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Prioritization of useful medicinal tree species for conservation in Wari-Maro Forest Reserve in Benin: A multivariate analysis approach

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ABSTRACT

Prioritization of medicinal plant species in conservation schemes is critically important in low income countries. This paper aimed at developing a multivariate prioritization approach to guide conservation of medicinal tree species of Wari-Maro Forest Reserve in central Benin. Ethnobotany surveys were conducted in communities surrounding the forest, using individual semi-structured interviews with 149 people. Additionally, 42 plots were established in the forest to assess the availability of reported species, using mensuration of ecological indicators. Ethnobotanical indices, harvesting risk index, economic importance, threat status, adaptability to climate variations and ecological indicators were computed and pulled into principal components for each species, to yield a compound priority value. Overall, 73 medicinal tree species were reported for 94 traditional medicinal uses. Using our approach, twelve species emerged as priority species for conservation. The most important priority species were *Afzelia africana*, *Khaya senegalensis*, *Milicia excelsa* and *Pterocarpus erinaceus*. Local perceptions on the availability of three of these species were perfectly congruent with ecological indicators. Enrichment planting and assisted rejuvenation were suggested as urgent conservation actions to be taken.

1. Introduction

Plants represent a fundamental basis for life on Earth (Schatz, 2009). They constitute one of the main sources of medicinal compounds, on which humans depend for their health (Whitton, 2013). Despite the development of modern medicine, many local communities around the world are using various plant species in traditional medicine (van Andel et al., 2012; Whitton, 2013). Unlike South American pharmacopeia where herbs are prominent (Albuquerque et al., 2007; van Andel et al., 2007), trees and shrubs play a greater role in African traditional medicine (van Andel et al., 2012). Nearly all the organs of trees and shrubs (leaves, barks, roots, stem, serf and flower) are used to cure a wide range of illnesses/pains. In a recent past, the exploitation of trees for non-timber purposes such as medicinal and food uses was more sustainable than timber uses. However, the shift from subsistence harvesting to extraction for commercial purpose has resulted in a decline of native populations of many medicinal plant species (Cunningham, 1993; Delvaux et al., 2009; Veldman et al., 2014; van Andel et al., 2015). This trend is likely to be exacerbated by the current demographic boom in African developing countries (Alamu and Agbeja, 2011).

In this context of degradation of natural resources, developing conservation strategies for the exploited plant species is urgently needed. Such conservation planning can contribute to an unconditional restoration or sustainable use of useful medicinal tree species (Hamilton, 2004), in order to ensure the persistence of those species for future generations. Unfortunately, due to the limited resources available in developing countries, it is not always possible to consider all species in conservation plans. In fact, species prioritization is becoming important for conservation decision and management (Hamilton, 2004).

Over the world, many ethnobotanical studies on local conservation priorities of plants have been carried out (Kala et al., 2004; de Oliveira et al., 2007; de Melo et al., 2009; Brehm et al., 2010; Idohou et al., 2012). Research approaches vary considerably (Hamilton, 2004) and many parameters have been taken into account, depending on the characteristic of each region and targeted useful plant species. In Brazil for example, local knowledge on the plant species, harvesting strategy, plant availability and economic importance were considered (de Oliveira et al., 2007; de Melo et al., 2009). In Sierra Leone, medicinal plants have been ranked using their importance in urban markets, habitat type, abundance and harvesting techniques (Jusu and Sanchez,

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2013, 2014). Elsewhere, other aspects related to distribution of plant species and current threats have been considered for prioritizing crop wild relatives (Brehm et al., 2010; Idohou et al., 2012).

Although it seems important to consider several criteria, it should be noted that some of these criteria such as ethnobotanical indices and ecological indicators might be correlated and therefore, collinearity effects should be carefully considered. Moreover, in the process of prioritization, some authors have mechanically pooled such criteria in an ordinal decisive parameter (de Oliveira et al., 2007; de Melo et al., 2009). Some recent works (Brehm et al., 2010; Idohou et al., 2012) have combined four different methods of ordinal classification for the prioritization of crop wild relatives. In these cases, the priority species were identified as those species most encountered at top positions of the different lists. However, any approach based just on one method of ordinal classification will most likely contribute to subjective results. Next to that, ranking methods are marred by biases associated with converting some quantitative data into ordinal data. Here we propose an alternative strategy for prioritization. To improve accuracy of the prioritization process without using several methods of ordinal classification or ranking, we performed multivariate analysis on multiple criteria in order to obtain a reliable statistical result.

We expect a multivariate analysis approach applied to yield efficient priority setting of over-exploited biodiversity. Here we use this approach to assess the conservation priorities of medicinal tree species of Wari-Maro Forest Reserve (W-MFR) in Benin. W-MFR is one of the biodiversity hotspots in Benin's Sudanian zone, where tree species are highly threatened by anthropogenic pressure such as agriculture, pastoralism, logging and extraction of firewood and plant organs for medicinal and food uses (Adomou et al., 2011). The Sudanian zone is a center of plant endemism sensu White (1983).

This study addressed the following research questions (i) how important is W-MFR plant species for local communities' medicine? (ii) Which of these species should be prioritized conservation? And, (iii) are local perceptions of species' abundance and ecology congruent with field observations?

2. Material and methods

2.1. Study area

W-MFR is located in central Benin (8°80′–9°10′ N and 1°55′–2°25′ E; Fig. 1) in the Sudan phytochoria (White, 1983). Covering an area of about 120,686 ha, this forest is part of the Mont Koufé region protected area network. The prominent vegetation types are *Isoberlinia* spp. woodland (50,057 ha) and savannah (56,088 ha) (Glèlè Kakaï and Sinsin, 2009). Soils are ferruginous with lateric concretions developed on granites and gneisses (Faure, 1977). Climate in the region is subhumid dry with a unimodal rainfall regime and a dry season lasting five months (November to March). Annual rainfall varies from 900 mm to 1200 mm with a peak in August (267.5 mm) (Gnanglè et al., 2011). Temperature ranges from 21 °C (December–January) to 40 °C (February–April) with an average of 32 °C. From December to February, the north-east wind called "*harmattan*" coming from the Sahara desert affects the climate making it dry and cold. The vicinities of this forest are inhabited by two main socio-linguistic groups: the Nagot and the Bariba, both being farmers and hunters. As a result of shifting cultivation as well as tree logging for timber extraction and construction, the forest has suffered drastic degradation as in many cases in Benin.

2.2. Data collection

Data were collected between November, 2013 and January 2014. Prior to the survey, a meeting was held with local leaders to provide details about the survey and to secure informed consent. Ethnobotanical surveys were conducted using individual semi-structured interviews with the traditionally most prominent authorities of local households (generally men). If he was not available, his wife or another member of the household was surveyed. Because of reluctance of some respondents, informants were selected depending on their willingness and interest in participating in the study. Overall, 149 people including 35 women were interviewed across ten different villages (Alafiarou, Agramarou, Koko, Banigri, Beterou, Sinahou, Ouberou, Wari-Maro, Wannou, and Igbere) located around the W-MFR. Informants' ages ranged from 18 to 87 years, with an average age of 48.23 ± 15.41. People were interviewed with a questionnaire in local languages with the help of local translators. The questionnaire focused on the tree species used for the treatment of human diseases, the different medicinal uses attributed, the plant parts used, the other non-medicinal uses, and the local perceptions on availability of the species (Supplementary File 1). Three categorical levels of availability (rare, common or abundant) were defined. The plants' names given by informants in local languages (Nagot, Bariba, Peuhl, Fon) were matched with their scientific names using plant catalogues (de Souza, 2008) and Benin's flora (Akoègninou et al., 2006). Informants were also accompanied in the field to identify and collect the plant cited during the ethnobotanical surveys.

Vegetation surveys were conducted along ten 2000 m transects from the edge to the core area of the W-MFR based on the spatial location of the 10 surrounding villages. A total of 42 rectangular plots (30 m × 50 m) were established on the 10 line transects. Diameters at breast height (dbh) of all trees (dbh ≥ 10 cm) were measured within each plot. Regeneration (seedlings and saplings with dbh < 10 cm) was counted in four subplots of 10 m × 10 m installed in the corners of each plot. Herbarium samples of plants not identified in the field were constituted and later identified at the National Herbarium of University of Abomey Calavi. All scientific plant names, authors and families were checked according to the latest taxonomic nomenclature (www.theplantlist.org).

2.3. Data analysis

The number of species, genus and families were used as ecological indicators for medicinal tree species richness. Medicinal uses attributed to those trees were grouped in medicinal use categories according to International Classification of Diseases of the World Health Organization (WHO, 1999).

For each medicinal use attributed to a given plant, the frequency of citation (FC) was calculated (Phillips and Gentry, 1993; Gómez-Beloz, 2002) as well as the informant consensus factor (ICF) (Trotter and Logan, 1986), which determine the agreement between informants according to the plants commonly used for a particular application.

In order to establish priorities for conservation of medicinal tree species, the medicinal (cultural) importance, harvesting risk, economic importance, threat status, adaptability to climate variations and ecological importances of trees were considered and combined as follows.

As far as *cultural or medicinal importance* is concerned, eight quantitative indices were originally considered: relative importance (RI) (Bennett and Prance, 2000), cultural importance (*CI*), relative frequency of citation (*RFC*), cultural value (*CV*), frequency of citation (*FC*), number of use-reports (*UR*), number of uses (*NU*) and use value (*UV*) (see Tardío and Pardo-de-Santayana, 2008 for computational details of these indices). These indices are more objective for evaluating relative importance of useful plants (Tardío and Pardo-de-Santayana, 2008). The list of ethnobotanical indices was further shortened to account for least correlated ones ($r < 0.7$). The two least correlated ethnobotanical indices were finally retained, namely relative importance (*RI*) and cultural value (*CV*) (Table 1).