International Symposium on Applied Geoinformatics (ISAG2021)

SPECTRAL SEPARABILITY OF TREE DEFOLIATION DURING THE HETEROBASIDION ANNOSUM SPREADING

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Introduction/Background

Nowadays, the forest health has become major concern in relations to climate change and invasions of forest pests, insects and various diseases (Hemery, 2008). Particularly, increasing soil temperatures may be favourable for root and butt rot caused by Herobasidion spp. species (Cermak et al. 2004, Boddy, 2016). Consequently, affected trees are more vulnerable to be damaged than healthy, vigorous trees in following disturbances (Fettig et al., 2007, Seidl et al., 2008). In order to reduce the spread of the infections, there are great need for novel attempts on early detection of infected trees before an invasion cause visible crown symptoms such as discoloration and defoliation. Against this background, the rapid development of remote sensing technology which contributed and expand its application (Emery and Camps, 2017) has lead remote sensing as one of the most attractive research fields. (Roy et al., 2017). Remote sensing technologies are widely applied for many applications, such as agriculture, forest monitoring and natural disturbances (Oliveira et al., 2018, Guimares et al., 2020). In particular, UAV based on multi and hyperspectral images provides a fast, -cost-efficient, non-destructive and spatio-temporal measures with reasonable precision that gives very detailed insight into forest dynamics (Nasi et al., 2015). Increasing levels of vegetation stress and in terms of high financial losses, due to dieback caused by the pathogens, require a development and use of appropriate method to locate of stressed and hence potential host trees (Hernández-Clemente et al., 2019). Therefore, the aim of this study was to investigate the spectral features of obtained images to distinguish the levels of health for individual trees in Scots pine stand affected by Heterobasidium spp. The main objective was to determine and test the most effective vegetation indices that classifies best the forest health levels. We hypothesed that the reduction of tree growth caused by the fungus Heterobasidium spp. can be detected in the early phases before tree crowns are becoming heavily discoloured or defoliated by using vegetation indices.

Materials and Methods (Design/methodology/approach)

The study area is located in eastern part in Latvia near Aiviekste, (25°57' E 56°40' N). The objective of sampling strategy was to cover entire area of Heterobasidion affected trees and adjacent area. A ground survey required for the analysis of the statistical relationship between Scots pine canopy health and spectral variables was conducted in July 2020. The positions of all individual trees were mapped by recording GPS coordinates using Leica GS16 GNNS receiver and Leica Flexline TS06 total station. Each tree was mapped, identified by species, given a health status (living, dead, declining, bent or fallen), classes according to Kraft's classification. The level of tree canopy defoliation was assessed by visual inspection and was rated in association to tree crown vitality, see Table 1 for description. In total 289 trees were measured.

Table 1 Numbers of trees in the different crown colour classes in two test areas

Class name	Description	Number of trees
Healthy	Trees of dominant and codominant according to Kraft's classification with conventional DBH increase	99
Reduced growth	Tree with reduced growth or no increments (calculated as the difference between individual DBH measured at 2015 and 2020), no visible crown damages	91
Crown damages	Tree with visible crown damages, such as yellow or brown needles in foliage and reduced growth	37
Dead	Trees with complete loss of green foliage	62

Multispectral images were acquired during the 2020 growing season. We used a DJI Matrice 210 an unmanned aircraft system (UAS, i.e., drone) equipped with SlantRange 3PX multispectral sensor. The sensor captures four separate wavelengths: green, red, red-edge and near-infrared. The flight height was set to 50 m above ground with 4.0±1 m s-1 ground speed. The calibrated imagery were exported into Agisoft Metashape Professional (v. 1.6.4.) and Structure from Motion (SfM) photogrammetric method was implemented for orthophoto production (Westoby et al., 2012).

The Maximum Likelihood classification (MLC) and relationship between tree health status and detected reflectance were characterized by using various vegetation indices based on the greenness and leaf pigments (chlorophyll) concentration. Each tree crown was delineated as polygons and statistics (means of four bands and all vegetation indices) within polygons were extracted using ArcGis 10.5.0. We run an error matrix where the accuracy measures such as overall accuracy, Kappa, user accuracy, and producer accuracy was calculated (Story and Congalton, 1986). All statistical data analysis was performed with R 4.0.3.

Results and Discussion

In this study many of tested vegetation indices showed no valid and meaningful results, hence in the further analysed we kept thus vegetation indices that showed good results in separability of tree health classes (Figure 1). The mean spectral signatures for each vegetation indices showed a clear association between chlorophyll content and increasing levels of vegetation stress. All tested indices showed significant differences ($p<0.05$) among different tree health classes applying spectral indices NDVI, NDRE, MCARI, MTVI2 and Clre. The linear relationships between tree health classes indicated better results for distinguishing the level of tree stress when the red-edge band were integrated in indices. The post-hoc analysis of all the tree health class pairs in the NDRE index showed that there were significant differences between Healthy and Reduced growth classes. Similar studies of pine defoliation have reported that the NDRE are more sensitive than NDVI (Eitel et al., 2011), suggesting that NDRE are better for early stress detection i.e. for distinguish classes with none or moderate levels of defoliation, while NDVI are more suitable to delineate severe defoliation Marx and Kleinschmit, 2017).

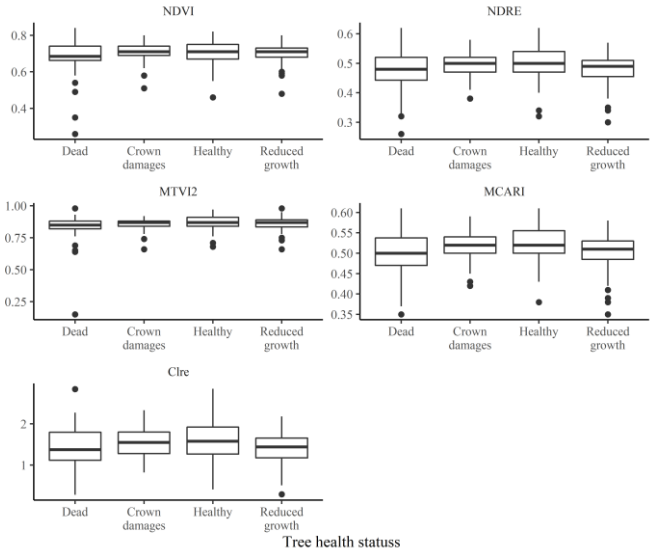

Figure 1 Competitions of vegetation index values of different forest health classes to assess the defoliation during the Heterobasidion annosum spreading in Scots pine stands

The best overall accuracy (50.4 %) of the Maximum Likelihood classification was obtained for MTVI2 index with a kappa

statistic of 0.33. The capability of detection of dead, damaged crowns, healthy and trees with reduced growth was 70.9 %, 49.3 %, 40.0 % and 41.3 %, respectively (Table 2.). In other studies, there has been also very challenging to classify the infestation of different tree health classes due to the weak separation of the infested and healthy trees (Nasi et al., 2015).

Table 2 Confusion matrix of best ML model for Scots pine damage classification for MTVI2 index. *N: number of samples*

Name	Dead	Damaged crown	Health	Reduced crown	N	Users accuracy, %	Producers accuracy, %
Dead	83	14	13	7	117	70.9	60.1
Damaged crown	12	33	11	11	67	49.3	41.8
Health	22	15	46	32	115	40.0	43.4
Reduced crown	21	17	36	52	126	41.3	51.0
N	138	79	106	102	425		
Kappa coefficient	0.33						
Overall accuracy, %	50.4						

Conclusion (Summary)

Identification of the early tree stress caused changes in spectral signature was possible by using multispectral data. The analyses of early detection of tree stress showed that class “Dead” was clearly distinguishable from class “Healthy” when the each of spectral bands was used separately. Indeed, more convenient separability of different tree health levels was reached when vegetation indices were used. Although, the results of the classification showed that the inaccurate tree crown delineation in dense canopy condition could affect the classification accuracy.

Keywords: *UAV Multispectral Images, Remote Sensing, Indices, Forest Disturbances, Crown Defoliation*

Acknowledgements

The study was prepared under the framework and funded by the Forest Competence Centre (ERDF) project “Technology for early diagnostics of genetically determined variation of resilience-related trait for Norway spruce” (1.2.1.1/18/A/004).

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