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Determining infestation of Pine Processionary Moth using remote sensing

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Abstract

Insects are one of the most important elements of the natural balance in forest ecosystems. Thaumetopoea pityocampa, which is one of the important pests of Turkey's forests, causes increment loss, tree dead and economic losses in the forest stands. Therefore, there is a need for alternative methods of detecting and monitoring beetle damage with low cost and acceptable accuracy. Remote sensing data is widely used in beetle damage detection. In this study, the infestation of Thaumetopoea pityocampa in Calabrian pine forests in Kahramanmaraş Regional Directorate of Forestry, Elmalar Planning unit was determined with Remote Sensing data. 70 forest stands (sub-compartments) belonging to the infested (2016) and non-infested (2022) periods were determined in the study area. The minimum, average, maximum and total values of NDVI values were calculated using Landsat 8 OLI satellite images. The Kolmogorov-Smirnov normality test was used to determine whether the NDVI values were normal. Using SPSS software, the difference in NDVI values in infested and non-infested forest stands were statistically analyzed using a paired sample t-test. According to results, there was a statistically significant difference between all NDVI values in the years 2016 and 2022.

1. Introduction

Insects are the most important factors that threaten the existence, productivity and sustainability of Turkey's forests (Onaran and Kat 2010; Özcan, 2017). The Pine Processionary Moth (PPM) (*Thaumetopoea pityocampa* Schiff (Denis & Schiffermüller, 1775) (Lepidoptera: Notodontidae), which can cause significant damage to the forests in the Mediterranean region (Salvato et al. 2002) and has been known for many years in Turkey, spreads along the whole coastline (İpekdal and Çağlar 2011). PPM larvae was feed on pine needles (Kanat et al. 2002; Kerdelhué et al. 2009), and in the advanced stage, they can cause the death of the trees. Due to the defoliation, they cause a great deal of needle loss and reduced tree growth. Generally, young trees suffer more damage than older trees (Jacquet et al. 2013).

PPM causes economic losses as it negatively affects diameter and height growth in trees, health problems due to its allergen and aesthetic problems due to defoliation of trees (Mendel 1990). While trees rarely die in old forest stands, significant decrease in increment can occur. It was determined that trees with significant defoliation decreased by 24% in diameter, 36% in height and 52% in growing stock (Carus 2004). It was reported that, increment in Calabrian pine forests was decreased as 38.2% (Kanat et al. 2002) and 22.3% (Kanat and Sivrikaya 2005). In the afforestation areas of Crimean pine, the annual increment decreased by 34.6%-39.7% compared to the general average, and decreased by 58.3%-43.1% the following year (Altunışık and Avcı 2016). General Directorate of Forestry uses biological, chemical, mechanical, biotechnical and integrated control methods against this harmful species.

In the control against pests, the spatial determination of the damage is important in terms of the precautions to be taken. However, detection of the PPM in field survey is a time and cost-consuming activity. Therefore, there is a need for alternative methods with lower cost and acceptable accuracy. In this context, remote sensing (RS) techniques are used effectively in the detection and monitoring of PPM. Detection of beetle infestation using RS data depends on leaf discoloration and degree of leaf damage (Wulder et al. 2006). Each satellite image reveals

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a different degree of beetle infestation in terms of its characteristics (White et al. 2006). Medium resolution satellite images such as Landsat satellite images are used effectively in beetle infestation detection studies due to their multispectral bands, covering large areas, 30 m spatial resolution and 16-day temporal resolution (Collins and Woodcock 1996; Franklin et al. 2003; Skakun et al. 2003).

The aim of this study is to determine the PPM infestation in the Calabrian pine forests with RS data in Kahramanmaraş Regional Directorate of Forestry, Elmalar Planning Unit. The results will contribute to the determination of PPM in large forest areas with less effort and time and taking the necessary precautions.

2. Method

The study area is located Kahramanmaraş Regional Directorate of Forestry, Kahramanmaraş Forest Enterprise, Elmalar Forest Planning Unit at 37°35'26" N, 36°53'04" E (WGS 84 datum, 37 zone) (Figure 1). The Mediterranean climate is in the south of Kahramanmaraş, and the continental climate is not harsh in the north. Winters are warm and rainy, and summers are hot and dry. The annual average temperature is 17.2 C°, the monthly average precipitation is 750.9 mm, the lowest temperature is -9.6 C° and the highest temperature is 45.2 C°. The total forest area in the planning unit is 13.575 ha, of which 11.223 ha (83% of the total study area) is productive forest and 2.352 ha (17% of the total study area) is degraded forest. The main tree species in the study area are Calabrian pine (*Pinus brutia* Ten.), Oak (*Quercus* ssp.), and Stone pine (*Pinus pinea* L.).

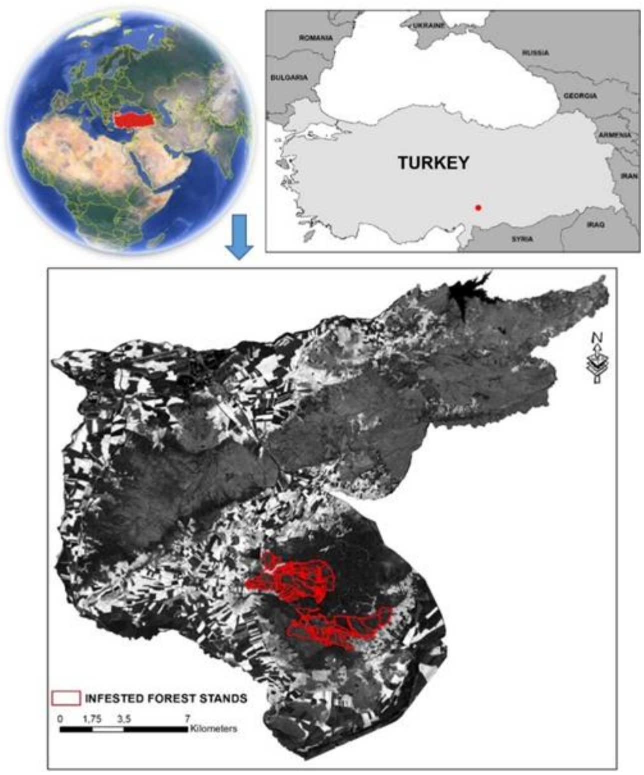

Figure 1. Study area location in Kahramanmaraş, Türkiye

In the study area, the natural outbreak was observed in 2015, followed by 2016, and 2017. Landsat images from *T. pityocampa* infested (2016) and non-infested (2022) periods were compared in Calabrian forests in Kahramanmaraş Regional Directorate of Forestry. Landsat 8 Operational Land Imager (OLI) images of two different time periods (2016 and 2022) were used to compare the (Normalized Vegetation Index) NDVI values in 2016 and 2022. These data with cloud cover less than 5% were downloaded from https://earthexplorer.usgs.gov (USGS, 2022) (Table 1). Some pre-processes were applied to make the Landsat 8 OLI satellite images to be used in the study ready for analysis. Atmospheric correction was made on Landsat 8 OLI satellite images and the digital number values of the bands (Red and NIR) to be used for NDVI were converted to reflectance values.

Table 1. The properties of Landsat 8 OLI images used in the study

Acquisition Date	Cloud cover (%)	Band Name	Central wavelength (µm)	Spatial resolution (m)
2016/04/23	0.52	Blue	0.45-0.51	
		Green	0.53-0.59	
		Red	0.64-0.67	30
		NIR	0.85-0.88	
		SWIR 1	1.57-1.65	
2022/04/16	3.29	SWIR 2	2.11-2.29	

In the study area, 70 forest stands (sub-compartments) were overlaid to satellite images of 2016 and 2022. NDVI values were estimated according to the obtained reflectance values. NDVI values for 70 selected forest stands were calculated according to the Eq. 1

$$NDVI = (NIR - RED) / (NIR + RED) \qquad (1)$$

Where NIR is the near infrared wavelength of the spectrum (0.851 – 0.879 µm), RED is the red region wavelength (0.636 – 0.673 µm), and NDVI is the vegetation index value.

Since the area of each forest stand and the number of pixels falling into these forest stands will be different, the minimum, average, maximum and total values of NDVI in each forest stands were calculated using ArcGIS 10.6. The normality of the NDVI values was performed using the Kolmogorov-Smirnov normality test. Paired sample t-test was used to statistically analyze the differences between NDVI values in infested and non-infested forest stands using SPSS software.

3. Results and Discussion

In recent studies, NDVI is a frequently used method for monitoring beetle infestation (Rullan-Silva et al. 2013). Figure 2 shows NDVI images of the study area for infested (2016) and non-infested (2022) periods that were generated to investigate the infestation by PPM in the Elmalar planning unit using Landsat 8 OLI images.

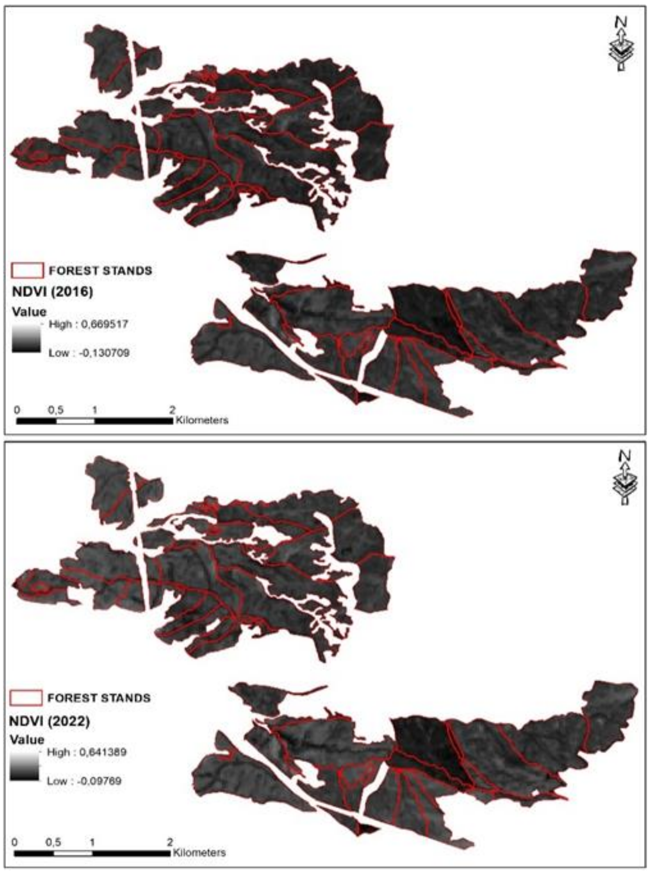

Figure 2. NDVI images in infested (2016) and non-infested (2022) periods (lighter pixels = high NDVI values, darker pixels = low NDVI values)

The minimum, average, maximum and total values of NDVI obtained from PPM infested (2016) and non-infested (2022) periods were statistically compared. All NDVI values were normally distributed according to the Kolmogorov-Smirnov test of normality. The paired sample t-test of the minimum, average, maximum and total values of NDVI results figure out that there was a statistically significant difference between all NDVI values in the years 2016 and 2022 (Table 2). Severe beetle infestation was in the study area in 2016. For this reason, the Regional Directorate of Forestry carried out successful efforts to control against beetle damage. The results also support this situation. In 2016, NDVI values are lower than in 2022 due to beetle damage.

Table 2. The result of the paired sample t-test for the minimum, average, maximum and total values of NDVI

Years	Mean	N	Std. Dev.	t	P
2016 Min.	0.071	70	0.019	-11.370	0.000
2022 Min.	0.086	70	0.025		
2016 Ave.	0.112	70	0.019	-25.154	0.000
2022 Ave.	0.139	70	0.024		
2016 Max	0.173	70	0.050	-8.417	0.000
2022 Max	0.210	70	0.055		
2016 Total	21.380	70	23.658	-7.761	0.000
2022 Total	26.612	70	29.054		

NDVI values were significantly reduced in the year of infestation due to the reduction in NIR band value (Junttila et al. 2015; Rock et al. 1988). De Beurs and Townsend (2008) used the NDVI and EVI indices in MODIS satellite images to determine the damage caused by *Lymantria dispar* (L.) (Lepidoptera: Erebidae) on deciduous trees in the central Appalachian region of the USA. NDVI decreases at the beginning of epidemic beetle infestation, according to research on oak mortality in California using high-resolution images (Kelly 2002). Townsend et al. (2012) successfully classified and mapped defoliation severity using NDIIb5 together with a logistic regression model in Landsat TM. Spruce et al. (2011) stated that NDVI is better at distinguishing moderate damage from low damage in a deciduous forest. NDVI has a strong positive linear correlation between 25% and 80% vegetation cover in forest ecosystems (Zhang et al. 2010).

4. Conclusion

Landsat satellite images with medium spatial resolution can be used to assess the damage caused by PPM outbreaks, identify and analyze their ecological impact. Our results are consistent with similar studies. Gooshbor et al. 2016 stated that NDVI values for 2002 (before infestation), and 2007 and 2014 (after infestation) showed a statistically significant decrease in oak forest infested by oak leaf roller.

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