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| **How early can we detect European spruce bark beetle attack using hyperspectral drone images with high spatial- and temporal resolution?** |
| The European spruce bark beetle (*Ips typographus*) is one of the main threats to coniferous forests in Central and Northern Europe, causing severe damage to Norway spruce (*Picea abies*). In Sweden, extreme events of drought and windstorms have become more frequent, resulting in peaks of bark beetle population and large outbreaks over the last few years.  Detecting infestations as early as possible is essential to effectively apply control measures (e.g., removal of deadwood, sanitary cuttings) and prevent further dissemination. However, detecting trees during the green attack stage is a challenge, since the crowns do not present symptoms visible to the human eye during this phase. Nevertheless, remote sensing technologies can be great allies to capture changes in tree physiological conditions. In particular, hyperspectral images (HSI) can reveal detailed information on the spectral signatures of the vegetation, which could enable the detection of anomalies exhibited by attacked trees.  In this study, we aim to investigate the potential of HSI for the early detection of European spruce bark beetle attack in Southern Sweden. A time-series of high-resolution HSI was acquired between the weeks 16 and 32 of 2023 in a controlled experiment in Remningstorp, in south-western Sweden (58°27'3.51"N, 13°39'51.64"E). We studied 24 circular plots distributed across four stands of Norway spruce forest. Each plot had a 15 meter radius and 42 trees on average. We used the hyperspectral cameras AFX10 and AFX17 mounted on a drone to capture spectral data ranging from 400 to 1700 nm. The acquired images have 112 spectral bands, providing a pixel size of 7 and 11 cm with the used configuration, respectively. Reference panels with known reflectance were used to correct for atmospheric and illumination effects. Simultaneously, a weekly field inventory was conducted to record indication on bark beetle damage in the plots (i.e., holes, dust, resin, bark damage, crown discoloration, and crown defoliation).  We use a tree crown segmentation to extract the spectral information at the individual-tree level. By matching this information with the field inventory data, we will be able to compare the spectral signatures of attacked and non-attacked trees. We will identify which are the spectral bands that provide the highest separability between these groups. Furthermore, we will test the performance of vegetation indexes commonly used to characterize vegetation health (e.g., NDVI, GNDVI, NDRE, NDWI, DSWI, CVI, CIG, GLI), as well as indices recently proposed in the literature (e.g., Multiple Ratio Disease-Water Stress Indices – MR-DSWI1, MR-DSWI2, MR-DSWI3, and MR-DSWI4; Normalized Distance Red & SWIR – NDRS; Green Shoulder Curvature Ratios – GSCR1 and GSCR2) to identify attacked trees. Finally, we will analyse the continuous spectrum of wavelengths to possibly identify better relationships that enable earlier identification of bark beetle attack.  We expect this study to improve our understanding of the potential of HSI to detect bark beetle attack in early stages. With development, our findings could contribute to monitoring systems of forest disturbances and increase the success of management efforts towards heathy forests. |