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Complementarity of native and introduced tree species: exploring timber supply on the east coast of Madagascar

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ABSTRACT

In Madagascar, nature conservation and human livelihood security both appear as crucial imperatives. The degraded secondary forest remnant of Analalava, on the east coast, near Foulpointe, is a protected area since 2006. The long-term conservation of the site's biodiversity can only be guaranteed by local support. Given that access to timber from native trees within the protected area is restricted, management of tree resources outside of the protected area represents a critical nexus between biodiversity conservation and human benefits linked to ecosystem services. We investigated and characterized the local farmer's use of available tree species, to provide a basis for satisfying the dual objectives of biodiversity conservation and sustainable and equitable rural development.

Our results showed that local people are interested in various types of trees for timber, both native and introduced. Furthermore, they demonstrated detailed knowledge about silvicultural traits of a large number of tree species. Regarding the important complementarity of properties and uses recognized for native and introduced species we conclude that free distribution of nursery seedlings of fast-growing introduced tree species should not be the only alternative to logging within the protected forest fragment offered to local people. Instead, a larger choice of tree species, including native ones, should be proposed. The cultivation of this diverse mix would allow people to take a more active part in the preservation and restoration of natural capital at the landscape scale and could enlarge the range of benefits obtained from trees that they plant.

RÉSUMÉ

À Madagascar, il est crucial de répondre au double impératif de protéger la nature et d'assurer des moyens de subsistance aux populations. Analalava, où se situe un fragment de forêt secondaire dégradée de la côte Est, à côté de Foulpointe, bénéficie d'un statut de protection depuis 2006. La conservation à long terme de la biodiversité de ce site ne peut être garantie sans la participation des populations. Étant donné l'accès restreint des populations à l'intérieur de l'aire protégée pour l'exploitation du bois, la gestion des sources d'approvisionnement en bois de construction à l'extérieur du site représente un trait d'union entre la conservation de la biodiversité et les bénéfices fournis aux Hommes par les services écosystémiques. Nous avons déterminé et caractérisé les relations entre ces populations locales et les espèces d'arbres qu'elles utilisent. Cette étude pourrait constituer une base à la mise en place d'une coopération qui satisferait à la fois aux objectifs de conservation de la biodiversité et de développement rural durable et équitable.

Nos résultats montrent que pour les populations locales, le bois de différentes espèces d'arbres, indigènes ou introduites, présente un intérêt pour la construction. En outre, les personnes interrogées ont montré une connaissance détaillée des traits sylvicoles d'un grand nombre d'espèces. Devant la complémentarité des espèces indigènes et introduites en termes de propriétés et d'usages, nous concluons que la distribution gratuite de plantules d'espèces introduites à croissance rapide ne devrait pas être la seule alternative offerte aux populations locales à l'exploitation du fragment de forêt protégée. Au lieu de cela, un choix plus large d'espèces d'arbres, y compris d'espèces indigènes, devrait être proposé. La plantation d'un mélange de diverses espèces permettrait ainsi aux populations de prendre part de manière plus importante à la préservation et la restauration du capital naturel à l'échelle du paysage, et pourrait étendre la gamme de bénéfices qu'ils retirent des arbres plantés.

INTRODUCTION

In an effort to conserve Madagascar's biodiversity, natural reserves were first established in the early 1900s. Since then, Madagascar's protected areas network (Système des Aires Protégées

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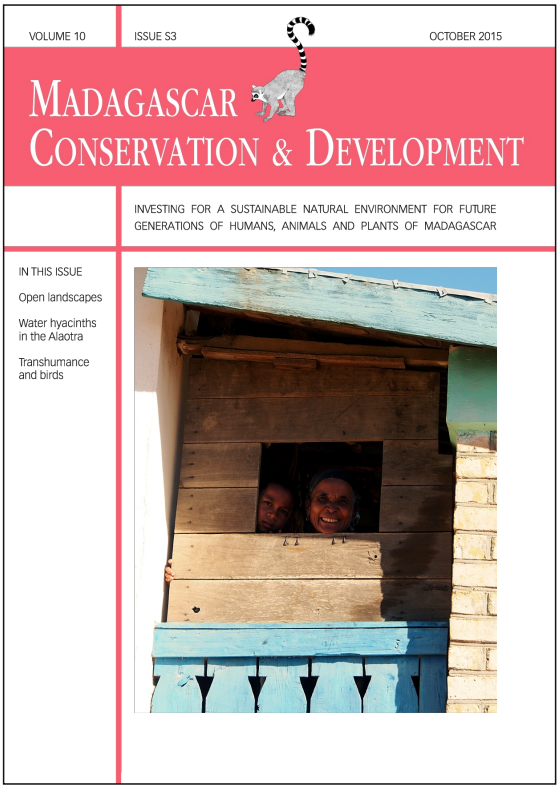

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de Madagascar, SAPM) is growing. In 2003, former President Marc Ravalomanana launched a program to triple the SAPM from 17,000 km² to over 60,000 km² (i.e., from 3%, to 10% of Madagascar's total land area). With help from various funders and NGOs, progress on achieving this goal was continuous until the coup d'état that threw the country into turmoil, in January 2009. Nevertheless, as of December 2013, 70,000 km² (11.77% of the country) of land of high conservation value has been earmarked for possible inclusion in the SAPM network, and many of these areas have been accorded a 'temporary protection' status (Ministère de l'Environnement et des Eaux et Forêts et al. 2012). While the original network of protected areas is managed by Madagascar National Parks, the recently created reserves are, for the most part, run by NGOs.

It appears clearly that two imperatives coexist in the landscapes surrounding protected areas in Madagascar. On the one hand, local people have crucial needs for economic development and access to the resources on which they depend. Indeed, rural Malagasy remain partially dependent on native tree resources for income and subsistence (Blanc-Pamard and Ralaivita 2004, Carrière et al. 2005). In many cases, the establishment of protected areas restricted local people's access and curtailed their access to natural resources (Marie et al. 2009), especially to wood obtained from native tree species. On the other hand, these special areas are critical for biodiversity conservation (Carrière and Bidaud 2012, Birkinshaw et al. 2013), and threatened: ongoing landscape fragmentation is harming and reducing habitat and inhibiting successful seed dispersion in many cases (De Wilde et al. 2012).

One response to the loss caused by the establishment of protected areas has been the introduction of fast growing species, since the beginning of the twentieth century; these species now play an important role in satisfying the needs of rural Malagasy populations (Pfund 2001, Carrière et al. 2008). More than 70% of introduced flora is considered as being useful (Kull et al. 2012). *Eucalyptus* spp. (Myrtaceae) cultivation furnishes a profitable income in particular as timber and fuel wood, and has become crucial for economic development (Aubert et al. 2003, Carrière and Randriambanona 2007). Kull et al. (2013) described the large range of ecosystem services supplied, i.e. introduced tree species: provisioning service by edible parts of the plant, regulation services through carbon sequestration, habitat service for native bird species (cf. Martin et al. 2009). Despite the invasive potential of some introduced tree species, they are clearly part of rural people's subsistence strategy and are, arguably, complementary to native species, in terms of services and as an alternative to native timber extraction (Carrière et al. 2008, Kull et al. 2013).

The protected area of Analalava is located on the east coast of Madagascar (E0 49°27'22", S 17°42'26"), seven kilometres west of Mahavelona-Foulpointe, a small town of 8,000 inhabitants, which is also a well-known seaside resort frequented by both Malagasy and foreigners. This region is characterized by a tropical humid climate with almost no dry season, and low rainfall during winter – although several weeks without rainfall can occur unpredictably at any time of the year. Mean average annual rainfall is 2,500 mm, with ca. 200 rainy days per year. Monthly average temperatures in Analalava range from 23 to 33°C. Most people in the villages studied belong to the Betsimisaraka. Originally farmers living in the forest with a subsistence economy, these people are now actively engaging in trade. Population growth, successive migrations, and migration of new people into the region in recent decades has led to logging and extensive land clearing for agriculture. The degraded secondary forest of Analalava has high conservation value because of its numerous endemic and endangered plant species (Rakotoarinivo et al. 2010, Missouri Botanical Garden 2011), and also because there is no other large fragment of lowland humid forest left in the vicinity. In the past 35 years, this forest has suffered from damage and isolation due to logging, slash-and-burn agriculture and related wild fires occurring each year in the area (Lehavana and Birkinshaw 2006). It has seen its area reduced by 47 ha, as compared to 250 ha in 1979. Since 2004, the conservation site is under management of the Missouri Botanical Garden (MBG), together with the local community. Economic alternatives are developed through an association of local stakeholders: ecotourism, fish-farming, introduced fast-growing species seedlings distribution.

The predominant landscapes around the protected area are characterised by: (i) irrigated rice fields; (ii) fields of cassava root and other crops often in association with fruit trees such as jackfruit, breadfruit and other trees such as *Harungana madagascariense* Lam. Ex Poir (Clusiaceae), *Albizia lebbeck* Benth. (Fabaceae), and *Litsea glutinosa* Lour. (Lauraceae); (iii) uncultivated woody grassland (or *savoka* in Malagasy) dominated by the native *Ravenala madagascariensis* Sonn (Strelitziaceae), the introduced *Eucalyptus robusta* Sm. and various ferns; and (iv) young secondary forest fragments and thickets in which *Ravenala madagascariensis* and other native trees, as well as various non-native, invasive shrubs and trees co-occur.

Improving the ecological resilience of these landscapes is vital. To answer this specific issue, we focused on tree species because of the diversity of ecosystem services they provide for local communities and also in view of their importance to conservation objectives. The goal of this study was to explore the knowledge and uses farmers have of the different tree species they use for timber in the largely agricultural landscapes surrounding the Analalava protected area (0–10 km radius). We sought to elucidate the appreciation by local people of different tree species' characteristics, and the relative importance of these characteristics. Our study is qualitative, and it aims to describe the relationships between a specific group of people and the tree species that are part of their lives and livelihoods. This is an illustration of the global call to take into account local environmental knowledge for more sustainable protected area management (Lescuyer 2008, Binot 2010). We expected that the substitution of a large range of native forest species by a few introduced ones imagined by government and NGOs to reduce deforestation and pressure on natural resources is not a sufficient response. We hypothesized that interest and attachment for some native tree species does exist among local people in our study area and that this aspect could be more usefully integrated in conservation and sustainable development strategies.

METHODS

DEFINITIONS AND CONCEPTS. The following key concepts were used in this study: 'Forest fragment' as defined by Urech et al. 2012: "The whole contiguous natural forest, including larger forest patches of more than 500 ha, has been classified as a forest massif. All natural forests smaller than 500 ha, surrounded by agricultural land or fallows and therefore not connected to the massif are considered forest fragments". 'Ecosystem services' are defined as the goods and services from ecosystems and its native

biodiversity perceived as direct or indirect benefits by humans (Millennium Ecosystem Assessment 2005). Following de Groot et al. (2009), we consider five types of ecosystem services: provisioning, cultural, supporting, regulating, and habitat. Species type terminology comes from Convention on Biological Diversity (2001) and Richardson et al. (2000). 'Native species' are species that occur naturally at a given location or in a particular ecosystem. They can either be endemic (found only within a particular region) or indigenous (found both within the region and elsewhere). 'Introduced species' are species in a given area whose presence there is due to intentional or accidental introduction as a result of human activity (synonyms: exotic species, alien species, non-native species, non-indigenous species). 'Naturalized species' are introduced species that reproduce consistently and sustain populations over many life cycles without direct intervention by humans. 'Invasive species' are naturalized species that produce reproductive offspring at considerable distances from parent plants.

SURVEY METHOD. The study took place from April to August 2013. The four villages studied were chosen within those the Missouri Botanical Garden works with because they were the administrative centers of *fokontany*, accessible by rural path and located on the outskirts of the Analalava reserve, less than 10 km from the protected area's edge. In what follows, the letters A, B, C, and D will designate the groups within the villages of Bongabe, Ambodivoarabe, Ambatobe and Morarano respectively.

The first author conducted 36 individual semi-structured interviews with the help of a translator, with random people from those four villages. The methodology used was the one developed by Olivier de Sardan (2003) based on participative observation, semi-open questions, conflict case study and information triangulation. These interviews coupled with observations of day-to-day life served to collect information on the trees present in farmers' fields, and their common use. As a result of these interviews, among local people timber was found to be the most appreciated of the services provided by the Analalava forest before it became protected. That is why the first author conducted afterwards four group surveys on timber sources and their uses. For the group surveys, each lasting one to two hours, we used the SAS2 method (Chevalier et al. 2013), known as 'Scoring tips'. This method is in turn based on the Rapid Rural Appraisal technique (FAO 2002). Each group was comprised of ten men, men being the only ones concerned by timber collecting. No distinction of age classes was made, and all participants were volunteers and received no incentives. Each group survey took place in one of the four villages, each village being composed by a lineage, or unilineal descent group. The objective of doing a group survey was to gather collective knowledge.

First, people were asked to list the tree species x_i they would use for timber, assuming they were locally available. Second, we asked people to list the different criteria y_j under which they would choose to plant a tree for timber use. These criteria were for example intrinsic timber qualities such as 'wood hardness' and also 'rot resistance' (to humidity or insects), the latter of which correlates with the material lifespan of cut timber. All respondents also cited silvicultural qualities such as 'growth rate' and 'upright growth form' as selection criteria. Third, we asked people to classify the different tree species according to the criteria of their choice. The different tree species were rated for each criteria y_j, using a total of $N(y_j)$ beans as markers. Finally, the different criteria were weighted, from the least to most important: the group was asked to put a number of beans $a(y_j)$ on each criterion (represented by a symbol on their sheets of paper), in proportion to its relative importance. A total number of M beans were used. Table 1 illustrates the method.

DATA ANALYSIS. We divided the score given to the species or to the criteria by the number of beans used in order to smooth out the ranking differences between groups. These data allowed us to classify each tree species according to their criteria, and also to highlight which criteria were the most important ones for each group.

Local vernacular names of trees were used during the exercise, to be assigned to their scientific name based on either Schatz (2001), the botanical inventories of the Analalava forest (Missouri Botanical Garden 2006) and on the expertise of one of the co-authors (C. M.).

RESULTS

A total of 35 tree species were cited, among the four groups, as being appreciated for their timber. These included ten non-native species and 25 native forest species. The most often cited tree species were introduced ones (Table 2). These trees are the

Table 1. Application of the SAS2 method 'Scoring tips' (according to Chevalier et al. 2013; the villagers participating in these studies were for the most part unable to read or write; hence the need for the use of tangible markers such as beans).

	y1	y2	y3
tree species x1	a (x1; y1)	a (x1; y2)	a (x1; y3)
tree species x2	a (x2; y1)	a (x2; y2)	a (x2; y3)
tree species x3	a (x3; y1)	a (x3; y2)	a (x3; y3)
total number of beans used N (yj)	N (y1)	N (y2)	N (y3)
weight of the criterion a (yj) using M beans	a (y1)	a (y2)	a (y3)

Table 2. Introduced and native tree species used for timber in four villages.

Trees	Bongabe	Ambodivoarabe	Ambatobe	Morarano
Introduced species				
Acacia mangium Wild.	x	x		x
Albizia lebbeck Benth.		x	x	x
Albizia sp.	x	x	x	x
Artocarpus altilis Fosberg	x			
Artocarpus heterophyllus Lam.	x		x	x
Eucalyptus citriodora Hook.	x	x	x	x
Eucalyptus robusta Sm.	x	x	x	x
Grevillea banksii R. Br.		x	x	
Pinus caribaea Morelet	x	x	x	x
Spathodea campanulata Beauv.	x	x		
Native species				
Anthostema madagascariense Baill.			x	x
Chaetocarpus rabaraba Capuron			x	
Colubrina faraloatra Capuron			x	
Cynometra spp.			x	
Dalbergia chapelieri Baill.			x	
Diospyros spp.			x	x
Dombeya oblongifolia Cay.				x
Faucherea sp. Lecomte		x	x	
Harungana madagascariensis Lam.		x		x
Homalium spp. Jacq.			x	
Intsia bijuga Colebr. (Kuntze)		x	x	x
Mauloutchia spp. Warb.				x
Ocotea spp. Aubl.				x
Oncostemum spp. A. Juss.				x
Phyllarthron madagascariense K. Schum	x	x	x	
Plectronia micranta Baker			x	
Pseudopteris sp. Baill.		x		
Rhopalocarpus spp. Bojer				x
Schizolaena spp. Thouars	x			
Stephanostegia capuronii Markgr.			x	
Streblus obovata Lour.			x	
Symphonia tanelensis L. f.			x	
Terminalia catappa L.				x
Uapaca louvelii Baill.			x	x
Xylopia sp. L.		x		

most abundant in the agricultural landscapes surrounding the villages, and people are used to planting them for income. Among native tree species (Table 2), people cited those with which, for various reasons, they have maintained relationships of use or belief. The most well-known native tree species, cited by three of the four groups, were: *Intsia bijuga* (Colebr.) Kuntze (Fabaceae) and *Phyllarthron madagascariense* K. Schum. (Bignoniaceae).

The 35 trees appreciated for timber are ranked together with their relative level of appreciation, regarding each criterion. Figure 1 shows the species that local people prefer to use for timber, depending on what they are willing to use them for. Introduced species cited ranked first with regards to growth rate, whereas native ones were the most valued species for intrinsic wood qualities such as rot resistance and timber hardness. However, *Pinus caribaea* Morelet (Pinaceae) was particularly appreciated for its upright growth form, regardless of the species type. Among introduced species, *Eucalyptus robusta* was said to present the best rot resistance, along with the hardest wood.

Whereas all groups interviewed use approximately the same introduced tree species for timber for construction and other uses (seven or eight in total for each group), we observed differences in terms of the number of native tree species used from one single group to another: 2 for A, 6 for B, 15 for C, and 11 for D. This can be linked to the size of the main forest fragment still occurring on the village's land. The more forest is left on their land, the more people use and know forest tree species (Table 3).

The most important qualities in dictating preferences for planting a tree species, from the perspective of using it for timber, are listed in Figure 2. We can observe that people value certain criteria more than others. Surprisingly considering their short-term needs in timber, the growth rate criterion was considered to be less important than the durability of the wood. Timber's intrinsic qualities such as rot resistance or hardness were cited as more important than the growth rate in three of the four villages. Fast growth was considered the most important criterion by informants of group C.

DISCUSSION

We acknowledge that our results are insufficient to allow detailed statistical analyses, since only four groups of people were surveyed. However, the people interviewed are all potential participants in cooperative forest management at Analalava. We can therefore assume that their responses are the ones that matter the most in this context.

MISCELLANEOUS NEEDS TO BE MET. Our results show that people in the villages where we undertook surveys are interested in and knowledgeable about diverse species of forest trees with value as timber. Among the introduced species, some are naturalized and abundant in agricultural landscapes surrounding the villages, particularly in *savoka* (fallows): *Eucalyptus robusta*, *Albizia* spp., and *Grevillea banksii* R.Br (Proteaceae). Others, fruit trees which do not propagate so easily, were planted in the fields: *Artocarpus altilis* Fosberg and *A. heterophyllus* Lam. (Moraceae). Certain native cited species regenerate readily in the *savoka*, such as *Harungana madagascariensis* and *Dombeya oblongifolia* Arenes (Malvaceae). The others are found only in the small secondary forest fragments, 0.1 to 1 hectare in size, and located between two and five kilometers away from the nearest village. Therefore, people use a large range of tree species: not only species that are abundant in the agricultural landscapes around the village but also native forest species that can only be found in little remaining forest fragments, located far from the village. Use and local access rules are drawn up regarding these forest fragments to prevent charcoal production from native species and to restrict the timber harvesting right to one or several lineages. However these rules are rarely enforced, which de facto leads to free access. Consequently, forest fragments are progressively disappearing.

Indeed, those native species have irreplaceable qualities. Traditional Betsimisaraka houses are raised on stilts and built from wood, especially the native *Ravenala madagascariensis* whose stem, leaves and trunk are used to construct walls, roofing and floor materials; twenty beams and thirty pillars are also required. The introduced species *Pinus caribaea* is used for the roof and wall thanks to its upright growth form, whereas *Eucalyptus ro-*

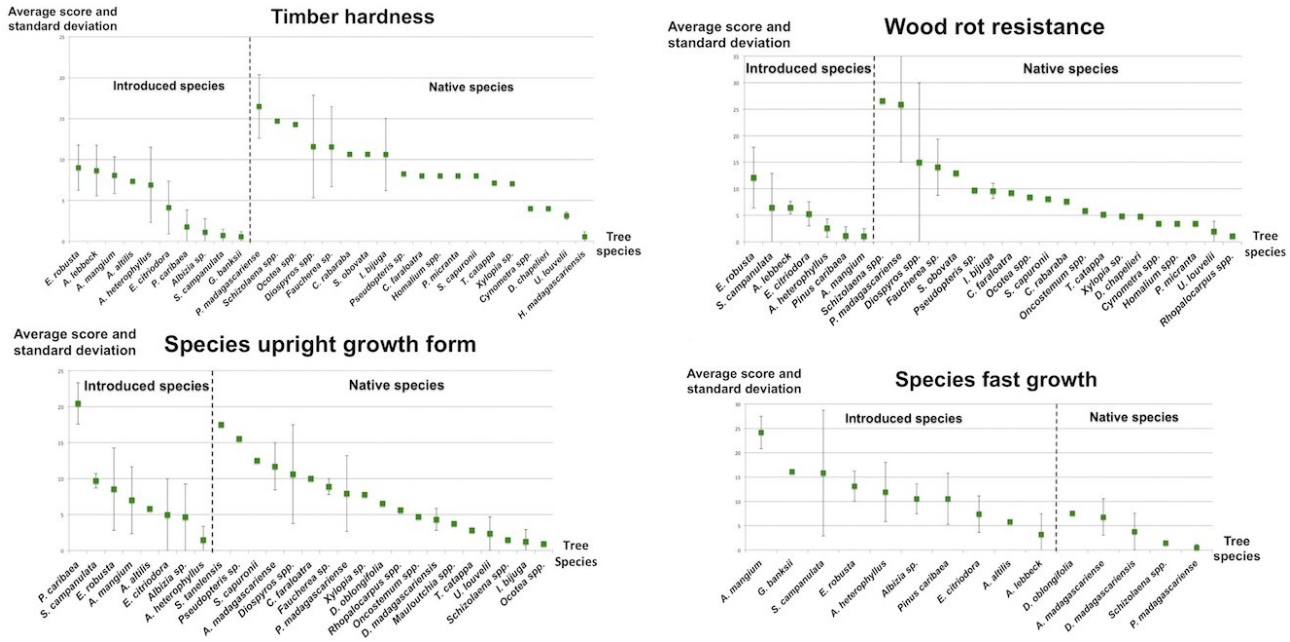

Figure 1. Ranking of interesting species regarding the most important criteria for use as timber. (the standard deviation corresponds to the difference between the four responses).

Table 3. The different villages characteristics, based on interviews and personal observations of several co-authors. (the relative wealth was estimated by criteria such as: number of families having a concrete house).

Village	Distance to Foulpointe (km)	Size of main secondary forest fragment	Relative wealth	Important land dispute
Bongabe	5	0	x	
Ambodivoarabe	10	< 0,5 ha	x	
Ambatobe	6	> 1ha		x
Morarano	12	> 0,5 ha		x

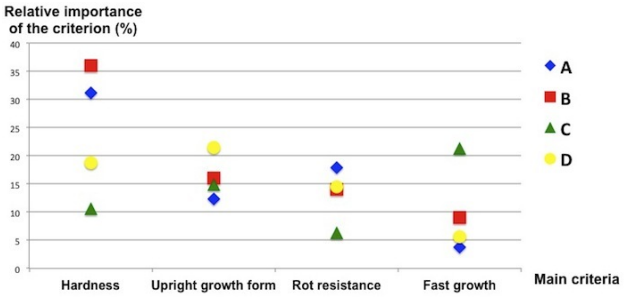

Figure 1. Ranking of interesting species regarding the most important criteria for use as timber. (the standard deviation corresponds to the difference between the four responses).

busta, harder and more resistant, is preferred for stilts. However, along the east coast of Madagascar, where cyclones are frequent, and heavy rainfall is a constant, the wood used to build houses must be resistant to rot. As one farmer put it: "Here we need solid wood for construction. With wood taken from native forests, the house lasts for more than 40 years. Using *Eucalyptus*, it has to be rebuilt every seven years and the pillars have to be changed every four years." Their exceptional timber hardness and rot resistance, but also their acceptable upright growth form, make species such as *Phyllarthron madagascariense*, *Faucherea* sp. (Sapotaceae), and *Diospyros* spp. (Ebenaceae) the most highly valued species for house stilts and pillars (Mahefa 2010). Rot resistant wood of *Albizia lebbeck* makes it desirable for pirogue building. To produce tools such as farm tool handles, or cooking tools, wood hardness is also an essential quality, and the hard wood of *Faucherea* sp. is also particularly appreciated for pestle and mortar fabrication (Mahefa 2010). Introduced species serve for common, everyday needs, but native species are used for specific needs, for example to change roof beams in one's house, or for funerals: exceptional rot resistance of *Diospyros* spp. makes them desirable for fabrication of coffin lids (Mahefa 2010). In sum, increasing the spectrum of usable species is also part of a risk management strategy, offering several alternatives to local people seeking to respond to varying situations. For all these reasons, native and introduced tree species are complementary for timber supply.

ECOSYSTEM SERVICES AND EXISTING TRADE-OFFS. Besides timber production, trees also provide other kinds of ecosystem services. Considering introduced species: for example, *Acacia mangium* Willd. (Fabaceae) fixes atmospheric nitrogen, in symbiosis with rhizobacteria, and thereby its building of soil fertility is known by the local population. The bark of *Albizia lebbeck* is used to treat conjunctivitis; *Pinus caribaea* is used as a living fence (Mahefa 2010).

Considering the native species: the multipurpose leguminous tree *Intsia bijuga* is used as a source of green manure, and is also valued for its highly durable wood (Mahefa 2010). The same is true of *Faucherea* sp., which is in the third category of quality wood classification (Gueneau 1971, Louvel 1922) and suits for cabinetwork. Other species have cultural importance: the sacred tree *Phyllarthron madagascariense* is used for ceremonies; *Terminalia catappa* L. (Combretaceae) symbolizes the location of the cemeteries; *Pseudopteris decipiens* Baill. (Sapindaceae) is planted in the villages for its aesthetic qualities, and also as a local traditional symbol of Malagasy culture; *Harungana madagascariensis* is used as an indicator of soil fertility, sap, leaves, etc. are used in traditional pharmacopoeia, and the wood is preferred for tool handles (Mahefa 2010). According to de Groot et al. (2010), the integration of ecosystem services is a tool for achieving better land use management. Before the protected area was established at Analalava, the forest fragment supplied provisioning ecosystem services to local people, in the form of firewood, timber, honey, bushmeat, fruits and mushrooms, medicinal plants, basketry material, and more. According to the conservation strategy used in the protected area of Analalava, trade-offs do exist between the above-cited provisioning services and economic development. Accordingly, alternative resources and services must be developed to compensate for the setting aside of the protected area and the resulting loss of services provided by the forest in the past. In this context, consider the case of timber taken from the forest, which is considered by local people to be the most valuable ecosystem service furnished in the past by the Analalava forest. For this provisioning service in particular, direct and indirect compensation offered to local people seems not to be sufficient, since they continue to harvest wood in the little forest fragments left in proximity to their villages. Furthermore, strong attachment remains to certain native species among local people, for the large range of services they provide, especially provisioning (medicine, timber), cultural (traditional spirituality, symbol, aesthetic value) and supporting to agriculture (soil fertility).

TAKING LOCAL KNOWLEDGE INTO ACCOUNT IN CONSERVATION AND SUSTAINABLE DEVELOPMENT. Ecological qualities of native trees used for ecological restoration, such as *Uapaca louvelii* Baill. (Euphorbiaceae) and *Intsia bijuga*, both of which are able to survive in abandoned fields, should be combined with the stakeholders' appreciation of the species. For example, experiments could be conducted on how some farmers would plant and use native tree species seedlings if they had access to them. This could be made possible if, in addition to distributing seedlings of non-native timber species, seedlings of sought-after native timber species were offered as well. Also, comparisons with on-going similar experiments within other community based conservation projects on the east coast of Madagascar, such as the one led by the Adefa association in Manompana (Adefa Association 2008), would be useful.

A major barrier to such plantation activities would be the unclear status of land tenure. It is obvious that this kind of activity cannot be pursued if the local population is afraid of possible land grabs. Turk (2005) considered the conditions under which native species planting could be implemented in Madagascar. One was that local managers and local population should agree on a common objective such as forest restoration or connectivity re-establishment. However, given the shortage of farming land in our study area, no lands are available for forest restoration outside the protected area. On the contrary, an approach that promotes diversity and heterogeneity should be encouraged (Rives et al. 2013) and a mix of introduced and native species should be pro-

moted for people to cultivate them on their own lands as part of a 'melting pot of biodiversity' (Kull et al. 2013). This would increase ecological resilience of the forest ecosystem and the semi-cultural landscape.

The relatively slow growth rate of native tree species could also stand in the way of their plantation. However, each individual has its own reasons to plant as Rialland (1999) puts it. It depends on the farmer's availability, objectives, knowledge, and mental representation of the trees. Some farmers will be likely to plant certain native species because of the services provided, including heritage values and soil fertility. Other farmers, especially those in precarious situations, with short-term needs, will more likely require other incentives to plant native tree species, such as direct or indirect payments via ecocertification of agricultural produce. One example of certification is the sustainable agriculture network implemented by Rain Forest Alliance within several communities in Northern Madagascar (Rain Forest Alliance 2011). A decrease in the possible choices of tree species would result in a loss of local traditional knowledge, or cultural biodiversity. Conversely, supporting knowledge about how people perceive and use their environment, and natural resources, may help in local management, both in and outside of protected areas.

CONCLUSION

Clearly, in our study area, introduced species are indispensable for timber production and have been part of people's lives for several decades. Yet, their wood cannot replace all the uses once served by wood originating from native tree species. Since a restricted range of species cannot perform all the functions nor be used for all the purposes for which local people need wood, it seems that species-level biodiversity has a social importance in the study area. The diverse uses of timber must be taken into account by conservation and development workers, including the spiritual and cultural importance of some tree species and their medicinal use. Fast-growing introduced tree species certainly have their place in Madagascar's agricultural landscapes; slower-growing native tree species have their place as well. The interest of local people in a certain range of species could be used to improve conservation and restoration strategies. This approach could help reduce the pressure on forest fragments and enhance landscape connectivity, thereby benefiting conservation, sustainable development and restoration goals.

Futhermore, conserving and reintroducing native species within a protected area is essential but may not be enough for their long-term conservation, nor a way to sustain local people's livelihoods. Promoting the active protection and reintroduction of certain native species when possible in the working landscapes where people live can contribute to both these goals. In this way, a more participative management of the Analalava protected area and surrounding landscapes, based on local ecological knowledge, could be implemented with beneficial outcomes for both, conservation objectives and human livelihoods.

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SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY.

S1. Characteristics of the introduced and native tree species used for timber in four villages.