or management of most of these NTFPs including those important for health, subsistence and income generation (Campbell and Luckert, 2002; Pinédo-Vasquez et al., 2002). Of the thousands of native plant species in Amazonia, it is estimated that less than 1% have undergone the process of domestication (Clement, 2007). However, there is nearly a score of extractive species with high enough market demand to become candidates for domestication (Homma, 2004).

Many timber tree species are also highly valued for their fruit, bark, exudates (Guariguata et al., 2010; Laird, 1999; Shanley and Luz, 2003). In Cameroon researchers found that 61% of the top 23

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timber export species were considered important NTFP species (Ndoye and Tieguhong, 2004). Five of the 12 most valuable fruit and medicinal species traded in eastern Amazonia are felled for their timber (Serra, 2010; Shanley and Luz, 2003). Lengthy distances to market, low density of goods, and lack of quantity, quality and uniformity, coupled with low prices are critical factors which inhibit the growth of markets for NTFPs (Clement, 2007; Shanley et al., 2002a). Additionally, the lack of understanding of NTFPs socioeconomic, cultural or spiritual values and functions in societies relegates them to a marginal economic status eclipsed by timber. As such, an emerging term in the literature for tree species with both timber and non-timber value is 'conflict of use' species (Counsell et al., 2007; Herrero-Jauregui et al., 2009; Laird, 1999).

In eastern Amazonia, decreasing densities of preferred timber species as well as increased demand for timber has resulted in the expansion of the number of logged species, often harvested in an unsustainable manner (Veríssimo et al., 1992; Uhl and Viera, 1989). Approximately 100 tree species of an estimated 200–300 species harvested for timber have non-timber values (Herrero-Jauregui et al., 2009; Martini et al., 1994). Widespread forest degradation caused by timber extraction and associated fire (Hall et al., 2003), along with agricultural expansion (Fearnside, 2008) contributes to a growing loss of and restricted access to NTFP species (Menton, 2003). Deforestation is causing a decline in access to certain Amazonian medicinal species used in the treatment of common and chronic ailments (Cunningham et al., 2008), some of which have scientific confirmation of efficacy (Viega et al., 2001; Younes et al., 2007). This trend is disturbing because plants are the primary source of food and health care for tens of thousands of forest-reliant Amazonians and provide income for an estimated one million people living within the Legal Amazon (Pastore and Borges, 1999). In addition, reduced access to natural resources can lead to increased vulnerability by catalyzing migration, decline in nutrition, loss of means to independently earn a living and cultural impoverishment (Dounias and Froment, 2006). In spite of the social, economic and environmental consequences of forest degradation, the topic of conflict of use has received scant attention from the conservation, development or policy sectors.

This paper presents a new analysis of three site and species-specific studies to explore the question of if and how conflict of use occurs in these sites and under what conditions management of these species (valued for their timber and non-timber products), becomes multi-use. We begin with a brief summary of the methods, followed by a short description of the ecology and use of the three species and a summary of local management practices encountered in each of the sites. Next, we use the selected species as a lens to examine conflict of use in eastern Amazonia. We present a case study of *Endopleura uchi* as an example of the impact of timber extraction at the local level and use state-level data documenting timber extraction to analyze the implications logging holds for the three selected species. We conclude by briefly assessing new policies effecting NTFPs and highlight the potential role of local ecological knowledge in multiple use management.

2. Materials and methods

2.1. Study site and species selection

Pará state lies in the eastern Amazonian region of Brazil and is situated in the "arc of deforestation". The state has 73% forest cover, 60% of which is viable for logging (Veríssimo et al., 2002a). In 2009, Pará accounted for 47% of all timber produced in the Legal Amazon, producing 6.6 million cubic meters (m^3) of wood and generating US$ 1.1 billion in revenue (Pereira et al., 2010). The state of Pará produced 62% (2.6 million m^3) of the timber exported in the Amazon in 2009, earning the equivalent of US$ 346 million (Pereira et al., 2010). While unauthorized and predatory timber extraction is rampant (Monteiro et al., 2010), there has been a decline in illegal timber exploration in conservation units and an increase in legally managed forest areas (Pereira et al., 2010; Veríssimo et al., 2002a,b).

The species of focus in this study were selected on the basis of the following criteria:

(1) A relatively broad distribution throughout Amazonia.
(2) An NTFP used widely for both subsistence and trade.
(3) An intrinsic regional nutritional and/or health value.
(4) Display an increasing exploitation for both timber and non-timber uses.
(5) Considered as meriting study by local forest farmers.

Based on these criteria, we selected and analyzed:

- Cumaru, *Dipteryx odorata* (Aubl) Wild. – (tonka bean) produces an aromatic seed commercialized for its essential oil, and
- Amapá amargo, *Parahancornia fasciculata* (Poir) Benoist – produces a medicinal latex,
- Uxi, *E. uchi* Cuatrec – is the source of a nutritional and regionally favored fruit.

2.1.1. Methods

Ecological data regarding densities, NTFP production and small holder management strategies for the three species presented was collected in four field sites in the state of Pará. Study sites were chosen as they represent major source areas of the study species. Cumaru data was sourced from Monte Alegre (Melo et al., 2010; Melo, 2008); Ponta de Pedras served as the field site for the amapá work (Serra et al., 2010); and uxi data was acquired from long-term research in the Capim river region and the peri-urban site of Boa Vista on the outskirts of Belém (Shanley and Gaia, 2004) (Fig. 1).

Market data was collected in the city of Belém and in the markets of each of the towns closest to where the studies were conducted. Over the course of four years (2006–2009), participant observation, semi-structured interviews, inventories of the species and studies of density, production and management served to describe the site-specific ecology and marketing of the three species. Principal sources of products and their prices along the market chain were identified by tracing urban wholesalers back to their supply areas.

Regional NTFP statistics from the *Instituto Brasileiro de Geografia e Estatística* (IBGE, Brazilian Institute of Geography and Statistics), were only available for one of the study species, cumaru. Data on volumes of specific species extracted as timber in the state of Pará were sourced from the published data of Sistema Sisflora/SECTAM (2007, 2008) for: Dipteryx spp.; *P. fasciculata* (including *Brosimum parinarioides*, also called amapá, another timber species producing latex used for similar medicinal purposes) and *E. uxi.*

3. Results

3.1. Ecology

Dipteryx odorata is a member of the Papilionaceae family and is an emergent species. Mature individuals can live to a mean age of 323 years (Laurance et al., 2003) and reach a height of 30 m in primary forest habitat, with diameters of up to 1.15 m (Silva et al., 2002). Cumaru follows a pattern typical of neo-tropical forest trees demonstrating high inter-annual diversity in fruit production (Corlett, 1990; Newstrom et al., 1994; Haugaasen and Peres, 2005).

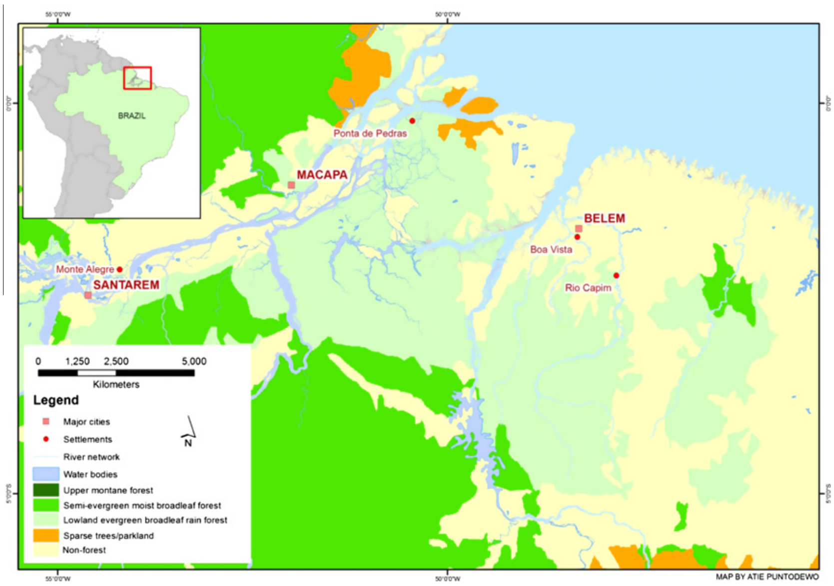

Fig. 1. Map indicating study sites, Pará, Brazil.

Interviews held within extractivist households in Monte Alegre suggest that cumaru has a tendency to exhibit mast fruiting every 4 years. Densities for cumaru are variable, for example, in the study site, cumaru occurs at densities of 5.4 inds/ha but much lower densities of 0.26–0.45 inds/ha have been documented (Projeto Radam Roraima Brasil, 1976) (Table 1).

Parahancornia fasciculata (Poir) Benoist, of the Apocynaceae family is locally known as amapá amargoso (bitter amapá). Other species within this family are also referred to colloquially as amapá amargoso. The Apocynaceae is considered an important family because of its high diversity and the frequent occurrence of plants rich in bioactive compounds (Cunningham et al., 2008). Adult trees can reach 35 m height (Le Cointe, 1947). Very high densities of amapá exist in the study site, where an average of 75 inds/ha occurs; although much lower estimates of 4 inds/ha (Salomão Pers. Comm.); 2 inds/ha (Milliken, 1998) and 0.91 inds/ha (Projeto Radam Roraima Brasil, 1976) have been documented. Results demonstrate that collectors use a number of indicators to determine whether trees are ready to tap, the most reliable being if latex runs rapidly when a small incision is made in the tree. Latex production positively correlates with DBH, but varies depending upon the tool used and cutting technique. Trees are not tapped until they are at least 25 DBH (Serra et al., 2010) (Table 1).

Endopleura uchi Cuatrec is a canopy species with a straight gray-colored trunk, attaining heights of 25–30 m, with diameters of 60 cm per mature individual (occasionally reaching up-to 1 m). Density of less than 1 individual tree per hectare (0.8 inds/ha) in the unmanaged forest site, stands in contrast to high densities found in managed stands (19 inds/ha) in the peri-urban area surrounding Belém. Densities recorded in the literature range from 0.04 inds/ha (Projeto Radam Roraima Brasil, 1976), to 1 to 7 individuals in two 20 ha plots of logged over forest (Wadsworth and Zweede, 2006), to 6 inds/ha in Platô Monte Branco (Salomão pers. comm.). Data from the long-term production study of uxi in our

Table 1
Ecology, dispersers and NTFP harvest season presented for *E. uchi*, *D. odorata*, and *P. fasciculata* in each of the field sites.

Species	Study site	Density (inds per ha)	DBH (cm)	Forest type	Regeneration requirements	Dispersers	Production NTFP per individual (est. mean)	Harvest season
Endopleura uchi	Capim River	0.8	20–90 Std = 21.2	Terra firme	Closed canopy, semi-open areas	*Artibeus lituratus* (Great fruit—eating bat), squirrel, deer, monkey, armadillo, macaw	1530 fruits *n* = 24	February–April
	Boa Vista (near Belém)	32	15–60 Std = 15.1				500 fruits *n* = 18	February–April occasional second harvest July
Dipteryx odorata	Monte Alegre	5.4	15–89 Std = 15.0	Terra firme	Open, semi-open; post-fire	*Rodentia* spp. *Chiroptera* spp. (Rodents & Bats)	40 kg seeds *n* = 53	August–November
Parahancornia fasciculata	Ponte de Pedras	75	20–50 Std = 13.6	Closed canopyTerra firme & varzea	Open, semi-open areas	*Alouatta* spp. (Howler monkeys)	500 ml latex[a] per year *n* = 57	Year round[b]

[a] Appears to be an unsustainable quantity, research in the amapá field site by Serra et al. (2010) suggests that an optimal quantity per tree is less – approx. 139 ml. There exists a significant positive correlation between DBH and latex production.

[b] Some harvesters believe that the latex is contaminated and of lesser quality during the month of June and refrain from extraction. There is no scientific study to verify or refute the claim.

case study demonstrate this species fruits relatively consistently; over 5 years 80% of individuals produced fruit each year (Shanley and Carvalho, 2010) (Table 1).

Average densities for cumaru (1.63 inds/ha) and particularly amapá (75 inds/ha) (Table 4) are high when compared with most tropical forest tree species which often occur at low densities or are locally rare – less than 1 adult tree per ha^2 (Schulze et al., 2008b). In the cases of amapá and cumaru, elevated densities may be artifacts of historical anthropogenic influence and subtle management which over time has augmented natural densities (Miller and Nair, 2006). In the case of uxi in the peri-urban site near Belém, current management practices are of high intensity (19 inds/ha) whereas average density in the more remote Capim site (0.8 inds/ha) reflects natural occurrence under conditions of low to no management (Shanley and Gaia, 2004).

3.2. Use

The three selected species have been used for centuries for both their timber and non-timber products. Cumaru is the most highly valued of the three species for its timber and has a relatively strong international market for its aromatic seeds which are sold to Europe for use in the perfume industry. Amapá and uxi are considered of lower value as timber species and principally appreciated by Amazonians for their latex and fruit.

3.2.1. Timber and trade prices

Bearing an attractive red wood, cumaru is one of the most prized and heavily exploited timber species in the Amazon estuary. Unprocessed, the average price of a cubic meter of a cumaru log in Pará is US$ 132; processed, the cost of a cubic meter of sawn timber rises to almost 4 times as much, US$ 504 (Pereira et al., 2010). Considered a species of relatively low commercial value, the off-white heartwood of amapá and its low-density timber works easily and finishes smoothly and thus is used as veneer. An unprocessed cubic meter of amapá costs US$ 84; after adding value, the price of sawn timber rises close to 4 times, reaching US$ 338 (Pereira et al., 2010). Uxi is a commercially less desirable and lower cost wood. It has practical application due to its durable heavy wood (0.93 g/cm^3). Such locally recognized qualities have also drawn attention to commercial markets and uxi is currently employed for construction including posts, beams, carpentry and cabinet making.

When small holders sell standing trees directly to loggers, prices for trees are markedly reduced. In the community held forests in the Capim region and Marajo island the price received by small holders for one amapá, cumaru or uxi tree bearing roughly 1.5–3 m^3 of wood is approximately US$ 1–10. In areas where high grading of the most valuable species has taken place, loggers often prefer to purchase trees per area rather than per tree, extracting any species, including those of relatively small diameter. In these deals, prices per tree can drop to less than US$ 1. In the region of the Capim communities and beyond, loggers frequently circumvent compensating community members. Payment may be the initial installment only, or a fraction of the agreed upon price, if received at all. There is rarely any negotiation. Cash poor, male leaders of communities generally accept the first price as stated by the logger, without gathering input as to comparative prices from neighboring communities, or the opinions of elders or women, some of whom have privately opposed sales.

3.2.2. NTFP

The three selected species cover a wide spectrum of uses – nutrition, health and income (Table 2).

The aromatic seed of cumaru provides an important income to rural families through its sale to national and international markets. It is also locally used for medicinal purposes and attracts game. The '*leite*' (milk/latex) of amapá makes a critical contribution to local health care, effectively used in the treatment of a variety of ailments particularly respiratory diseases and including tuberculosis (TB) (Schultes and Raffauf, 1990; Serra, 2010). In light of the current crisis of drug-resistant tuberculosis (EDR-TB) (Dorman and Chaisson, 2007), both the ecology of the tree and the chemical properties of the latex merit further investigation.

At the subsistence level uxi supplies fruit which contains a wide variety of nutrients (potassium, magnesium and phosphorus) and vitamins. Uxi pulp contains 6 times more vitamin C than oranges, higher concentrations of vitamin B than most fruits, as well as anti-cholesterol properties (IBGE, 1999). Of equal nutritional importance is the game attracted by the fruit, which makes uxi a favorite for hunters who place traps beneath it or wait for prey nearby. Popular with human populations alike, the fruit is widely consumed and sold regionally and the pulp is used to make ice-cream, popsicles and fruit juices. Based on its market demand which exceeds supply, uxi has been identified as a good candidate for domestication (Homma, 2004), and a key multi-purpose species that could benefit from restrictions on harvest rates to conserve fruit for community consumption as well as wildlife populations (Menton, 2003).

Alongside direct cash incomes generated from marketed non-timber forest resources, important indirect returns also exist for those without market access. One example is provided by the game attracted to amapá and uxi trees which constitutes a significant contribution to the protein intake in small holder family diets. Of a sample of 24 uxi trees, on average, 69% of fruit fall per individual uxi tree is consumed by forest fauna (Shanley and Gaia, 2004). Local hunters favor such sites and in one community uxi trees provided an average of 38 kg of game meat to families throughout the course of the hunting season (Shanley and Carvalho, 2010). In Ponta de Pedras, the fruit of amapá also serves to attract game and is also occasionally consumed by small holders. To replace fruit and game that are consumed free from the forest, families would

Table 2
Three NTFP species and their uses; each species is also extracted from the Amazon for timber.

Species	Non-wood plant part used	Subsistence use	Medicinal use	Market
Endopleura uxi	Fruit, seeds, bark, endocarp	Fruit; game attractant; oil; medicinal; jewelry; spiritual, marketed	Arthritis, cholesterol, diabetes, sinitus, gas[a]	Local, regional
Dipteryx odorata	Seeds	Medicinal, game attractant, marketed	Bronchial dilator, combat cancer, intestinal pains, menstrual cramps, antibiotic, fungicide, anticoagulant, analgesic[b]	Local, regional, national, international
Parahancornia fasciculata	Latex	Medicinal, game attractant, marketed	Severe respiratory diseases, tuberculosis, asthma, syphilis, fortifying tonic, anemia, appetite stimulant[c]	Local, regional, national

[a] Sources: Shanley and Gaia (2004).
[b] Sources: Rodrigues et al. (2006).
[c] Sources: Ribeiro et al. (1999), Velloso et al. (1998), Alves (2003), Berg and Silva (1988), and Schultes and Raffauf (1990).

require significant sums of cash which they are unlikely to have access to.

3.2.3. Income and NTFPs

Living in isolated areas, without technical assistance, small holders in each of the study areas have elaborated their own strategies and mechanisms to develop, manage and trade their resources. In Monte Alegre, cumaru trees produce a large volume of seeds every four years. This variation in harvest size has a notable gender dynamic. During years of low seed productivity, household income is controlled by the women. During these seasons, women invest profits generated in food and basic resources such as clothing and school supplies required to sustain the family. When a year of heavy production occurs, men control the income and generally invest in the purchase of higher cost goods including motorcycles and chainsaws.

Of the three NTFP species, only cumaru seeds have a sizeable export market. The international market generates significant cash, with established sales in the United States, Europe, India, China and Hong Kong. In 2009, the state of Pará produced 97 tons of cumaru seeds, generating the equivalent of US$ 397 million. From 2008–2010, the average price of cumaru seeds more than doubled from US$ 2.00/kg (IBGE, 2008) to US$4.30/kg (IBGE, 2010). In the study area, each family collected on average 40 kg of seeds, annually receiving approximately R$3 or US$1.8/kg in comparison to retail prices which are six times this amount (Melo et al., 2010). Based on production, approximately 2700 families in the region are involved in extraction of cumaru seeds. In Monte Alegre the price of cumaru seeds fluctuates with producers receiving a fraction of the cost of the product as sold by wholesalers and exporters. Harvesters identify two principal problems in marketing cumaru seeds, the generally low price paid to producers for seeds and the lack of a guarantee of purchase.

In Ponta de Pedras some families specialize in the collection of amapa latex ($n = 12$), earning 47% of the house-hold income from amapá, freely available in the forest. Others use it as supplementary income, collecting and selling a wide range of other NTFPs. The majority of the latex collected is sold in Belém, with small volumes used and traded locally. Volumes of amapa collected and sold, depend, in part, on whether or not harvesters hold secure land tenure (Serra et al., 2010).

In the peri-urban study area in Boa Vista, on average, uxi provided households with 20% of their overall income ($n = 15$) and a handful of other fruits and forest goods accounted for most of the remaining income (Shanley and Gaia, 2004). The annual fruiting season is a boon to families as it helps to purchase basic necessities as well as covering additional annual costs such as transportation, school tuition, agricultural tools and construction materials for house building and repairs. In the Capim site, distance from market hindered the sale of uxi fruit and NTFPs, but favored the sale of timber, as loggers routinely visited forested communities offering cash to village leaders and families.

3.3. Management innovations

In each of the case study sites, small holders manage forests to meet both their timber and NTFP needs. NTFP producing trees may be extracted as timber, but generally in their senescent phase, when they are no longer as productive for their fruit, latex or seed. Household focus on managing NTFPs is in part due to the accessibility of the resource and steady market demand for the three products, with the exception of the Capim River site which is distant from markets. In addition, the families' managing cumaru and amapa have relatively small land holdings which are insufficient to sustainably derive a living from timber. Compounding this, timber prices paid to small holders in or near each of the study sites is relatively minimal. Due to neighboring deforestation in each of the sites, NTFP management has become concentrated, marginalizing collectors to forest fragments and creating an unofficial zoning which separates small holder multiple use management from unrestricted logging.

Each of the field sites provided evidence that local management of the study species occurs (Table 3). In each case, land title is a critical variable in establishment of patterns of land use and management (Vosti et al., 2003). During the cumaru production season of September to November in Monte Alegre, residents migrate each day to their approximately 25–100 hectare forest and agricultural plots where cumaru grows and dedicate their time specifically to collection and management. Residents clean beneath trees to aid in the collection of seeds, select germplasm, liberate competing vegetation from cumaru seedlings and plant seeds to encourage regeneration and higher density of productive trees. Seeds are collected at the base of the trees, after which they are cracked to liberate the seed, and transported to the residences of the collectors where they are left to dry. Throughout the year, collectors also harvest other forest resources such as *Uncaria tomentosa*, commonly known as unha-de-gato (cat's claw), and a diversity of palms for human consumption and animal feed.

In Ponta de Pedras, collectors harvest amapá latex on both open access and privately held lands. Open access areas demonstrate less sophisticated management and a higher incidence of damaged trunks than trees tapped on private lands (Serra et al., 2010). Although the current degree of amapá management in terms of planting, weeding and selecting germplasm appears relatively low, higher concentrations of trees in harvested areas indicate that management to increase densities may have occurred over time. Some collectors have become specialists in tapping amapá and offer instruction for other harvesters prior to the tapping season. As knowledge of the tree has increased and new tools have become available, collectors have developed improved harvesting techniques. Historically harvesters cut trees unsustainably with an axe; next, they began using a large machete-type knife, which also caused considerable damage to trunks. Later, when tools from the rubber tapper (*seringuerios*) trade became available in the 1970's, harvesters transferred this technology to tap amapá using a much smaller implement. The '*faca da seringuiera*' or rubber-tappers knife, incurs less damage to the tree, reduces loss of latex, and increases latex flow per harvest and, although it adds more time per harvest, it is the preferred method of harvest to extractors because of the benefits of sustainability (Serra et al., 2010) (Fig. 2). Amapá is collected based upon demand from local markets and outlets in Belém.

Uxi is the most highly managed of the species, but notably, only in the peri-urban site where residents have land title, access to

Table 3
Stand level management techniques encountered in study sites.

Species	Study site	Pest control	Select germ plasm	Increase density	Plant seedlings	Clean beneath trees	Thin competing vegetation	Remove non-productive trees
E. uxi	Capim River						√	
	Boa Vista	√	√	√	√	√	√	√
D. odorata	Monte Alegre		√	√	√	√		
P. fasciculata	Ponte de Pedras		√	√	√			

Fig. 2. Latex extraction with a rubber tapper's knife (left) and a machete (right). Photo: Murilo da Serra Silva.

market is relatively easy and demand for fruit from the burgeoning population of Belém is growing. In the early 1970's, renowned Brazilian botanist, Paulo Cavalcante presciently described uxi as hard to manage and, unless the price of the fruit improved, economically unviable to domesticate (Cavalcante, 1972). Harvesters confirm this remarking that, "uxi is tricky and needs to be transplanted with care". In the following four decades, the rising demand and escalating prices for uxi fruit has stimulated harvesters in the peri-urban region surrounding Belém to develop sophisticated forest management systems resulting in a landscape composed of a score of economically useful palm and fruit tree species including uxi. Formerly called, "fruta de pobre" (fruit of the poor), due to its low price and accessibility to the poor, this name has faded from memory as uxi has gained a respected position in the marketplace with its price doubling to reflect this. The rising demand for forest goods in the city of Belém has incentivized some small holders living near the city to invest in managing their land holdings principally for NTFPs (Homma, 2004). The resultant management system is highly diverse in species composition, independently designed and evolves in response to changing markets.

Through generations of experimentation and management, small holders have augmented densities of favored fruit, latex and fiber, palm and tree species. Residents practice a range of management techniques, such as twice annual clearing of vegetation under trees to aid in fruit collection, the laying of organic compost at the base of fruit trees and ant and pest control through the use of fire. Bruised fruit are left on the ground to insure a substantial number of seeds are available for regeneration. Because uxi is slow to germinate, harvesters preferentially select naturally sprouting seeds from the trees producing the tastiest fruits and carefully transplant these into clearings. Farmers also weigh the fruit production potential of trees such as *E. uchi*, *Platonia insignis* (bacuri), *Caryocar villosum* (piquia) and *Theobroma grandiflorum* (cupuaçu) to decide which fruit trees to maintain and which to fell. When an uxi tree becomes unproductive, it is extracted to make use of its timber and to make way for other fruiting species. Likewise, farmers may cut down one species of tree, such as cupuaçu, to favor a more productive fruiting species, such as uxi. By contrast, in the Capim region where loggers regularly visit communities to purchase trees and where sales outlets for fruit or other NTFPs are distant, less active stand management is encountered. Here, where pressure from logging is high, community members protect seedlings of valuable species such as uxi, medicinal oil and valued timber species as part of their agricultural practices and leave seedlings during selective weeding of agricultural plots.

In the Capim, Monte Alegre and Ponta de Pedras, areas surrounding the study sites are becoming deforested through pressure from other forms of land use (i.e. logging and ranching). However, given effective marketing outlets, accessible transportation and a profitable NTFP species, residents in Monte Alegre and Ponta de Pedras have preferentially chosen to manage their forested areas primarily for cumaru seeds and amapá latex respectively.

3.4. Conflict of use

3.4.1. Local and state level timber extraction

A large amount of data is generated for target timber species and an analysis of such data with a focus on NTFP species can offer insights into the impacts of logging on livelihoods. For example, data on the number of trees legally felled for timber in Pará (01/07–04/08 – Sistema Sisflora/SECTAM, 2008), can be used to estimate the area of forest needed to attain these volumes (Table 4) and where non-timber resource extraction is likely to have been affected. Estimates are based upon information provided by the Institute of Tropical Forestry (IFT) on average volume (m^3) of timber per tree, per species. State-level data from 2008 suggests that 16,945 individuals of cumaru, 4153 individuals of amapá and 2098 individuals of uxi were felled legally for timber. However, little to no analysis exists regarding the implications of timber extraction on the livelihood changes incurred upon local extractivist communities (Menton, 2003).

During the period of January 2007–April 2008; 7953 m^3 of uxi; 19,933 m^3 of amapá including *P. fasciculata* and *Brosmonium parinarioides* (each produces medicinal latex) and 78,795 m^3 of cumaru were legally extracted for their timber generating roughly US$ 315,000, 874,000, and 3912,930 respectively (Sistema Sisflora/SECTAM, 2007). Between December 2006 and July 2007, cumaru ranked 5th of the top 7 most highly commercialized timber species in the state (Sistema Sisflora/SECTAM, 2007). These are underestimates as there is no inclusion of the large volumes of timber *illegally* extracted from the region. Using available sources of data on legal extraction of timber for the three selected species we are able to compare the source areas of legal timber for uxi, cumaru and amapá, against the 23 prime timber sourcing municipalities of Pará as identified in the aggregate analysis of Lentini et al. (2005) (Fig.. 3).

Fig. 3 demonstrates where these species are likely to have been exhausted in old frontiers, as well as identifying the potential new frontiers. For example, Redenção, Marabá, Itupiranga, Cametá and Capitão Poço are old frontiers where these species would be

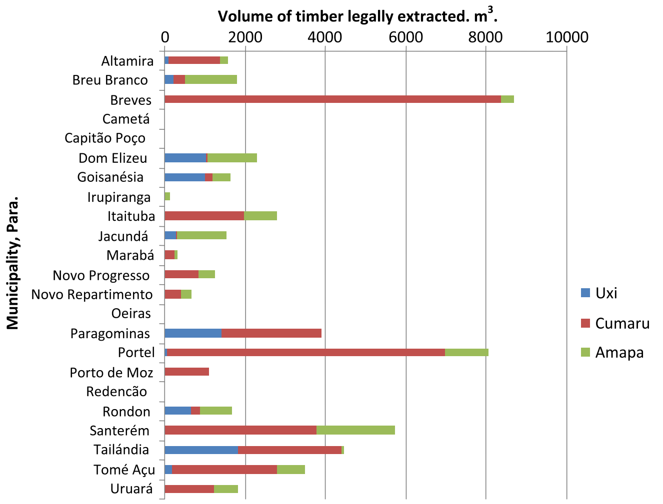

Fig. 3. Timber volumes of *E. uchi*; *P. fasciculata* and *D. odorata* (Sistema Sisflora/SECTAM, 2008) originating from the 23 main timber sourcing municipalities of Pará (Lentini et al., 2005) for the period-01/07–04/08.

Table 4
Estimated area of land exploited to achieve recorded legal timber volumes as documented by Sistema Sisflora/SECTAM (2008).

Common name	Timber legally extracted 01/07–04/08 (m^3).	Estimate number of individuals	Average species density per ha^2	Estimated area exploited (ha^2)
Uxi	7953	2898	0.82[a]	3534
Cumaru	78,495	58,565	1.63[b]	35,929
Amapá	44,391	6414	4.49[c]	1429

[a] Sources: Salamão (2008), Wadsworth and Zweede (2006), Shanley, (2000), and Projeto Radam Roraima Brasil (1976).
[b] Sources: Melo (2008) and Projeto Radam Roraima Brasil (1976).
[c] Sources: Serra et al. (2010), Salamão (2008), Shanley (2000), Milliken (1998), Projeto Radam Roraima Brasil (1976), and Wadsworth and Zweede (2006).

expected to be locally exhausted. Alenquer, Óbidos, Oriximiná and Monte Alegre are sites of current cumaru extraction yet they are not captured in the data presented in Table 4. It is possible that the volume of wood extracted from these towns is accounted for in the large port city of Santarem, where regional timber production is amassed. In areas where significant logging of cumaru has taken place, communities experience a loss of both present and potential future income. Communities report that income from timber does not compensate for loss of cumaru seeds. In the Capim, Monte Alegre and Ponta de Pedras sites, impacts of timber extraction include more frequent fires, lessening game capture and declining availability of forest fibers and other NTFP forest resources.

This data highlights the need for further site- and species-specific research as many species fall out of aggregate studies. Tucurui and Moju are towns in Pará which our analysis highlighted as prime timber sourcing regions for each of the three species presented here, yet are not captured as major timber sourcing regions in aggregate data. This likely occurs because figure of timber felled for less-valuable timber species are comparatively low when compared to prime timber species. The higher volumes of prized timber account for the majority of extraction and therefore mask the lower volumes extracted of what might be locally valuable and vulnerable non-timber species. Analysis of this kind can identify a starting point to understand comparative vulnerability.

The intensity and range of conflict of use varies spatially and temporally depending on many factors including whether the NTFP is used for subsistence or market, degree of reliance, seasonality, local preferences, opportunities and market value. In terms of relative value for timber in the four study areas, cumaru experiences the highest pressure from the timber industry, while also being the species with the most established market. This finding complements results of a study identifying cumaru as one of four species in Pará representing the highest potential of conflict of use (Herrero-Jauregui et al., 2009).

The Capim study site provides evidence of the impact that species extraction can have on communities at the local level, eventually resulting in conflict of use. Extraction during the first few logging operations was limited to a selected handful of high-value timber species (excluding uxi or other locally valued fruit or medicinal oil trees) which posed limited impact on the availability of locally valued NTFPs (Shanley et al., 2002b). In the mid-1990s when stocks of these high value timber species declined in the region, the timber industry expanded the number of species extracted from half a dozen to over 300, including locally valued fruit and medicinal tree species (Martini et al., 1994).

During the late 1990's and early 2000's, timber deals involved the wholesale purchase of trees by land area as opposed to a few select species. In spite of the negative impacts on NTFP availability, small holders continued to sell timber. Decisions to continue timber sales by various leaders of the community were due to many factors including: exclusionary decision-making processes; paternalistic relationship with loggers; insufficient negotiation skills; limited sources of income; rising market needs and desires; and poor harvest seasons resulting in lower agricultural incomes (Medina and Shanley, 2004).

After successive loggings over a decade-long period, 16 trees (63%), of a sample of 24 uxi trees were extracted (Shanley and Carvalho, 2010). Post logging, households demonstrated a marked decline in consumption of NTFPs including uxi, other forest fruits, fibers and game (Shanley et al., 2002b). Synergistic effects of logging, fire, and wind have contributed to raise the risk of mortality for remaining trees and for many species the adverse ecological conditions and cycles that ensue after logging periods (Barlow and Peres, 2007; Cochrane et al., 1999; Laird, 1995) preventing a return to pre-logging species composition (Hall et al., 2003).

4. Discussion

4.1. Implications at multiple scales

Although logging of particular species of value to local communities may seem inconsequential given the scale of Amazonian deforestation, there are numerous implications to consider. First, at the local scale, the significance to rural communities can be grave, threatening livelihoods and diminishing their quality of life. Declining availability of game, fruit and medicinal plants can result in nutritional deficiencies, illness and/or the loss of income from forest products. Second, the data above represent only legal logging. Between 2008 and 2009, 73% of the logging in the state of Pará was unauthorized including illegal exploration of timber in conservation units (Monteiro et al., 2010). Therefore, it is likely that a great number of conflict of use species being extracted throughout the region remain undocumented. This is true of areas both within and outside of protected areas in the commonplace scenario where local communities are poorly equipped and/or have few rights to make decisions regarding timber extraction. Newly designated Conservation Units throughout Amazonia, including Extractive Reserves and Sustainable Development Reserves offer excellent opportunities for small holders to have some degree of control over forest management, but only if regulations against illegal logging are enforced and communities are better informed (Kluppel et al., 2010).

Furthermore, on the broader scale, fragmentation of and loss of plant and animal species holds immeasurable consequences for Amazonian biodiversity and ecosystem value and function. Recent predictions indicate forest loss coupled with climate change and fire can destabilize the Amazon's hydro-geological system and lead the Amazon to a threshold when it could shrink to one third of its current size in 65 years (Vergera et al., 2010). Resolving the issues which conflict of use species present could offer a safeguard for local well being, particularly in areas where logging directly interfaces with community use and management of forests. Because conflict of use species will vary by region and throughout time, far-sighted management would entail protection of not only product-specific forests serving current markets, but forests which might hold potential species of interest to meet future needs.

4.2. Obstacles to creating public policies: knowledge gaps

NTFPs hold a peripheral status in public policy worldwide; both the products and those that use them are invisible to decision makers (Laird et al., 2010). This is due to many factors including the vast nature of such a group of products, the difficulty to assess value of NTFPs; their often low densities, high cost of labor to extract, and the fact that less powerful, often vulnerable members of society use and benefit from NTFPs (Laird et al., 2010; Clement, 2007; Shackleton and Shackleton, 2004; Homma, 1992). Of amapá, uxi and cumaru, only cumaru is recorded in IBGE data (IBGE, 2009). According to the IBGE, timber products generated approximately US$ 1.7 billion of the extractive production in 2009, while the recorded value of NTFPs appears meager by comparison, totaling approximately US$ 293 million. Close to 90% of this NTFP production is accounted for by only six species: açaí (*Euterpe oleracea*); babassu (*Attalea speciosa*); piassava (*Attalea funifera*); native erva-mate (*Ilex paraguariensis*); carnauba (*Copernicia prunifera*); and Brazil nut (*Bertholletia excelsa*) (IBGE, 2010). The number of NTFP species for all of Brazil recorded by IBGE in 2005 was 19, rising in 2009 to 25; however, even this slightly higher number represents a fraction of only the medicinal species (200–300) daily sold in one outdoor market in Amazonia (van den Berg, 1984; Shanley and Luz, 2003) or the thousands of species cited as used by people in the region (Lleras Pérez and Mariante, 2009). Lack of documentation of the actual trade, income and employment generated by NTFPs worldwide has contributed to their marginalized status as compared to timber (Shackleton et al., 2007).

Filling in knowledge gaps regarding NTFPs and multiple-use will require concerted efforts from numerous actors, including harvesters, researchers, policy makers and training institutes (Guariguata and Evans, 2010; Vedeld et al., 2004). At the state and national levels, there is significant room for improvement for better monitoring of the trade in NTFPs. For example, in Pará the body responsible for collecting data on traded forest resources, the IBGE, includes only a few species with volumes recorded as over 100 tonnes per year. All of the remaining species are grouped in a blanket category of 'other' making specific analysis impossible. Of amapá, uxi and cumaru, only cumaru is recorded in IBGE data (IBGE, 2009). Another branch of IBGE – the *Secretaria* Municipal *de Economia do Município de Belém* (SECON) collect market price and demand data at the state level, but in Pará only for a subset of four NTFP species, and only for those products which arrive by boat. Because no formal body is responsible for collecting data on forest products, the vast network of small holders engaged in this trade and their manifold products remain imperceptible to governmental agencies and policy makers. Fairly simple complements to measures already underway could offer a means to capture valuable data, for example, reference to NTFPs in the national agricultural census. Timber statistics, such as those synthesized by the Institute of Man and the Amazon Environment (IMAZON) (Lentini et al., 2005; Pereira et al., 2010), can shed light on the status and vulnerability of both timber and non-timber forest species. State and national governmental agencies could broaden the scope of their data collection to include both national and export trade of NTFPs and trade in, and employment generated by, a more extensive range of forest resources. In this way, international agencies such as United Nations Food and Agricultural Organization (FAO), can more accurately report on global NTFP value and trade.

Making visible the lesser known contributions of forest resources to society can improve cost benefit analysis and land use decision making. Such insights can help to develop targeted policy (e.g. for who, how many and for which species) and avoid policy failures such as those which add further burdens on forest-reliant households (e.g. taxation on collectors, limits on access, burdensome regulations). Cross-regional case studies demonstrate that caution in policy making is advised as state and federal policies have frequently contributed to, rather than ameliorated, the difficulties encountered by rural extractivists (Laird et al., 2010). For example, in attempting to protect *Heteropsis* spp. from overharvest, the state of Amapa, Brazil developed regulations requiring management plans and license for extraction. The well intentioned regulation placed unfair burden on small holders, who lacked capacity to develop management plans, while inadvertently favoring larger enterprises (Wallace et al., 2010). Instead, policies that endorse secure land tenure and accessible collection and trade of NTFPs for small holders, can help to support the conditions needed for multiple use forest management. In the state of Pará, for example, state agencies, such as the State Institute of Development Policy of Extractivism (Ideflor), employed statistics on the volumes of NTFPs traded and number of collectors, as support to develop a state policy for extractivists. This has resulted in the provision of previously inaccessible social service benefits to NTFP collectors (Ideflor, 2008). At the Federal level the government eased restrictions on travel authorization for NTFPs, facilitating marketing and transportation by small holders (Kluppel et al., 2010).

4.2.1. Policy recommendations and capacity building for moving from conflict of use to multiple use

Aligning sustainable timber extraction with NTFP extraction systems is regarded as an important step by the research community (Secretariat of the Convention on Biological Diversity, 2001). Further, it is recognized that the relationship between the harvest of NTFPs and timber needs inclusion in forest management and planning (Guariguata et al., 2010, 2008; Mollinedo et al., 2001; Laird, 1999, 1995). However, agricultural policy is often overlooked as a key factor in influencing land use and forest management practices. Within the agricultural sector, there is growing attention toward the use of agro-forestry systems to restore millions of hectares of degraded lands with economically useful tree species. Given the increasing rates of urbanization in Amazonia, focus on restoration of areas on the periphery of cities with locally used and valued species can restore biodiversity while generating employment and income (Homma, 2004).

Regulating policy specifically directed at NTFPs in the Brazilian Amazon creates many uncertainties due to the high number of species and the particular requirements of each, by species and by site (Kluppel et al., 2010). Despite the complexity, globally Brazil is at the forefront of NTFP policy, partly influenced by the strong national appreciation of traditional heritage and cultures and its pro-poor stance on policy development. The Brazilian commitment to provide 50 million ha of public forests (Veríssimo et al., 2002a,b) likely to include vast areas of timber concessions (Merry et al., 2003) provides an opportune time to better manage the relationship between timber and non-timber forest resources. In extractive Reserves and Sustainable Development Reserves, it is feasible to organize multi-use management, because local communities are in the position to determine the relative value of each species and to create their own management plans. In National Forests which may be ceded to timber concessions, it is unlikely that multiple or sustainable use forestry will become a reality unless sections of the National Forest are designated for local communities to manage on their own behalf.

Some species are nationally protected from timber extraction explicitly to conserve non-timber resources; examples include the Brazil nut tree (*Bertholettia excelsa*); Rubber tree (*Hevea* sp.) and the Parana Pine tree (*Araucaria angustifolia*). The Amazonian states of Amapá, Acre, Pará and Amazonas have implemented legislation in support of forests and forest-reliant families. Acre is arguably foremost and provides subsidies to rubber tappers, to secure their way of life and to ease the rising rates of urban migration. Amazonas has also written a new state law that prohibits timber extraction of two important medicinal oil species – *Carapa guianensis, C. paraense* (andiroba) and *Copaifera trapiezifolia, C. reticulata, C. multijuga* (Copaiba) (Kluppel et al., 2010). State level commitment coupled with the call from communities and unions for equitable forest management create an opportunity for supporting and expanding small holders' efforts in managing forests for multiple uses.

Certification could also be a tool to help curb conflict of use through conservation of species with an important socio-cultural role. Brazil has made pioneering advances in forestry such as implementation of reduced impact logging (RIL), improved procedures for increasing access to small and low intensity managed forests initiative (SLIMF) and has certified more NTFPs under the FSC system than any country worldwide (Pinto et al., 2008; Shanley et al., 2008). Despite these gains, forest management standards are highly subjective (Schulze et al., 2008a) and still difficult to apply to the reality of communities managing for multiple products (Pinto et al., 2008). Furthermore, there remains a persistent disconnect between managing forests to meet ecological or social objectives. For example, while ecologists have characterized *Tabebuia impetiginosa* (ipé roxo or pau d'arco) as a threatened species, meriting classification on CITES, prized timber of this medicinally valuable NTFP species continues to be prominently marketed in the US as certified and sustainable (Guariguata et al., 2010; Pinto et al., 2008; Schulze et al., 2008a,b).

Another formidable challenge is that many forestry agencies have limited understanding of, or capacity to promote, multiple-use (Guariguata et al., 2008; Guariguata and Evans, 2010). Trained forestry personnel will be important for multiple use management to be administered on a broad scale. The Institute of Tropical Forestry (IFT) identifies lack of trained forestry personnel as a critical challenge to the expansion of sustainable forest management in Brazil. While IFT has trained 4000 workers and professionals, they estimate that 30,000 trained professionals will be needed to manage Brazil's long-term needs (IFT, 2010). Understanding how to integrate management of timber and NTFPs and to manage for multiple-use will require even greater training and expertise and governmental support to relevant state and federal agencies. To meet these needs, forestry and agricultural training which includes ample field study with small holders engaged in multiple use management can offer an effective approach. When founded upon the basis of long-term observation and experimentation small holder knowledge and management can reflect a profound knowledge of ecological processes (Sears et al., 2007). Local management techniques showing promise can be transferred to other areas through farmer networks, rural workers unions, extension agencies and training materials (Shanley et al., 2010).

4.2.2. Priority species, local knowledge, and management practices

Change in assessing forest value and implementing multiple-use needs to begin with including NTFPs in inventories to better understand the full suite of species valued in the region. In regions where conflict of use is an issue, foresters need to look to rural communities to identify what they regard as valuable species, including game and game-attracting tree species. For example, fruiting trees insure a viable population of wildlife, some of which are seed dispersal agents, and/or integral to local nutrition and culture. Distribution maps utilized by the timber industry could provide a starting point for joint inventories, as well as a tool for modeling the impact of land-use change, fire and timber extraction on non-timber species that are important locally. These maps could offer socio-cultural orientation and zoning initiatives whereby timber and NTFP species are sustainably managed for community use or trade (Cronkelton et al., 2010; Guariguata et al., 2010).

After community identification of locally valued NTFPs, technical recommendations for multiple-use can be implemented which support compatible extraction and reduce damage for locally valued NTFPs (Guariguata et al., 2010). Small holder management practices should be taken into account as these constitute under-utilized tools which can provide useful information towards integrating management of timber and non-timber species (Padoch and Pinédo-Vasquez, 1996). Recommendations may include, imposing restrictions on harvest rates of the species identified as meriting priority, and designing timber extraction to limit structural damage and the number and the size of clearings (Menton, 2003). These practices can conserve locally valued fruit, medicine and game-attracting species as well as helping to insure reasonable access to the resource post-logging. To encourage future harvests and regeneration post-logging, silvicultural treatments may be necessary, particularly to promote seedling regeneration and growth by surviving trees valued by communities. Post-logging enrichment planting will be particularly important for trees demonstrating poor regeneration after harvesting as some valuable species can become locally extinct (Schulze, 2008; Schulze et al., 2008a). Although widespread application of recommendations such as these, are costly and presently unrealistic within large forest concessions, such an approach may correspond well with community forest objectives and Extractive Reserves (Allegretti, 1990; Menton, 2003).

5. Conclusion

Results indicate that for conflict of use to diminish and multiple use to increase, additional attention will need to be given to agricultural policies, zoning and land tenure, as secure property rights represent a basic foundation for incentivizing sustainable forest management and restoration of degraded areas. Policies designating extractive reserves and sustainable development reserves in Brazil are major steps towards insuring the foundation for multiple use forest management on a significant geographic scale. Effective safeguards will be needed to guarantee that local residents have and retain resource access rights and means to management of conservation units. In the substantial geographic areas outside of reserves where rural communities manage forests, small holders need access to market and regulatory information to make more informed decisions regarding land use options and sale of timber and other forest products. Furthermore, regulations on timber industries and agri-business, including fire prevention measures, need to be implemented in frontier regions, particularly those interfacing forest communities.

Our analysis of uxi, cumaru and amapá offers three examples of small holder innovations in multiple use forest management. These three trees represent a subset of the scores of NTFP species currently sought by the timber industry irrespective of their non-timber value. In spite of the monetary and direct use values of numerous tree species to rural communities, logging can pose a threat to the population viability of conflict of use species (Guariguata et al., 2010; Schulze et al., 2008b). However, the latex, seed and fruit produced by the three species here presented, offer sufficient market value to influence small holders to develop sophisticated management regimes where secure land tenure exists. Small holder management innovations are particularly important given that limited scientific studies on the germination, NTFP production, management and/or harvesting have been undertaken for these and many other NTFP species of local and regional value. Thus, relatively unnoticed, small holders in pockets of Amazonia are serving multiple and critical functions that have impacts beyond the local sphere: augmenting scientific understanding by experimenting with and generating knowledge about lesser known species; supplying local markets with foods of high nutritional and health value; protecting essential ecosystem services; and conserving germplasm of a suite of species which bear multiple values for society (e.g. via their medicinal and cultural properties and for the role that they play in forest ecology). Better understanding of multiple use management can best be achieved through evaluation of small holder management systems, particularly peri-urban areas where market demand intensifies management of NTFPs. For this to occur, agriculture and forestry training institutes need to provide opportunities for students to spend substantial time in rural communities, where multiple use is not an academic concept but a reality.

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