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Hyperspectral discrimination of tree species with different classifications using single- and multiple-endmember

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ABSTRACT

Discrimination of tree species with different ages is performed in three classifications using hyperspectral data. The first classification is between Broadleaves and pines; the second classification is between Broadleaves, Corsican Pines, and Scots Pines, and the third classification is between six tree species including different ages of Corsican and Scots Pines. These three classifications are performed by having single- and multiple-endmember and considering five different spectral measure techniques (SMTs) in combination with reflectance spectra (ReflS), first and second derivative spectra. The result shows that using single-endmember, derivative spectra are not useful for a more challenging classification. This is further emphasized in multiple-endmember classification, where all SMTs perform better in ReflS rather than derivative in all classifications. Furthermore, using derivative spectra, discrimination accuracy become more dependent on the type of SMTs, especially in single-endmember. By employing multiple-endmember, the within-species variation is significantly reduced, thereby, the remaining challenge in discriminating tree species with different ages is only due to the between-species similarity. Overall, discrimination accuracies around 92.4, 76.8, and 71.5% are obtained using original reflectance and multiple-endmember for the first, second, and third classification, which is around 14.3, 17, and 8.3% higher than what were obtained in single-endmember classifications, respectively. Also, amongst the five SMTs, Euclidean distance (in both single- and multiple-endmember) and Jeffreys–Matusita distance (in single-endmember and derivative spectra) provided the highest discrimination accuracies in different classifications. Furthermore, when discrimination become more challenging from the first to second and third classification, the performance difference between different SMTs is increased from 1.4 to 3.8 and 7.3%, respectively. The study shows high potential of multiple-endmember to be employed in remote sensing applications in the future for improving tree species discrimination accuracy.

1. Introduction

Airborne hyperspectral imaging technology has been applied in a variety of research fields as it can provide significant improvements in spectral information content when compared with broad-bands (Ghiyamat and Shafri, 2010; van der Meer et al., 2012). Several research to date have been conducted for discriminating tree species using airborne hyperspectral imagery (Dibley et al., 1997; Clark et al., 2005; Zhang et al., 2006). In tree species identification, classification is based on the assumption that each species should have a unique spectral signature. However, species show within-species spectral variation which is sometimes high, leading to the failure of a unique spectral identifier per species. Example of such spectral variation can be due to the variation in reflectance, absorption, transmission properties of leaves and wood, foliage age (Roberts et al., 1998), position in the canopy (Danson and Plummer, 1995), chlorophyll content (Zarco-Tejada et al., 2003), water content (Lee et al., 2010), the presence of lianas (Castro-Esau et al., 2004; Sánchez-Azofeifa et al., 2009), viewing geometry (Pu, 2009), and a host of other environmental factors such as microclimates, soil characteristics, precipitation, topography and soil moisture (Portigal et al., 1997; Lee et al., 2010).

In tree species or vegetation discrimination, several factors could affect discrimination accuracy, in which one of them is the age of species. When a tree is young, some of their important parameters such as chlorophyll content or the leaves color is different

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from the mature and old trees, which cause to reflect slightly different spectra. Based on our best knowledge, so far there is no report on discrimination of tree species with different ages for determining the effect of different species with the same age. A primary study has been done with the same group to discriminate tree species with different ages using two different red-edge position techniques (Shafri et al., 2006). It is the interest of this paper to study the challenges in discriminating tree species with different ages and to find the relationship between different species with the same age.

Spectral measure techniques (SMTs) are one of the key important elements for discriminating tree species. They have advantages over parametric methods such as discriminate analysis and maximum likelihood, where SMTs can be used with an established spectral library of species and are not dependent on GPS positional data. Various SMTs have been used to classify tree species using hyperspectral data. Traditionally, each SMT compares the target spectra with reference spectra, where there is only one reference spectrum per species. Recently, multiple reference spectra per species known as multiple-endmember are used to improve discrimination of Savanna tree species (Cho et al., 2010), mapping two Eucalyptus subgenera (Youngentob et al., 2011), mapping urban green space (Jie and Xiangnan, 2009), and comparison of ASTER and AVIRIS imagery in discrimination of soil, grass/forb, and sagebrush abundance (Fairweather et al., 2012). In this study, five SMTs common in remote sensing applications including spectral angle mapper (SAM), spectral information divergence (SID), combination of SAM with SID, Jeffries–Matusita distance, and Euclidean distance, are used to compare their ability in discriminating tree species with different ages considering single- and multiple-endmember in combination with reflectance and derivative spectra. Specifically, the objectives of this study are:

i. To determine the ability of hyperspectral imagery in discriminating tree species with different ages.
ii. To determine spectral relationship between different species with the same age.
iii. To compare compatibility of derivative and reflectance spectra in combination with different SMTs with multiple-endmember for discriminating tree species with different ages.
iv. To determine the usefulness of multiple-endmember in discriminating tree species with different ages compared to single-endmember.

In the next section, the study area and the hyperspectral data with the theoretical background are presented. Results and discussion are presented in Section 3 followed by conclusion section.

2. Methodology

2.1. Study area and hyperspectral data

Fig. 1(top) shows the location map of the Thetford Forest used in this study. Fig. 1(left) shows the hyperspectral data that was acquired by the HyMap sensor over the Thetford Forest in East Anglia (0°41′40.89″ to 0°43′50.96″N and 52°26′40.43″ to 52°25′14.72″E) on 17 June 2000. Thetford is the largest man-made pine forest in Britain, which occupies an area of approximately 22,000 hectares and it consists mainly of planted and managed Corsican and Scots pine of different age classes. The hyperspectral data has a spatial resolution of 5 meters and an average spectral resolution of 15 nm. It consists of 126 bands from 0.45 μm to 2.48 μm, as the other detail spectral characteristics of the HyMap data are shown in Table 1. The HyMap sensor provides an excellent signal to noise ratio of >500:1. For the Thetford hyperspectral data, a ground reference vector data generated from the UK Forestry Commission's GIS is available as shown in Fig. 1(right). The ground reference is labeled with six tree covers including Broadleaves (BL), old Corsican pine (OCP), mature Corsican pine (MCP), young Corsican pine (YCP), old Scots pine (OSP), and young Scots pine (YSP), where the young, mature, and old trees had around 16, 34, and 70 years old, respectively in the data acquiring time.

Table 1
Spectral characteristics of the HyMap sensor.

Spectral configuration			
Module	Spectral range	Bandwidth across module	Average spectral sampling interval
VIS	0.45–0.89 μm	15–16 nm	15 nm
NIR	0.89–1.35 μm	15–16 nm	15 nm
SWIR1	1.40–1.80 μm	15–16 nm	13 nm
SWIR2	1.95–2.48 μm	18–20 nm	17 nm

Adapted from HyVista (2002).

In this study, three classifications are considered for discriminating tree species, which are

(1) discrimination between Broadleaves and pines tree species;
(2) discrimination between Broadleavs, Corsican pines (CP), and Scots Pines (SP); and
(3) discrimination between all the six tree covers Broadleaves; Old, Mature, and Young Corsican Pine; and Old and Young Scots Pines.

For this purpose, several groups of pixels in the form of region of interest (ROI) are selected from each tree cover. The ROI is used since the individual tree crowns from the hyperspectral image is not distinguishable due to the low spatial resolution (5 m), therefore, each ROI might contain pixels from only one tree or more trees from the same tree cover. The number of ROIs and the total number of pixels per tree cover that are selected in this study are shown in Table 2. Each ROI in this study contains approximately about 50 pixels. The ROI selection is performed manually and randomly from different locations for each tree cover.

2.2. Theoretical background

2.2.1. Reflectance and derivative spectra

Reflectance spectra are the pure information that can be extracted from the hyperspectral image. While reflectance spectra are used in most species discrimination studies as the benchmark, derivative is also used commonly in several remote sensing applications due to its simplicity.

For discriminating tree species using reflectance spectra, the sample data extracted from the hyperspectral data is directly used for statistical analysis.

For discriminating tree species using derivative of the reflectance spectra, the same sample data used in reflectance spectra are used in derivative spectra, with the only difference is that the sample data are first differentiated and then the statistical analysis applied on the differentiated data. In general, considering a sample

Table 2
The number of ROIs and total number of pixels selected per species and total number of target pixels.

Species	BL	MCP	OCP	YCP	OSP	YSP
No. of ROIs	6	6	6	6	6	4
Total no. of pixels	321	308	306	318	328	216
Total no. of target pixels	231	218	216	228	238	156