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Review of studies on tree species classification from remotely sensed data

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ABSTRACT

Spatially explicit information on tree species composition of managed and natural forests, plantations and urban vegetation provides valuable information for nature conservationists as well as for forest and urban managers and is frequently required over large spatial extents. Over the last four decades, advances in remote sensing technology have enabled the classification of tree species from several sensor types.

While studies using remote sensing data to classify and map tree species reach back several decades, a recent review on the status, potentials, challenges and outlooks in this realm is missing. Here, we search for major trends in remote sensing techniques for tree species classification and discuss the effectiveness of different sensors and algorithms based on a literature review.

This review demonstrates that the number of studies focusing on tree species classification has increased constantly over the last four decades and promising local scale approaches have been presented for several sensor types. However, there are few examples for tree species classifications over large geographic extents, and bridging the gap between current approaches and tree species inventories over large geographic extents is still one of the biggest challenges of this research field. Furthermore, we found only few studies which systematically described and examined the traits that drive the observed variance in the remote sensing signal and thereby enable or hamper species classifications. Most studies followed data-driven approaches and pursued an optimization of classification accuracy, while a concrete hypothesis or a targeted application was missing in all but a few exceptional studies.

We recommend that future research efforts focus stronger on the causal understanding of why tree species classification approaches work under certain conditions or – maybe even more important - why they do not work in other cases. This might require more complex field acquisitions than those typically used in the reviewed studies. At the same time, we recommend reducing the number of purely data-driven studies and algorithm-benchmarking studies as these studies are of limited value, especially if the experimental design is limited, e.g. the tree population is not representative and only a few sensors or acquisition settings are simultaneously investigated.

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1. Introduction and review approach

1.1. Importance of tree species information

Remote sensing-assisted classification of tree species is motivated by a wide variety of applications confronting the forest management and conservation sectors. These applications include questions linked to resource inventories (van Aardt and Wynne 2007), biodiversity assessment and monitoring (Shang and Chisholm, 2014), hazard and stress management (Cho et al., 2010; Fassnacht et al., 2014), monitoring of invasive species (Boschetti et al., 2007), wildlife habitat mapping (Jansson and Angelstam, 1999) as well as the overarching aim of a sustainable forest management (European Environmental Agency, 2007). Many studies highlighted the importance of tree species maps either as standalone products for forest management (e.g. Dalponte et al., 2012; Heinzel and Koch, 2012) or as an input for species-specific growth and yield models (e.g. Vauhkonen et al., 2014) or any species-specific allometric model (Ørka et al., 2013). In this realm, Korpela and Tokola (2006) demonstrated the importance of tree species information in remote sensing-based single tree inventory approaches to avoid unwanted averaging effects (e.g. when calculating growing stock volume). Knowledge on tree species distribution may also affect forest harvesting and management policies (Dalponte et al., 2012; Jones et al., 2010; Plourde et al., 2007). In urban areas, the sustainable management of urban trees requires species information as well and remote sensing approaches have been discussed as an efficient alternative to field inventories (Jensen et al., 2012).

Spatially explicit information on tree species composition over large areas are also relevant for an improved understanding of the ecology of tree species for example concerning community dynamics and the contribution of species to ecosystem functions and services (Chambers et al., 2013; Van Ewijk et al., 2014). Other environmental studies for instance focusing on wildlife habitat mapping (Pausas et al., 1997) or estimation of insect abundances in forests (Kennedy and Southwood, 1984) also benefited from tree species information.

1.2. Objectives

The objectives of this review on tree species classification are to:

1. Quantify general trends in remote sensing studies focusing on tree species classification
2. Provide a detailed overview of the current approaches for classifying tree species from typical sensor types
3. Identify research gaps and future trends for tree species classification using remote sensing data