

Monitoring the Epidemic of Bark Beetles Determined in Uludag Fir Stands in Ilgaz (Derbent and Doruk) Via Landsat Satellite Images

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Abstract

Results of the studies carried out in Ilgaz (Derbent and Doruk) in 1999-2000 showed that *Cryphalus piceae* (Ratz.), *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig), *Ips (Pityokteines) curvidens* (Germ.), *Tryphodendron lineatus* (Oliver) (Scolytidae), *Pissodes piceae* (Illig.) (Curculionidae) were important insect species where the Uludag fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) is the dominant tree species at altitudes between 1,700 and 2,000 m, mostly on north and northwest aspects, stand closures between 80 and 100%, slopes between 35 and 100%, at ages between 50-120, and dbh between 20 and 70 cm. It was also another result that those bark beetles were higher in pure fir stands and they preferred fir trees where Scots pine (*Pinus sylvestris* L.) and Anatolian black pine (*Pinus nigra* Arnold. subsp. *pallasiana* var. *caramanica*) exist in the stand composition. It was determined that *Ips (Pityokteines) curvidens* and *Cryphalus piceae* in fir stands, and *Ips sexdentatus* (Boerner) in Scots pine and Anatolian black pine stands have been increasing during last years.

In this study, Landsat images (of August 1, 1998; July 13, 2000 and August 15, 2009) were used and both geometrical and atmospherically corrections were applied to these images. Epidemic of the bark beetles was observed via the spatial and temporal variation via the NDVI data of the geometrically and atmospherically corrected images.

It was concluded that certain openings have been occurred between 1998 and 2000 due to windfalls and snow breaks. This condition has been proven via satellite images. It could be concluded that fir stands show improvement in observations whereas the population densities of certain bark beetle species (*I. curvidens*, *C. piceae* and *I. sexdentatus*) are increasing in the last years according to the insects caught in pheromone traps.

Keywords: Ilgaz, Bark beetles, NDVI, Landsat, Uludag fir

Introduction

Protecting the health of forest ecosystems is a vital resource management function. An effective forest health protection program requires many kinds of information; information is needed about the condition of forests with respect to growth rates, levels of stocking, fuels, diversity and age. Information is also needed on the status of insects, diseases, and other damaging agents that can adversely affect the ability of forests to produce the goods and services for which they are managed and on the ecological, social, and economic consequences of those agents (Anonymus, 2000).

Firs (*Abies* spp.) grow on shady and humid conditions and may become a pure stand with a single-layered canopy in case Scots pine (*Pinus sylvestris* L.) and Anatolian Black pine (*Pinus nigra* Arnold. subsp. *pallasiana* var. *caramanica*) is removed from the stand (Şimşek, 2003; Şimşek and Öner, 2003). Therefore, bark beetle outbreaks may become possible due to the suitable ecological conditions for these insects. Natural events (windfalls, snow breaks, diseases, etc.) may cause forest to become suitable for insect pests. It is reasonable for firs

to encounter certain harmful agents such as insects due to their longer life span than the broadleaved species. It is observed that these conditions emerged in Ilgaz mountains and fir has become a dominant tree species (Şimşek and Öner, 2003).

Studies carried out between 1999 and 2000 showed that the most common and harmful insect species in fir stands have been *Cryphalus piceae* (Ratz.), *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.), *Pityogenes quadridens* (Hartig), *Ips (Pityokteines) curvidens* (Germ.), *Tryphodendron lineatus* (Oliver) (Scolytidae), *Pissodes piceae* (Illig.) (Curculionidae). These bark beetle species were mostly common in fir stands, they prefer firs when mixed with Scots pine, however they do not exist in pure Scots pine stands (Şimşek and Öner, 2003).

It is understood that aerial imaging systems were commonly used in order to determine insect infestations in agriculture, forests and wildlife areas in various countries. These systems provide faster data acquiring and cost less than ground surveys (Everitt et al., 1998).

Mapping and assessment of damage caused by foliage feeding insects is one of the most widely used applications of remote sensing in forest health protection. Both conifers and broadleaved trees are subject to periodic outbreaks of defoliating insects, which appears as a red-brown or gray discoloration of the forest canopy (Anonymous, 2000).

After 80's, many studies have utilized aerial photography (Everitt et al., 1998; Goodwin et al., 2008), however, it is known that satellite images give more accurate results than aerial photographs (Goodwin et al., 2008). It is understood that certain bark beetle species could be monitored via remote sensing data (Renez and Nemeth, 1985; Murtha and Wiart, 1989; Everitt et al., 1998; Cook et al., 2007; Goodwin et al., 2008). Also, recent studies carried out in Turkey show that satellite images could be utilized in order to monitor *Leptoglossus occidentalis* (Heidemann) (Hemiptera: Coreidae), *Monochamus galloprovincialis* Olivier (Coleoptera: Cerambycidae), *Ips sexdentatus* (Boerner) (Coleoptera: Curculionidae) (İnan and Hızal, 2011) and *Dichelia cedricola* (Diakonoff) (Lepidoptera: Tortricidae) (Çoban et al., 2011).

This study is carried out in order to research the bark beetle outbreak progress in Ilgaz via satellite images which is rather newly used in Turkey to determine forest pests' damage.

Materials and Methods

The main material in this study were Uludag fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) trees which were infected with bark beetles; Landsat satellite images, stereo microscope, icebox, altimeter, magnifying glass were used as the other materials.

The study area is inside the boundaries of Ilgaz (Doruk and Derbent) forests of Çankırı province, and the study was carried out between 1999 and 2000. The location of the study area is shown at Figure 1.

In the field studies, three bark-beetle-infected fir trees have been chosen. Studies were carried out according to the previous method (Şimşek, 2002) on the bark samples that have been taken from 0.5-2.0 m height with a 300 cm² bark area. Also, a sticky trap has been attached to one fir tree. Thus the adult flight has been monitored. Chosen fir tree was covered with 1 m² sticky trap layers in each direction. Captured insects on sticky traps were removed from the trap while recording insect and capture direction.



Figure 1. Location of the study area on satellite image (Google Earth)

Branch samples 25 cm in length were cut from previously chosen trees and carried in icebox to laboratory. Branch barks were removed with a knife in a circular shape. Young and old adult bark beetles were removed with a needle and all beetles were recorded. All counts were completed on a total 300 cm² area of 3 branches. Counts have been carried out twice a week and completed in the same day.

The Landsat ETM+ satellites (Enhanced Thematic Mapper) provide spectral bands 1-8 ranging from visible to infrared wave lengths. The Landsat channels 3 (red) and 4 (near infrared) can be used to compute the so-called NDVI (the Normalized Difference Vegetation Index). Living vegetation absorbs light in the frequency range of band 3 but shows almost no absorption in the range of band 4. So from the intensity difference of the two bands, the activity of vegetation (NDVI) could easily be measured (Roettger, 2007).

The NDVI values increase as green cover density in forestry (Lo, 1997) and is calculated by using red and near infrared reflection values (Jiang et al., 2008; Myeong et al., 2006; Fung and Siu, 2000) a wide-range used in vegetation cover indices (Coops et al., 2008; Jung et al., 2005). NDVI is a reliable ecological indicator to successfully monitor temporal and spatial variation in forestry density as well as the health and viability of plant cover (Jiang et al., 2008; Weng et al., 2004; Wang et al., 2001; Fung et al., 2000).

Landsat TM and ETM images (August 1, 1998; July 13, 2000 and August 15, 2009) were used in this study in order to monitor the bark beetle damage. After atmospheric and geometric corrections, the Normalized Difference Vegetation Index (NDVI) formula was applied to the images. Erdas 9.1 was used to for NDVI processing.

In all three NDVI maps, green colored areas show the healthy vegetation (lesser bark beetle damage), and red colored areas show non-healthy vegetation (intense bark beetle damage).

Results and Discussion

After the studies carried out between 1999 and 2000 in Ilgaz (Derbent and Doruk); *Cryphalus piceae* (Ratz.), *Ips acuminatus* (Gyll.), *Orthotomicus erosus* (Woll.),

Pityogenes quadridens (Hartig), *Ips (Pityokteines) curvidens* (Germ.), *Tryphodendron lineatus* (Oliver) (Scolytidae), *Pissodes piceae* (Illig.) (Curculionidae) were the most important insect species where the Uludag fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) is the dominant tree species at altitudes between 1,700 and 2,000 m, mostly on north and northwest aspects, stand closures between 80 and 100%, slopes between 35 and 100%, ages between 50 and 120, and at dbh between 20 and 70 cm. These findings show that the damage of the bark beetles reach its peak level on older trees on higher slopes. Another result was that the bark beetle population was higher in pure fir stands and they preferred fir trees where Scots pine (*Pinus sylvestris* L.) and Anatolian black pine (*Pinus nigra* Arnold. subsp. *pallasiana* var. *caramanica*) exist in the stand composition.

Similar studies carried out in the latter years (2003-2005) at the same area show that the density of *C. piceae* was very low.

The NDVI data maps derived from the Landsat satellite images (1998, 2000, and 2009) for monitoring the bark beetle activity (mainly for *C. piceae*, a major fir pest) related to the outbreak between 1999 and 2000 are shown in Figure 2.

According to this figure, the NDVI data map of the study area in 1998 (Figure 2a) looks mostly in green color meaning that the fir stands consist of mostly healthy trees. However, fir trees were in a weaker state than in 1998 due to the outbreak of bark beetles, mainly *C. piceae* in the NDVI data map of the study area in 2000 (Figure 2b). When in 2009, the NDVI data map shows fir stands in a much better vigorous state (Figure 2c).

If the results of this study are evaluated together with the NDVI data maps, it could be concluded that fir stands in the study area were healthy in 1998; the effects of the outbreak of *C. piceae* between 1999 and 2000 is clearly visible in the NDVI data map of the study area in 2000, and the fir stands achieved almost the same state in 1998 until 2009.

However, it was determined that *I. curvidens* and *C. piceae* in fir stands, and *Ips sexdentatus* (Boerner) in Scots pine and Anatolian black pine stands have been increasing during previous years (Unpublished data, Ilgaz Forest Service).

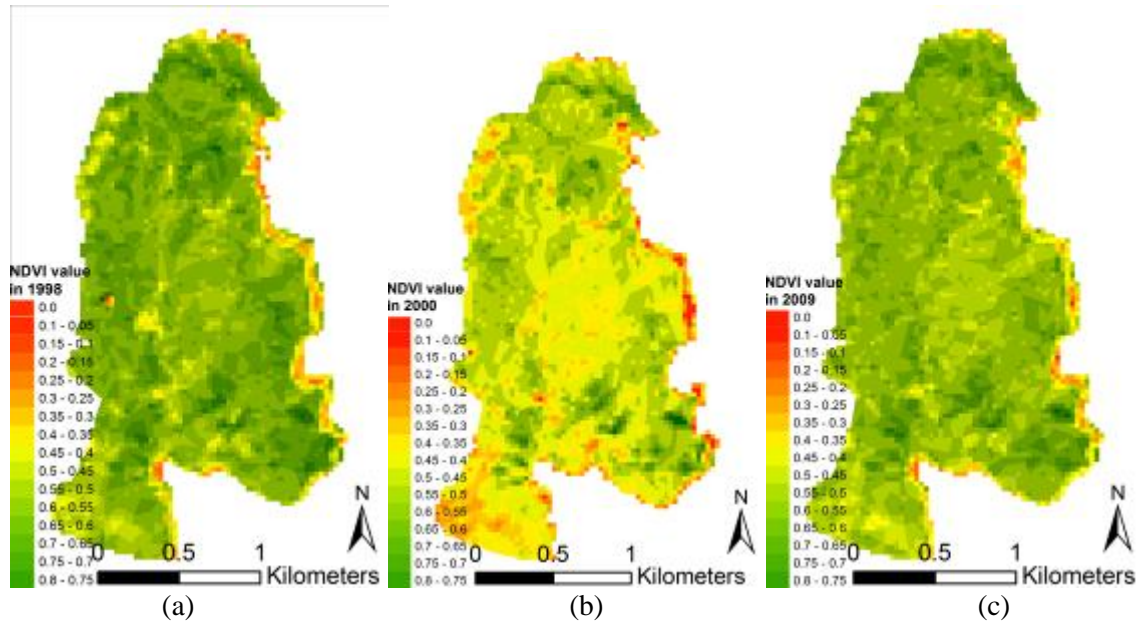


Figure 2. NDVI data maps of the study area derived from Landsat images of 1998 (a), 2000 (b) and 2009 (c)

Consequently, it was determined that the progress of bark beetles (mainly *C. piceae*, and *I. acuminatus*, *O. erosus*, *P. quadridens*, *I. curvidens*, *T. lineatus*, *P. piceae*) which are harmful in fir stands could easily be monitored via satellite images. When NDVI data maps show any outbreak signs, ground surveys and samplings may help determination of the damaging insect species. Besides, NDVI maps can help for determination of new insect outbreaks at the beginning, especially in hard-to-reach areas. Thus, it could be possible to take preventive measures in time. It is also understood that utilization of satellite imaging systems which are rather new in Turkey may help prediction and early warning for many insect pests.

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