remote sensing

Editorial

Preface: Remote Sensing of Biodiversity

Susan L. Ustin

Department of Land, Air and Water Resources, University of California-Davis, Davis, CA 95616, USA; slustin@ucdavis.edu; Tel.: +1-530-752-0621; Fax: +1-530-752-1552

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Since the 1992 Earth Summit in Rio de Janeiro, the importance of biological diversity in supporting and maintaining ecosystem functions and processes has become increasingly understood [1]. Biodiversity "connects the web of life," that is, biodiversity represents the diversity of species in an ecosystem, landscape, region and globe. It is their combined interactions, with each other and their environment that alters biogeochemical cycles and the climate system. In recent years, biodiversity has come to broadly include diversity in terms of taxonomic, systematic and genetic attributes, morphological and structural attributes, and their ecological and functional traits. Human actions are driving climate change and land use changes throughout the globe, causing major losses of biodiversity [2,3]. These actions impact the climate, influencing magnitude and the timing of disturbance events, e.g., drought and wildfires, create pollution and contamination in water, air, and soil, and cause many other impacts that accelerate species losses, altering ecosystem functions and their services. The loss of biological diversity impacts ecological processes at scales comparable to other drivers of global environmental change [4] and likely interacts synergistically with climate change [5]. Biodiversity is recognized as a key factor in the maintenance of healthy ecosystems and for the sustainability of conservation efforts. Losses of biodiversity reduce the stability and resilience of ecosystems through the loss of functional traits associated with resource capture and decomposition [1]. The rapid pace of global change requires increased knowledge about species composition, numbers of species, and the states of health and the conditions for global ecosystems in order to respond effectively. Tittensor *et al.* (2014) [6] show that many of the 20 Aichi indicator targets from the Convention on Biological Diversity are unlikely to be met by 2020. The development of large plant trait databases like TRY [7,8] that have data on thousands of vascular plant species (46,085 species) still remain significantly under-sampled, particularly outside the northern temperate zone [9]. Remote sensing provides the only feasible way to measure and monitor biodiversity changes at the scales necessary. Nonetheless, until recently, there has been little success in monitoring ecologically meaningful aspects of diversity (e.g., alpha, beta, and gamma diversity). Today, there are an increasing number of remote sensing satellites and aircraft instruments that can provide a wide range of observational capability, in terms of spatial, temporal, and spectral resolutions, especially when combined with "big data" computational capacity and *in situ* monitoring systems. Similarly, significant progress in image processing algorithms has increased the potential for the successful characterization of biodiversity at various scales.

We are pleased to present this special issue of 18 state-of-the-science papers [10–27] covering a wide range biological diversity issues assessed from different spatial, spectral, and temporal scales of remote sensing instruments that use different methodologies, but which illustrate the many ways remote sensing data are being used to address biodiversity concerns. The papers range from the detection of phylogenetic variation in oaks [10] using full-range (400–2500 nm) leaf level spectroscopy to habitat models for seven dolphin and whale species [11] that assimilate sea surface temperatures and sea height data for training and validating model predictions. In a study of drivers of oak woodland productivity, Santos *et al.* [12] analyzed a 15-year time series of EVI Landsat data to identify trends in productivity in relation to climate in Southern Portugal. Suitable chimpanzee habitat was modeled using Landsat data for each of the four populations that cover its current range [13]. In a boreal study of full-range (380–2500 nm) hand-held spectral reflectance of mammal pelts [14] showed that it was possible to separate mammals from snow and show promise for discriminating species, with polar bear fur being most distinctive. In terms of vascular plant species mapping in tropical forests, McManus *et al.* [15] show promise for differentiating phylogenetic relationships among foliar traits in tropical forest species. Graves *et al.* [16] address developing operational models for species classification using imaging spectroscopy and addressed the accuracy problems of imbalanced training data. Chadwick and Asner [17] collected Carnegie Airborne Observatory data at high spatial and spectral resolution and map leaf mass area (LMA) and several key mineral nutrients including foliar nitrogen, phosphorous, magnesium, potassium, and calcium. Revermann *et al.* [18] used land surface phenology metrics from MODIS and Shuttle Radar Topographic Mission (SRTM) data to map alpha diversity across the Okavango Basin, one of the largest inland deltas in the world, originating in the Angolan Central Plateau and terminating in the Okavango Delta of Botswana.

Two papers address species richness in grasslands. Wang *et al.* [19] followed seasonal changes measured with a field spectrometer for NDVI-species richness relationships at the Cedar Creek Prairie experiment and in grazed dry grasslands on the Baltic Island of Öland, Sweden. Möckel *et al.* [20] flew an imaging spectrometer (414–2500 nm) and present best results for predicting species richness and Simpson's diversity using spectral responses from all wavebands analyzed with partial least squares regression (PLSR). Wang *et al.* [21] also address grassland productivity in a Southern Alberta prairie using airborne imaging spectrometry combined with ground sampling and eddy covariance data, showing greater productivity in sites with higher biodiversity based on species richness and the Shannon Index. Garroutte and Hansen [22] evaluated the quality of grasslands for elk habitat in the Yellowstone River Basin using seasonal MODIS EVI and NDVI. Zhao *et al.* [23] address the optimal detection of biochemical indicators for species mapping, and two papers show the potential of mapping foliar traits related to ecosystem functionality. Chadwick and Asner [17] used airborne imaging spectroscopy to map leaf mass area (LMA) and the foliar concentrations of nitrogen, phosphorus, calcium, magnesium and potassium for dominant trees in the Peruvian wet tropics, and McManus *et al.* [15] address the relationships between foliar reflectance spectra and the phylogenetic composition of a tropical forest on Barro Colorado Island, Panama. The paper by Coops *et al.* [24] take into account forest fragmentation and land use with distribution modeling to predict forest species migration in the Pacific Northwest of North America under climate change, while Zhang *et al.* [25] identify a MODIS based Dynamic Habitat Index Analysis using the Photosynthetically Active Radiation (fPAR) product for China that characterizes terrestrial biodiversity, while Barboas *et al.* [26] used imaging spectroscopy data to identify the subcanopy invasive species *Psidium cattleianum* in Hawaiian forests. The three-dimensional structural complexity and niche diversity in forest habitats are key predictors of biodiversity. Zielewska-Büttner *et al.* [27] describe an automated detection method to retrieve forest gap structure and height from LiDAR data and stereo imagery, which were independently validated using stereo imagery for the Northern Black Forest in Southwestern Germany.

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