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Amazonian White-Sand Forest: A Black Future?

Photograph 1.
Typical aspect of a Peruvian white-sand forest (varillal) showing a high density of small diameter stems.
Photograph R. de Oñate.

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RÉSUMÉ

LA FORÊT AMAZONIENNE SUR SABLES BLANCS : UN SOMBRE FUTUR ?

Les forêts amazoniennes sur sables blancs sont des peuplements arborés très particuliers et fragiles, dispersés en zones basses humides sur des dalles de sols fortement oligotrophes, qui recèlent un fort endémisme végétal. Ces surfaces boisées sont dédaignées pour leur mise en culture ou l'exploitation du bois, mais néanmoins leurs tiges de faible diamètre, compris entre 5 et 15 centimètres, détiennent une forte durabilité et constituent une ressource traditionnellement extraite par les populations locales pour construire leurs logements. Toutefois, cette valorisation locale reste invisible vis-à-vis de la réglementation forestière, ce qui pourrait aller à l'encontre de l'avenir de ces forêts sur sables blancs. Cette étude a pour objectif d'apporter les connaissances de base de structure forestière et de composition floristique, essentielles pour mener à bien la gestion durable de ces massifs forestiers. Les résultats montrent que, malgré leur fragilité, ces forêts sur sables blancs présentent aussi certains atouts du point de vue de leurs possibilités d'aménagement par rapport aux autres types de forêts tropicales humides : il s'agit d'une forte fréquence (26 %) d'espèces de valeur, de la remarquable dominance d'un petit groupe d'espèces, dont la plupart (67 %) sont d'intérêt commercial, et du fait que les tiges potentiellement utiles ne comptent que pour dix-sept pour cent de la surface terrière ; et il en résulte que dans la situation actuelle, il n'est pas nécessaire d'appliquer des techniques telles que l'exploitation à faible impact, puisque les pieds exploités sont de faible taille, que les engins mécaniques ne sont pas utiles et que le transport est réalisé à dos d'homme et/ou par flottaison.

Mots-clés : forêt sur sables blancs, bois rond, diversité d'espèces, structure du peuplement, forêt tropicale, bois varillal.

ABSTRACT

AMAZONIAN WHITE-SAND FOREST: A BLACK FUTURE?

Amazonian white-sand forest, a distinctive and fragile type of lowland rainforest, usually occurs on scattered highly oligotrophic soil patches and holds a high number of endemism species. It is neither suitable for agriculture nor for timber production. However, it is a valuable resource for local communities since its small diameter (5-15 cm) straight round wood shows long durability and is widely used for house building. Despite that, local management remains invisible to forestry regulation and it might blacken the future of Amazonian white-sand forests. The purpose of this work is to provide basic knowledge on white-sand forest stand structure and floristic composition, which is essential for sustainable management planning. It shows that, in spite of its fragility, white-sand forests also show some strengths regarding sustainable management possibilities, as compared to other rainforests: the high percentage of valuable species (26 %), the striking dominance of a small set of species most of them (67 %) with commercial interest and the fact that potentially harvestable stems only account for seventeen percent of the total basal area, induce that technical requirements like "Reduced Impact Logging" are not necessary since harvested stems are thin, no machinery is involved and transportation is carried out only on foot and/or by river.

Keywords: white-sand forest, round wood, species diversity, stand structure, tropical forest, round varillal.

RESUMEN

EL BOSQUE SOBRE ARENAS BLANCAS AMAZÓNICO: ¿UN FUTURO SOMBRÍO?

Los bosques sobre arena blanca amazónicos son un tipo singular y frágil de bosque tropical húmedo de selva de zonas bajas, que aparecen dispersos sobre teselas de suelo muy oligotrófico y albergan un alto porcentaje de endemismos. No son susceptibles de aprovechamiento maderero ni de uso agrícola, pero su madera redonda de pequeño diámetro (5-15 cm) posee gran durabilidad y es un recurso extraído tradicionalmente por los pobladores locales para construir sus viviendas. A pesar de ello, este aprovechamiento local permanece invisible para la reglamentación forestal, lo que puede perjudicar el futuro de estos bosques sobre arena blanca. Este trabajo tiene por objetivo aportar conocimientos básicos sobre la estructura forestal y la composición florística de estos bosques, lo que es esencial para poder planificar un gestión sustentable. Los resultados muestran que, a pesar de su fragilidad, los bosques sobre arena blanca también presentan ciertas ventajas en vista de sus posibilidades de gestión sustentable en comparación con otro tipo de bosques tropicales húmedos: debido a un alto porcentaje de especies comerciales (26 %), a la clara dominancia de un pequeño grupo de especies, la mayoría de ellas (67%) con interés comercial y al hecho de que los fustes potencialmente aprovechables sólo suponen el diecisiete porciento de la área basimétrica total, resulta que en la situación actual, no es necesario aplicar técnicas de aprovechamiento de impacto reducido, puesto que los pies aprovechados son de pequeño diámetro, que no se utiliza maquinaria y que el transporte se realiza únicamente a hombros y/o por flotación.

Palabras clave: bosque sobre arena blanca, madera redonda, diversidad de especies, estructura forestal, bosque tropical, madera varillal.

Introduction

Sustainable Forestry (SF) has been a major topic for scientific debate since the XIXth century. Achieving SF is particularly difficult in tropical moist forests due to their extremely high levels of structural and biological diversity, the complexity and intensity of their deficiently known webs of plant-animal relationships and social implications, especially regarding local communities (GÜNTER *et al.*, 2011). Most scientific literature dealing with SF concentrates on Sustainable Timber Yield (STY) of valuable species and Sustainable Forest Management (SFM). Likewise, the forestry and environmental institutional control concentrates on timber yield in most tropical countries. However, there is usually neither control nor management regulation on other renewable products which are not suitable for exportation but are often highly valuable for local communities (SHACKLETON *et al.*, 2011). That is the case of edible and medicinal plants (HERRERO-JAUREGUI *et al.*, 2009), some palm species, such as Irapay, *Lepidocaryum tenue* Martius, whose leaves are used for thatching rural houses, or small diameter round-wood, an essential material for wooden house structures. Their exploitation and trade is either unregulated or usually escapes regulation and thus remains hidden or invisible to regional Institutions. The achievement of the long-term maintenance of the ecosystems providing those useful resources (the so-called coarse-grain or systemic conservation approach) requires the incorporation of human needs as a conditioning factor of management strategies (MEFFE *et al.*, 2002; GUARIGUATA *et al.*, 2010; POKORNY *et al.*, 2010) and hence the implementation of an integrated, adaptive, community-based management approach.

Photograph 2.
Wooden house structure made with small diameter round wood coming from white-sand forests.
Photograph R. de Oñate.

White-Sand (WS) forest, or heath forest, a distinctive and fragile type of lowland rainforest (photograph 1), usually occurs on highly oligotrophic siliceous-sand soil patches scattered throughout other extensive types of lowland rain forest (AUBRÉVILLE, 1958; ANDERSON, 1981; PROCTOR, 1999). It has been found in South America (Peru, Brazil, Colombia, Venezuela, French Guyana and Surinam) as well as in Malaysia (Borneo) and in tropical Africa (ANDERSON, 1981; PROCTOR, 1999). It is known as varillal in Perú, campina, campinarana or caatinga in Brazil; bana, cunurí or yaguácanan in Venezuela, wallaba forest in Guyana and pedang or kerangas (the land that will not grow rice) in Borneo. WS forest stand structure and leaves exhibit features (high density, low to medium height, sclerophylly and yellowish to reddish colour) that seem to respond to nutrient-poor soils and/or high drought sensibility or soil toxicity (AUBRÉVILLE, 1958; ANDERSON, 1981; COOMES & GRUBB, 1996; PROCTOR, 1999; FINE *et al.*, 2006, 2010). Maybe due to the same reasons, they show a rather low biodiversity levels but a high number of plant and animal endemisms and thus should be prioritized for conservation (AUBRÉVILLE, 1958; DUIVENVOORDEN, 1996; FINE *et al.*, 2010).

White-Sand forest is neither suitable for agriculture nor for timber harvesting. However, it is a highly valuable resource for local communities, since the small diameter (5-15 cm) straight round wood of many of its typical species shows long durability for house building (photograph 2). That is why its trade is also a major source of money for rural families (VALDERRAMA, 2003; PYHÄLÄ *et al.*, 2006). Although harvesting usually concentrates only on commercial species and sizes (diameter and length) the increasing demand of WS forest products might lead to unsustainable management mostly in the environs of rivers, towns, villages and other human settlements. Since in the outsides of urban centres, slums are built basically with small diameter round wood. On the other hand, the white sand of these forests is used to make concrete for other type of buildings.

This study describes basic features of the stand structure and floristic and commercial composition of Amazonian WS forest as a necessary step to design integrated, adaptive, community-based sustainable management practices. The specific goals were: to describe their stand structure and floristic composition; to analyze the contribution of commercial small diameter round-wood species to stand structure and floristic composition; to provide essential information for designing WS forest sustainable management.

Photograph 3.
Different kinds of white-sand forest products, according to diameter and length. Iquitos (Perú).
Photograph R. de Oñate.

Material and Methods

Study area

The study was conducted in the Department of Loreto, North-East Peru, in the lowland rainforest Amazonian region, with an annual rainfall usually over 2,400 mm, no drought period and an average monthly temperature over 24ºC. The dense river net is the usual communication method, since terrestrial communication is almost impossible due to the lack of roads. Therefore, most human communities are located at riversides.

In North-East Peru, WS forests occur on small land patches (2-4 km^2) scattered throughout other rainforest formations (DUIVENVOORDEN, 1996; FINE *et al.*, 2010). ENCARNACIÓN (1993) and GARCÍA *et al.* (2003) described different types of Amazonian WS forests regarding their soil properties and floristic composition.

Stem harvesting concentrates only on commercial species showing a 5-15 cm diameter class straight bole. There are several kinds of products regarding stem diameter (D) and length (L): common caibro (D: 5.5-6.5 cm, L: 6 m), special caibro (D: 6.5-7.5 cm, L: 7 m), solera (D: 7.5-9 cm, L: 8 m), viga (D: 9-15 cm, L: 8 or 10 m), and shungo (D: › 10 cm, L: ‹ 6 m) (photograph 3). Cutting is carried out by machete. After cutting, debarked stems are left to dry in the forest for 15-30 days since they should be taken on foot to the nearest river (photograph 4) and later transported by floating to local communities or to Iquitos (photograph 5). That type of harvesting limits management possibilities to the environs of rivers, towns, villages and other human settlements.

Since WS forest products are carried on foot from the stand to the river and then transported to local communities, where they are used, or to Iquitos, where they are sold, our study area was the Nanay river basin. Another hypothesis was that harvesting intensity should be inversely proportional to the distance from the stand to Iquitos (trade center and lowest part of the Nanay river basin). Therefore, three local communities were considered: Puca-Urco (PU), San Juan de Ungurahual (SJ) and San Juan de Yuto (YU), located respectively in the upper, middle and lower Nanay river basin (figure 1). The distance from Iquitos to PU is 105 km (a two-day trip), to SJ 70 km (a one-day trip) and to YU 35 km (a 6-hour trip).

The National Reserve Allpahuayo-Mishana was established in 1999 with the aim of protecting local biodiversity and especially over-exploited WS forest. Nowadays, each family is authorized to fell only a small amount of WS forest stems each year. That is why the population of San Juan de Yuto has declined since that date.

Photograph 4.
Cutting of white-sand forest trees is carried out by machete. After cutting, debarked stems are left to dry in the forest since they should be taken on foot to the nearest river.
Photograph R. de Oñate.

Plot selection and data collection

Plot selection and data collection were carried out in 2009 and 2010. At each study site, local people aided us to select nine 10 x 10 m WS forest experimental plots that had not been harvested for at least the last decade. In every case, they were located at a minimum of 30-minute and a maximum of one-hour trip on foot from the river, since there were no unharvested WS forest at shorter distances and transporting their products on foot for more than one hour was considered too hard a work. All trees with a diameter at 1.3 m (DBH) over 5 cm (minimum harvestable DBH) were identified at species or morphospecies level and their diameter recorded. Voucher specimens were collected and identified at the Herbario Amazonense (Iquitos, Perú).

The commercial interest (yes or not) and quality (first and second) of each species or morphospecies for small diameter round-wood was assessed by asking people from every local community as well as from trade companies at Iquitos. However, if commercial species are scanty, non-commercial species showing adequate diameter, length and straightness might be felled as well.

Data analysis

According to the local small diameter round-wood commercial interest, two DBH classes were defined: 5-15 cm and › 15 cm. Density and Basal Area (BA) were calculated for a) the whole plot, b) each DBH class, c) commercial and non-commercial species, and d) commercial and non-commercial species for every DBH class. Basal Area, or the sum of all the tree-trunk cross section areas at breast-height (1.3 m), was used since it has proved to be the best predictor of plant biomass and production in forests. Tree alpha-diversity was estimated through the Shannon-Wienner index and similarity between study sites through the Jaccard index.

Stand variables (density, basal area, mean height) and species composition indexes were tested through ANOVA techniques and Tukey post-hoc comparisons with SPSS v.15 software to analyze possible differences among locations.

Photograph 5.
White-sand forest stems are transported by floating to Iquitos.
Photograph R. de Oñate.

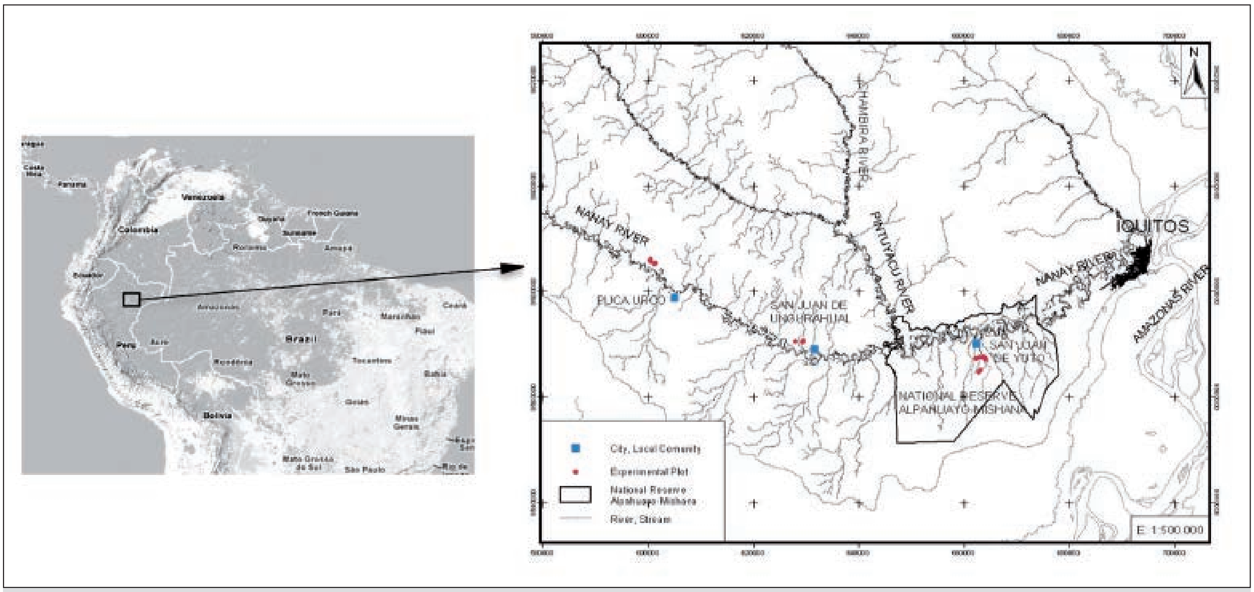

Figure 1.
Map of the study area (Distrito Loreto, North-East Perú) showing the three study sites: Puca Urco (upper Nanay river basin), San Juan de Ungurahual (middle Nanay river basin) and San Juan de Yuto (lower Nanay river basin).

Results

Stand structure

White-Sand forest average DBH is small (10.6 cm), according to its local name (varilla: long, slender straight stem). Average height is noticeably low (12.1 m) for a tropical rainforest, while BA (31.4 m²/ha) is normal and density (2,541 stems/ha) rather high. There is no significant differences between study sites for BA and only slight differences for mean DBH, mean height and density (table I).

The 5-15 cm DBH class contribution to total density is very high: 85.5% (2,181 stems/ha). Hence, the ›15 cm DBH class contributes with only a 14.5% to the total density. Commercial species are well represented in density, both in the 5-15 cm DBH class (potential harvestable stems) (38.3 % of the total density and 44.6 % of the 5-15 DBH class density) and in the › 15 cm DBH class (potential seed-producer trees for commercial species after harvesting) (8.20 % of the total density and 58.24 % of the › 15 DBH class density) (table II).

Commercial species contribute with 52.9% to the total BA (table III). However, the contribution of potentially harvestable stems (commercial species within the 5-15 cm DBH class) to the total BA is only 17,3 % or 5.43 m²/ha. In spite of their low contribution to total density, commercial species over 15 cm DBH contribute with 35.5 % to the total BA and with 67.3 % to the commercial species BA. On the other hand, the non-commercial species BA amounts to 47.1% of the total BA: 14.8 m²/ha. Non-commercial species of the ›15cm DBH class contribute with 25.9% to the total BA. There are no significant differences in BA for the following factors: study site, commercial species and non-commercial species.

Floristic composition

A total of 686 individuals were encountered in the three study sites and separated into 114 species and morphospecies (71 genera and 37 families). A list of them that also includes their common names (when they existed), Braun-Blanquet´s frequency indexes, number of individuals encountered in each study site and commercial interest is shown in Appendix of DE OÑATE (2013). Quantities of 49 species were found in PU, 68 in SJ and 57 in YU. Only 15 of them (13%) were found at the three study sites. There were no significant differences in the number of species per plot between study sites. Similarity between study sites was low, averaging 27% (Jaccard´s Similarity index figures: PU-

Table I.
Parameters characterizing WS forest average DBH (with a diameter at 1.3 m), height (H), stem density (N) (DBH over 5 cm) and Basal Area (BA) of the three study sites (9 plots per site).
Standard deviation included between brackets. Different superscript letters show significant differences.

Study site	Mean DHB (cm)	Mean H (m)	N (stems/ha)	BA (m²/ha)
PU	9.6 (1.5)^{a}	14.3 (4.9)^{a}	2,611 (596)^{ab}	24.6 (8.9)^{a}
SJ	12.3 (1.0)^{b}	10.5 (3.8)^{b}	2,044 (296)^{a}	35.8 (5.8)^{a}
YU	10.0 (1.9)^{a}	11.4 (4.4)^{b}	2,966 (1,021)^{b}	33.8 (23.6)^{a}
Average	10.6 (1.5)	12.1 (4.7)	2,541 (465)	31.4 (6.0)

Table II.
Parameters characterizing WS forest density.
N: density (stems with DBH over 5 cm). SD: Standard Deviation.

			N (stems/ha)	SD	%
TOTAL			2,541	465.1	100
Commercial species	5-15 cm DBH class	1st quality	700	283.5	27.6
		2nd quality	270	115.6	10.7
	›15 cm DBH class	1st quality	119	28.0	4.7
		2nd quality	93	23.1	3.6
Non-commercial species	5-15 cm DBH class	-	1,204	497.1	47.4
	›15 cm DBH class	-	152	55.9	6.0

YU: 0.29; PU-SJ: 0.27; SJ-YU: 0.26). On the other hand, 15 species (13%) were found exclusively in PU, 32 (28%) in SJ and 22 (19%) in YU. The Shannon-Wienner´s Diversity index varied between 2.5 and 3 but showed no significant differences between study sites.

A high percentage (40.35%) of the species were represented by only one individual. On the other hand, 13% were represented by 10 or more individuals and amounted to 66.7% of the total density and 50.7% of the total BA (table IV), most of them being commercial species. Indeed, the commercial species among the top 15 amounted to 40.4% of their total BA. The most abundant species is, by far, *Caraipa utilis*, which amounts to 18.4% of the total number of individuals and 12.5% of the total BA and is the only one representing the V Braun-Blanquet´s frequency index (85%). It is considered to be the one with the highest commercial quality for wooden house structures.

The number of species represented in the › 15 cm DBH class (51) is much lower than that of the 5-15 cm DBH class (108). 63 species (55 %) were represented only in the 5-15 DBH class, while 6 (5 %) where represented only in the › 15 DBH class and 45 (40 %) were found in both DBH classes. 11 commercial species were found only in the 5-15 cm DBH class while no commercial species was found only in the › 15 cm DBH class.

Table III.
Parameters characterizing WS forest Basal Area (BA).

			BA (m²/ha)	SD	%
TOTAL			31.4	6.0	100
Commercial species	5-15 cm DBH class	1st quality	3.7	1.3	11.9
		2nd quality	1.7	0.7	5.4
	›15 cm DBH class	1st quality	5.6	2.3	17.7
		2nd quality	5.6	1.2	17.9
Non-commercial species	5-15 cm DBH class	-	6.7	1.7	21.2
	›15 cm DBH class	-	8.1	5.1	25.9

BA: Basal Area (stems with DBH, diameter at 1.3 m, over 5 cm). SD: Standard Deviation.

Table IV.
Contribution of the 15 most abundant species (represented by 10 or more individuals) to the stand structure of WS forest and their commercial quality.

Species	Dens.	% BA	5-15 cm	› 15 cm	Com. Int.
Caraipa utilis	18.4	12.5	113	11	1
Pachira brevipes	9.3	3.6	61	1	No
Euterpe catinga	6.7	1.8	46	0	No
Sloanea spathulata	4.6	3.2	27	4	No
Dicymbe uaiparuensis	3.9	5.5	16	9	1
Parkia igneiflora	3.6	6.3	16	3	2
Dendropanax umbellatus	3.3	1.5	22	0	No
Chrysophyllum sanguinolentum	3.2	2.2	19	2	1
Marlierea caudata	2.8	2.0	16	3	2
Macrolobium microcalyx	2.3	2.4	12	3	1
Tachigali paniculata	2.1	5.4	8	5	2
Caraipa tereticaulis	1.8	0.7	10	2	1
Pouteria cuspidata	1.7	1.1	10	1	1
Aspidosperma excelsum	1.5	0.9	9	1	1
Hevea guianensis	1.5	1.7	7	3	No
TOTAL	66.7	50.8	392	48	

Dens.: density (over 5 cm). Stems with DBH (with a diameter at 1.3 m). BA: Basal Area (stems with DBH over 5 cm). 5-15 cm: number of stems of the 5-15 cm DBH class in our experimental plots. › 15 cm: number of stems of the › 15 cm DBH class in our experimental plots. Com. Int.: commercial interest (No: without commercial interest; 1: commercial interest, first quality; 2: commercial interest, second quality).

Discussion

Stand structure

WS forest plots studied belongs to the varillal (tall caatinga) type, since their average height is between 10 and 20 m (COOMES & GRUBB, 1996; GARCÍA *et al.*, 2003). Average height (12.1 m) is lower than that of other surrounding Terra Firme (TF) forest types due to edaphic specialization (GENTRY, 1988; FINE *et al.*, 2006, 2010). However, BA (31.4 m^2/ha) is quite similar and stem density (2,541 stems/ha) is higher, due to the high proportion of small diameter stems, which are usually overlooked in TF rainforest inventories, with a DBH cutoff of 10 cm (DUIVENVOORDEN, 1996; FINE *et al.*, 2010). Anyway, WS forest stand structure (average height, stem density and BA) seems to be fairly homogeneous between study sites.

The 5-15 cm DBH class (the one with potential commercial interest for small diameter round wood) amounts for a high proportion (85.5%) of the total density but only for a small one (38.5%) of the total BA. However, the potentially harvestable stems (commercial species, 5-15 cm DBH class) amount only to 38.3% of the total density and a mere 17.3 % of the total BA, and those are only potential figures since commercial interest also depends on stem straightness and length. As a consequence, even a monocyclic treatment affecting every potentially harvestable stem would leave 26 m^2/ha of BA, a conservative figure regarding those considered for sustainable forest treatments in other rainforest types (GÜNTER *et al.*, 2011). Commercial species of the › 15 cm DBH class, that could be regarded as potential seed sources for natural regeneration after harvesting, since light does not seem to be a critical limiting factor in WS forests (COOMES & GRUBB, 1996), amount to 8.3% of the total density and 35.6% of total BA.

Floristic composition

As stated by other authors (AUBRÉVILLE, 1958; GENTRY, 1988; TER STEEGE *et al.*, 2000; FINE *et al.*, 2010), the WS tree species diversity is lower than that of other surrounding TF rainforests, being the tree species diversity positively correlated with average height (DUIVENVOORDEN, 1996). Despite being fairly homogeneous in stand structure, the floristic composition similarity between study sites was rather low, averaging 27%, as stated by FINE *et al.* (2010). However, WS forests show a striking dominance of a small set of 15 species that account for 66.7% of all individuals and 50.7% of total BA, as FINE *et al.* (2010) described for Peruvian WS forests. Furthermore, *Caraipa utilis*, which according to its specific name is the most valuable commercial species, shows an amazing dominance (18.4 % density and 12.5 % BA) with a V Braun-Blanquet´s frequency index (85 %). *Pachira brevipes*, the most common species in the study carried out by FINE *et al.* (2010), showed a III frequency index and is the second species regarding density (9.3 %) and BA (3.6 %) in our plots. That difference might be explained because FINE *et al.* (2010) included some plots of chamizal (scrub or stunted WS forest), and did not separate harvested from unharvested WS forests (varillal). Clusiaceae, represented by 6 species, is the most important family in our WS forests.

Conclusion

By way of conclusion concerning the implications for sustainable management: several authors have pointed out that Withe-Sand forests are extremely fragile, show a distribution fragmented in few isolated small patches and include a high percentage of endemic or “specialist” species so they should be given a high conservation priority. Their usefulness for human communities could become an additional threat should usual harvesting be unsustainable. This work shows that, despite those threats, White-Sand forests show some strengths regarding possible sustainable management, among them:

- The percentage of commercial species is much higher than those of most Terra Firme rainforests (30 species).
- White-Sand forests show a striking dominance of a small set of species, most of them (67 %) with commercial interest.
- Most commercial species are represented both in harvestable stems and potential seed producers and many of them have been reported to regenerate easily throughout the year since light does not seem to be a critical limiting factor. Therefore, natural regeneration would not be highly endangered by traditional harvesting.
- Potentially harvestable stems amount to only 17 % of the total basal area and many of them would never be felled due to unsuitable stem straightness or length.
- Reduced Impact Logging is not necessary since no stem over 15 cm of diameter is logged, no machinery is involved and transportation is carried out only on foot and/or by river.

Therefore, we speculate that traditional harvesting of White-Sand forests carried out by local communities does not seem to be an important threat. However, a deeper insight is required on effects of current harvesting practices, trends of small diameter round wood demand, household livelihood sources and administrative control, with the aim of guaranteeing long term conservation of Amazonian White-Sand forests.

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