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The economic viability of smallholder timber production under expanding açaí palm production in the Amazon Estuary

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ABSTRACT

Relatively little attention has been paid to the economic potentials and limitations of tropical timber production and management at smallholder scales, with the most relevant research focusing on community forestry efforts. As a rare tropical example of long-lasting small-scale timber production, in this study we explore the economics of smallholder vertically integrated timber use to better understand the activity in the context of its primary land use alternative in the Amazon Estuary, açaí palm fruit production. We use data from landowner and firm surveys, participatory monitoring of firms, and detailed forest and sawmill operation monitoring to devise financial returns models of smallholder timber micro firms and açaí palm fruit production. We then compare the economics of the two activities to better understand how differences may shape decisions at the small holder scale that impact current land use shifts in the region.

Introduction

In the mouth of the Amazon River, smallholders have developed a micro-scale vertically integrated system of timber production (Pinedo-Vasquez et al., 2001; Sears et al., 2007). Contrary to community

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led efforts elsewhere, these informal micro firms are owned individually and commonly integrate timber extraction and processing in local circular sawmills. For decades, hundreds of these micro firms have produced sawn lumber sold primarily at local and regional markets (Barros and Uhl, 1995). As past research in Amazon tidal forests have documented the potential for small-scale sustainable timber management, these micro firms bear special relevance to the potential role of smallholders in sustainable timber management (Barros and Uhl, 1995; Pinedo-Vasquez et al., 2001). Surprisingly, one of the largest threats to micro-firm timber production in the estuary appears to be the production of açaí palm (*Euterpe oleracea*) fruit. Characterized as a non-timber forest product by some or as a driver for forest conversion by others, it is nevertheless an increasingly popular alternative to timber production in the Amazon Estuary (Brondizio, 2004; Weinstein and Moegenburg, 2005). While açaí can be harvested from mixed stands, intensified açaí production often results in mono-specific stands where most competitor species (including timber species) are eliminated while the abundance of açaí is increased from natural regeneration and additional plantings. As a rare tropical example of long-lasting small scale timber production, in this study we explore the economics of smallholder vertically integrated timber use to better understand the activity in the context of increasing açaí palm fruit production, the most important land use alternative to timber in floodplain forests of the Amazon estuary.

While the majority of timber management literature from the Amazon has focused on industrial operations, it is estimated that 95% of rural properties in the Amazon are less than 500 ha, providing as much as 28% of regional timber output (Lentini et al., 2005). Government settlements in the Amazon alone account for approximately 500,000 smallholder families that commonly sell timber (Lima et al., 2006). Surprisingly, relatively little attention has been paid to the potentials and limitations of timber management in smallholder scales, with the most relevant research focusing on community forestry efforts (d'Oliveira, 2000; Rockwell et al., 2007b; Humphries et al., 2012).

Smallholder timber operations may vary substantially from industrial operations in techniques, technology, capital availability, market reach and ecological impacts (Salafsky et al., 1998; Rockwell et al., 2007a; Keefe, 2008). Without the proper knowledge and consideration of the potentials and limitations of smallholder timber management, most legislation on timber use in the tropics has focused on the industrial scale, leading to unrealistic expectations to smallholders and communities (d'Oliveira, 2000; Rockwell et al., 2007a; Zarin et al., 2007).

In this study we use data from multiple sources including landowner and firm surveys, participatory monitoring of firms, and detailed forest and sawmill operation monitoring to develop a financial returns model of smallholder timber micro firms. With this model we determine the financial costs and revenues of timber micro firms and the factors most influence long-term economic viability of timber production by micro firms. We then use a simple açaí financial returns model to better understand how the differences in economics between the two activities may shape ongoing land use shifts in the region through decisions at the small holder scale.

Study region

We conducted our research in the 160 sq km Mazagão watershed at the western side of the Amazon estuary (Fig. 1). The Mazagão watershed has a long history of timber use (Pinedo-Vasquez et al., 2001) with current micro scale timber extraction as part of diverse livelihood strategies that often also include palm fruit, fishing, and cropping. Mazagão is similar in composition and land use history to several adjacent watersheds, as confirmed by region wide inventories and surveys conducted in 2005 (Fortini, *unpublished data*). Mean annual temperature is 27 °C and average daily temperature varies by less than 3-C from month to month. Mean annual precipitation is 2550 mm and occurs mostly in the wet season months of January–May. This part of the Amazon estuary is characterized by freshwater tidal fluctuations of 2–3 m. Because of the elevated river level in the wet season, local forests may flood twice daily during high tides.

The floodplain smallholder timber production system is characterized by local family-owned micro scale timber producing firms centered around small sawmills that process locally harvested timber to be sold regionally. Although past research suggests sawmills worked independently from those who extracted timber and sold as logs (Barros and Uhl, 1995), forest extraction in Mazagão is largely

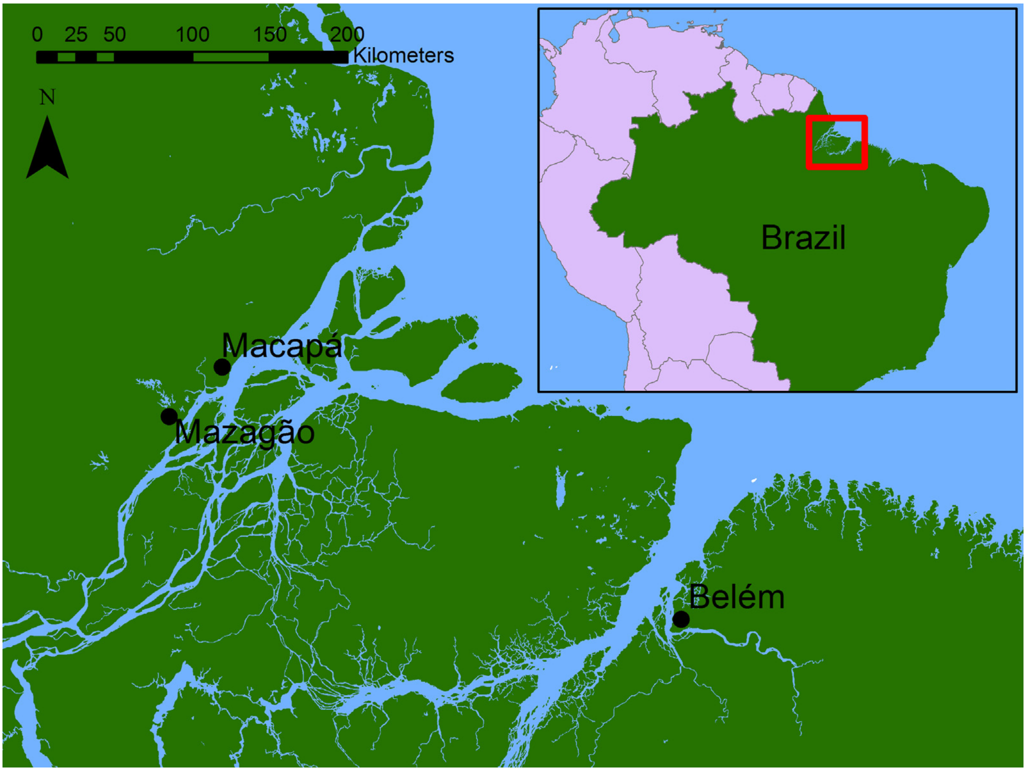

Fig. 1. Map of study site.

performed by the same 4–5 person crew responsible for sawmill operations (Lentini et al., 2005). While up to 10–20 years ago felling by axe was common in the region, now chainsaws are prevalent (Barros and Uhl, 1995; Lima et al., 2006). One of the characteristics of these firms is the high dependence on manual labor. Once trees are felled, tracks are manually cleared where bucked logs are pushed over small rails made from small non-commercial stems to river edge. Logs are then manually floated with the aid of tides to the mill using float wood or larger rafts (Barros and Uhl, 1995). As of 2008, 12 micro firms where established in the watershed.

Methods

Monitoring of extraction and sawmill activities

We monitored extraction activities between June and August 2008 to quantify all costs and production of related activities. Because crews alternate time spent in the forest and sawmill, we monitored the activities of two crews from two of the 12 firms present in the region. The two firms were chosen for being in the middle of the range in terms of size when compared to all other firms present. While there was variability in size of firms present in the region, that variability is small as firms operate using a same standard sawmill configuration based on a circular saw powered by a single two-stroke diesel engine. Because of that, our selection of firms studied should not have large impacts on overall research results and implications.

The field methodology was based on similar methodology used to closely monitor conventional and reduced impact logging operations in upland forest (Holmes et al., 2002). However, we adapted the methodology to incorporate the many aspects of floodplain logging not considered in the original

Fig. 2. Timber production activities monitored and modeled in research: (a) felling and bucking; (b) clearing path and laying tracks; (c) pushing logs; (d) floating logs, and (e) saw timber milling.

methodology (e.g., manually floating logs vs heavy machinery use). We devised a monitoring methodology to record time spent by each crew in each of five activities: felling and bucking; clearing path and laying tracks, pushing logs, floating logs, and transportation to and from forest sites (Fig. 2). All trees and tracks between felled trees and river edge were mapped and geo-referenced. Using a tree, log and trail numbering system, the production for any particular activity (e.g., volume felled, m trail created) was related to time spent on each category. To calculate harvest efficiency, we measured total stem volume (i.e., from base to crown base) and harvested log volume for each felled tree by measuring diameter along the stem. We calculated transportation efficiency simply as the total log volume harvested per harvest operation vs total volume reaching the sawmill.

The same two firms monitored during extraction activities were chosen for a similarly detailed sawmill monitoring between May and October of 2007. We recorded the processing time, volume and yield of each log processed and all related labor, fuel and food expenses. Additional cost and production data was obtained through the participatory monitoring of three average-sized firms from 2006 to 2008. Based on past collaborative data collection methods used in community wildlife monitoring through hunting diaries (Constantino et al., 2008) and timber harvest monitoring efforts (Pokorny and Steinbrenner, 2005), we used simple accounting books where firm owners registered all log and tree purchases by species, listing the place of origin, species, volume or number of logs, stumpage/log costs and related sawmill processing costs during that period. To check the daily cost and revenue estimates above and complement them with estimates of capital investment, equipment durability for depreciation calculations, and maintenance costs, we also conducted detailed surveys about costs and revenues with all firm owners present in the Mazagão watershed in July–August 2008. These surveys included questions about the minute details of firm operations including cost of timber; fuel costs and consumption; costs, maintenance, durability of required equipment (e.g., chainsaw, boat, sawmill parts and engine); size and productivity of harvest and sawmill crews; and firm production and sales. These surveys were similar in methodology and depth as those conducted by Merry et al. (2005) and Lentini et al. (2005). Because this study follows 4 years of local rapport building during other related research, we expected our close monitoring to accurately reflect timber activity in the region. We report all cost and revenue values in U.S. dollars based on the average exchange rate during the period of data collection (May 2006 to August 2008; R$1.93 per U$1).

Financial returns model

The field data collected was used to construct a single firm financial return model that assumes a firm operates under short run conditions, no market power and no economies of scale for a period of 30 years. The 30 year time horizon was selected to include the lifespan of a sawmill and at least one full typical harvest rotation (10–30 years according to Brazilian forestry legislation). To reflect the way timber is usually produced in the watershed, the model includes two modes of production: firms purchasing standing trees, and firms purchasing felled logs delivered to the sawmill's port.

We depreciated capital assets as a means to annualize periodic replacement costs (i.e., an annual contribution necessary to ensure future replacement costs) to avoid peaks in year-to-year costs based on estimates of equipment durability. We calculated straight line depreciation based on use or time depending on whether the durability of the asset was dependent on usage (e.g., mill engine, chainsaws) or time (e.g., mill housing, wood boats). Operational costs were modeled for all stages of production from felling to milling. Since chainsaws are used for extraction and for longitudinally splitting large logs in the sawmill, we divided chainsaw depreciation and maintenance costs according to their proportional use in extraction and milling. Similarly, we excluded a portion of boat and boat engine depreciation and maintenance costs proportional to the estimated boat use unrelated to timber production. The final model also included changes in extraction practices during the flood season (i.e., shorter pushing distances). Annual firm revenue was calculated as firm output (based on harvest, transportation and sawmill efficiency), allocated among the four predominant board types and their respective market prices. Revenue from the sale of solid wood residues to charcoal producers was also included in the model. The model's outputs include cost and revenues by year and m^3 processed and calculate net present value (NPV) of the firm by discounting all costs and revenues over the 30 year projection period. Due to the limited economic opportunities of the region, we used an interest rate of 6.79% for discounting. This is based on the national average savings rate from 2006 to 2008 and reflects the lack of alternative investment opportunities beyond the two activities considered. This is in the middle of the range of discount rates utilized in similar tropical forest economic studies (Chomitz, 2007). As both timber and açaí production are long-term activities, preliminary analyses showed comparisons among these two activities did not change substantially based on discount rate changes.

Model perturbation and sensitivity analyses

Following model creation and parameterization, we performed perturbation analysis to evaluate parameter importance to overall model output using multiple model runs with parameters varying randomly within their observed ranges (Boltz et al., 2001). Since results of the perturbation analysis are based on the observed variability of each model parameter, we consequently relied instead on a simpler elasticity analysis that considered the effect of a 1% reduction in mean parameter value on model output NPV. We used a standard formula to evaluate the arc elasticity of model output to changes in individual parameters (Eq. (1); Klemperer, 1996).

$$\text{Elasticity}_i = \frac{\Delta NPV/|NPV|}{\Delta \text{parameter} \quad i/|\text{parameter} \quad i|}$$

This elasticity formula allowed us to evaluate the direction and relative change in model NPV, with elasticity values >1 or <−1 indicating greater proportional change in NPV arising from changes in a given model parameter value.

Evaluating açaí costs and revenues

To compare the attractiveness of timber production to açaí fruit production, we used previously published data along with interviews with açaí producers in the watershed to quantify startup costs (e.g., clearing and planting), and yearly management and harvesting costs (Hiraoka, 1992; Munizmiret et al., 1996). Average per ha production estimates for the region were calculated by estimating average açaí stand density from 25 açaí stand inventories conducted in Mazagão and using a second degree, no-intercept polynomial function relating per hectare production and açaí stand density calculated from previously published data (Brondizio and Siqueira, 1997).

$$\text{Production} \quad (\text{baskets}) = 3.56 \times 10^{-4} \times \text{açaí} \quad \text{clumps}^2 + 0.243 \times \text{açaí} \quad \text{clumps}$$

Since production is highly seasonal and largely synchronous across households, we used production and price data collected from a single household between 2005 and 2008 to calculate the weighted average revenue per 18 kg basket of açaí for the region (Munizmiret et al., 1996). Startup costs, annual

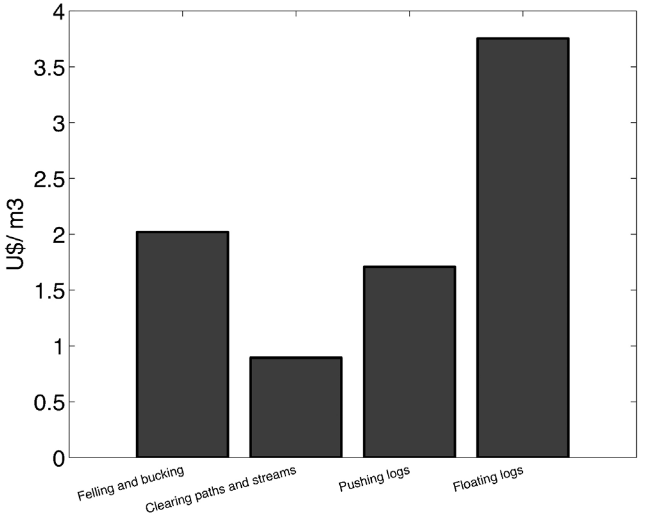

Fig. 3. Average costs per extraction activity standardized by timber volume delivered to sawmill.

revenues and management costs were used to calculate the NPV of establishing a one ha stand of açaí from recently undisturbed forest and managing it for 30 years. Açaí stand NPV was calculated as a finite payment series (where each yearly payment represents total yearly revenues minus costs) discounted from the year of first harvest minus initial startup costs. This approach reflects the local açaí management that includes the continuous thinning of older less productive stems that allows for continuous production without the need for clearing and replanting stands every 15–20 years as described elsewhere (Munizmiret et al., 1996).

Results

Extraction practices

The annual costs of extracting 750 m^3 of standing volume to sawmill harbor (the average per firm in the watershed) was \$4457. This value excludes stumpage costs and results in an average of 532 m^3 of timber reaching the sawmill based on a 71% timber harvest efficiency and 100% transportation efficiency. Costs of extraction standardized by volume output show floating costs to transport timber from forest river edge to sawmill is larger than all other activities including felling and bucking (Fig. 3). As expected due to the low level of mechanization, labor related expenses (\$6.62/m^3) entirely overshadow fuel and equipment costs (\$0.49/m^3 and \$1.27/m^3, respectively). Forest monitoring also revealed that on average 15% of labor time is spent in traveling to and from the forest.

Sawmill practices

Based on detailed sawmill monitoring data, firms produce on average 195 m^3 of sawn wood per year with a mean sawmill processing efficiency from logs to sawtimber of 37%. A two-way ANOVA also revealed differences in milling efficiency between sawmills and among species sawn (Species df = 4, F = 3.36, $p < 0.01$; Mills df = 1, F = 12.83, $p < 0.0004$; Species × mills df = 3, F = 4.84, $p < 0.002$). However, in practical terms these differences were small with mean processing efficiency varying little between sawmills (0.41 vs 0.36) and among species, with *Mora paraensis* and *Platymiscium filipes* having mean values around 0.3 and *Calycophyllum spruceanum*, *Carapa guanensis* and *Licaria mahuba* having mean values around 0.4. Surprisingly, while volume input and output per log were strongly related ($r = 0.82$, $p < 0.0001$), log use efficiency was not correlated with log diameter. This is likely a result from an

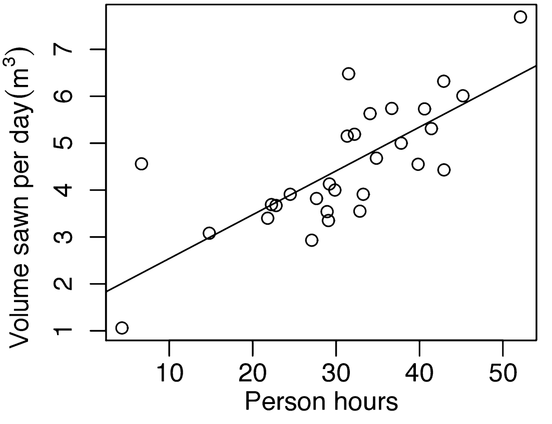

Fig. 4. Sawmill volume processed by person days of work.

increased proportion of irregularities and defects with age and due to the use of chainsaws to split large logs that sawmill saws could not process. Perhaps due to these patterns, while it clearly took longer time to process larger logs ($r = 0.61$, $p < 0.0001$), volume output per hour was not related to log size. Lastly, a link between mill volume processed daily and person hours of effort was apparent (Fig. 4; $r = 0.75$, $p < 0.0001$).

Costs and revenues of micro timber firms

Firms need approximately $7451 to cover startup costs (e.g., sawmill machinery and housing, chainsaws, assorted equipment) and spend considerably more on milling than in forest operations ($47.35 vs $8.38/m^3 output, respectively). Only when purchasing extracted timber as logs does the cost of raw materials approach yearly processing costs ($6892 vs $9246, respectively). On the other hand, average yearly depreciation and maintenance costs ($619 and $968/yr, respectively) are relatively low due to the highly labor dependent system of production. Gross revenue per m^3 of sawn lumber produced was $95.75. In comparison, total production costs per m^3 of sawn timber was $89.83 or $77.68, depending on whether firms purchased logs or standing timber. According to model simulations, both modes of firm production were very profitable (Table 1); however, differences in profitability among the two modes of firm production were large and resulted in differences in the time required to recoup initial startup costs and internal rates of return (IRR; Table 1).

Model elasticity analyses revealed labor related parameters such as daily wages and work hours per day exert important influence over the NPV of a micro timber producing firm (Table 2). The discount rate also has a very large influence over a firm's NPV, especially because it may vary largely above the range of values used in calculating elasticity. Given the high costs of processing, several sawmill production parameters had a large influence over NPV as well (e.g., mill processing efficiency, processing capacity and days of operation). Asset related values had minimal impacts on the profitability of a

Table 1
Economic indicators of timber and açaí production.

Activity	Production mode	NPV	Initial investment	IRR	NPV/investment ratio	Payback period	Ha of logged forest to recoup startup costs	Equivalent annual annuity
Timber	Purchased trees	$40,296	$7451	84.00%	5.41	3	31.2	$3179.11
Timber	Purchased logs	$8206	$7451	52.00%	1.10	9	95.4	$647.39
Acaí		$3230	$1114	22.00%	2.90	8	9.0	$254.82

Table 2
Example model parameters and their elasticities.

Description	Mean estimate	Units	Purch. trees	Purch. logs
Discount rate	0.0679		−0.75	−1.20
Wages	9.76	US$ day^{-1} person^{-1}	−1.39	−5.07
Work hours per day	9	h day^{-1}	3.10	11.09
Diesel price	1.15	US$/L	−0.46	−2.26
Gasoline price	1.38	US$/L	−0.09	−0.12
Sawmill diesel consumption	3.26	L/m^3	−0.67	−3.29
Harvest efficiency	0.71	m^3/m^3	0.84	0.03
Stumpage cost	7.77	US$ tree^{-1}	−0.49	0.00
Extracted timber price	12.95	US$ tree^{-1}	0.00	−11.36
Mean volume per tree	3.98	m^3	0.61	0.01
Mean distance to stream	41.39	m	−0.07	−0.01
Mill efficiency	0.367	m^3/m^3	6.06	29.72
Mean days of mill operation	9.59	d mo^{-1}	1.71	3.96
Mill processing capacity	0.14	m^3 person^{-1} h^{-1}	1.77	8.68
Mill engine price	2072.54	US$	−0.09	−0.44
Mill engine use	12.83	Yr	0.04	0.19
Mill engine salvage value	0.31		0.02	0.08
Mill equipment maintenance	401.21	US$ yr^{-1}	−0.13	−0.66
Output for felling and bucking	2.64	m^3 person^{-1} h^{-1}	0.15	0.02
Output for clearing path and laying tracks	12.21	m person^{-1} h^{-1}	0.12	0.01
Output for pushing logs	44.12	m^3 m$_{pushed}$ person^{-1} h^{-1}	0.25	0.03
Output for floating logs	0.40	m^3 person^{-1} h^{-1}	0.68	1.66
Product price	11.97	US$	2.30	11.30

firm, whether in terms of initial price, durability, salvage value or maintenance. Surprisingly, output of extraction activities had a generally small impact on NPV, with only output for floating logs having a moderate effect over NPV.

Açaí fruit production costs and revenues

Average startup costs for clearing and planting 1 ha of açaí was $948. Yearly revenue based on the seasonality of production and average açaí stand density in the region is $1040. Yearly management and harvesting costs are approximately $518. Nearly all costs associated with açaí fruit production were labor related since no special equipment is needed for the activity (except for a $41 yearly expense in harvest baskets). NPV for the establishment of 1 ha of açaí was $4222.

Timber and açaí comparison

NPV over initial investments show timber production yields a better return per dollar invested than açaí fruit production only when firms mill timber purchased standing (Table 1). Payback periods to recoup timber production startup costs varied greatly depending on the source of raw material (3–9 years; Table 1). Açaí payback period was also long at 8 years, due to the initial 4 year wait between planting and full production.

Discussion

The smallholder timber micro firm

The total cost of timber extraction and transport of $11.12 per m^3 of this study is among the lowest values reported for tropical forests for either conventional and reduced impact logging (Verissimo et al., 1992; Barreto et al., 1998; Holmes et al., 2002; Pokorny and Steinbrenner, 2005). This particularly low value is due to a combination of logging costs slightly below other studies and transportation costs within the lowest reported elsewhere ($7.37 and $3.75 per m^3, respectively). Estimated stumpage costs per m^3 are also near the lowest bound of reported values ($2.75/m^3) being only larger than those reported by small scale conventional logging operations (Verissimo et al., 1992; Stone, 1998). While there are generally few economic studies of timber use in the Amazonian floodplains (Barros and Uhl, 1995; Lentini et al., 2005), this study supports the notion that varzea extraction can be substantially cheaper than upland timber extraction (Barros and Uhl, 1995).

Despite the high incidence of buttressing of floodplain trees (Parolin et al., 2004), harvest and transportation efficiency of monitored forest operations was high. The majority of wood volume unutilized in forest operations was due to left over stem volume after bucking of stems into 3 or 4 m logs. This result could be partially explained by the small scale of extraction which led to no observed lost logs or felled trees and the utilization of logs as small as 20 cm in diameter, resulting in little stem volume unutilized below the crown. Additionally, the apparent selectiveness of the sawyer (who commonly is also the firm owner who pays landowners per tree harvested) means partially defective trees were avoided. Vertical integration of production means micro firms buying standing trees can select trees that give better return with no incentive to intensify harvests per area. On the other hand, since firms pay for trees extracted and not trees felled, trees damaged during harvests that could be partially utilized may be left in the forest if they are deemed not worth the tree-based stumpage price, effectively shifting inefficiencies to the harvesting operations.

The estimate of processing costs per m^3 is in par with average Amazon wide estimates, when corrected for exchange rate fluctuations ($47 vs $51 per m^3, respectively; Lentini et al., 2005). However, this study's processing cost estimate is notably higher than previous survey based, exchange rate corrected values for similar circular sawmills ($47 vs $26 per m^3, respectively; Lentini et al., 2005). The estimate of sawmill processing efficiency obtained from detailed per log monitoring (0.37) is higher than those published for similar micro sawmills elsewhere (0.28 and 0.35; Barros and Uhl, 1995, Lentini et al., 2005, respectively) but within range of Amazonian wide industry estimates (Lentini et al., 2005). On the other hand, the present estimates of yearly processing volume per firm are markedly lower than previous survey based studies. Based on measured average sawmill daily processing capacity and mean number of days of mill operation per month, the 532 m^3 of timber processed annually by sawmills in this study is only a third of values published in previous studies (Barros and Uhl, 1995; Lentini et al., 2005). This difference is likely partially explained by the fact that nearly all timber in the present study was purchased standing (and not as logs, thus requiring all firms labor split between forest and mill operations) and smaller average sawmill crew size. Nevertheless, it is unclear how methodological differences may have also shaped these differences, as this study relied on long term rapport with fewer firms and detailed quantitative monitoring while previous studies utilized survey methods of a much larger number of firms (Barros and Uhl, 1995; Lentini et al., 2005).

The micro firm's dependence on manual labor instead of oil subsidized mechanized work means costs of pushing and floating logs are relatively high compared to other harvesting costs and explains why low density (i.e., lighter, more buoyant) timbers have been traditionally preferred. Although the current analysis is based on the processing of a mix of timber species with varying wood density, the observed differences in handling and processing difficulty between high and low density species suggest that a shift in harvests toward either end of the spectrum would likely impact production costs. This link between wood density and labor costs is particularly relevant in the Mazagão watershed where previous research has shown that current intensive reentry logging practices may be suppressing long term yields of low wood density, high value species (*Virola surinamensis* and *Carapa guianensis*; Fortini and Zarin, 2011).

Micro firm profitability

In general, timber production by estuarine micro firms is very profitable. This extremely high profitability is likely a consequence of multiple favorable factors. Besides the low stumpage, extraction, transportation and milling costs and no legal costs, as vertically integrated operations, micro firms profit from both extraction and processing. Although IRRs are rarely reported elsewhere, high profitability may be common in the Amazon timber industry, with IRRs commonly reported above 30% for the Amazon and other tropical regions (Bacha and Rodriguez, 2007; Humphries et al., 2012). Lastly, operating outside legality and the physical danger of the activity due to a lack of basic safety precautions during extraction and processing adds substantial risk to the activity, naturally leading to higher

Table 3
Net present value of household cash flows for timber and açaí production.

Activity	Production mode	NPV	Initial investment	NPV/investment ratio
Timber	Purchased trees	$96,290	$7451	12.92
Timber	Purchased logs	$49,807	$7451	6.68
Acaí		$8898	$166	53.60

expected rates of return for those involved. The shift of part of the physical and law enforcement risks to land owners that do the timber harvest themselves likely explain the differences in profitability between the firms that purchase standing timber vs harvested logs.

Comparing timber vs açaí production economics in the Amazon estuary

While timber is more profitable to micro firm owners than açaí, net yearly revenue per firm is small with a system of production that is not easily scalable. A firm's typical small size is likely what has allowed the industry to operate largely in the informal sector. Micro firms also require much larger initial investments where financing options are not available, whereas smaller initial investments for açaí production can be easily scalable by area planted. However, açaí has a delay between planting and production commonly between 3 and 5 years (Hiraoka, 1995). In the past, cropping (e.g., manioc, bananas) ensured a continuous revenue stream during this waiting period (Hiraoka, 1995). However, agriculture in the region has nearly vanished due to competition from cheaper imports (Almeida, 1996). While the two activities provide employment opportunities due to high labor use and low dependence on outside inputs, açaí production startup and maintenance costs are almost entirely based on household labor and not capital, resulting in minimum cash outlays (Anderson and Jardim, 1989). On the other hand, timber firm startup costs not only are larger, but are commonly paid in cash as few financing options are available. However, açaí production is highly seasonal (Munizmiret et al., 1996), making the full reliance on the activity challenging if household finances are not carefully managed. In contrast, a timber firm's year round operations commonly require at least 4–5 workers and thus often require cash outlays in the form of paid wages.

In the preceding analyses, all daily wage costs were calculated using the standard regional rate whether the wage was supplied by the entrepreneur's household or not. To a timber or açaí entrepreneur, however, labor provided by household members often does not require cash payments and is likely valued much lower than daily wage rates as limited investment alternatives and few employment options lower the opportunity cost of household labor (López-Feldman and Taylor, 2009). By alternatively computing NPV of cashflows to and from entrepreneur's household (i.e., setting household labor rate as zero and assuming two household workers available based on local observations), the relative financial attractiveness of the two activities (in terms of NPV per initial investment) changes significantly (Table 3). While these values show that at the household level açaí management becomes much more worthwhile, these values are only valid within a limited size of açaí management area that can be managed by two household members (likely less than 10 ha based on the amount of area typically managed by households in the region). These results may partially explain why açaí management is being increasingly adopted in the Amazon estuary generally at scales smaller than 10 ha per household while the number of micro firms in the region have been on a long decline (Barros and Uhl, 1995; Hiraoka, 1995; Lentini et al., 2005).

One major disincentive for smallholders to produce timber is the challenge to operate legally. Current harvesting licensing procedures seem incompatible with small scale timber production (Hirakuri, 2003; Scherr et al., 2004). While recent laws attempt to address this issue by simplifying small scale forestry licensing procedures, licensing is still very costly as it requires in many cases full forest inventories and a management plan drafted by a licensed forester, thus resulting in the dependency on outside institutional support (Hirakuri, 2003). While uncommon, some firm owners in the region have received fines for not adhering to timber harvest regulations. Consequently, while açaí fruit harvesting is highly physically demanding and dangerous, unregulated timber production commonly involves the performance of even more dangerous tasks under an absolute lack of safety procedures and equipment and may partially explain the shift in preferences among the two activities. Thus, it is likely that the related legal and physical risks of timber production have pushed some local entrepreneurs away from timber and toward açaí production in the region.

Interactions between timber and açaí production

The price of micro firm timber is limited by its low quality and quantity of production that restricts sales mostly to regional markets and principally for low income housing (Pinedo-Vasquez et al., 2001). The low prices in the local and regional markets have left local firms in a challenging situation as, with the spread of açaí, fewer landowners are interested in selling timber to firms at current stumpage prices. A secondary effect of the spread of açaí management is the increase of local wages alleged by local firm owners. With açaí producers during the harvest season easily earning two to three times the daily wage rate by harvesting açaí, firm owners now have a hard time finding labor during summer months.

Within diversified livelihood systems common in the Amazon estuary (Anderson and Ioris, 1992), it is not surprising to find that timber and açaí production is not entirely antagonistic. Firstly, açaí and timber are not temporally exclusive activities because açaí harvests peak in the dry season when low water levels makes access to distant timber harvest areas difficult. Harvest monitoring also revealed some level of integration between the two activities. Chainsaw operators showed concern for unnecessary damage to wild açaí stock and directionally felled trees away from açaí clumps. Logging crews commonly felled old less productive wild açaí stems to use as rails for pushing logs from forest to stream. Loggers were aware this practice was beneficial to the wild açaí stock as thinning of old stems is a common practice to ensure continuous açaí production (Anderson and Jardim, 1989). While the $124 timber subsidy per hectare of forest converted to açaí is far from sufficient to cover initial planting costs (based on an average of 16 harvestable trees per hectare, sold standing at $7.77), many locals showed some degree of preference in converting recently logged areas into açaí stands. However, this timber 'subsidy' effect is further limited by the fact that areas selected for açaí management are in areas close to households where timber density is likely less than in more isolated forests.

Conclusions

While this research explores the economic rationale and consequences of Amazon estuary smallholder timber and açaí management, many questions regarding which of these two activities is most compatible with conservation are left unanswered. As both activities currently provide positive returns to smallholder investment, their comparative effects on landscape level carbon balance, erosion, plant, fish and faunal populations should be explored. While açaí at the intensity of planting observed in the region can be classified as forest conversion (Weinstein and Moegenburg, 2005), it is not necessarily the worse alternative to timber extraction since it is an intense land use and a conversion to a forest type that likely still provides some valuable environmental services (Brockerhoff et al., 2008; Paquette and Messier, 2010). For an average firm extracting 532 m^3 of timber yearly, operating under the legal extraction limits of 10 m^3 every 10 years or 30 m^3 every 30 years per ha requires a minimum management area of 532 ha. On the other hand, only 12.5 ha of permanent açaí cultivation is needed to provide the same NPV as a timber firm processing purchased trees. This simple calculation shows how the 'açaization' of the estuary (Hiraoka, 1995) has the potential of changing the dynamics of human disturbance in the Amazon estuarine forests from widespread nearly ubiquitous logging disturbance (Fortini et al., 2006; Fortini and Zarin, 2011) into highly intensified, albeit still forested açaí production areas.

The present economic analysis highlights some of the clear advantages and disadvantages between timber and açaí production in the estuary and particular challenges for each of these activities. This information, along with an accounting of the ecological and societal benefits and impacts of the activity, could be used to devise alternative strategies to sponsor either activity. If after more robust ecological analyses açaí is deemed a better choice in balancing conservation and community wellbeing, help to overcome startup and management costs in pre-production years could have large effects. If timber is deemed the better alternative, financing of startup costs or research leading to improvements in sawmill processing technology could have large impacts in the activity.

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