Investigating the Potential of Thermal Infrared UAS Imagery for Detecting the Health Status of Pine Trees

1. Introduction

Pine trees *(Pinus brutia)* are classified as Mediterranean flora due to their adaptability to arid ecosystems. Pines are discussed concerning environmental protection as it helps to stabilize the climate, reduce soil erosion, and provide habitat for wildlife (Kukarskih et al., 2020). Pests are considered as one of the primary factors that affect forest health. In the 1990s, expansion of the production of *Marchalina hellenica* was widely introduced in Greece by the ministry of Agriculture to support the pine honey economy. *Marchalina hellenica* is one of the pests that attacked and infested Pine trees in the Mediterranean region, which led to contamination of some parts of the trees that can be used as a food source for honeybees. In order to detect these threats, remote sensing techniques can be relied upon. This study aims to evaluate the prediction accuracy of the multispectral UAV imagery as well as thermal infrared data for detecting forest health decline and, in particular, Pine trees in Lefka Ori National Park in west Crete, Greece.

2. Methodology

The study area is Lefka Ori National Park, suited in the west part of Crete island, Greece, with an area of 8336 km^2.

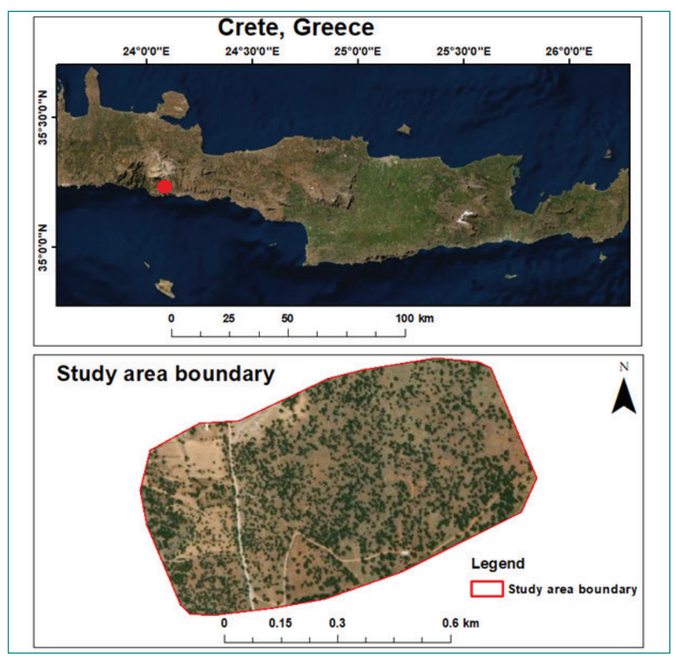

Figure 1: Study area Lefka Ori National park, Crete, Greece.

2.1. Data collection

One hundred nine individual trees were selected based on their accessibility and representativeness. DJ Phantom 4 UAV was used with mounting FLIR Vue Pro R and Parrot Sequoia cameras to capture thermal and multispectral images in addition to the RGB camera. LEICA differential GPS was also used to record the location of the ground control point, as well as individual sample trees. Pine trees' health and infestation status during the fieldwork were observed and recorded (Figure 2). UNECE and EU-based classification approaches (Table.1) were applied to assess the defoliation percentage and health status of the Pine trees.

Figure.2: Field observation considering defoliation level.

Table.1: Tree health classification based on UNECE and EU classification (Michel et al., 2014)

Class	Discoloration Status (%)	Defoliation Status (%)	Class
None/Healthy	Up to 10%	Up to 10%	0
Slightly unhealthy	>10-25%	>10-25%	1
Moderate unhealthy	>25-60%	>25-60%	2
Severe unhealthy	>60-<100%	>60-<100%	3
Dead	100%	100%	4

In order to observe the infestation level caused by *Marchalina hellenica*, information related to the discolouration was also collected. In this case, discolouration implies the colour change in the pine trees' bark, stem, and branches as a result of infestation (Figure.3). A modified UNECE and EU tree health classification (Table.1) were also applied for discolouration identification, and classes were defined accordingly.

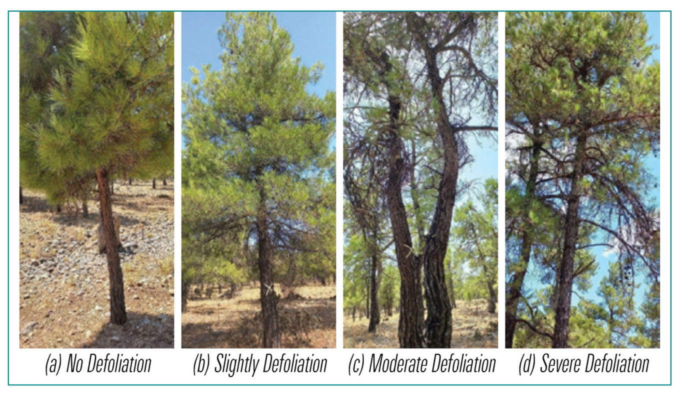

Figure.3: Field observation considering discolouration level.

For image acquisition for the selected study area, DJI Phantom 4 UAV was used. A Parrot Sequoia camera was used to acquire multispectral images, and a FLIR Vue Pro R camera with a bandwidth of 7.5 – 13. 5 µm was used to capture TIR images.

Figure.4: DJI Phantom 4 UAV (Source: ITC Geoscience-laboratory).

Three vegetation indices were used in the classification process (i.e., NDVI, SAVI, and NDRE).

Table.2 Vegetation indices were applied in this study

No.	Vegetation indices	Abbriviation	Equation
1	Normalized Difference Vegetation Index	NDVI	$NDVI = \frac{NIR - RED}{NIR + RED}$
2	Soil-Adjusted Vegetation Index	SAVI	$SAVI = \frac{(1+L)(NIR - RED)}{(NIR + RED + L)}$
3	Normalized Difference Red Edge Index	NDRE	$NDRE = \frac{NIR - RE}{NIR + RE}$

In this study, the random forest (RF) method was applied to classify the health and infestation status. RF classifiers have remarkable potential in forest health classification. A confusion matrix was used to evaluate the performance of the RF classifier. The health status of the study area was classified based on two scenarios:

1. A classification map of the health and infestation status is generated using vegetation indices obtained from multispectral data as an input.
2. A classification map of the health and infestation status is generated using canopy temperature obtained from TIR data as an input.

3. Results

Three different vegetation indices were retrieved and presented in Figure. 5.

Concerning health status, when the classified map was generated using vegetation indices as an input (Figure 6a), more than half of the delineated trees were classified as severe unhealthy, followed by approximately 30% healthy and 15% moderate unhealthy. However, the result suggests that when canopy temperature was applied as an input, 6%, 40%, and 54% of the study area were classified as healthy, moderate unhealthy, and severe unhealthy, respectively (Figure 6b).

The study area was classified using discolouration characteristics as an indicator to assess the infestation caused by *Marchalina hellenica*. As can be seen from Figure 7a, since the number of healthy trees was rare, less than 4% of the classified map was covered by healthy trees using vegetation indices. However, roughly 34% and 62% of the study area were classified as moderate and severely unhealthy. The classification for infestation status using canopy temperature indicates that 6%, 40%, and 54% of the study area were classified as healthy, moderate unhealthy, and severe unhealthy, respectively.

The vegetation indices layer obtained a higher producer, user, and overall accuracy than the canopy temperature in classifying trees concerning defoliation with 52% and 45% overall accuracy, respectively. In discolouration-based classification, both layers had the same producer accuracy (42%). However, the overall accuracy was higher when classified using vegetation indices (55%) than canopy temperature (48%).

Table 3: Accuracy assessment Classification using four different scenarios.

Scenarios	Layers	Accuracy		
		Producer	User	Overall
Defoliation	Vegetation Indices	80%	47%	52%
	Canopy Temperature	70%	41%	45%
Discolouration	Vegetation Indices	42%	57%	55%
	Canopy Temperature	42%	42%	48%

4. Discussion

- Concerning defoliation, the vegetation indices-based classification achieved a moderate overall accuracy. Also, the canopy temperature classifies obtained a reasonable overall classification accuracy; nonetheless, the accuracy was less compared with vegetation indices.
- The classifier in defoliation misclassified the moderately unhealthy class in both layers (i.e., vegetation indices and canopy temperature) due to the inconsistency of tree structure in the moderately unhealthy sample trees.

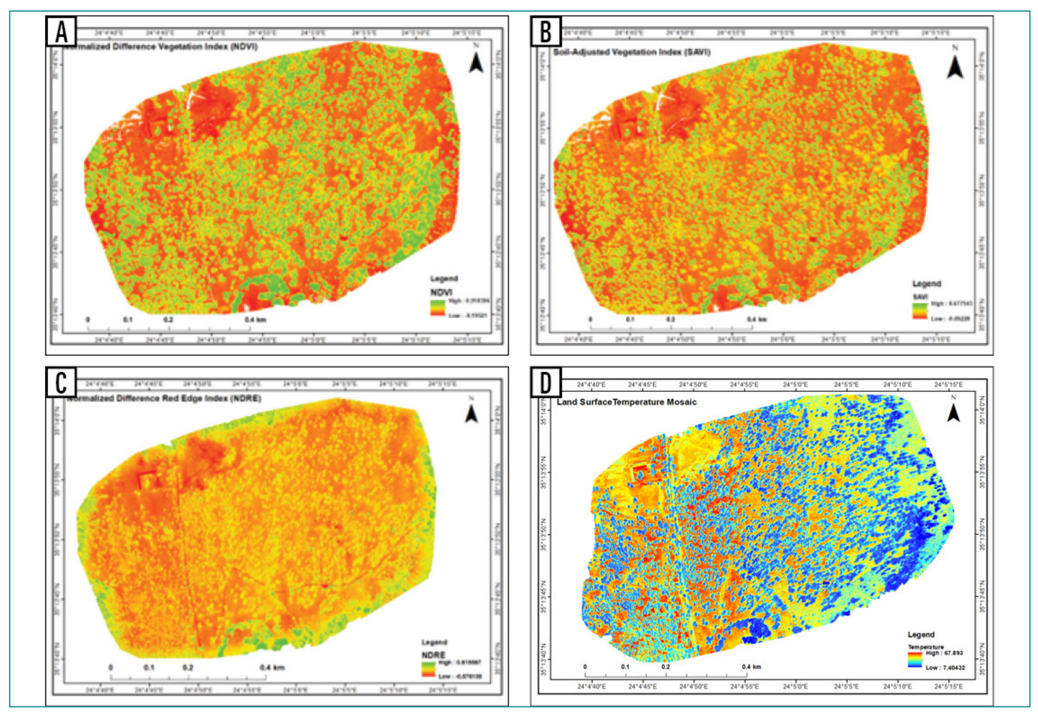

Figure.5: vegetation indices retrieved using multispectral data and canopy temperature computed using Thermal infrared data

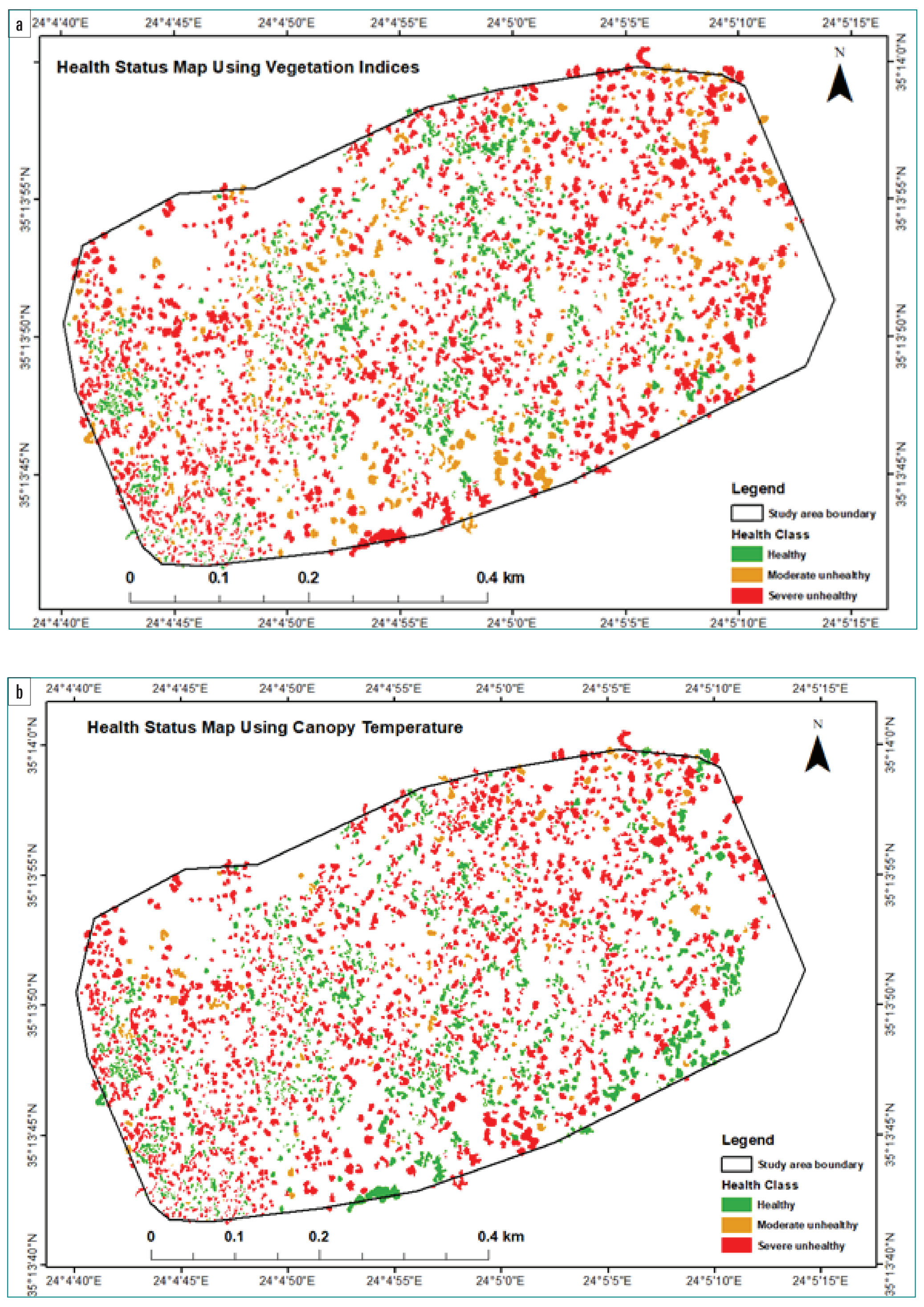

Figure 6: Health status map of the study area generated using vegetation indices (a) and canopy temperature (b) as an input using a random forest classifier

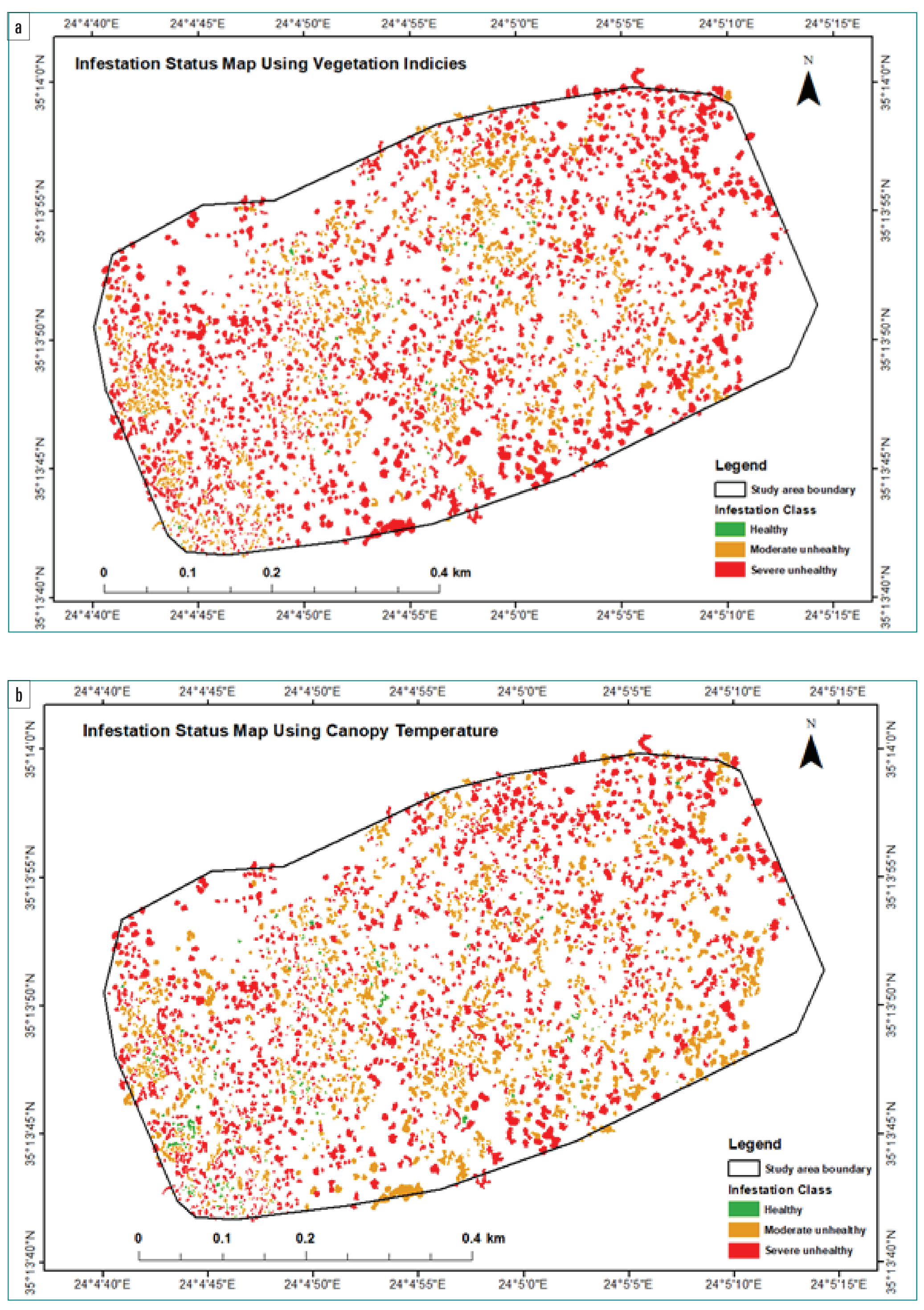

Figure. 7: Infestation status map of the study area generated using vegetation indices (a) and canopy temperature (b) as an input using a random forest classifier.

For more information

Azeb Gidey Kahsay[1], Elnaz Neinavaz[2], Panagiotis Nyktas[2]

[1] Department of Geoinformatics, Faculty of Geo-Information Science and Earth Observation, University of Twente, the Netherlands.
[2] Department of Natural Resources, Faculty of Geo-Information Science and Earth Observation, University of Twente, the Netherlands.

e.neinavaz@utwente.nl, p.nyktas@utwente.nl, a.g.kahsay@student.utwente.nl

References

Kukarskih, V. V., Devi, N.M., Surkov, A.Y., Bubnov, M.O., Gorlanova, L.A., Ekba, Y.A., Hantemirov, R.M., 2020. Climatic responses of Pinus brutia along the Black Sea coast of Crimea and the Caucasus. Dendrochronologia 64, 125763. https://doi.org/10.1016/J.DENDRO.2020.125763.
Michel, A., & Seidling, W. (2014). Forest Condition in Europe: 2014 Technical Report of ICP Forests. Report under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). Vienna: BFW Austrian Research Centre for Forests. BFW-Dokumentation 18/2014. 164 p (p. 3).

UNIVERSITY OF TWENTE. | ITC