environmental sciences proceedings

MDPI

Proceeding

Differentiation of tropical tree species with leaf measurements of hyperspectral reflectance †

Juan Carlos Valverde [1,*], Dagoberto Arias-Aguilar [2], María Rodríguez-Solís [2] and Nelson Zamora Villalobos [2]

1 Cooperativa de Productividad Forestal, Departamento de Silvicultura, Fac. Ciencias Forestales, Universidad de Concepción, Concepción, Chile.
2 Escuela de Ingeniería Forestal, Tecnológico de Costar Rica, Cartago, Costa Rica.
* Correspondence: juvalverdeo@udec.cl

† Presented at the 3rd International Electronic Conference on Forests (IECF2022) —exploring new discoveries and new directions in forests. 15-31 Oct 2022, Available Online: https://sciforum.net/event/IECF2022

Citation: Valverde, J.C.; Arias-Aguilar, D.; Rodríguez-Solís, M.; Villalobos, N.Z. Differentiation of tropical tree species with leaf measurements of hyperspectral reflectance. *Environ. Sci. Proc.* **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Giorgos Mallinis

Published: date

Abstract: Developing non-destructive indicators from leaf-level hyperspectral reflectance is the first step in mapping endangered tree species in the tropic. Therefore, hyperspectral reflectance at the leaf level was implemented to differentiate 15 tree species from Costa Rica's forests. Hyperspectral reflectance (310 to 1100 nm) was evaluated in six individuals per species (30 leaves per individual) in rainy season, in addition, specific leaf area (SLA) and leaf thickness (LT) were evaluated. The data were first analyzed with one-way ANOVA to identify differentiating bands between species. Then, linear discriminant analysis (LDA) was used to classify species and define the degree of similarity; the contribution of each narrow band to the classification was estimated with the absolute value of standardized coefficients associated with the discriminant function (kappa value). Subsequently, it was analyzed whether the SLA or LT correlated with species differentiation. The results showed that wavebands al 350, 700, 750, 780, 790, 800 and 1010 nm were key to differentiating the species, with an average kappa value of 0.88. Furthermore, the correlation of hyperspectral reflectance with SLA and LT was ruled out. Our results suggest differentiating tropical tree species with non-destructive methods, which will facilitate mapping endangered populations and the development of conservation strategies.

Keywords: conservation; tree, species; tropic

1. Introduction

The tropical forests present in Costa Rica have more than 2000 species of trees identified, organized on the national territory [1]. Many of these species have been little studied due to the lack of funding for research, the degree of complexity of the studies, and the fact that multiple evaluation campaigns are required from individuals in the field [2]. The aspects that have influenced most studies have focused on the biological aspects of rapid domestication evaluation [3], including: botanical characterization, growth, abundance, and ecological dynamics [4].

The development of non-destructive indicators to differentiate tree species is the key to improving the knowledge of the distribution of populations and the ecological response to the phenomenon of climate change [5]. An option that has shown viability has been the hyperspectral reflectance of leaves [6]. It has been shown that in the range of 300 to 1100 nm it is possible to have information on photosynthetic capacity, hydric stress, carotenoids, and chlorophyll production in real time and without affecting the individual [7].

Clark et al. [7] found that the signature is unique for 20 tropical species and suggested that the range from 540 to 600 nm is the point of differentiation of each species due to the availability of nitrogen. For their part, Ballanti et al. [8] determined hyperspectral differentiations between 300 and 370 nm for three species of the Eucalyptus genus and from 530 to 580 nm, allowing the species to be differentiated with aerial multiband images, which facilitated the quantification and distribution of individuals in northern Australia. The potential for the use of the spectral signature is wide; it can be used to differentiate species and understand the degree of health or nutrition of plants; this is due to the shape of the curve being governed by the effects of the absorption of chlorophyll and other pigments of leaves of the plant [9]. The study analyzed the differentiation of 15 tropical tree species through spectral reflectance at the leaf level.

2. Materials and Methods

The study analyzed 15 tropical species from Costa Rica (Table 1), they were selected based on productive commercial interest or relevance to be conserved, the selection criteria are detailed in Valverde et al. [10]. In each species, five individuals were analyzed and characterized by not being affected by pathogens, water, or nutritional stress that affected growth; per individual 30 leaves were selected and it was considered that they were partially or totally exposed to light, did not show damage or atypical colors to the rest of the treetop (n= 150 leaves per species).

Then, characteristics were measured: leaf thickness (LT, with a micrometer), specific leaf area (SLA, with Valverde [11] methodology) and leaf spectral reflectance with the UNISPEC SC hyperspectrometer model (a range from 310 to 1130 nm with a minimum resolution of 3 nm). Statistical analysis considered a mixed model, first using an analysis of variance (ANOVA) to identify the band lengths that showed significant differentiations, to later use a linear discriminant analysis (LDA) to classify species and define the degree of similarities, following the methodology of [12]. The discrimination coefficient for each species (kappa value) was estimated, and subsequently a Pearson correlation analysis was used to assess whether there was a correlation with LT and SLA. The analyzes were developed in the R program with a significance of 0.05.

3. Results and discussion

Significant differences were found in the 350, 500, 780, 790, 800 and 1010 nm bands (Table 1). Seven species showed only one significant differential band; in contrast, six species showed two differentiating bands and only two species required differentiation from three hyperspectral bands. For all species, a discriminatory analysis (kappa value) greater than 0.88 was obtained, which evidenced a good accuracy at the moment of differences between the species with specific points of the spectral signature. However, it was obtained that differentiation did not show a significant correlation with SLA and LT, suggesting that both variables do not show an influence trait when identifying the species with this method.

The results obtained explored the potential use of hyperspectral reflectance for species discrimination, a result similar to that proposed by Burkholder et al. [13] with tree species that found an accuracy between 60 and 85% for tree species. The use of specific bands has traditionally been used for the development of indicators of hydric stress, chlorophyll production, and photokinetic production, among others [14]. However, its use to differentiate species has been limited to species in the tropics. Identification and differentiation of spectral bands by species at the leaf level is the first scaling step to create identifiers to analyze populations through satellite images and flights with spectral cameras [15].

In addition, the use of techniques such as machine learning, deep learning, or neural networks must allow the development of highly accurate non-destructive models. But the limitation of tree hyperspectral collections (quantity and quality) and the financing for this type of research in the tropical region have limited its scale. An aspect that should be reconsidered given its potential use for monitoring species in danger of extinction or vulnerable to climate change.

Table 1. Differentiating bands of spatial reflectance, average kappa value and Pearson correlation values of the bands with SLA (specific leaf area) and LT (leaf thickness) for 15 tropical tree species (ns: no significative, * *p*>0.05 and ** *p*>0.01).

Botanical family	Scientific name	Diferenciative bands (nm)	Kappa value	Correlation	
				SLA	LT
Bignoniaceae	*Handroanthus ochraceus*	350	0.90	0.22 ns	0.33 ns
Meliaceae	*Swietenia macrophylla*	700	0.88	0.26 ns	0.20 ns
Fabaceae	*Platymiscium pinnatum*	350, 780	0.92	0.33 ns	0.19 ns
Araliaceae	*Dendropanax arboreus*	780, 790	0.91	0.50 ns	0.10 ns
Fabaceae	*Inga marginata*	350, 800	0.89	0.33 ns	0.36 ns
Fabaceae	*Erythrina poeppigiana*	800	0.89	0.40 ns	0.41 ns
Apocynaceae	*Tabernaemontana litoralis*	800, 1010	0.92	0.26 ns	0.55 ns
Anacardiaceae	*Anacardium excelsum*	700, 1010	0.96	0.30 ns	0.56 ns
Meliaceae	*Trichilia havanensis*	800	0.95	0.33 ns	0.20 ns
Euphorbiaceae	*Croton draco*	350, 800, 1010	0.97	0.36 ns	0.14 ns
Euphorbiaceae	*Cronton niveus*	350	0.90	0.33 ns	0.33 ns
Solanaceae	*Acnistus arborescens*	750, 780	0.91	0.26 ns	0.40 ns
Verbenaceae	*Citharexylum donnell-smithii*	700, 800, 1010	0.92	0.21 ns	0.50 ns
Meliaceae	*Cedrela tonduzii*	1010	0.89	0.22 ns	0.56 ns
Rubiaceae	*Tocoyena pittieri*	750	0.88	0.20 ns	0.66 ns

4. Conclusions

Developing methods to identify and differentiate tropical tree species with non-destructive methods is key to understanding population dynamics in the context of climate change. The results obtained give a first step in the use of a system that can be scaled at the canopy level and connected with geographic information systems, which opens the development of spatio-temporal monitoring of species considered in danger of extension or endemic.

Author Contributions: Conceptualization, J.C.V.; methodology, J.C.V., D.A. and M.R.; software, J.C.V.; resources, J.C.V., D.A. and M.R.; data curation, J.C.V; writing—original draft preparation, J.C.V., D.A. and M.R; writing—review and editing, J.C.V, D.A and M.R.; funding acquisition, J.C.V., D.A., and N.Z. All authors have read and agreed to the published version of the manuscript.

Funding: We would like to thank the Vice-Rectory for Research and Extension of Instituto Tecnológico de Costa Rica for the financial support of the study.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Arias, E.C., et al., Recurso forestal amenazado: seis especies en peligro crítico de extinción en Costa Rica. 2014: Instituto Tecnológico de Costa Rica.
2. Shi, Y., et al., *Tree species classification using plant functional traits from LiDAR and hyperspectral data.* International Journal of Applied Earth Observation and Geoinformation, 2018. **73**: p. 207-219.
3. Lieberman, D., et al., Growth rates and age-size relationships of tropical wet forest trees in Costa Rica. Journal of tropical ecology, 1985. **1**(2): p. 97-109.
4. Zhang, J., et al., Intra-and inter-class spectral variability of tropical tree species at La Selva, Costa Rica: Implications for species identification using HYDICE imagery. Remote Sensing of Environment, 2006. **105**(2): p. 129-141.

5. Lang, C., et al., Near infrared spectroscopy facilitates rapid identification of both young and mature Amazonian tree species. PloS one, 2015. **10**(8): p. e0134521.
6. Prospere, K., K. McLaren, and B. Wilson, Plant species discrimination in a tropical wetland using in situ hyperspectral data. Remote sensing, 2014. **6**(9): p. 8494-8523.
7. Clark, M.L., D.A. Roberts, and D.B. Clark, *Hyperspectral discrimination of tropical rain forest tree species at leaf to crown scales.* Remote sensing of environment, 2005. **96**(3-4): p. 375-398.
8. Ballanti, L., et al., Tree species classification using hyperspectral imagery: A comparison of two classifiers. Remote Sensing, 2016. **8**(6): p. 445.
9. Shen, X. and L. Cao, Tree-species classification in subtropical forests using airborne hyperspectral and LiDAR data. Remote Sensing, 2017. **9**(11): p. 1180.
10. Valverde, J.C., et al., Relación de la variabilidad climática con el crecimiento diamétrico de ocho especies arbóreas de bosque seco en Costa Rica. Ecosistemas, 2021. **30**(1): p. 2092.
11. Valverde, J.C., Estimation of leaf nitrogen content from non-destructive methods in Eucalyptus tereticornis and Eucalyptus saligna plantations. Revista Facultad Nacional de Agronomía Medellín, 2021. **74**(3): p. 9655-9666.
12. Hovi, A., et al., Evaluation of accuracy and practical applicability of methods for measuring leaf reflectance and transmittance spectra. Remote Sensing, 2017. **10**(1): p. 25.
13. Burkholder, A., et al., Seasonal trends in separability of leaf reflectance spectra for Ailanthus altissima and four other tree species. Photogrammetric Engineering & Remote Sensing, 2011. **77**(8): p. 793-804.
14. Heckmann, D., U. Schlüter, and A.P. Weber, Machine learning techniques for predicting crop photosynthetic capacity from leaf reflectance spectra. Molecular plant, 2017. **10**(6): p. 878-890.
15. Ross, J.K. and A. Marshak, *Calculation of canopy bidirectional reflectance using the Monte Carlo method.* Remote Sensing of Environment, 1988. **24**(2): p. 213-225.