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Methods to Study the Ethnobotany of Wood Resources: A Critical Evaluation

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ABSTRACT

In this review, we aim to discuss current methodologies used by ethnobotanical and related studies that investigate wood use. This text focuses on state-of-the-art studies concerning wood uses, with information from interviews, techniques for measuring harvested or consumed wood and techniques for analyzing the use pressure based on the joint analysis of ethnobotanical and ecological data.

Keywords: firewood, human ecology, use pressure, wood products

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INTRODUCTION

Woody plant species are very important for maintaining forest physiognomy and composition. These species are also responsible for supplying subsistence needs and they usually are a source of income for local populations (Cocks and Wiersum 2003). Specifically, wood is one of the most heavily exploited forest products on the tropics (Walters 2005a, 2005b), and it is widely use for a number of ends, such as house and fence construction, confection of handicrafts and for fuelwood (firewood and charcoal) (Walters 2005a, 2005b; Gaugris *et al.* 2006; Albuquerque *et al.* 2008; Ramos *et al.* 2008a, 2008b; Nascimento *et al.* 2009).

However, despite this scenery that elucidates the importance of wood products for local populations and the importance of conserving these resources for the maintaining of forest ecosystems, there is still a small amount of ethnobotanical studies that deals with wood uses by local communities (e.g., Nagothu 2001; Cocks and Wiersum 2003; Walters 2005a, 2005b; Gaugris *et al.* 2006; Naughton-Treves *et al.* 2007; Albuquerque *et al.* 2008; Ramos *et al.* 2008a, 2008b; Nascimento *et al.* 2009; Medeiros *et al.* 2011). In fact, most ethnobotanical investigations are dedicated to the study of medicinal and edible plants or they are general studies, which include woody use-categories but do not investigate them in depth.

Another important aspect in the context of ethnobotanical studies of wood products, probably resulting from the low dedication to the subject, is related to methodological directions to access information concerning knowledge, use, preference and collection and consumption patterns. Many techniques were created in order to estimate, for example, wood consumption, but their advantages and limitations were poorly discussed. Therefore, this paper seeks to give an overview of the works related to wood uses by local communities, in a way to examine the methods and techniques applied and what they can answer. We will comment on ethnobotanical studies concerning wood uses and on studies that do not name themselves as etnhobotanical, but which have similar approaches. We will also analyze some general etnobotanical works which have a large mention to wood products, in order not to leave our analysis restricted only to the few studies that exclusively approach wood. This text will focus on the state of art of studies concerning wood uses, with aspects from interviews, techniques for measuring harvested or consumed amount of wood and techniques to analyze use pressure based on the joint analysis of ethnobotanical and ecological data.

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Invited Review

GENERAL AND ETHNOBOTANICAL APPROACHES IN THE STUDY OF WOOD USES

Use-categories

Studies about wood products have not been equally distributed among use-categories. Certainly, fuelwood is the wood use category which aggregates the majority of studies, due to its high local use and importance. To this use, most ethnobotanical and ethnobotanical-like studies are concentrated in countries of Asia like India (Mahapatra and Mitchell 1999; Samant *et al.* 2000; Bhatt and Sachan 2004a, 2004b), Cambodia (Top *et al.* 2004a, 2004b), Bangladesh (Miah *et al.* 2003); Tanzania (Luoga *et al.* 2000a) and Indonesia (Pattanayak *et al.* 2004).

The few works exclusively dedicated to the construction category (e.g. fence and house construction) were mainly developed in Africa, in countries such as South Africa (Gaugris *et al.* 2006; Gaugris and van Rooyen 2006) and Uganda (Kakudidi 2007). It is notable the lack of studies only dedicated to technological resources, like work handicrafts, wood artifacts, etc.). For these categories, some notable works were performed with canoes in Tonga (Oceania) (Nikum 2008) and woodcarving around the world (Cunningham *et al.* 2005).

Even the general wood studies, that is, those which include more than one wood use category, are still scarce, perhaps due to difficulties in methodological standardization for more than one use category since those use-categories may have distinct use dynamics and spatial patterns. Some of these investigations bring considerable differences in consumption and collection patterns among use-categories and these differences are not often considered. Walters (2005b), in a survey performed in central Philippines, noted that while people tend to select specific diametric classes for construction ends, there is no diametric requirement for fuelwood and the harvesting for this use-category is more flexible in terms of wood size. In a study carried out in northeastern Brazil, Medeiros *et al.* (2011) found that, although domestic construction wood uses require more destructive patterns such as the use of green wood trunks, the use-category that causes more use-pressure on forests is fuelwood, since about 90% of wood consumption is destined to energetic needs.

Therefore, differences on demand and collection patterns among use-categories can be very important to direct conservation strategies and therefore it is essential to know which use-categories are responsible for higher use pressures.

Approaches

Surveys with wood resources have arisen with several approaches and questions. Ethnobotanical studies with ecological-conservationist focus stand out (Banks *et al.* 1996; Luoga *et al.* 2002; Obiri *et al.* 2002; Ogunkunle and Oladele 2004; Walters 2005a, 2005b; Nkambwe and Sekhwela 2006; Pote *et al.* 2006; Tabuti 2007), economic focus (Luoga *et al.* 2000a; Pattanayak *et al.* 2004), cultural recording focus (Cocks *et al.* 2006) and studies focusing on wood properties and physical characteristics (Abbot *et al.* 1997; Abbot and Lowore 1999; Jain and Singh 1999; Kataki and Konwer 2001; Bhatt and Tomar 2002; Ramos *et al.* 2008b).

Studies with ecological focus generally use joint ethnobotanical and ecological information to diagnose the *status* of local vegetation and to point species which suffer higher use pressure (see *Joint use of ethnobotanical and ecological data*). Economic focus mainly seeks at verifying cost-benefit relations for plant resource use or also at giving economic values to forest goods (see *Economic valuation of wood products*). In its turn, cultural recording approach helps registering traditional wood uses which are not the classical wood products related to house construction, technological uses and fuelwood (see *cultural recording of wood uses*). At last, physical properties approach is widely related to fuelwood use, by calculating the Fuel Value Index of plant species (FVI) (see *Ethnobotany and wood physical properties*).

METHODS FOR INVESTIGATION OF WOOD PRODUCTS

An important aspect in the context of ethnobotanical studies of wood products, probably due to the lack of dedication to the subject, is about methodological directions to access information regarding knowledge, use, preference and consumption and collection patterns. There were many techniques created to estimate, for example, wood consumption, but there was little discussion about their advantages and limitations. Therefore, we will show some methodological tools which are used in ethnobotanical studies of wood uses or in studies which do not name themselves as ethnobotanical, but have similar approaches and aims, in order to analyze what each technique can reach, that is, what they can and cannot answer. We will also analyze some general ethnobotanical works with large mention to wood uses, in order not to restrict our analysis to the few wood-exclusive ethnobotanical studies.

Interviews

The interview is certainly the most used methodological instrument in ethnobotanical studies. It is applied to get information about the most known, used or preferred species for a given end, and about resource collection and consumption patterns. But, precisely regarding wood use information, some precaution has to be taken to avoid hasty conclusions deriving from the application of interviews. As follows, we will discuss some of the aspects frequently approached in works which adopt the interview as a methodological strategy.

Used species – It is common to examine local importance of wood products by directly questioning the respondents about the species used by them (Kristensen and Baslev 2003; Top *et al.* 2004a; Ramos *et al.* 2008a; Sá e Silva *et al.* 2009). However, this kind of information must be relativized, especially when dealing with studies about use pressure. The point is that a species can be used for many people to a given end, but in little quantity and with a small frequency, while other species can have its use restricted to few people, but in much higher quantity and frequency. So precaution is needed not to assume that the most cited species are also the most pressured ones (see Albuquerque and Lucena 2005; Oliveira *et al.* 2007; Silva *et al.* 2008). Furthermore, equal attention shall be given to use citations in each category, since some wood use-categories, depending on its context, can demand higher amounts of wood than others.

Preferred species – Many studies concerning wood uses apply the preference parameter in addition or substitution to questions about use (Lykke 2000; Holmes 2003; Miah 2003; Tabuti *et al.* 2003; Gaugris and van Rooyen 2006; Shah *et al.* 2007; Ramos *et al.* 2008). Most of these studies seek to directly ask people about preferred species for a further analysis of those which had higher preference citations. Another way of assessing preference can be seen in the studies of Miah *et al.* (2003) and Jashimuddin *et al.* (2006), both in Bangladesh. The authors used a pair-ranked exercise so that informants indicated one preferred species between two that were shown, and the species which was not indicated as preferred was excluded for a new one to form the pair. Herewith, plants were compared two by two until the preferred species was reached. Another way of assessing preference was performed by Chettri and Sharma (2007), which used a ranking matrix to get collective information about preference using a participatory method known as Participatory Rural Appraisal (PRA). By means of this technique people collectively indicate the preference order for plant species.

Preferred species can be seen as the potentially most explored, but not always the most preferred are also the most used (Marufu *et al.* 1997). Species availability can be an interference factor in the use/preference relation, given that if a species is widely preferred in a given place, but its population is too small, it will probably not be among the most used, especially concerning wood uses since for those uses the harvested part is a significant portion of the individual and often the local demand is only supplied with the extraction of several individuals. Relation degree between preference and use can have serious implications in terms of conservation. If in a given place wood product use is ruled by preference, it is likely that use pressure is concentrated in few species that are preferred. But, on the other hand, if the most used species are also the most available and not necessarily the preferred, then use pressure will be directed to species with higher populations, what in most cases is more interesting for maintaining plant populations.

Amount of consumed wood – A way to estimate the amount of consumed wood without the need to perform a stock monitoring, is by directly questioning informants about the amount of resources that they consume in a given stretch of time. This kind of approach is generally performed in two distinct ways: (1) questions about the amount of wood consumed for a given end based on local measurement units (Godoy *et al.* 1995; Campbell *et al.* 1997; Mahapatra and Mitchell 1999; Cocks and Wiersum 2003; Homes 2003; Ogunkunle and Oladele 2004; Gavin and Anderson 2007; Pérez-Negrón and Casas 2007), and (2) the researcher asks the informant to separate the consumed amount per unit of time and this amount is weighted (Banks *et al.* 1996; Marufu *et al.* 1997; Kituyi *et al.* 2001; Pote *et al.* 2006). Among the surveys based on local unities, Mahapatra and Mitchell (1999) and Holmes (2003) recorded quantities based on firewood bundles. Ogunkunle and Oladele (2004) estimated weekly domestic firewood consumption based on a standard headload, that is, the amount of wood that local dwellers are used to carry in their heads when collecting firewood; and based on the total load carried by a pick-up van in the case of the bakeries. Cocks and Wiersum (2003) estimated quantities of wood based on the transportation method (such as a headloads or cartloads). The amount of wood that a donkey is able to transport was also used as a local unit in a work performed by Pérez-Negrón and Casas (2007).

Although the estimation of wood consumption using informant's answers is a practical alternative to assess this kind of information, some limitations are clear in this approach:

a) Respondent's answers concerning quantities can be imprecise, be it because of the respondent's lack of interest on correctly answering, because of the inadequate knowledge about the subject, or even because of an intentional distortion of the information (Shankar *et al.* 1998).
b) This imprecision can be even larger in the cases of wood uses with high turn-over time. Regarding house construction, when just one or few deteriorated elements are substituted at each time, it can be difficult for the respondent to indicate the quantity consumed in a given time interval, once this kind of consumption is occasional and there is not a periodical collection of the material.
c) Estimating consumed quantities by means of interviews may not allow detailing amounts by each species. Getting to know consumed (or even collected) quantities by species makes the analysis even more imprecise, once in random collection events it can be difficult for the respondent to remember the collected quantity of each species. Regarding consumption, this information is also prejudiced, since it can be a temporal variation on species consumption.
d) Seasonal differences can interfere on wood consumption and, therefore, on respondent's answers about consumed quantities.

Turn-over time or harvesting frequency - In addition to quantifying resources through interviews or direct measurement, some studies have indicated the importance of turn-over time in the case of consumption (Albuquerque *et al.* 2008; Medeiros *et al.* 2011) or harvesting frequency when the work is directed to collection (Cocks *et al.* 2006). This type of information can remove the study from the static universe (considering only the moment of approach) and transform it to the dynamic universe (considering the resource amount consumed per unit of time). Observing the consumption behavior of resources based on a static analysis can be a source of bias in a study. For example, Albuquerque *et al.* (2008), when measuring the wood volume by use category in an urban-rural community of northeast Brazil, found that the "construction" use category had a higher volume than the "fuelwood" category. However, the authors acknowledged that if they considered the turn-over time, the wood volume in "fuelwood" would be higher than in "construction" since turn-over time for "fuelwood" lasts only a few weeks, while it may be several years for the "construction" category. This observation was confirmed by the work developed by Medeiros *et al.* 2011 in the same community, which showed that fuelwood was the main wood demanding category when considering turn-over time. Information on turn-over time is especially valuable when it is not possible to monitor the materials' entry and exit dynamics, but this information is also susceptible to imprecise responses from informants.

In situ inventory

With the technique of *in situ* inventory, the plant material in a residential unit is registered. This technique has the advantage of not depending on an interview to obtain information about the real and current use of resources. For research on wood uses, the *in situ* inventory may help to highlight the most used species for a particular use category, or even the most frequent or demanded use categories. However, this approach also has some disadvantages, namely:

e) Some buildings and other wood structures are covered by materials such as clay or stone, making it difficult to identify the material. If the covered material is predominant in the area being studied, it is preferable to use another technique or to use it only to compare wood use categories (e.g., construction versus fuelwood) rather than analyzing consumption by classifying the material in terms of species. However, if this situation occurs only rarely, the technique can be used.
f) It is not always possible to know the degree of reliability of local information on wood identity. To minimize this problem, it would be interesting to make a reference guide to plants of the region to allow researchers to distinguish the species. This guide would involve the collection of wood samples of each species and the morphological description of these samples in order to facilitate the identification of materials in the residences based on the samples and descriptions of the guide. Another option is to employ the checklist-interview technique by displaying wood samples to informants so that they can speculate on the identities of these samples, as in the work performed by Medeiros et al. (2008). Thus, an *in situ* inventory based on local information would only be carried out if the rates of correct identification of the material were high. The in situ inventory has three applications, as we shall see below.

Verification of species and/or use category - In this approach, only species and/or use categories present in the residences are recorded, without a quantitative focus of mass or volume (see Dahdouh-Guebas *et al.* 2000). In terms of data analysis, this information allows researchers to know the frequencies of the species or use categories in the residences. However, if the study aims to generate information on use pressure, the frequency alone cannot be a good parameter by which to highlight the most locally consumed species, as it often does not indicate wood quantity.

Counting of elements - Some studies use the technique of *in situ* inventory, and in addition, to check the frequencies of species and/or categories, they also perform a counting of elements. Abbot and Homewood (1999) observed the number of beams used in the construction of houses and identified the different types of beams that were part of the buildings' structures. Luoga *et al.* (2000a) also counted poles in 18 buildings. The total numbers of poles, canoes and other equipment in 42 residences were recorded by Kvist *et al.* (2001). The counting of elements places the approach at an intermediate stage between the qualitative and quantitative registration of wood resources. While quantitative analysis can be performed and some conclusions on demand can be drawn, these tests do not replace effective measurement by means of units of mass and volume of the material.

Measurement of mass or volume – This is done by recording the species or use categories and measuring the mass or volume of the material. It reveals the species and/or categories that demand greater amounts of wood. The measurement of volume may be performed by obtaining the geometric measurements of wood elements (e.g., radius and height in the case of cylindrical elements) (Gaugris *et al.* 2006; Gaugris and van Rooyen 2006; Albuquerque *et al.* 2008; Medeiros *et al.* 2011). Especially in the case of firewood use, it is also common to use pile volume as a parameter for stockpile measurement (Türker and Kaygusuz 2001; Top *et al.* 2004a; Sá e Silva *et al.* 2009). The mass can be obtained by direct weighing on a balance. As a time-intensive technique, the *in situ* inventory with direct measurement is especially suitable for small communities where the number of residences participating allows for completion of the work in a reasonable amount of time. Moreover, this technique forces the researcher to spend a substantial amount of time with one interviewee; thus, depending on the occasion, it is advisable that the *in situ* inventory be performed by another party on a different day to avoid depletion of the interviewee.

It is necessary to remember that the application of the *in situ* inventory method can be very invasive since, depending on the focus of the study, researchers must have access to the inside of the house and spend some time measuring materials. Therefore, the degree of openness that the group has with the community to be studied must also be considered, in addition to how people feel about this type of research taking place in their residences. Among the studies that have used the *in situ* inventory with measurements of volume, Albuquerque *et al.* (2008) determined the wood volume by species and use category. Gaugris *et al.* (2006) and Gaugris and van Rooyen (2006) quantified the wood volume used for residential buildings. Gaugris and van Rooyen (2006) also carried out a comparison of three data collection techniques: interviews, partial *in situ* inventory (considering only one of the wooden buildings in the residential unit visited, even if there were several), and total *in situ* inventory (considering all residential buildings, such as the main house, outside buildings, etc). The authors observed that although questionnaires provide qualitative information that could not be accessed by the *in situ* inventory, the number of significant differences between methods leads one to question the strength of the results of a model based only on interviews or partial *in situ* inventories, as the richness of information on the effective use of species is reduced with the use of interviews and partial *in situ* inventory.

In terms of number of species, Monteiro *et al.* (2008) compared the *in situ* inventory with general interviews (covering several use categories) and specific interviews (only for one use category). They observed that in the case of fences, specific interviews recorded a higher number of species, since in the interviews the informants mention not only the used species, but also other known species. The *in situ* inventory yielded the next highest number of species, and general interviews provided the lowest number of species for fence construction since the interviewees' attention was directed to other use categories. However, when considering fuelwood, the *in situ* inventory yielded fewer species than the general interviews. The authors attribute this finding to the fact that stockpiles of firewood constantly change, and the *in situ* inventory recorded only one snapshot of this species richness, suggesting that that an *in situ* inventory should be performed more than once in the case of fuelwood. Moreover, preferences for certain species can cause them alone to be observed on stockpiles, yielding no information on other useful species for fuel. Thus, these examples show the importance of using more than one research method; for example, an *in situ* inventory can be coupled with an interview showing which plants are known to be useful for a certain end.

Techniques for estimating firewood collection or consumption

Firewood is certainly the most studied wood use from the ethnobotanical point of view, possibly due to its importance to local communities and its scope in various urban and rural regions. Perhaps therefore, methodologies to estimate consumption or collection of firewood (and sometimes charcoal) have been better developed than estimates of the other wood uses. Some of the techniques used with wood will be discussed below, but it is important to clarify that it is sometimes possible to adapt a technique to the study of other wood uses.

Technique of tracks evaluation (footpath survey) - The evaluation of tracks focuses on the estimation of collection from the sources of resources. It can be performed for various wood uses (McCrary *et al.* 2004), but is generally considered for the case of firewood collection (Ganesan 1993; Shankar *et al.* 1998). The technique consists of mapping the exit points of forest resources and observing each point for a particular time interval. All collectors leaving the forest by that point will have their material weighed. It is preferable that this assessment be performed repeatedly (e.g., Ganesan 1993) and not as a single event.

Extensive criticisms have been raised concerning this technique. Shankar *et al.* (1998), for example, claimed that the results obtained by this technique have little scientific value. Among the other criticisms, authors have argued that for large forest areas and those surrounded by residences, there are many unknown access points to the forest, which makes it extremely difficult to specify the amount of wood that comes out of the forest for use as fuel. In addition, this type of technique requires a large team to track entries into the forest and the total amount of weighed material (Shankar *et al.* 1998).

Another issue facing tracks evaluation is that wood collection for fuel is also performed in anthropogenic zones (Kituyi *et al.* 2001; Ramos *et al.* 2008a), not just in areas of native vegetation. Wood can also be obtained by purchasing or even collecting in close native vegetation areas that are not targeted in the evaluation. Therefore, studies should not assume that the amount collected is the amount consumed by the local population.

In the case of small vegetation areas and with well known/delimited entrances and exits, this technique, tied to a vegetation study, may be useful to determine the amount of pressure degree the area is under.

Weight survey method – This method is used to measure firewood consumption. With this technique, a stack of firewood is weighed at the beginning of the day and left near the kitchen of the residence. The researchers ask the residents to use firewood only from that stack and, if it becomes necessary to use more, to remember the additional quantity used. After 24 hrs, the stack in question is weighed again, and the difference between the initial and final weights is the daily consumed amount (Fox 1984; Bhatt and Sachan 2004a, 2004b). Shankar *et al.* (1998) used a similar methodology, visiting the residences selected in the afternoon and weighing the total stock of wood for fuel available at the residence. The authors took care to observe whether the families had enough wood that they would not need to collect more in the next 24 hrs. The team then returned a day later and weighed the amount of wood remaining in stock. This type of approach is usually performed more than once at the same residence to avoid the situation in which the amount of firewood consumed is estimated on one atypical day of use, which would complicate the interpretation of the study results. Fox (1984) conducted a weight assessment by residence at four different times. If there are strong seasonal weather differences in the study area, it is also important that the repetitions of weightings are evenly distributed according to the seasons. Shankar *et al.* (1998) studied the fuelwood consumption in an area of the Mysore district, India; the weightings were distributed throughout the three seasons of the year in the study area (summer, "monsoon" and winter).

As the focus of this approach is consumption, it is important that some sources of bias be avoided. For example, if a study seeks to determine the amount of wood consumed with the focus on local forest areas, the researchers must investigate beforehand whether all of the material used is of local origin or whether wood is acquired by purchasing from other regions. Another issue is related to the identification of the weight by species. The total weight cannot be broken down by individual species, as the wood kept separate for residents' use during the day is randomly chosen or the most convenient for the researchers or residents (e.g., wood that was on top of the stack). Thus, the material in question is not a true sample of the variety of species used and their proper use proportions.

Other quantitative techniques for firewood use - Türker and Kaygusuz (2001) calculated the volume of wood stocks piled for fuel in the sampled residences. This type of analysis is typically static, and therefore, caution should be used in assuming that larger stocks mean greater consumption. Collection events may be rare but intense, forming large inventories, or they may be frequent and less intense, in such a way that consumption is high but no conspicuous stocks are observed.

Another approach was taken in the study by Brouwer and Falcão (2004). In this study, a sample of residences was selected, and residents were encouraged to register and weigh all of the wood that they consumed for fuel during a month. This methodology can provide the exact amount consumed without estimates, but once again the issue of reliability is in question in the local information.

Samant *et al.* (2000) performed a community approach in which ten bundles of wood were randomly chosen and measured for their total weight and by species. From data such as total days of collection and number of collectors per residence, the authors could estimate the average amount of wood used for fuel per day, per residence and per species.

Abbot and Homewood (1999) monitored the wood used for fuel for seven consecutive days per month over a period of 11 months. In the morning of the first day, the stock was weighed, and new elements that were collected or purchased were weighed daily. The material output (donated or sold) was also recorded. The stocks were weighed again on the last day in order to obtain a measurement of the weekly wood consumption for fuel.

Measurement units of wood amount: Mass × volume

Both mass and volume are used in studies that measure wood consumption and/or collection. The choice may be related to the practicality or purpose of the study. For studies on wood extraction, for example, it may be more interesting to measure volume since it represents more accurately the extraction dimensions than mass. In some cases, such as measuring material for buildings' construction (Gaugris *et al.* 2006; Gaugris and van Rooyen 2006), it is not possible to remove the material to perform the weighing. Therefore, for this case it is only possible to measure the volume directly and, if appropriate, to transform it secondary to mass measures.

To study firewood or other stockable wood materials, an alternative to taking geometric measures of all elements, one by one, is to calculate the volume of stacked wood (Türker and Kaygusuz 2001; Batista and Couto 2002; Top *et al.* 2004a; Sá e Silva *et al.* 2009). The calculation is performed by multiplying the length, width and average of five heights of the stack. The stacked unit volume is the stereo, which is equal to 1 m^3 of wood stacked, and can have its values estimated and converted in terms of mass (Top *et al.* 2004a). In studies of general wood uses, it is not interesting to use the stereo to measure some uses and the conventional volume to estimate others, as the comparison among uses measured by natural and stacked volumes is not reliable. In these cases, it is possible to use a conversion factor to turn pile volume into solid volume. FAO (1983), for example, indicates that the average headload conversion factor for domestic fuelwood may be between 0.35 or 0.40, but these values can have great variations depending on wood size. Therefore, these conversions may result in less precise estimates for converted pile volume.

Measurements in terms of weight are particularly used in studies of fuelwood (Fox 1984; Nagothu 2001; Bhatt and Sachan 2004a, 2004b; Brouwer and Falcão 2004). The preference for using units of mass for this type of use category may be related to the ease of handling and weighing the material. Fuelwood is often placed in piles and it is not part of a larger immeasurable unit, as in the case of mud houses or buildings, where wood and mud are placed together and wood cannot be taken away for mass measurements.

Some studies convert between units based on density information. Naughton-Treves *et al.* (2007) monitored combustion events in an area near the Kibale National Park in western Uganda. Wood logs weighing less than 40 kg were weighed, while larger logs had their circumference and height measured to calculate the volume. From the density calculated by the study, or using secondary data, the volume of the larger logs was converted into mass. The authors, however, admit that the estimates were more accurate for smaller wood pieces for which the weight was directly calculated without being converted. The opposite path was taken by Brouwer and Falcão (2004), who turned mass into volume.

JOINT USE OF ETHNOBOTANICAL AND ECOLOGICAL DATA

The joint use of ethnobotanical and ecological information allows researchers to assess the local status of populations of useful species and to determine if there is use pressure in these populations based on supply-demand ratio and age structure. Comparisons between the abundance of useful species and their extraction rates can identify the risks of maintaining certain exploitation patterns of some species and often highlight the potential for increased use of other species under low pressure, information that can be useful to guide conservation strategies (Pérez-Negrón and Casas 2007). Among the studies that have examined the local availability of species and their uses, Pérez-Negrón and Casas (2007), in a general ethnobotanical study, observed that the fuelwood category caused the greatest risk to some plant populations by being the use category with the highest consumption rate and because its extraction is highly destructive. The authors also indicated that from the repertoire of species commonly used as fuelwood, the extraction does not seem to be a risk to some locally abundant plant populations, while others are disadvantaged by being restricted to small environmental units.

Lucena *et al.* (2007), testing the hypothesis of ecological appearance, found a strong relation between the use values of species used for construction and fuelwood and their importance value indices (environmental parameter), indicating that the most available species are also the most used. This finding may have positive implications as the increased extraction is occurring in species that are more conspicuous in the vegetation, which minimizes the risk of large losses to small populations. However, Ramos *et al.* (2008a), studying the use of firewood and coal in the same community, found no relation between citation of species use and species' availability. This difference between the findings of Lucena *et al.* (2007) and Ramos *et al.* (2008a) is in the parameters used, as the latter used the "use citations" (and not VU) as an ethnobotanical indicator and total density as an ecological parameter. A new question related to the hypothesis of appearance and other assumptions that consider the availability and use of plants concerns what is meant by availability (number of individuals? Total biomass of species in the area?) and what is meant by use (use citations in interviews? total volume of resources used in a time x?). In summary, the examples from the work of Lucena *et al.* (2007) and Ramos *et al.* (2008a) show that the results can vary according to the ecological and ethnobotanical parameters used.

Regarding the creation of models with supply and demand, Banks *et al.* (1996) combined information on demand for wood obtained in interviews with offer data from phytosociological studies in two settlements (Athol and Welverdiend) located in a savanna area in South Africa. The model generated by this study exhibited a balance between supply and demand in the settlement of Athol, while in Welverdiend there was a discrepancy between them, such that the maintenance of current collection practices would lead to serious deforestation in 15 years.

Pote *et al.* (2006) also used a model of supply and demand to understand the process of collection and its influence on local vegetation, but supply data were based on ecological data. In this study, a supply index was calculated based on the percentage of fair individuals of a species *x* among all fair individuals of the whole inventory and a demand index based on the percentage of cut individuals of a species *x* among all cut individuals. Thus, the ratio between demand (%) and supply (%) was calculated for each species in such a way that, considering their respective values, species were classified according to their collection as: preferred (ratio > 1.25), random (ratio < 1.25 and > 0.80) and avoided (ratio < 0.80). Based on the same principle, Obiri *et al.* (2002) and Tabuti (2007) calculated a collection index based on the proportion of stems collected (in stumps/ha) in relation to those stems available to be collected (stumps and intact trees/ha). These indices generally highlight species that have greater demand than they can fulfill for sustainable use, and therefore high indexes values may indicate priority species for conservation.

Other studies have been based on the age behavior of the plant to assess whether or not it is threatened (Lykke 1998; Obiri *et al.* 2002; Tabuti 2007; Tabuti and Mugula 2007). The diameter classes of woody species act as a sign of this age structure. The inverted-J model has been identified as ideal (Obiri *et al.* 2002; Tabuti 2007; Tabuti and Mugula 2007), in which plant populations are out of danger. The inverse J-shaped distribution represents a situation in which the number of individuals decreases as diameter class increases. When studying *Albizia chorioretinal* Welw. ex Oliv., a multiple use species at the site studied, Tabuti and Mugula (2007) observed that the population may be threatened since it fit weakly to the inverse J-shape. This information corroborated with the local indications that the species population was threatened. Local indicators also showed that wood uses make a strong contribution to the species' decline.

Obiri *et al.* (2002), based on the inclination values of the diameter distribution, classified the species being studied into four groups: (1) very low fitness to the inverse J-shape, composed of species characterized by low seedling establishment, inability to produce branched stems and presence of mature trees with high diameter values (these are usually used for medicinal purposes and presently have populations in decline); (2) low fitness to the inverse J shape, with species of low establishment but higher than in group 1 (also consisting predominantly of plants for medicinal use); (3) fitness to the inverse J-shape, including species of multiple uses; and (4) high fitness to the inverse-J shape, with species that present high recruitment.

Some care must be taken when drawing conclusions from data integrated from ethnobotany and ecology.

• If the vegetation area being inventoried is used by many communities and the study only covers one of these populations, the remaining vegetation structure may reflect the use of all nearby communities and not necessarily that of the focus community in the study.

• The status of some local species of vegetation may not be the result of wood use, although this is taken as the use that exerts the most pressure by having the most destructive extraction method. It is therefore advisable to perform a basic general study before starting a specific study of wood uses in order to become familiar with the uses of the wood from a given species and to be able to infer the importance of these additional uses. It is also appropriate to observe, for a vegetation inventory, in addition to the cut and intact individuals, whether there are individuals with signs of damage caused by other uses (e.g., signs of bark removal for medicinal use). Even for specific works on wood uses, it is always important to consider the multiplicity of uses, since the plant is often pressured by a set of factors and not only by use for a given category.

ECONOMIC VALUATION OF WOOD PRODUCTS

The economic approach was developed by Luoga *et al.* (2000b) in eastern Tanzania. The authors aimed to create a cost-benefit analysis of charcoal production in order to observe the contribution of its production to local trade. However, Pattanayak *et al.* (2004) aimed to understand the role of wood fuels in rural households by employing a method of evaluation known as travel cost, which is based on assigning monetary values to the effort of collecting wood for fuel. The study showed that the higher the travel cost, the less of these resources were collected.

CULTURAL RECORDING OF WOOD USES

There are few studies on wood use related to cultural and/or religious traditions. Accordingly, Cocks *et al.* (2006) studied the significance of species used for the construction of two cultural artifacts in communities from southeast South Africa. Each of these artifacts are related to religious events of a genus: the *ubuhlantii* is a type of fence with wood cuttings used for male rituals, while *Igoqo* is a wood pile located in front of a residence that is part of women's religious practices. The authors observed that, despite being non-traditional communities, they still have conspicuous practices of construction of these artifacts. The study performed by Almeida *et al.* (2008) in an urban-rural community of northeast Brazil recorded the use of wood for the making of bonfires in June's festivities that honor the Catholic saints John, Peter and Anthony. The authors observed that although the tradition is still strong in the community in question, the growth of Protestant religions in the site has led to a reduction of this practice since the making of bonfires and cults of saints are not part of the local Protestant traditions. In addition to the cultural approach, this study aimed to gain insight about the environmental sustainability of making fires, noting that most of the resources for this purpose were collected from exotic plants in anthropogenic areas, which reduces the pressure on native forest products.

ETHNOBOTANY AND PHYSICAL PROPERTIES OF WOOD

One of the approaches requiring more dedication in terms of scientific research is the study of physical properties of wood. Most of these studies are directed to fuel resources to calculate the FVI of various species. In this index, the product of the calorific value and density is divided by the product of the ash content and moisture in the branch or trunk of a species (1996). However, the FVI has many adaptations.

Abbot and Lowore (1999) argued that the ash content and calorific value are parameters that vary little and their absence does not interfere significantly in the outcome of the FVI, so the index can be reduced to the ratio of the density (in kg/m^3) and moisture content (%). Although these studies have approaches for physical properties, few ethnobotanical studies have associated physical properties with local preferences by species in order to verify if the physical characteristics of wood explain the predilection for certain species (Abbot and Lowore 1999; Ramos *et al.* 2008b). Accordingly, Abbot and Lowore (1999), studying species used for fuel in an area of Malawi, showed that the species preferred by local populations were those of greater fuel value. Ramos *et al.* (2008b) found a high correlation between the fuel values of species and their citations of preference in a rural community in a semi-arid area of Brazil. Chetri and Sharma (2009), in a study performed in India, also found a relation between species preference and their FVI, calculated by the complete formula: (density × calorific value)/(moisture content × ash content). However, calorific value alone exhibited a better correlation with species preference than did the FVI, what indicates that people tend to select as preferred the species with higher calorific value instead of other characteristics that together form the FVI (density, moisture content and ash content).

CONCLUSION

Each method of research on wood uses has its advantages and limitations, making each suitable for specific objectives. Therefore, before selecting research methods, it is necessary to bear in mind the objective of the study and the context in which the community is inserted into the research. Above all, it is necessary to consider:

• Degree of openness with the community.
• Which uses will be investigated (wood uses in general, firewood, house building, among others).
• What aspect of wood use is being investigated (knowledge, use pressure, collection patterns, among others).
• Community size.
• Available time to develop the research.

Regardless of the chosen technique, it is important that a study establishes that its chosen technique can answer its research question and acknowledges its limitations.

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