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Can we really manage tropical forests without knowing the species within? Getting back to the basics of forest management through taxonomy

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ABSTRACT

Considering the pressures on tropical forests from deforestation and the recent expansion of harvesting through forest concessions in the Brazilian Amazon, it is imperative that forest management systems are scrutinized to ensure sustainability. One of the basic problems in forest management is the correct identification of species within the forest stand. While this is a well known issue, little consideration is given to how to mitigate this problem or its affects on management practices and conservation. This paper examines the current practice of forest inventories in the Brazilian Amazon, as part of the mandatory system of reduced impact logging (RIL), using extensive forest inventory verification. The results show that the RIL management plan implemented in the project area was based on a highly inaccurate forest inventory. At least 132 species or 43.5% of all species identified after botanical checking did not appear in the forest inventory and the common practice of matching vernacular names to scientific ones proved to be severely deficient. In contrast, a high percentage of field identifications based on local people's expertise were correct. We suggest changes to current practices, including the training and use of parataxonomists, the collection of samples for verification, and stricter government control over current practices, which will achieve greater accuracy in data collection and forest management planning. Ultimately, we argue that in the current climate of extensive deforestation and forest use, it is essential that all aspects of RIL systems are reevaluated in order to achieve economic and ecological sustainability.

1. Introduction

Tropical forests give shelter to more than 50% of world's known species (Laurance, 1999; Dirzo and Raven, 2003; MA, 2005) in an area that represents 7% of the Earth's surface. Given its implicit importance, documenting the state of the tropical forest biome is a challenge of extreme significance (Bradshaw et al., 2009). Such a challenge, however, not only includes the monitoring of tropical forest areas, but also the need catalogue and protect species while diminishing the various drivers of forest degradation. Brazil, which hosts approximately 40% of the world's remaining tropical rain forests (Kirby et al., 2006), has seen intense pressure on such natural resources. The main causes of tropical forest degradation, such as agricultural expansion, high levels of wood extraction and the extension of roads and other infrastructure into forested areas (MA, 2005), are common occurrences in Brazil. Additionally, Brazil is also contending with pasture creation for cattle ranching which represents the foremost driver behind deforestation to date in the Amazon (Steinfeld et al., 2006).

Despite Brazilian government efforts to reduce deforestation, the area converted into non-forest activities has reached levels of over 11,000 km^2/year (INPE, 2009). A recently developed environmental policy in Brazil has established forest concessions on public land to private companies in an attempt to reduce deforestation through market regulation. Concessions within public forests have rapidly increased over the past few years: in 2008 311,715 ha were supplied to logging companies; in 2009 1,000,000 ha; and in 2010 there is a potential area of 8.7 million ha of pristine forest up for auction with a minimum target area of 2 million ha. The technical requirements for logging in such concessions are reduced impact logging (RIL) which has specific criteria for harvesting operations (such as minimum cutting diameter and maximum yield per ha) and is the same criteria as that required for private-land logging. The Brazilian government considers RIL prescriptions in Brazil as a sustainable forest management (SFM) system; however, RIL logging parameters have not been proven as sustainable. Recent publications have demonstrated problems with this methodology and negative impacts on the remaining forest stand relating to long-term modification of forest structure, genetic diversity and timber yield regulation (e.g. Lee et al., 2002; Degen et al., 2006; van

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Gardingen et al., 2006; Lacerda et al., 2008a; Sebbenn et al., 2008). Therefore the use of RIL in the newly concessioned areas does not guarantee ecological or economic sustainability and may result in further forest degradation.

As deforestation rates in the Brazilian Amazon continue to climb and new areas for logging are now open through governmental concessions, the need to establish scientifically proven parameters for sustainable use of the forest is imperative. In fact, even the most basic step in any forest management system – the identification of species – is still neglected despite its importance in conservation (Prance, 2006; Richard and Evans, 2006). While the problem of species identification is a well known tenant of forest management, little discussion has focused on mitigating against misidentification and the problems associated with current practices.

The accuracy of plant identification depends strictly on the expertise of the specialists or on how people use the available literature, such as plant guides (considering that there is literature available and it is of good quality) (Hopkins and Silva, 2003). In the field, correct identification is dependent on the capacity of an experienced plant identifier whose background might be scientific or practical.

In the Brazilian Amazon, the most common method used to identify tree species in the field is through the use of local people and local ecological knowledge (LEK). The identification of trees using the expertise of local people is based on the comparison of trees' vegetative parts. This method of identification is intrinsically informal as it is derived from an individual's interaction with the environment and is "accumulated on a trial-and-error basis through learning from feedback and interaction" (Chalmers and Fabricius, 2007). As forest inventories are one of the main legal requirements for forest management in the Brazilian Amazon, timber companies use people with some practical local ecological knowledge for tree identification, which in many cases refers to local community members or small holder foresters (*mateiros*). The inventories created are lists of all trees larger than 50 cm dbh (diameter at breast height) by their common names, geographical position (X, Y), dbh, and trunk height. The vernacular names are then matched to scientific Latin names based on pre-existing lists and are used in management plans, trading and inspection (Lacerda, 2007; Rockwell et al., 2007). These lists are created by the companies themselves and are not regulated sources for vernacular-scientific name matching.

The process of translating forest inventories from vernacular to scientific names is inherently problematic in that the naming of species can be individual, local or community specific. Thus, a tree called by one name in one region might not be the same for the same species in another region; moreover, one common name might be used in multiple regions but in reference to different species (Hopkins and Silva, 2003; Lacerda, 2007; Rockwell et al., 2007). The inaccuracy of plant identification both in the field and through incorrect translations has distinct and problematic consequences. These range from trading timber without the properties desired, to buying plants with unwanted pharmacological effects, to compromising the foundation of management programs and therefore threatening sustainability (Hopkins and Silva, 2003).

As the central idea of forest management systems is to ensure the sustainability of the forest, it is essential that the information regarding which species are to be managed is accurate in order to effectively manage each species in a sustainable way. This paper presents a case study from the Brazilian Amazon with the objective of exploring the affects of botanical identification on the sustainability of species and forest management. The case study examines the accuracy and verification of one forest inventory and considers the impact of the botanical identification accuracy on forest management and species' conservation through the analysis of species' spatial pattern. Finally this paper examines some possible solutions to the issue of misidentification and mistranslation of vernacular names through partnerships with local ecological experts and parataxonomists, timber companies, and government organizations.

2. Methods and database

The database used in this case study was a forest inventory carried out by a logging company in a 546 ha area in the Tapajós National Forest, Pará State, Brazil. This area was part of a pilot project which aimed to define criteria for government concessions given to private companies to manage public forests in the Brazilian Amazon (IBAMA, 2007). The forest inventory consists of a list of all trees with dbh larger than 45 cm by their vernacular and scientific names, their dbh, commercial height (trunk height), local coordinates (X, Y), and sequential number, block (a logging compartment), lines (block subdivision) and the identification of trees planned for logging. The trees local coordinates were transformed into geographical coordinates (UTM, datum WGS84) for analysis.

All species listed in the inventory (both common and scientific names) were verified by a group of botanical experts as part of the Dendrogene project (Embrapa/DFID). For each name listed in the inventory, a minimum of five individuals were checked in the forest and had botanical samples collected from each. Additionally, for one set of species (and respective similar species) all trees larger than 20 cm dbh had their entire population verified in the forest plot. The samples collected were herborized and compared to the IAN herbarium (Embrapa Amazônia Oriental herbarium, Belém, Brazil) collection and when fertile the specimen was included in the IAN's collection.

In the forest inventory, tree identification was based on vernacular names, making use of local expertise. Subsequently, the company responsible for logging used a pre-existing list to match the common names with scientific names as part of the requirement to gain official approval for their forest management plan. The list is not locality-specific but based mainly on the IBAMA's (Brazilian Environmental Agency) list of Brazilian species (Camargos et al., 2002). IBAMA's list is a general register for all known Brazilian tree species. This list includes the scientific name and all vernacular names by which each species is referred. Many trees have a number of vernacular names which can refer to multiple scientifically identified species. For this reason, confirmation of tree identification for every species found in the dataset was carried out in the field as part of this study and did not use the pre-existing list available from IBAMA.

After botanical checking the original forest inventory was revised. When a species with a large number of individuals was identified with more than one corresponding scientific name, these species were grouped into one due to the impracticality of a complete census; in such cases the name used congregates the most common species name followed by "group".

3. Results

The analysis of the botanical accuracy of the studied forest inventory demanded three years (2002–2004) of field work and more than 3000 samples were collected, herborized and compared to the IAN herbarium collection.

In the forest inventory carried out at the Tapajós National Forest, 222 vernacular names were found. Using the pre-existing list, these names were matched to scientific names, resulting in a final list of 171 species. Some species identified in the field by different common names were later identified as having only one scientific name. However, in most cases, a common name in the inventory referred to more than one scientifically defined species.

After a botanical checking of all names found in the inventory, covering both common and scientific names, 303 species were identified. In more than 70% of the cases, the species identified in the botanical checking were given the wrong scientific name in the forest inventory. If we consider just the number of species and not the accuracy of the names, at least 132 species or 43.5% of all species identified in the botanical checking process were not listed in the inventory. In some extreme situations, the identification error was very serious. Abiurana (*Pouteria guianensis*) as it was named in the inventory actually comprises a group of eight species from different genera (*Chrysophyllum*, *Courataria*, *Micropholis*, and *Pouteria*). In the case of the common name breu-manga, which should refer to *Tetragastris altissima*, the name refers in the inventory to a group containing four species of different genera and even botanical families (*T. altissima*; *Protium apiculatum*—Burseraceae; *Pouteria oppositifolia*—Sapotaceae; *Erisma uncinatum*—Vochysiaceae). In another case, the name cupurana has no scientific correlate in the inventory and is listed as NI—not identified. However, the name actually refers to six different species including *Theobroma guianense*, *Sterculia frondosa* (Sterculiaceae), *Lueheopsis rosea* and *L. duckeana*, *Luehea speciosa* and *Luehea* sp. (Tiliaceae).

The botanical checking revealed not only an inaccuracy in the identification of species in the inventory, but it also demonstrated a clear bias in the inventory creation process against species not considered commercially valuable. Recording of a species' population depends on the employee's personal appraisal of the species' "importance" to the company commissioning the inventory. Therefore, species such as *Cecropia* sp. and *Pourouma guianensis*, species that have no value to timber companies, did not have their populations fully listed. As a result, the forest inventory presented an unrealistic spatial and density distribution of some species and in other cases they are completely ignored (Fig. 1a). The consequences are an inaccurate assessment of forest diversity and structure and an underestimated impact of logging on the remaining stand.

The results of the botanical checking show a tendency toward more accurate field identification of species which cannot be mistaken for any other, for example species which have one or more characteristic(s) (bark, leaves, sap, etc.) that allow for easy identification. In contrast, some species that are very similar to each other were grouped under only one name (discussed further below). Thus, plant identification based on local people's expertise using common names presents some problems. The importance of such knowledge is evident and the involvement of local communities is essential in forest management; however, the observed inconsistencies in the forest inventory demonstrate that relying on a system in which people's expertise is affected by differences in individual experience is problematic. For example, different teams working on the forest inventory were responsible for serious inconsistencies, such as a species being identified in some areas whereas in other parts they were completely left out of the inventory (Fig. 1b).

The problem of misidentifications is, however, not limited to the non-traditionally harvested species such as those discussed above. The analysis showed misidentifications for some of the most valuable and heavily logged species, such as the commercial species *Manilkara* spp. and *Hymenaea* spp.

Manilkara comprises a group of species which are widely harvested in the Brazilian Amazon because of its commercial value; these species are commonly known as maçaranduba and maparajuba. After checking all trees in the inventory named by maçaranduba, maparajuba and *Manilkara*, three species were found (*Manilkara bidentata*, *Manilkara paraensis* and *Manilkara*

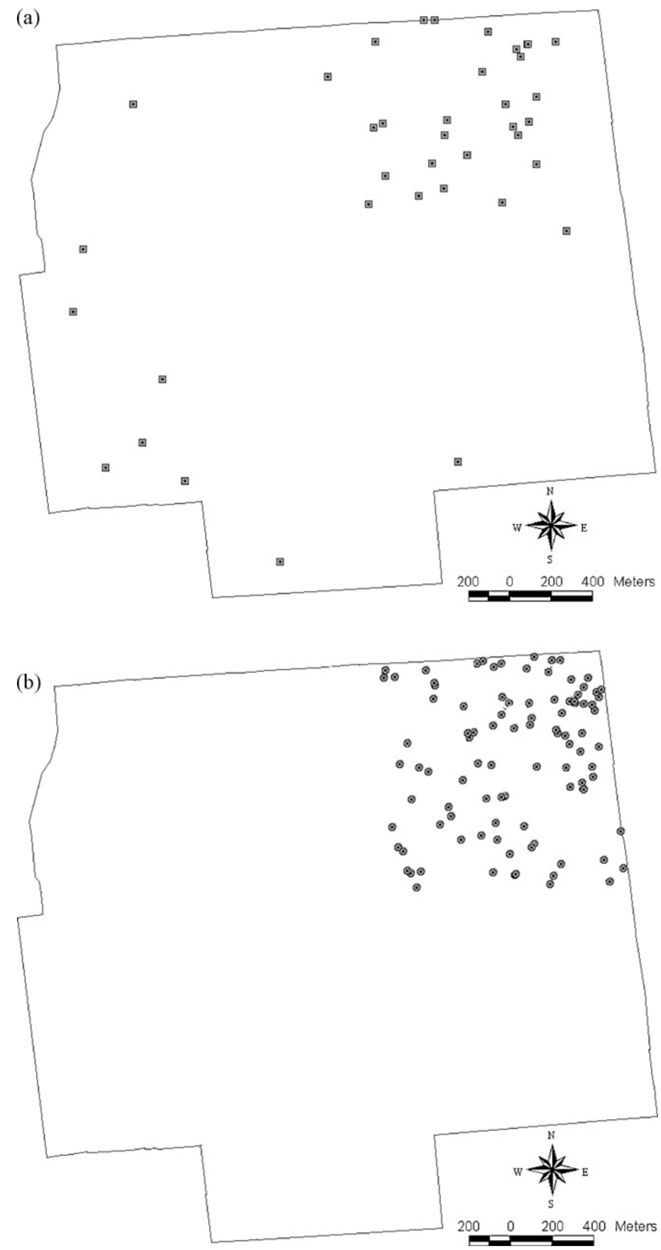

Fig. 1. Maps showing the inaccuracy in the identification of two species caused by differences in the way field workers perceive the "importance" of a species and his ability to identify it: (a) considered by most people as a species of no commercial importance, embaúba (*Cecropia* sp.) was identified by just one field worker and (b) a mix of inability to identify the species and personal judgment of its importance: urucurana (*Sloanea nitida*) was identified by just one field worker who decided to identify the species in only one area.

cavalcantei) none of which correspond to the scientific name cited in the inventory (*Manilkara amazonica*) (Fig. 2a and b).

The genus *Hymenaea* comprises another important commercial group of species of which *Hymenaea courbaril* is usually the only one harvested and it is one of the most logged and valuable timber trees in the Amazon. In the study area, *H. courbaril* occupies the canopy, has emergent individuals reaching heights of more than 60 m, and it occurs in densities of less than one tree per hectare ($\sim$0.35 trees/ha, dbh $\geq$ 45 cm) (Lacerda, 2007). In the forest inventory three species were listed from the genus *Hymenaea* corresponding to four vernacular names: *H. courbaril* named as jatobá; *Hymenaea parvifolia* as jutaí-mirim; and *Hymenaea intermedia* http://www.tropicos.org/name/13005955as jutaí and jutaí-bolacha. The analysis of the field identifications (vernacular

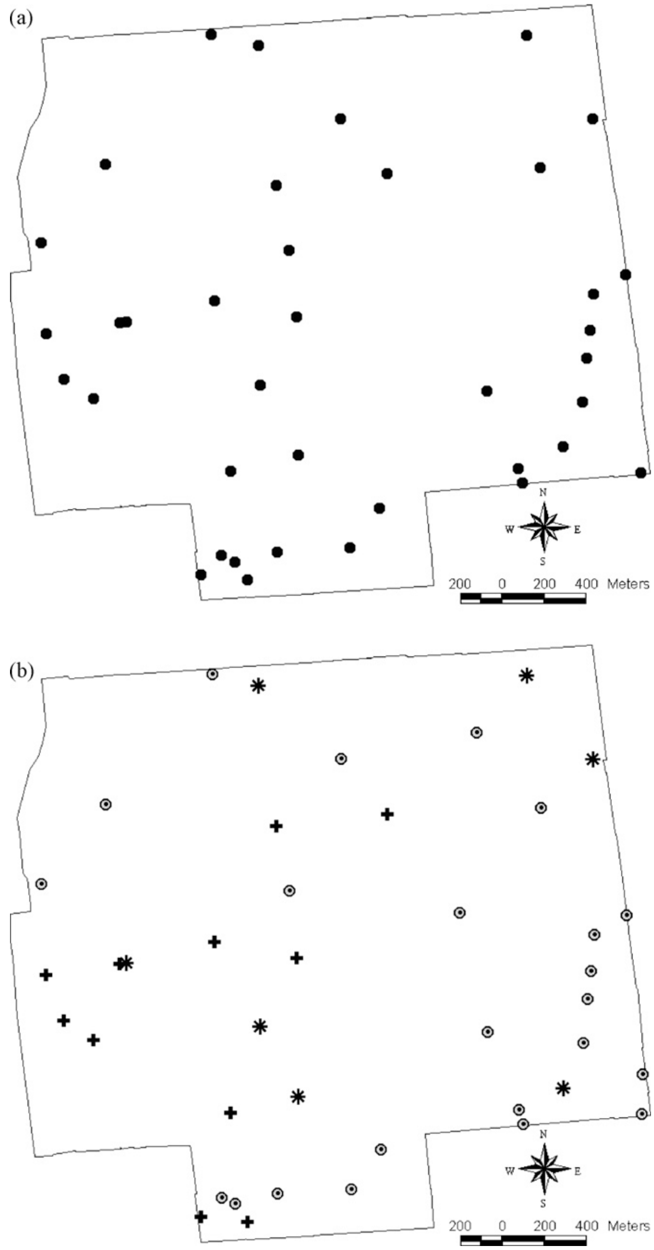

Fig. 2. Spatial distribution of *Manilkara amazonica* before and after botanical checking. (a) *Manilkara amazonica* trees distribution based on forest inventory (dots); (b) after botanical checking, no *M. amazonica* tree was found but *M. bidentata* (asterisk), *M. paraensis* (cross) and *M. cavalcantei* (dots) were identified instead.

names) showed a highly accurate capacity of distinction among *Hymenaea* species by local people through the following identifications: jatobá—*H. courbaril*; jutaí or jutaí-mirim—*H. parvifolia*; and jutaí-bolacha—*Hymenaea reticulata*. Among 55 trees identified as jutaí/jutaí-mirim only one error was observed (more than 98% of name accuracy). Among the 199 trees (dbh $\geq$ 20 cm) identified in the field as jatobá and named as *H. courbaril* in the forest inventory, only nine errors were observed (eight were mistaken as *H. parvifolia* and one as *H. reticulata*), meaning an accuracy of approximately 95%. The only jutaí-bolacha tree in the forest was correctly identified in the field although it was later translated into the scientific name *H. intermedia*.

Despite the fact that the capacity for identification of the three *Hymenaea* species in the field was high, when the vernacular names were matched to the pre-existing list aiming for scientific names, misidentifications increased significantly. From 33 trees named as jutaí, 32 were matched incorrectly as being *H. intermedia* and only one was correctly called *H. parvifolia*, resulting in an error of 97% on the inventory. Among 22 individuals identified as jutaí-mirim no error was detected, representing 100% accuracy in matching vernacular names to scientific names. The final analysis of the scientific names for *H. parvifolia* shows that the population formerly described in the inventory as having 23 individuals had in reality 62, thus representing a 63% larger population that documented (Fig. 3a and b).

Further in relation to the *Hymenaea* species, a unique specimen of jutaí-bolacha, was cited in the inventory and listed as *H. intermedia*. However, the specimen was confirmed to be *H. reticulate*: *H. intermedia* is present in the Amazon but there is no record of the species occurring in the study region. The field identification was again able to differentiate this species from the others and it was only during the translation of the vernacular to scientific names that the mistake was generated. This example also

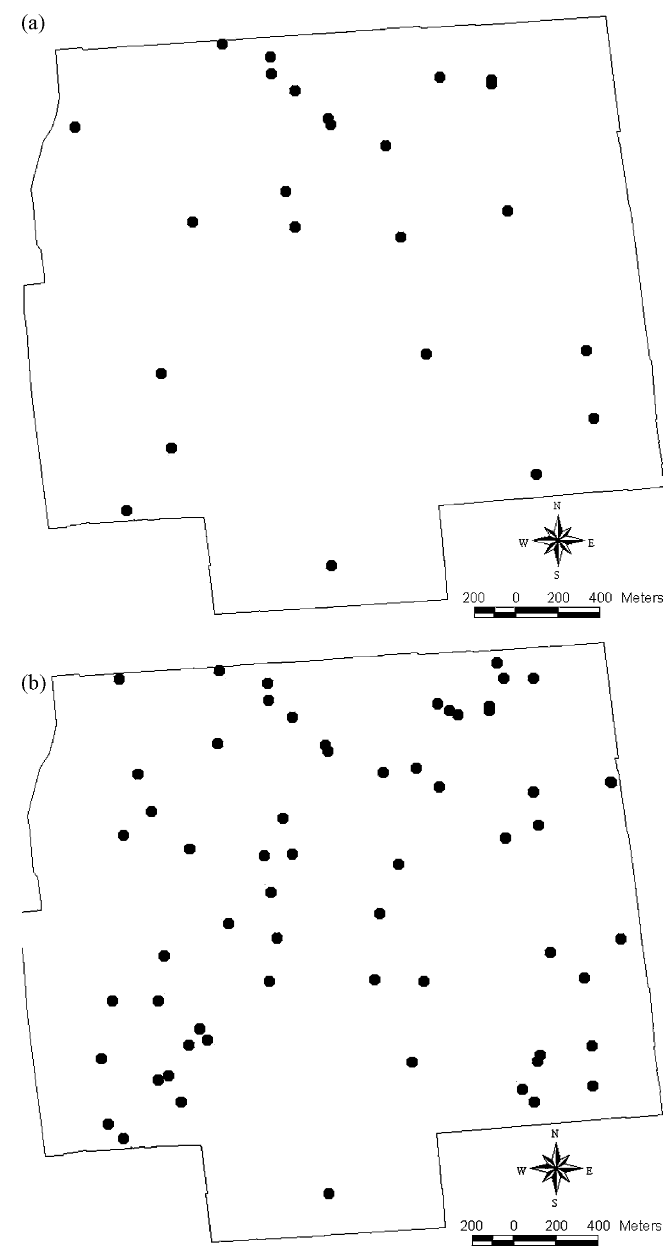

Fig. 3. Spatial distribution of *Hymenaea parvifolia* trees before and after botanical checking (trees location represented by dots). (a) *H. parvifolia* distribution based on the forest inventory and (b) *H. parvifolia* distribution based on the botanical checking.

highlights the problem of handling (very) low density species. Such species are commonly grouped together with more frequently occurring species for convenience during the name-matching process even if they are differentiated in the field.

Such misidentifications have important implications for the evaluation of species diversity. As mentioned above, in the inventory 222 vernacular names were listed corresponding to 171 scientific names. After the botanical checking of the inventory, 303 tree species were identified, but considering all species collected during a floristic survey that took place alongside the inventory checking, 357 tree species were found. The discrepancy in the number of species is partly the result of sample collection from species that were below the minimum dimensions required for inclusion in the inventory. However, such a discrepancy does suggest problems related to new legislation in Brazil. Recent changes in Brazilian legislation regarding forest management raised the general minimum cutting diameter threshold from 45 to 50 cm dbh. It has also, however, introduced a new rule which allows a reduction of such thresholds in species specific cases, for example when a species reaches maturity at a diameter less than 50 cm. We expect that the problems related to misidentification, and therefore with management sustainability, will increase if cutting thresholds are reduced. Knowledge of a tree species is closely related to its use. Therefore, the vast number of species that currently do not reach the standard threshold are not only less known, and consequently more difficult to identify, but are also more likely to have little or no information recorded about its population distribution and ecological requirements. This situation might pose new challenges for guaranteeing ecological and economical sustainable management.

4. Discussion

The results of the case study demonstrate three major problems with current approaches to forest management inventories in the Brazilian Amazon. Firstly, field identifications were inconsistent in their accuracy. Secondly, the recording of certain species was dependant on perceived value. And thirdly, the translation of common names used for field identification into scientific names was inaccurate and not context specific. In order to mitigate against these problems with practical solutions, it is important to explore the root of the inaccuracies and how forest management practices can be modified to improve inventories and therefore sustainable management.

The first issue forest managers must address in order to improve the precision and effectiveness of forest inventories is the accuracy of field identification. The results of the botanical checking demonstrate a tendency for more accurate field identification of very distinct species which cannot be mistaken for any other (such as castanha-do-pará (*Bertholletia excelsa*), andiroba (*Carapa guianensis*)). Local exerts also demonstrate the ability to correctly identify and distinguish between very similar types of trees, such as the in the *Hymenaea* example discussed above. In contrast, some species that are very similar to each other were grouped under only one name. Therefore, plant identification based on local people's expertise which uses only common and locally specific names is not a complete and reliable method. The importance of local people's expertise is evident. Anthropological and ecological studies have demonstrated the need for local and indigenous participation in forest management practices and the importance of incorporating local ecological knowledge (LEK) with scientific practices (Ellen and Parkes, 2000; Klooster, 2002; Yli-Pelkonen and Kohl, 2005; Menzies, 2007). Integrating local communities into forest management not only fulfills the demand for greater participation and stewardship opportunities, but it also provides employment and training. Therefore, working with local experts in creating forest inventories should be encouraged. In the context of the rural Amazon forest, local ecological knowledge can be defined as "lay or experimental ecological knowledge, which can be a blend of learned scientific knowledge and knowledge based on a resident's own observations and experiences from surrounding nature" (Yli-Pelkonen and Kohl, 2005). What is important about this definition is that it acknowledges the incorporation of scientific knowledge with what is learned locally through either traditional means or through experience.

This case study demonstrates that in many cases the LEK is a valuable tool in forest inventories. However, it is clear that botanical identifications must incorporate some learned scientific knowledge in order to increase the accuracy of forest inventories. One approach which could have a major impact on the local population and local experts is to provide training and supervision from a botanist in order to develop a team of parataxonomists (Kanashiro et al., 2002; Basset et al., 2004; Janzen, 2004). Parataxonomists can be described as "a resident, field-based, biodiversity inventory specialist" (Janzen et al., 1993; Janzen, 2004). In Brazil, the training of local experts to become parataxonomists has been undertaken successfully during a small number of notable research projects. One example is the Dendrogene project (Embrapa/DFID), in which local experts were trained in botanical identification alongside the main goals of the project to study the long-term impacts of logging on the Amazon (Kanashiro et al., 2002). The outcome was a team of parataxonomists prepared to accurately undertake forest inventories solicited by timber companies. Although the project was very successful, such an effort represents an isolated case and not a governmental or organizational policy. By providing local people with training in botanical identification that incorporates their knowledge and experience, timber companies and government organizations can ensure greater accuracy of forest inventories, more profitable outcomes, and more sustainable forest management practices.

Another approach which will help to improve accuracy of field identifications by local experts is the mandatory collection of samples from previously identified problem species. This case study showed a tendency for groups of trees with very similar features (such as the *Manilkara* family discussed in Section 3) to be grouped together or identified incorrectly. Part of the role of the parataxonomist is to collect and prepare species samples to aid in the identification process (Basset et al., 2004). Adopting an approach which requires inventory takers, or parataxonomists, to collect samples from identified problem species will ensure greater accuracy of the inventory. This approach will also help local experts to identify differences through comparison of exsiccate samples in regional herbariums, improve the herbariums and encourage local experts to maintain their own reference collection. Considering current developments in plant genetic barcoding (Lahaye et al., 2008; Rubinoff et al., 2006), the collection of samples for use in barcoding alongside field identification and herbarium comparisons will in the future help to further improve species identification in forest inventories. In order to achieve these modifications, partnerships with universities, research institutions and herbaria are necessary.

The second major issue that the case study uncovered is the process of matching common names with scientific names from an existing, general, list. The case study demonstrates that this method of obtaining the scientific classification is highly inaccurate. Not only does this process tend to group different species into one or only a few species, but it also results in errors in the common-scientific name match. The forest inventory names analyzed in this study were based mainly on IBAMA's catalogue of Brazilian trees (Camargo et al., 1997). This resource lists 4000 trees by scientific species and 10,000 vernacular names by which these species are commonly known. Although it is an important bibliographical reference it clearly does not consider all names used in every different region or community within Brazil. Using this list, the botanical checking showed that less than 30% of all scientific names used in the commercial inventory were correct. Therefore 70% of the trees in the forest stand were not considered in management plans thus completely negating the purpose and effect of the inventory. There are obviously serious flaws with the name-matching system and such general lists should only be used with caution.

The results of the case study also demonstrate that the use of general lists does not replace the appropriate identification carried out by trained personnel. In fact, the current forest management legislation should be more specific on how plant identifications are carried out and minimum levels of acceptable accuracy should be incorporated. Currently, timber companies are not required to use the IBAMA catalogue in the creation of their inventory. Many timber companies have compiled their own lists of vernacular-scientific names which are not regulated by the government and whose accuracy is questionable. While employing unverified general lists is problematic, such lists can be very useful in the preparation of forest inventories when regional differences are considered. Since forest inventories are submitted to Brazil's environmental agency, such lists can begin to be compiled on a regional level by creating a database that incorporates regional differences and includes botanical confirmations from samples taken in the field, as discussed above. The creation of a database accessible to forest management and timber companies would not only increase the accuracy of species identification, but it also allows for the flexibility necessary when classifying a highly diverse ecosystem.

Finally, the third major issue the case study highlights the creation of false population and distribution data through the grouping of similar species together under one name and the bias against trees which are commercially insignificant. As noted in the case study, tree species which were not deemed important to the inventory in some instances were left out completely or their population was under-represented. Similarly, the grouping of similar species under one vernacular name (such as abiurana, discussed above, and other cases including angelim (*Andira surinamensis*, *Dinizia excelsa*, *Hymenolobium excelsum*, *Hymenolobium modestum*, *Hymenolobium pulcherrimum*, *Hymenolobium petraeum* and *Vatairea paraensis*) (Ferreira et al., 2004) and tauari (*Couratari guianensis*, *Couratari oblongifolia*, *Couratari stellata*, *Couratari tauari*, *Cariniana micrantha* and *Couratari decandra*) (Procópio and Secco, 2008)) masks the existing population dynamics. Such practices create an inherent bias in the forest inventories which tends to overestimate the timber production potential of commercial trees. Although this bias is negative both ecologically and for the consumer, it might be of interest to logging companies. If some species are grouped under a common name, this "species" appears in the inventory with an overestimated volume. Therefore, a logging company could harvest a species at a level that exceeds its capacity to regenerate; this is especially problematic if low density species are logged based on false population sizes. Furthermore, this overestimation can be used by timber companies to mask illegal logging practices by adding illegally logged trees to the harvest to reach the approved volume limit. Similarly, by ignoring commercially unviable species when creating inventories, management planning is based on false population sizes and densities. Therefore, forest management practices do not reflect the real world situation thus leading to inadvertent consequences and outcomes within the forest stand.

From an ecological perspective, inaccurate botanical identification prevents a clear analysis and understanding of a species population and consequently jeopardizes the capacity to plan sustainable harvesting. Forest management (and fragmentation) are drivers that influence natural processes both directly and indirectly, such as genetic flow, mating system, random genetic drift and spatial genetic structure (Kanashiro et al., 2002). Logging reduces the density of tree species which can isolate reproductive trees or even create sub-populations in which the capacity for exchanging genetic material is reduced or ceases. The consequences are detrimental for reproductive success and gene flow of not only tropical trees, but other organisms as well (Nason and Hamrick, 1997; Dayanandan et al., 1999). Logging has the potential to affect pollinator movement and therefore the capacity of pollen dispersal which could spatially and genetically isolate trees and lead to a higher susceptibility to local extinction (Nason and Hamrick, 1997). Although tropical species have commonly long-distant pollinations (see Nason and Hamrick, 1997; Nason et al., 1998; Konuma et al., 2000; White et al., 2002; Dick et al., 2003; Kenta et al., 2004; Latouche-Hallé et al., 2004; Carneiro et al., 2007; Cloutier et al., 2007; Lacerda et al., 2008b; Silva et al., 2008), forest management in high intensities might affect the sustainability of some species (Sebbenn et al., 2008).

The problem of over- or under-estimating species populations' size and density requires similar solutions to those discussed above. The identification of species by local experts who receive additional botanical training, such as parataxonomists, would help to ensure some problematic groups of species are correctly differentiated. Additionally, verification of management plans in the field should confirm the identification of species by using trained parataxonomists; currently, the verification of the inventory is undertaken by technical personnel not trained in species identification and considers only the dendrometric information listed in the inventory. These modifications, along with botanical checking through sample collection, would also help to increase the accuracy of inventories. Similarly, educating both local experts and timber companies on the importance of understanding *all* tree species populations in forest inventories is essential. Particularly with low density tree species, this practice will result in an even more inaccurate estimation of the existing stand and the possible loss of species. Finally, the importance of a more specific and restrictive legislation which requires minimum levels of accuracy is clear.

5. Conclusion

Forest management programs, such as RIL, are based on a foundation of field data regarding species identification and tree measurements. If this data is inaccurate, forest management programs are compromised as true details of the stock are unknown and therefore both ecological and economic sustainability are at risk. Although RIL has considerably less detrimental impacts on the forest compared to traditional non-planned systems (e.g. Putz et al., 2000; Sebbenn et al., 2008), some authors have affirmed that RIL practices might not be sustainable in the long term (e.g. van Gardingen et al., 2006; Lacerda et al., 2008a; Sebbenn et al., 2008). Such studies have shown that RIL might have significant impacts on species' genetic, demographic and production levels. The results of these studies demonstrate that sustainability should not be taken for granted with the adoption of RIL. Appropriate levels of harvesting are still not known for most species and such information is essential in achieving a sustainable forest management system. With the recent changes to Brazilian legislation regarding forest management and the move towards increasing concessions in public forests, the problems outlined in this paper require immediate action. No harvesting plan will succeed in providing human needs while preserving viable populations unless the components of such populations are known. Therefore, precise identification of the species under management is the first and basic requirement for the conservation of tropical forests.

Forest management based on accurate information, specifically regarding species occurrence, requires that correct botanical identification is recognized as essential and brought into the management process. Different measures, such as those suggested here, will be necessary and involve governments, timber companies, and local stakeholders. Changes to the current system include working with local experts and providing parataxonomy training which incorporates both LEK and scientific knowledge, encouraging logging companies to employ trained parataxonomists, and requiring stricter controls within governmental agencies regarding the verification of forest inventories. However, the most important changes are related to the misconception that the identification of species is just a formal and unimportant requirement to be fulfilled, and the belief within forestry that because identification is a basic level of forest management, it is a procedure well under control. A turnover in this mentality is the initial and most basic step toward the sustainable use of forest resources in highly diverse tropical forests.

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