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Abstract
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Comparing Forest Species Emissivity Using Airborne Thermal Infrared Hyperspectral data in a Mixed Temperate Forest

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Challenge

The need to identify and remotely speciate different vegetation classes in mixed forest environments continues to be an important area for ecosystem conservation and management purposes. Such applications generally rely on the biochemical and biophysical properties found in the VNIR (0.3–1.0 μm) and SWIR (1.0–2.5 μm) regions. Nevertheless, foliar spectral behaviour in the TIR (8–14 μm) domain has significant interspecies variability that has been shown to correlate with the spectral features of key plant constituents. Different plant species have been successfully discriminated in the laboratory using leaf emissivity spectra. However, given the complexity of emissivity at the canopy level, species discrimination using canopy emissivity spectra obtained from airborne TIR remains unexplored. This study aims to compare the differences in the canopy emissivity spectra obtained from the airborne TIR hyperspectral data among and between various vegetation covers in a mixed temperate forest.

Methodology

The vegetation classes were investigated using airborne TIR hyperspectral images captured using AISA Owl thermal hyperspectral sensors during a flight campaign under clear skies in Bavaria Forest National Park in south-eastern Germany. Thermal infrared data pre-processing steps, including radiance calibration, radiometric and geometric correction and data masking, were performed prior to the separation of land surface temperature from canopy emissivity. Canopy emissivity spectral measurements were then extracted based on the locations of tree species as recorded during the EUFAR and BIOSPACE fieldwork projects. For analysis, the pairwise Mann-Whitney U test was used to assess whether different vegetation cover types (e.g., spruce, beech and fir) exhibit both inter and intra-species statistical differences by means of their canopy emissivity spectra. Furthermore, multiple Mann-Whitney U test comparing the emissivity spectra of species at each of the 102 spectral channels was done to determine the specific wavelengths in which species could be distinguished. Subsequently, the level of species separability in the hyperspectral space was quantified based on the Jeffries-Matusita and Bhattacharya distance measures.

Expected results

The research showed the presence of intra and interspecies canopy emissivity variation. The differences in canopy emissivity between beech and spruce ($U = 2541872$, p-value = 0.001) as well as between beech and fir (U = 774369, p-value = 0.003) were statistically significant. While the differences in canopy emissivity between spruce and fir (U = 617202, p-value = 0.672) were not statistically significant. Comparing the spectral emissivity variability within species, the results of this study demonstrate that the spectral emissivity responses vary among beech and spruce tree species growing in different locations. The differences in canopy emissivity were statistically different for 4 out of 23 beech trees and 6 out of 20 spruce trees, which all had high leaf area index (LAI) values. As previously suggested, the differences in biophysical properties, specifically LAI, influenced spectral emissivity variability within species. Additionally, the MWU test specifically identified nine wavelength locations: 9.71 μm, 10.06 μm, 10.11 μm, 10.16 μm, 10.70 μm, 11.55 μm, 11.60 μm, 11.89 μm and 11.90 μm as able to distinguish at least one species. Finally, the spectral separability showed that the results showed that while the species are not entirely separable, the spectral pair of spruce and beech were more discriminable in the hyperspectral space than either pair of fir and spruce or spruce and beech.

Outlook for the future

Firstly, this study demonstrated that the AISA Owl TIR hyperspectral sensor is suitable for data acquisition from materials with prominent spectral features, such as gases and geologic samples, but is also feasible for acquiring information from materials with very subtle spectral signatures, such as vegetation. Nevertheless, future projects may need to consider other TIR sensors with finer specifications to obtain better spectral emissivity contrast. Secondly, this study predominantly used the Mann-Whiney U test because of the uneven sample size. However, its statistical power can be diminished with increasing uneven sample groups. Therefore, future projects may explore other statistical tests, such as the analysis of variance tests with quadratic discriminant analysis, to avoid the limitations of pairwise analysis. Finally, analysing other factors, such as vegetation dryness, tree age, and soil, that impact inter and intra-species spectral variation would improve this study.

(a) *(b)*

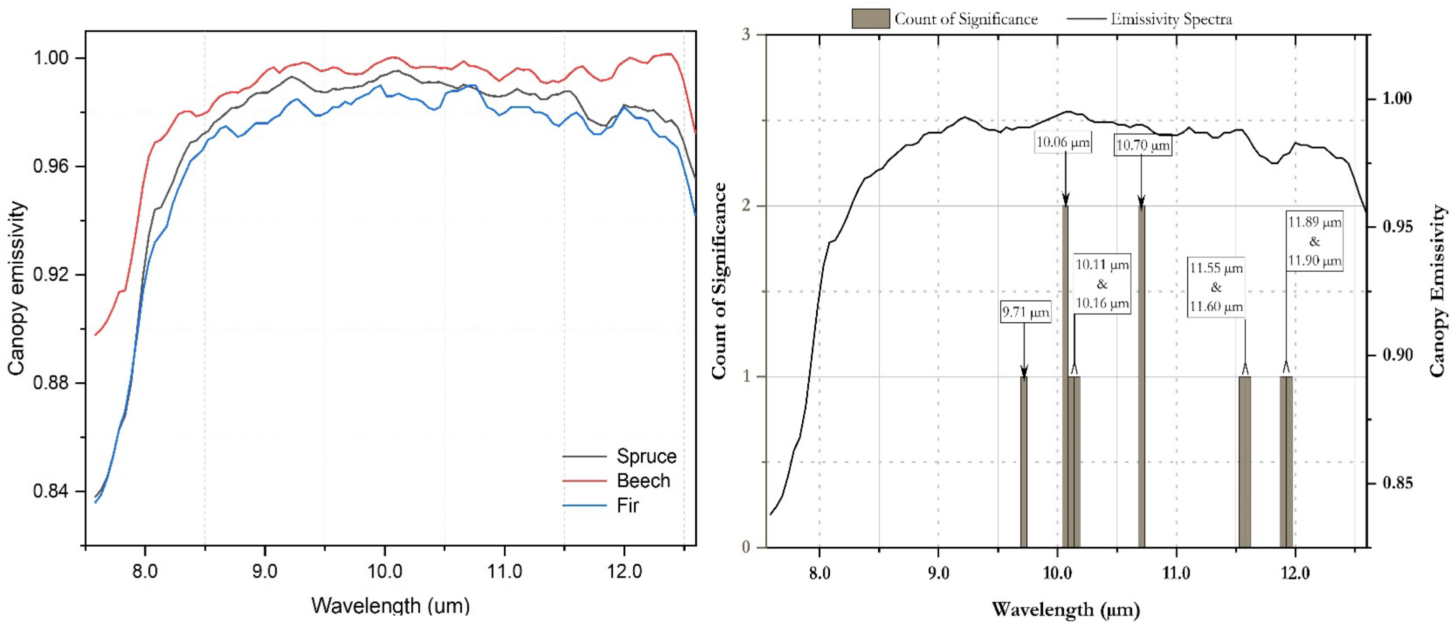

Figure **(a)** Canopy emissivity spectra plots for spruce, beech and fir against wavelengths. The colour black represents spruce, the colour red represents beech, and the colour blue represents fir; **(b)** Frequency plot of statistically significant differences between tree species: beech, spruce and fir. Prominent wavelength locations are identified and labelled. Alongside, a typical emissivity spectra is plotted to show the wavebands.