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Recognizing Amazonian tree species in the field using bark tissues spectra

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ABSTRACT

The identification of tree species in the field is often a subjective process and misidentifications cause many problems for forest management in the Amazon Forest. Near infrared spectra from dried leaves of herbarium specimens are able to distinguish species in tropical forests. However, toolsto improve species identification directly in the field are needed. In this study, we tested whether spectral reflectance of bark tissues (rhytidome and phloem) collected with a portable spectrometer in the field can be used for the discrimination of tree species. Spectral data was collected for 254 trees of 8 families, 10 genera and 11 species from terra firme forests in Central Amazon with an ASD field spectrometer. Data consisted of reflectance values within 350–2500 nm wavelengths. We compared the rate of correct species recognition for different datasets using linear discriminant models. The rate of correct species assignment using this technique was 98% when using spectra from the inner bark (phloem) and 94% with outer bark (rhytidome) spectra. We suggest that the application of this technique can improve the quality of species identification directly during field inventories, fostering better forest management practices.

1. Introduction

The identification of tree species in forest inventories is a key activity in maintaining high quality of forest management. In the field, trees are frequently identified to species by para-botanists ('mateiros') and voucher specimens are only rarely collected for comparison with herbaria or consultation with plant specialists. In the Amazon region, high tree species diversity (ter Steege et al., 2016; Cardoso et al., 2017) and poor sampling make it difficult to recognize species with confidence (Nelson et al., 1990; Hopkins, 2007; Gomes et al., 2013). Problems relate to both finding scientific names for species, and also to the grouping of trees into the same species at local scales (Gomes et al., 2013). While the first problem is complex, as the Amazon has many undescribed species (62% of the estimates of ter Steege et al., 2013) and taxonomic uncertainty abound, the second problem, crucial to the sound management of plant populations, can be more easily tackled. Recent studies suggest that near-infrared spectroscopy may increase the quality of grouping trees into local species and, given a robust model, to also obtain a scientific name for them (Durgante et al., 2013; Lang et al., 2015). Hence, near-infrared spectroscopy is a promising technique for increasing the accuracy of local species delimitation and also for their taxonomic assignment, a problem that impairs our understanding of basic diversity patterns for the Amazon (Cardoso et al., 2017).

It is common practice in forest inventories, particularly for forest management, to identify trees only in the field without the collection of herbarium specimens for plant identity confirmation. This activity is most frequently conducted by para-botanists, lacking formal training, who use morphological characteristics, such as trunk shape, bark type and texture, wood color, the presence or absence of exudates, odor and other vegetative traits to identify trees into local species in the field. This is conducted in a cognitive way and the actual characters used are hard to untangle (Procópio and Secco, 2008; Gomes et al., 2013). These field observations allow varying identification of trees to family, genus and species, with uncertain scientific names frequently extracted from vernaculars used during fieldwork. Vernacular names also vary among regions and para-botanists, causing the same species to have different vernaculars, and the same vernaculars are used for different species (Martins-da-Silva et al., 2003; Procópio and Secco, 2008). Hence, the extraction of scientific names from vernaculars is prone to large errors, with negative consequences to the management of plant populations, and this is likely the most frequent method by which inventories for timber exploitation are conducted. The clustering of different species with the same vernacular causes overexploitation of rare species,

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overestimation of the size of populations of commercial species, and jeopardizes the integrity of commercial transactions of forest products (Procópio and Secco, 2008; Gaui, 2013).

A more reliable process to recognize species is conducted when herbarium samples are collected for morphological comparison with specimens identified and deposited in herbaria, or with the aid of the botanical literature. Rarely all individuals are collected, so the problem of grouping trees into local species may persists if this process is conducted in the field without caution to difficulties caused by poor taxonomy, cryptic variation and ontogeny in local species assignment (Gomes et al., 2013). Moreover, in many plant groups it is frequently necessary to have reproductive material to identify taxonomically a local species from an inventory, and most samples collected in inventories are sterile due to irregular phenological patterns (Newstrom and Frankie, 1994), and also due the low importance that the problem of local species and taxonomic assignments receives in forest inventories in general (Gomes et al., 2013; Procópio and Secco, 2008; Martins-da-Silva et al., 2003).

The problem of species identification in the Amazon is also increased by the taxonomic quality of the reference collections. Herbaria with plants from the Amazon are the most important reference to obtain a taxonomic name for a local species from a forest inventory. However, different plant taxonomists and specialists may identify plants in a single herbarium collection. Hence, different people may have different levels of training and see different things (Gomes et al., 2013), and even specialists in a single plant group may differ in their taxonomic concepts. This is exemplified by the fact that duplicates of the same samples in different herbaria have distinct taxonomy, amounting to more than 50% of incongruence for the name of some tropical species (Hopkins, 2007; Goodwin et al., 2015).

Therefore, it is necessary to improve the processes by which trees are assigned into local species in forest inventories, and also the quality of reference collections with better sampling and taxonomic definitions. Some new technologies promise to greatly change the way plant species are defined and may be recognized. Molecular data is causing a revolution in taxonomic practice (Hollingsworth et al., 2009), and is likely to be in the near future the main reference for plant identification despite current limitations of plant molecular barcoding (Kress et al., 2009; Gonzalez et al., 2009). However, the use of molecular data for assigning trees into species at local scales, a non-trivial problem in Amazonian forests (Gomes et al., 2013), is difficult to operationalize. For this task, when species taxonomic definition is not at stake, technologies using chemometrics data, like visible and infrared spectra (NIR and SWIR) of plant tissues, are showing excellent results in the discrimination of plant species in tropical forests (Pastore et al., 2011; Durgante et al., 2013). Visible and infrared spectroscopy is a fast and non-destructive tool (Pasquini, 2003) that together with multivariate techniques identifies, quantifies and characterizes organic samples (Tsuchikawa, 2007). This tool has been used to discriminate plant species using absorbance extracted from dried leaves and wood. In the Amazon, recent studies show high predictive power of NIR spectra from dried leaves to discriminate closely related species in Lecythidaceae (Durgante et al., 2013), 111 species of 34 families from a large-scale plot (Curty, 2014), species of Burseraceae at different stages of development (Lang et al., 2015), and species with samples from different Amazon regions (Botelho, 2017). Absorbance data from wood has been used to discriminate endangered species from other species with similar wood characteristics, and to assist in the monitoring of illegal logging (Pigozzo, 2011; Braga et al., 2011; Pastore et al., 2011; Bergo et al., 2016). NIRs technology is on the list of new forensic methodologies for detecting illegal logging (Dormontt et al., 2015).

The majority of studies on leaf and wood spectroscopy were performed under laboratory conditions. The development of field methods with portable equipment is necessary to improve the recognition of tree species in forest inventories with high reliability, a problem that can be tackled otherwise only by extensive botanical sampling (Gomes et al., 2013). Portable devices have been used in remote sensing to study forest canopy vegetation through leaf reflectance (Asner, 1998), as well as to discriminate species in tropical forests by spectra from fresh leaves (Clark and Roberts, 2012; Asner et al., 2014). Local species assignment during forest inventories would greatly benefit from the possibility of using information from the bark of trees, lowering costs and improving accuracy. The trunk is easier to access in forest inventories than leaves and the possibility of using spectral data from the bark would diminish the need for herbarium samples once a spectral model is build, greatly facilitating studies and inventories that conduct frequent censuses of trees in permanent plots. Here, we ask whether spectra obtained from the external or internal bark of trees, collected with a portable spectrometer in the field, would permit to discrimination of 11 selected species in an Amazonian forest.

2. Material and methods

2.1. Study area

The study was carried out at the ZF-2 Experimental Station of the National Institute for Amazonian Research (INPA), located 90 km north of Manaus - AM, Brazil (2°38′38″S and 60°09′49.9″W). The station has a total area of 21,000 ha, covered by tropical rainforest (Higuchi and Santos, 1997), characterized by high floristic diversity (Higuchi et al., 1998; Carneiro, 2004; Gaui, 2013). The trees were selected in the 12 permanent plots of 1 ha of BIONTE Project that has been monitored since 1989 (Higuchi and Santos, 1997). Herbarium specimens were collected for all trees for taxonomic identification by comparing this material with specimens deposited at the INPA herbarium references and with the aid of specialized literature (Gaui, 2013).

2.2. Species sampling

We selected 254 individuals with DBH ≥ 10 cm of 8 families, 10 genus and 11 species, choosing the most abundant species in the plots, capturing broad phylogenetic variation, including different types of external bark (rhytidome) and species with and without exudates (Table 1). This study is a first step to recognize tree species in field by bark tissues. To test the method to recognize species with bark spectra we used species that are considered easy to identify in the field, as to better separate the power of bark spectra to recognize species with species delimitation problems.

2.3. Spectral data

Spectral reflectance measurements were obtained directly from the bark of living trees in the field with a portable spectrometer (Field Spec 3, ASD inc., 2010). The data collection time was 0.1 s per spectrum.

Table 1
Number of individuals per species used to obtain reflectance data.

Family	Species	Vernacular	N
Apocynaceae	*Geissospermum argenteum* Woodson	acariquara-branca	20
Apocynaceae	*Ambelania acida Aubl.*	pepino-da-mata	15
Lecythidaceae	*Corythophora rimosa* W.A. Rodrigues	castanha-jacaré	24
Lecythidaceae	*Corythophora alta R.Knuth*	ripeiro-vermelho	28
Euphorbiaceae	*Croton matourensis* Aubl.	dima	23
Euphorbiaceae	*Micrandropsis scleroxylon* (W.A.Rodrigues) W.A.Rodrigues	piaozinho	44
Sapotaceae	*Pouteria anomala* (Pires) T.D.Penn.	abiurana-olho-de-veado	21
Moraceae	*Brosimum rubescens* Taub.	pau-rainha	22
Malvaceae	*Scleronema micranthum* (Ducke) Ducke	cardeiro	25
Coulaceae	*Minquartia guianensis* Aubl.	acariquara-roxa	21
Humiriaceae	*Endopleura uchi* (Huber) Cuatrec.	uxi-amarelo	11