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Editorial

Novel Approaches in Tropical Forests Mapping and Monitoring–Time for Operationalization

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For more than three decades, the remote sensing scientific community has successfully generated predictive models of tropical forest attributes and ecological processes at the leaf, canopy, patch and landscape scale by linking field-measured data to remotely sensed spectral values, as well as other variables derived from remotely sensed data. The main interest of these applications is to help describe ecological and functional patterns occurring at larger geographic scales with sufficient accuracy and precision and enable scientists to better understand ecological processes, such as the relationship between atmospheric fluxes, plant structural and ecophysiological traits, soil attributes, anthropogenic use, species occurrence and animal movement. However, as the earth's environment suffers from ever-increasing human use and abuse, detecting spatiotemporal changes in these variables has become a necessary decision-making tool in conservation action and natural resources' management. Moving from modeling into the study of soil, plants, wildlife and socioecological processes using remotely sensed data requires the extrapolation of single time-step models to its application on a time series of data with the same expected accuracy. The challenges in this matter are not trivial, since changes in soil moisture conditions, cloud contamination, canopy and leaf-level geometry and physiology can affect the strength of the proposed models. In this context, the term 'Operationalization' refers to migration from single time-step models to time series but also refers to the design and implementation of user-friendly tools to increase the efficacy of communicating spatiotemporal trends to the users.

Today, dense time series of optical, radar, and LiDAR in proximal, airborne, and space-borne sensing systems have become publicly available and are accessible through cloud-based platforms. In addition, efficient data processing using desktop or web-based interactive programming software has helped scientists develop new ways to detect changes in tropical forest attributes at multiple geographic and temporal scales using dense time series of remotely sensed data. This Special Issue, entitled "Novel Approaches in Tropical Forest Mapping and Monitoring—Time for Operationalization I", focuses on state-of-the-art research that addresses the challenges of upscaling biological, biophysical and biochemical attributes of tropical forests in complex landscapes and understanding their dynamics at multiple spatial and temporal scales.

In the first submitted communication, Portillo-Quintero et al. [1] review the state-of-the-art in modeling techniques for forest-cover changes, forest structure, species composition, and structural and functional vegetation attributes. Portillo-Quintero et al. indicate that current operational monitoring systems are mostly focused on biomass and forest cover change, and recommends integrating multiple data sources and techniques to monitor structural, functional, and compositional attributes using tropical forest monitoring systems. This paper also recommends a decentralized implementation of methods to adjust to local climatic and ecological characteristics and ensure proper end-user engagement.

The work by Pacheco-Angulo et al. [2] shows an overall precision of 94.3% when using a novel approach to efficiently map selective logging and forest degradation in the Venezuelan Amazon. Their analytical approach used Landsat-based linear spectral unmixing to map soil fraction and predict the location of log landings, logging roads and logging gaps, and then estimate the approximate area of forest degradation by selective logging within a buffer of 300 m. Their methods are intended as a local-based computing analytical approach, capable of functioning under conditions of limited internet connectivity in remote areas.

Gao et al. [3] evaluated how trend and seasonal model components of the Breaks for Additive Season and Trend (BFAST) algorithm contribute to disturbance detection in different forest types. Their results showed that, for all forests combined, the amplitude and the data quality of the stable historical period and its length contribute the most to disturbance detection. This has implications for proper BFAST output evaluation and developing forest-monitoring schemes using the BFAST algorithm.

Hernandez-Stefanoni et al. [4] generated improved moderate-resolution spatial models of carbon density and species richness for the tropical forests of the Yucatan Peninsula, Mexico, based on field data from the Mexican National Forest Inventory. The authors used random forest regression modeling to predict species richness and carbon stocks from backscatter coefficient values and texture metrics derived from Advanced Land Observing Satellite Phased Array L-band Synthetic Aperture Radar (ALOS-2 PALSAR-2), as well as climate data, at a 25 m pixel resolution. The paper discusses the challenges and opportunities of the large-scale monitoring of carbon and species richness in the study area using radar data.

Solorzano et al. [5] demonstrated that, compared to the random forest algorithm, the deep learning algorithm U-Net performs better when obtaining accurate land-cover classification in complex tropical environments, especially when combining multispectral imagery and radar imagery. Their study was applied in the Selva Lacandona region in Mexico.

Kacic et al. [6] present a methodology to generate high-resolution maps (10 m) of canopy height, total canopy cover, Plant-Area-Index and Foliage-Height-Diversity-Index based on Sentinel-1, Sentinel-2 and Global Ecosystems Dynamics Investigation (GEDI)-derived vegetation attributes. Their assessment was performed in the tropical forests of the Paraguayan Chaco, but the presented methodology is also a promising data analysis strategy for other tropical forest environments. Multiple observations from GEDI will allow for the multi-temporal monitoring of vegetation structure, e.g., to detect degraded forests due to differences in canopy height.

Wang et al. [7] characterized the structural features of tropical species from Handheld Laser Scanning (HLS) data with 23 LiDAR structural parameters, involving six branch, eleven crown and six entire-tree parameters, and evaluated five machine learning (ML) models. The authors found that the support vector machine with a polynomial kernel outperformed other selected models, yielding a classification accuracy of 84.09%. The study shows that HLS can be a time- and cost-efficient method for the in situ monitoring of tropical forest structural traits and species classification.

Takeshige et al. [8] tested whether gray-level co-occurrence matrix (GLCM) textures metrics derived from Landsat data and Sentinel-1 C-band SAR data were helpful for discriminating between fern thickets, vine-laden forests, and logged-over forests without ferns and vines in the tropical forests of Sabah, Malaysian Borneo. The authors used the gradient-boosting decision tree method, implemented using the extreme gradient boosting (XGBoost) algorithm, which has been reported to have a high predictive performance in land-cover classification. Their study showed that GLCM texture variables were especially effective at separating fern/vine vegetation from the non-degraded forest, but the SAR data showed a limited effect.

Escobar-Lopez et al. [9] were able to predict the location and distribution of three types of coffee agroforestry systems in the tropical forests of Chiapas, Mexico through the use of Sentinel-1, Sentinel-2 and ALOS-PALSAR images. The methodological approach was efficient at differentiating coffee agroforestry systems within forest landscapes, reported as a common issue when using conventional satellite images. The study used multitemporal imagery and a two-step classification approach using machine learning and a probabilistic algorithm that ensured that each coffee agroforestry system was individually assessed in the classification process. Their method achieved a 95% overall accuracy and, interestingly, the authors found differences between the spectral indices and bands that better explained the presence of each coffee agroforestry system.

Overall, the presented articles demonstrate the use of advanced tools and techniques in remote sensing to address operational geographic problems in tropical forest mapping and monitoring. The studies applied novel continuous change detection as well as machine learning and deep learning techniques for the time series analysis, classification and modeling of reflectance values and textures metrics derived from optical, radar and LiDAR data. Some of these studies also propose different conceptual frameworks for tropical forest monitoring from local to landscape scales. The work here presented is the result of research occurring in 17 institutions: Texas Tech University, Centro de Investigacion Cientifica de Yucatan, Universidad de los Andes, Universidad Autonoma de Sinaloa, University of California at Berkeley, Universidad Nacional Autonoma de Mexico, Colegio de la Frontera Sur, Universidad Iberoamericana Ciudad de México, University of Freinburg, German Aerospace Center, The Hong Kong Polytechnic University, University of the Punjab, Kyoto University, Forestry and Forest Products Research Institute, Tokyo University of Agriculture, Sabah Forestry Department and CONACYT. As of September of 2022, all articles have accumulated more than 11,000 full-text views, which corroborates the quality and relevance of this Special Issue.

We believe that all the contributions to this Special Issue, entitled "Novel Approaches in Tropical Forest Mapping and Monitoring—Time for Operationalization I", constitute advanced remote sensing applications for tropical forest research. More importantly, a theme of all these manuscripts is the urgency of ensuring that these methodological approaches are useful for tropical forest conservation action. Therefore, we hope that these contributions can inform tropical forest scientists and GIS/RS analysts on the best practices for identifying and monitoring ecological patterns and anthropogenic threats using state-of-the-art remote sensing data and techniques.

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