AERIAL HIGH RESOLUTION IMAGING OF THE MISTLETOE FOR THE ASSESSMENT OF FOREST DECLINE IN FIR STANDS

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ABSTRACT:

Silver fir (*Abies alba* Mill.) is the most widely distributed and the most important commercial conifer species in Croatia. The growing stock of silver fir accounts for about 65% of the total conifer growing stock in Croatia. However, silver fir is also the most endangered tree species in these regions. The results of field research show a significant presence of mistletoe (*Viscum album* L. ssp. *abietis* (Wiesb.) Abrom.) on silver firs in Croatia. The current work deals with the issue of mistletoe detection. The purpose of preliminary research was to develop an efficient method of mistletoe detection. Ground-based tests, performed in May 2004 on mistletoe and silver fir, were aimed at formulating a method that will be implemented in the aerial acquisition system. A high-resolution digital camera MS-3100 (four 8 bit channels in VNIR wavelengths, 1392x1039 pixels) and a hyper spectral line scanner V9 (up to 90 channels in VNIR wavelengths) were used with the acquisition systems. The expectation that mistletoe can successfully be detected with a high-resolution digital VNIR camera MS3100 was confirmed by preliminary results.

1. INTRODUCTION

No systematic research into mistletoe based on remote sensing methods has been conducted in Croatia so far. This also refers to mistletoe infesting the silver fir. Silver fir is the most endangered tree species in Croatia. It is distributed in Gorski Kotar and the Dinaric mountain range, as well as in the mountainous regions between the rivers Sava and Drava (Vukelić & Baričević 2001). The decline of forests of silver fir is a serious and current commercial and ecological problem (Prpić et al. 2001). In natural stands of silver fir in the area managed by Hrvatske Šume, the results of field research indicate abundant presence of mistletoe on the silver fir. According to the research, one third of all the inspected trees in Gorski Kotar are infested (Idžojtić et al. 2003). Mistletoe largely infests physiologically weakened trees, where it spreads in large quantities and additionally exhausts the host with its irrational water consumption (Fisher 1983, Lamont 1983, Ehleringer et al. 1986). In a combination with strong attacks of secondary pests and diseases, it exacerbates tree vitality and accelerates dieback. Research has shown that an increase in the intensity of mistletoe infestation in an area leads to its expansion to more vital and less damaged trees of silver fir. These trees may be expected to reach a higher damage status in the near future. Mistletoe-infested fir trees do not display any visible external signs (defoliaton and a change in the needle color); however, as the infested trees are already physiologically weakened and predisposed for accelerated decline, they should have a cutting priority in commercial forests, while their timber still retains its commercial value (harvesting the severely damaged and dry trees causes high economic losses due to the lower value of such trees).

A possible method of detecting the decline of fir forests involves the use of mistletoe as a bioindicator of the decline (Idžojtić et al. 2003). However, mistletoe cannot be detected with small-scale color infrared aerial photographs (1:5000 to 1:7000), (available for operational use in Croatia since 1988) (Kalafadžić et al. 1994), due to their coarse spatial resolution. A feasible solution entails the application of a simpler aerial acquisition method, based on a digital high-resolution camera working in the visible and near infrared wavelengths (VNIR) (Bajić 2003). The analysis of spectroradiometer measurements of forest trees (Koch et al. 1999) showed that the influence of leaf parameters on the reflection spectra are minor compared to the external parameters of the natural biosphere, like illumination, shadow and background. The airborne hyper spectral measuring of reflectivity is possible in Croatia with the available equipment (Bajić et al. 2004), but in the current analysis it was used only as a source of additional information. The results of pilot tests performed on the ground confirmed the possibility of detecting mistletoe in high-resolution digital images in VNIR wavelengths. Consequently, aerial imaging of the mistletoe will be the next activity.

2. AIM OF RESEARCH

The aim of preliminary research was to develop an efficient method of mistletoe detection. Detection of mistletoe on the fir should be so reliable that the correlation between mistletoe occurrence and tree damage (health status) can be established. The visibility of mistletoe in the VNIR high-resolution images was confirmed, which allows for further research into fir decline.

3. METHODS OF WORK

Ground-based tests, performed on mistletoe and silver fir in May 2004, were aimed at finding a method to be implemented in the aerial acquisition system. In order to enable ground imaging that simulates aerial imaging, a mistletoe-infested fir tree was felled (10-15 bushes in the crown). Research dynamics was as follows: 8.30 – felling of the fir, 9.05 – beginning of hyper spectral imaging, 9.20 – beginning of imaging. The

acquisition of VNIR images was performed with the following system:

1) Digital high-resolution camera MS-3100, four channels in the wavelength range from 430 to 900 nm (NIR - near infrared, R - red, G - green, B - blue), computer controllable acquisition and control of imaging angles.
2) Hyper spectral line scanner V9, possible measurement of reflectivity from 430 to 900 nm in 99 channels; with separate computerized acquisition.
3) Sensor FODIS for the measurement of solar irradiance.

The felled mistletoe-infested fir and the distant firs with mistletoe were recorded with a digital camera MS-3100. Immediately upon felling, one mistletoe bush was separated from the fir and hyper spectral reflectivity was measured with FODIS and V9 (Fig. 1).

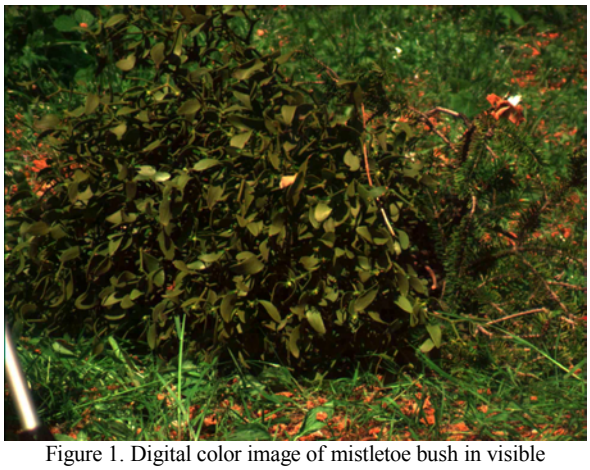

Figure 1. Digital color image of mistletoe bush in visible wavelenghts

Mistletoe reflectivity was sampled during 3h 40 min. Solar irradiance was also measured with FODIS and V9 and was found to be very changeable.

4. RESULTS AND DISCUSSION

Pilot recordings of the mistletoe-infested felled fir and the mistletoe itself provided a set of digital VNIR images in the infrared (700 – 900 nm) and visible wave bands (430-500, 500-600 and 600-700 nm), which allows for the application of objective interpretation methods aimed at detecting mistletoe both on the felled (Fig 2) and on adjacent firs (Fig. 3).

Figure 2. Digital black and white IR image of mistletoe-infested felled fir

Figure 3. Digital CIR image of mistletoe on distant fir

The measured spectrum of mistletoe reflections was read in the lines from 100 to 400 (Fig. 4).

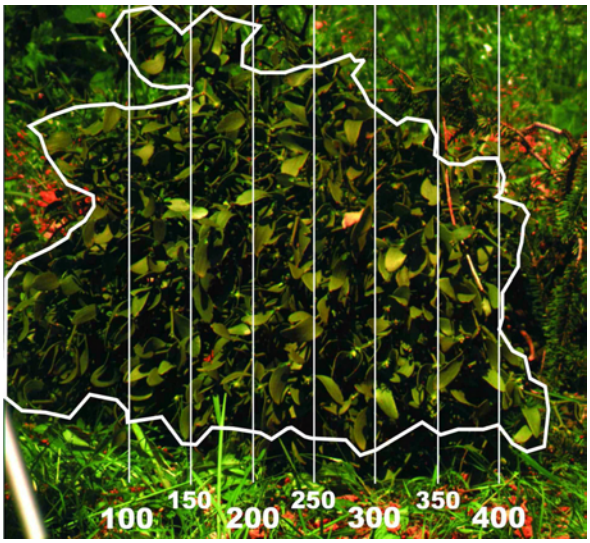

Figure 4. The measured spectrum of mistletoe reflections in the lines from 100 to 400

The examples of measurement results are shown in Figure 5 and 6.

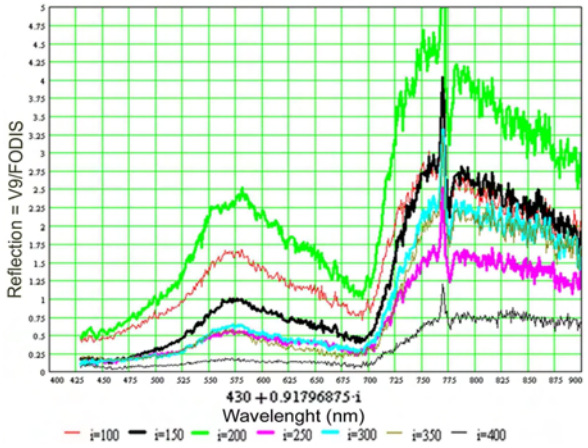

Figure 5. Reflection in 08.01 h

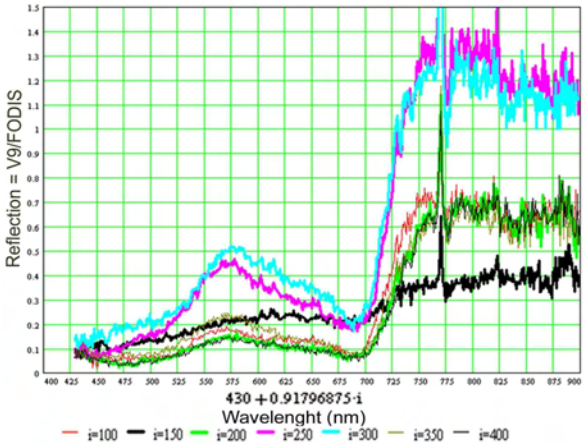

Figure 6. Reflection in 11.40 h

Insolation was highly changeable during the imaging in the period from 08.01 to 11.40 h. It changed unpredictably and very rapidly. The minimal recorded insolation was at 10.31 h (green) and the maximal at 09.59 h (blue), when the FODIS sensor was saturated (Fig. 7).

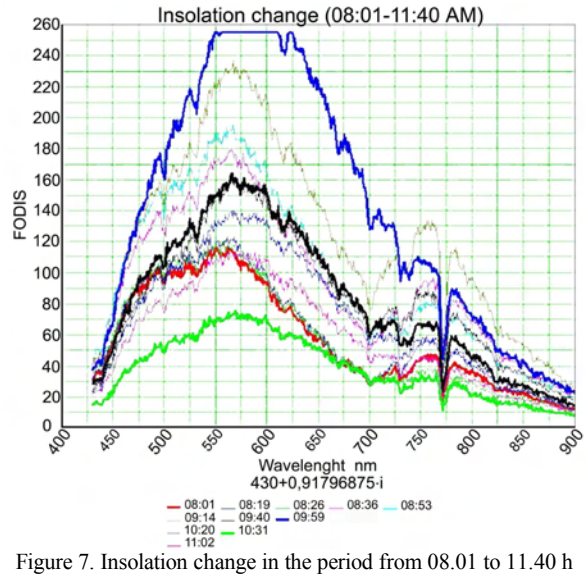

Figure 7. Insolation change in the period from 08.01 to 11.40 h

It was caused by the shifting of the shadows of the nearby hill and the high trees as the Sun rose and by rapidly changing cloudiness.

5. CONCLUSION

- Preliminary results confirm the expectation that mistletoe can be successfully detected with a high-resolution digital VNIR camera MS3100.
- The hyper spectral mistletoe analysis provided the first images of mistletoe reflection spectrum.
- Insolation measurement showed that stable, monotonous and slowly changing insolation should be ensured in the future.
- The benefits of using digital sensors and computerized acquisition were recognized. Data are available during the aerial mission and their integrity and quality can be checked. Aerial acquisition can be repeated if necessary.
- Aerial imaging of mistletoe in fir forests using a high-resolution digital camera in the VNIR wavelengths will be applied in further research.

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