SPECTRAL VARIABILITY OF ATLANTIC FOREST SPECIES

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ABSTRACT

This paper investigates the spectral variability of Brazilian Atlantic Forest trees. Spectroscopy data (reflectance and transmittance) of full sunlight leaves were collected. The root mean square difference between pairs of spectra were used to estimate within- and between-species variability. It was also performed a feature selection procedure to identify spectral regions where the species most differ. Results show that between- is greater than within-species variability, evidencing the potential of spectroscopy measurements to species discrimination. Moreover, it was verified that spectral diversity of species is concentrated on the optical and near-infrared domain. Differences in leaf internal structure and leaf pigments (chlorophylls and carotenoids) concentration may be responsible to the observed variation.

Index Terms— Tropical forest, spectroscopy, species discrimination

1. INTRODUCTION

Tropical tree species recognition using remotely sensed data is a research topic in an increasing stage of development. The precept for species recognition is that among-species spectral variability should exceed within-species spectral variability. This presents a challenge because spectral signatures of plants are very similar due to a small number of biophysical parameters that govern vegetation reflectance [1]. However, some studies demonstrated that spectral variability can be explored for species recognition using hyperspectral data [2], [3]. Although investigations involving this issue have already been performed in tropical sites [4], little is known about the Brazilian Atlantic Forest (AF). Considered a biodiversity hotspot for conservation priorities [5], AF harbors an expressive number of endemic species and high biodiversity. A better understand of the spectral variability of AF tree species can contribute for monitoring efforts of this biome that will make use of hyperspectral technology. In this paper we investigated within- and between-species variability of seven AF species using spectroscopy measurements. We also performed a feature selection procedure to identify regions along the 400-2500 nm spectral range where the species most differ.

2. DATA AND METHODS

2.1 Data acquisition

Spectroscopy measurements were collected of full sunlight leaves from Atlantic Forest tree species (Table 1) located on the surroundings of Porto Alegre city, south of Brazil. A Plant Probe accessory, combined with the Leaf Clip assembly (Analytical Spectral Devices (ASD), Inc., Boulder, Colorado), coupled in a high resolution spectroradiometer ASD/FieldSpec®3, were used to measure reflectance and transmittance of species leaves, immediately after being detached from tree branches.

TABLE I. DATA COLLECTED FOR REFLECTANCE AND TRANSMITTANCE MEASUREMENTS

Species names	Nº of trees sampled	Nº of leaves per tree sampled
Psidium araca	3	15
Schinus terebinthifolius	3	15
Ocotea spixiana	3	15
Tabebuia impetiginosa	3	15
Ceiba speciosa	3	15
Bauhinia forficata	3	15
Eugenia uniflora	3	15

2.2 Spectral analysis

Aiming to assess within- and between-species spectral variability we computed the metrics D proposed by [3], calculated as follows:

$$D = \left[\frac{1}{\lambda_b - \lambda_a} \int_{\lambda_a}^{\lambda_b} \left[S_1(\lambda) - S_2(\lambda) \right]^2 d\lambda \right]^{1/2} \quad (1)$$

D corresponds to the root mean square difference between a pair of spectra (S_1 and S_2), averaged over the spectral interval (λ_a to λ_b). The spectral interval used to calculate this metrics was 400-2500 nm.

D was calculated at the following levels for leaf spectra:
1. Within-tree. Multiple leaves were sampled per tree of each species (Table 1), D was computed for all pairwise combinations. Note that the total number of pairwise combinations was calculated as n ((n-1)/2) and equaled 105, with n being the number of leaves;

2. Between-tree/within-species. Multiple trees of same species were sampled (Table 1) and leaf spectral responses of each tree were averaged. D was computed for all pairwise combinations (i.e. 3);

3. Between-species. An averaged spectrum per species was calculated and D was computed for 21 pairwise combinations (i.e. all possible number of pairs between species).

Finally, Wilcoxon rank sum test were performed to determine whether within-species and between-species spectral variability were statistically significantly different.

2.2 Feature selection procedure

Our interest lay on identifying regions of the electromagnetic spectrum in which the species most differ from each other. Therefore, it was performed a feature selection procedure based on a one-way analysis of variance (ANOVA) followed by a post-hoc Tukey honestly significance test (Tukey HSD). Prior to performing the statistical tests, it was verified normality and homoscedasticity (homogeneity of variances) of the reflectance and transmittance values across each waveband. All processing procedures were performed in R environment [6].

The ANOVA tested the following hypothesis:

$\mathbf{H_0} = \mu_1 = \mu_2 = ... = \mu_n$

$\mathbf{H_1}$ = Not all μ_n (i) are equal

Where μ_n represents the reflectance or transmittance of the nth species (n=1, 2…7) and i denotes the waveband. Rejection of the null hypothesis (H_0) indicated the wavebands, at a 99% (p-value < 0.01) confidence level, in which the species statistically differ. H_0 rejection was followed by pairwise multiple comparisons with the post-hoc Tukey HSD test. By counting the number of pairs that are statistically significantly different on each waveband, it was possible to identify the spectral regions where the species most differ. Only the wavebands with at least ten significantly different pairs out of a total 21 (>50%), were considered in this study.

3. RESULTS AND CONCLUSIONS

Within- and between-species variability differed statistically (Wilcoxon rank sum test p-value < 0.01). Results showed that within-tree and between-tree/within-species D was lower than between-species D (Fig. 1). This difference highlights that classification methods based on statistics can be used to automatically discriminate the species studied.

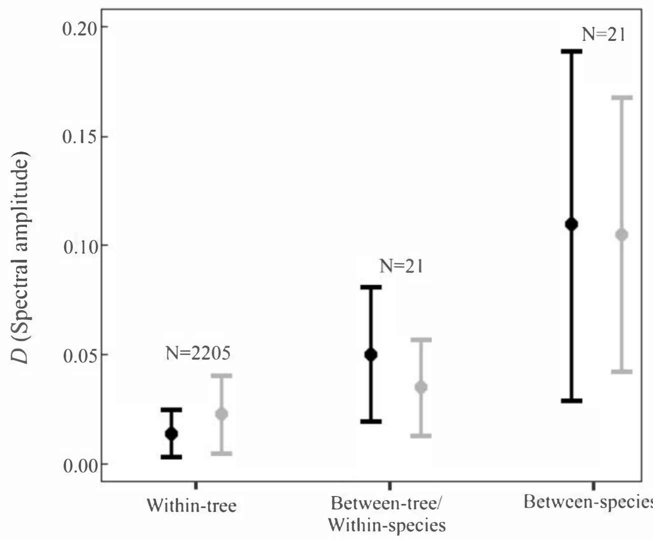

Fig 1. Mean spectral amplitude (D) (± 1SD) of leaf reflectance (black) and transmittance (gray) spectra of Brazilian Atlantic Forest tree species. Number of samples to calculate each mean is indicated.

One-way ANOVA results indicated that species are likely to be spectrally separable (p-value < 0.01) at 1,688 wavebands on the reflectance spectra (80.4% of a total 2,100) and 1,659 wavebands on the transmittance spectra (79% of a total 2,100). Post-hoc Tukey HSD test resulted in a total of 195 and 63 wavebands presented at least ten statistically different pairs for the reflectance and transmittance measurements, respectively (Fig. 2-a, b). These bands concentrate the spectral variability of species and were found on the major absorption features of chlorophylls and carotenoids, which demonstrate that species studied have varied concentrations of such pigments. Chlorophylls absorb light in the vicinity of 445 and 645 nm [7] and are considered the most important leaf pigment. Carotenoids are the second major group of plant pigments and can absorb incident radiation in the 350-450 nm spectral range [8].

At the near-infrared (NIR, 700-1200 nm) the species presented also variable spectral responses (Fig. 2), particularly at the red-edge (680-730 nm). Most notably for reflectance measurements, several wavebands were selected at this region. As leaf internal structure controls NIR reflectance [9], leaf internal tissue is an important parameter to differentiate the species.

Assessment of spectral variability of Brazilian Atlantic Forest tree species carried out in this work, evidenced that classification methods based on statistics can take advantage of this difference. Future work will focus on the automatic discrimination of tree species based on spectroscopy measurements and hyperspectral imagery.

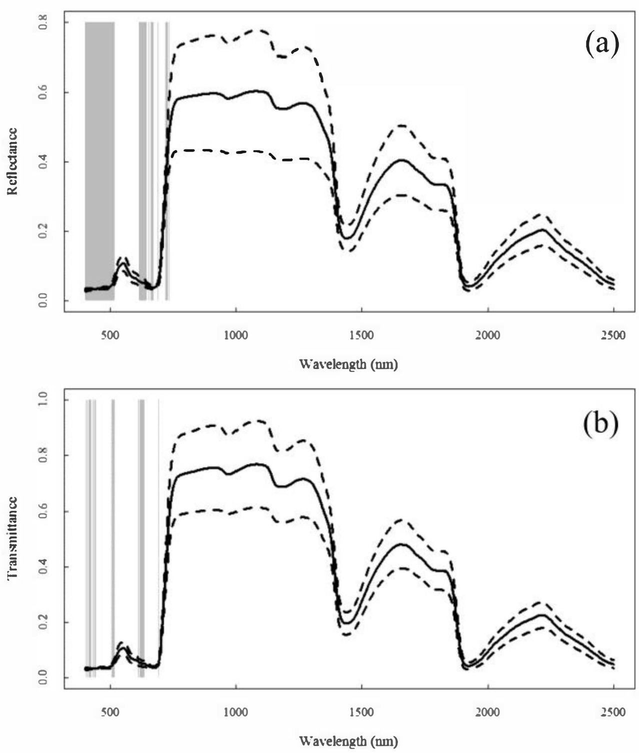

Fig. 2. (a) Reflectance and (b) transmittance spectra of the tree species. Solid lines: Means; Dashed lines: ± 1 SD. The gray areas represent the wavebands where at least 60% of species pair combinations were statistically significantly different from each other.

4. REFERENCES

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