Early detection of spruce bark beetle damage in Southern Sweden with hyperspectral drone images

Forest disturbances have increased across Europe in recent decades, making remote sensing a fundamental tool for monitoring their occurrence, spatial patterns, and causal agents on larger scales. In particular, populations of the bark beetle *Ips typographus* tend to escalate during hot and dry summers and following abiotic disturbances such as droughts and windstorms. Sweden has experienced several outbreaks of *I. typographus* infestations in Norway spruce (*Picea abies*) forests, resulting in significant economic and ecological impacts. Early detection of these outbreaks is crucial for enabling timely and effective management interventions. Previous research has explored early detection using multispectral satellite and drone imagery. However, these systems are limited to a small number of spectral bands, which may not capture the subtle physiological changes occurring in the early stages of infestation. In this study, we used high-resolution hyperspectral drone imagery to assess how early infested trees could be detected under field conditions. The study was conducted at the Remningstorp research site in southern Sweden (58°27'18"N, 13°39'8"E), where we monitored four spruce-dominated forest stands. Between April and August 2023, we collected a time series of hyperspectral drone images, covering wavelengths from 400 to 1,700 nm. Within each stand, six 15-meter radius plots were established and a pheromone bag was placed in the central tree to attract bark beetles. Weekly field inventories were conducted to monitor bark beetle damage progression, ultimately identifying 109 infested trees by the end of the growing season. Spectral data was extracted at the individual tree level by applying a watershed segmentation algorithm to the drone images. We investigated which spectral bands were most sensitive to stress caused by bark beetle infestation and evaluated how well vegetation indices based on these bands could detect infested trees over time. Additionally, we compared the performance of hyperspectral imagery with that of multispectral systems used in previous studies and assessed which spectral regions contributed most to early detection. Preliminary results indicate a moderate improvement in early detection using the hyperspectral system, particularly in capturing subtle changes in the green-shoulder region. Red-edge metrics also showed potential when normalized against the trees initial condition.

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