# ESTIMATION OF VEGETATION PARAMETERS FROM POLARIMETRIC SAR DATA

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**Commission VI, WG VI/4**

KEY WORDS: LAI, optical transmission coefficient, radar backscatter, radar extinction coefficient.

**ABSTRACT**

This work presents the analysis of the capability to use the radar backscatter coefficient in semi-arid zones to estimate the vegetation crown in terms of Leaf Area Index (LAI). The research area is characterized by the presence of a pine forest with shrubs as an underlying vegetation layer (understory), olive trees, natural grove areas and eucalyptus trees. The research area was imaged by an airborne RADAR system in L-band during February 2009. The imagery included multi- parameter radar images. All the images were fully polarized i.e., HH, VV, HV polarizations. We measured LAI using the ΔT Sun Scan Canopy Analysis System. Verification was done by analytic calculations and digital methods for the leaf's and needle's surface area. In addition, we estimated the radar extinction coefficient of the vegetation volume by comparing point calibration targets (trihedral corner reflectors with 150cm side length) within and without the canopy. The radar extinction in co- polarized images was ~27dB and ~24dB for pines and olives respectively, compared to the same calibration target outside the vegetation. The variability among corner reflectors in the open was +/- 3dB.

We used smaller trihedral corner reflectors (41cm side length) and covered them with vegetation to measure the correlation between vegetation density, LAI and radar backscatter coefficient for pines and olives under known conditions.

Reversed correlation between the radar backscatter coefficient of the trihedral corner reflectors covered by olive branches and the LAI of those branches was observed.

The correlation between LAI and the optical transmittance was derived using the Beer-Lambert law. In addition, comparing this law's principle to the principle of the radar backscatter coefficient production, we developed a model associating the radar backscatter coefficient with the LAI.

## 1. INTRODUCTION

Remote Sensing provides the ability to map large areas and extract bio- and geo-data quantitatively. In this research we use radar systems, which present a small part of the electromagnetic spectrum, for estimation of the vegetation parameters including the Leaf Area Index (LAI) in semi- arid and Mediterranean climates.

Radar penetration into the vegetation layer is deeper than that of optical sensors, which is an advantage of SAR systems in vegetation structure data extraction (Leeuwen et al., 1994). The use of the radar in the estimation of vegetation parameters (and LAI amongst them) is based on the fact that scattering and attenuation of the radar radiation by the vegetation medium is a function of radar frequency; hence, the radar wavelength is an important parameter.

LAI is defined as an index that quantifies the leaf area per ground area. The index takes into account the crown layer and provides information about the physical area of the leaves compared to the effective projected area on the ground.

Remote Sensing is the only alternative to estimate LAI at regional and global scales (Clevers and Leeuwen, 1996). The fraction of the radiation that penetrates the canopy is described by the optical transmittance coefficient (τ). The radiation that is absorbed by the canopy is defined by (1- τ), and the radiation that continues to the ground canopy is defined by τ. Campbell and Norman, (1998) describes this coefficient by

$$\tau = \exp(-KL_e) \quad \textbf{(1)}$$

where

K- the extinction coefficient of the canopy
L- LAI effective

The extinction depends on the leaves angular distribution in the canopy space and on the incident angle of the radiation:

$$K = \frac{\sqrt{x^2 + \tan^2\theta}}{x + 1.774(x + 1.182)^{-0.733}} \quad \textbf{(2)}$$

where

θ- incidence angle of the radiation
x- the ratio of the vertical to horizontal projections of the canopy volume (Campbell, 1986).

## 1.1 RESEARCH OBJECTIVES

The objective of this study is to estimate the Leaf Area Index of a forested area from polarimetric SAR data and to calculate the radar extinction coefficient in the forested area.

## 2. RESEARCH METHODS

During February 2009, the research area was imaged by polarimetric airborne radar system in L-band. We used 150cm side length trihedral corner reflectors for the calibration of the radar images and smaller ones (41 cm side length) for the LAI measurements and extinction coefficient calculations. During the imaging, these reflectors were covered by clusters of pine and olives branches in 7 different density levels each, from sparse to very dense.

According to Campbell, (1986), the extinction coefficients of pines and olives were calculated by measuring the vertical to horizontal ratio of the illuminated crown area of the representative tree/ branch (figure 1), and then using this parameter in equation (2).

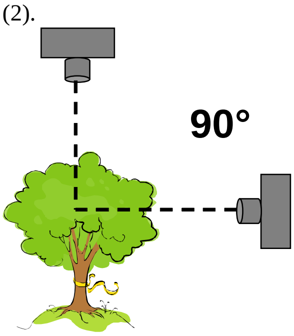


**Figure 1.** A visual presentation of the vertical to horizontal ratio of illuminated crown area of a representative tree.

In this research, we estimated the olive and pine clusters from a vertical to horizontal imaging point and classified each image based on a segmentation technique implemented in eCognition (using Definiens Developer 7.0 software). We then calculated the ratio between the vertical and horizontal area of the leaves and branches to assess the x- parameter for olives and pines which were used for the extinction coefficient's calculations.

## 3. RESEARCH RESULTS

To understand the relationship between LAI and the attenuation of the radar signal trihedral corner reflectors were used located in the forested area and in the open. The backscatter from these reflectors located in the vegetated area was lower than that from reflectors which were located in the open. The explanation for this is that the vegetation, because of its geometry, density and space distribution of the crown elements, causes the higher backscatter than that from the ground, but compared to the trihedral corner reflectors it reduces the backscattered signal. Therefore, in the cases where trihedral corner reflectors were covered by vegetation there is attenuation but also scattering caused by the vegetation elements (figure 2).

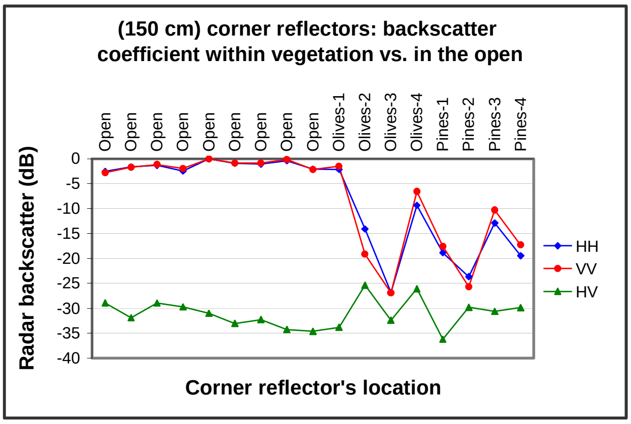


**Figure 2.** An attenuated backscatter from trihedral corner reflectors located in the vegetated area compare to high backscatter of those located in the open.

As is seen in figure 2, the co- polarized backscatter from the reflectors that were located in the open is about 0 dB. On the other hand, covered reflectors show attenuation depending on crown thickness, its density, geometry of the vegetation and radar wavelength. Nonetheless, for the reflectors which were located in apparently the same cover conditions in pines and olives, different backscatter values were obtained. The difference between backscatter values of the reflectors in the olives orchard is a result of proximity to the borderline between the orchard and the open field. The backscatter from the reflectors which were located far from the open field (Olive-2, Olive-3) were attenuated by 27 dB compared to those located close to the open field (Olive-1, Olive-4) that were attenuated only by 2-7 dB. The backscatter of the reflectors in the forested area (pines cover), located below the dense cover (Pine-1, Pine-4), were attenuated by 17 dB compare to those in the open. The difference between the backscatter of the reflectors Pine-2, Pine-3 was significant (15 dB). Field measurements showed that there trunks in front of one of the reflectors (Pine-3), probably causes an increase in the backscattered signal because of double bounce. Pine-2 was covered by a very dense crown and was attenuated by 25 dB.

In order to give an additional explanation for the difference between radar backscatter from covered corner reflectors, we related the cover parameters to LAI and by this to optical transmittance for the 41 cm side length reflectors which were covered by clusters of branches during the radar imaging. After extracting the optical transmittance coefficient, the next step was to express it as a function of the radar backscatter coefficient for those covered reflectors. However, we should remember the difference between two coefficients. When the optical (Sun) energy incidences the canopy, the fraction of the energy that penetrates the crown medium and reaches the ground, is defined by optical transmission coefficient $\tau$. This coefficient depends on LAI and the extinction coefficient of this canopy (equation 1). When the radar penetrates the canopy, similar process occurs, however radar receives the backscattered energy after it crossed the vegetation medium twice: ones from the sensor to the ground, and on the way back from the ground to the sensor, again through the vegetation medium. If we express the radar backscattered energy, which penetrates the vegetation layer twice, in terms of optical transmittance coefficient, $\tau^2$ will be accepted. Figure 3 shows the results of the expression of the optical transmittance coefficient of olives as a function of the radar backscatter coefficient received from the reflectors covered by clusters of olive branches.

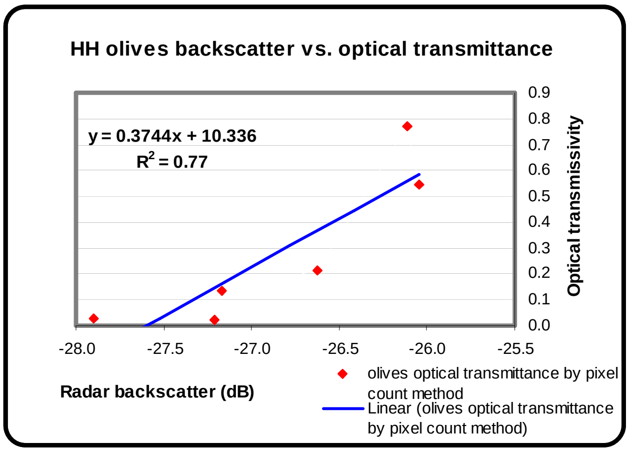


**Figure 3.** The optical transmittance coefficient of olives as a function of the radar backscatter coefficient received from the reflectors covered by clusters of olive branches.

From figure 3, there is a strong association ($R^2$=0.77) between the optical transmittance coefficient and the radar backscatter coefficient received from the reflectors covered by clusters of olive branches. As the optical transmittance coefficient increases, the radar backscatter coefficient increases also.

Because there is an inverse relationship between LAI and optical transmittance coefficient (figure 4), an inverse relationship between radar backscatter coefficient of covered reflectors and LAI of clusters of covering branches is expected.

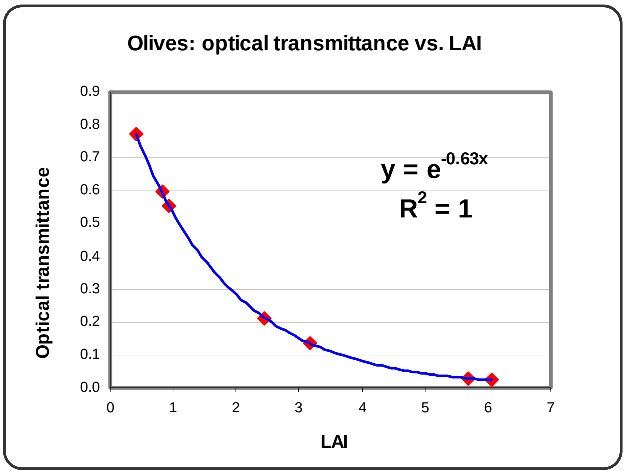


**Figure 4.** An opposite relationship between LAI and optical transmittance coefficient.

In order to define empirical coefficients for the relationship between LAI and the radar backscatter coefficient, we used the equation of the optical transmittance coefficient obtained from LAI (figure 4) and the radar backscatter coefficient (figure 3). The calculation process is as follows.

$$\tau = e^{-0.63*LAI}$$

$$\tau = 0.3744*\sigma^{\circ}_{\substack{\text{covered}\\\text{reflector}}} + 10.336$$

$$0.3744*\sigma^{\circ}_{\substack{\text{covered}\\\text{reflector}}} + 10.336 = e^{-0.63*LAI}$$

$$\sigma^{\circ}_{\substack{\text{covered}\\\text{reflector}}} = \frac{e^{-0.63*LAI} - 10.336}{0.3744}$$

## 4. DISCUSSION AND CONCLUSIONS

This research deals with the estimation of the correlation between the vegetation parameters such as LAI and the optical transmittance coefficient, and the radar extinction coefficient in a forest crown. We quantified the backscatter received from the vegetation layer and compared it with the backscatter from the ground and from reflectors underneath vegetation. We extracted the correlation between LAI and the radar backscatter coefficient. Our future work will investigate the physics of the two processes that occur when the illuminates the vegetation layer: (1) transmittance of the signal through the canopy to the reflector wile attenuating the backscatter from the reflector; (2) backscatter from the vegetation layer (volume scattering and increasing of the received signal).

## 5. REFERENCES

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## 6. ANKNOWLEGMENTS

We would like to greatly thank Dr. Ruth Rotman, Dr. Ori Oron and Dr. Shaul Shalem for all their time and effort.