

# The Role of Spatial Resolution in Vegetation Studies by Hyperspectral Airborne Images

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## ABSTRACT

In this paper we present a study carried out by MIVIS airborne hyperspectral data in an forest area, to evaluate as different spatial resolution can affect the vegetation spectral response and can discriminate among different vegetation communities. Images acquired at two flight altitudes in the same day, were processed and analysed. Field reflectance data were acquired to transform remote data into reflectance and to verify the accuracy of remote data at different scales. Classification were performed by two different techniques: *Maximum Likelihood* and *Spectral Angle Mapper*. Comparison were performed between classification data at different altitudes.

## Introduction

In several studies on vegetation based on remote sensing images it has been demonstrated that the choice of spatial resolution is a critical issue, particularly in highly fragmented areas. In Italy in particular, heterogeneity of the territory is quite diffused and mixed forest often occur, thus suggesting the use of hyperspectral, high resolution sensor data to provide accurate analysis in vegetated regions. However, it is known that environmental or urban growth management can be performed at different spatial scales, and therefore a single spatial resolution can not satisfy different applications [Song and Woodcock, 2002].

About the ability of discriminating among single objects in a scene depends on the spatial pattern of the elements (which is an important characteristic of ecological relationships between individuals) and on their relationship [Turner et al., 1989]. Recent studies indicate that the spatial pattern of trees within a scene can have a strong effect on canopy reflectance [Coops and Culvenor, 2000].

The purpose of this study is to evaluate the effects of the different spatial resolution of MIVIS images on the spectral response and on the discrimination of environmental targets in an area characterised by high naturality and high fragmentation degree. Two MIVIS images were acquired at different altitudes, 2000 m and 5000 m, and classified using two different techniques: *Maximum Likelihood* (ML) and *Spectral Angle Mapper* (SAM) algorithms.

In this study, the term “landscape unit” describes a surface characterised by complex mixtures of vegetation and/or soil, or even a surface consisting of different plant associations. Each association has a distinctive faithful species and a group of high-presence or constant species which gives the community a cohesive structure [Pignatti, 1995].

The spatial heterogeneity of landscape units was described by means of physiognomic-structural relevés of vegetation carried out during field surveys.

## Study area

The study area is located in Central Italy, in the Natural Reserve of Vico Lake (Figure 1), about 60 km north of Rome; this region is a volcanic area characterised by three different ecosystems: lacustrine, forestal and agricultural. The principal habitats around the lake (500 m a.s.l.) are reed-bed communities (*Phragmites australis*), natural meadows, and *Corylus avellana* cultivations. At 600 m a.s.l., *Castanea sativa* woods and deciduous broad-leaved forests with *Quercus cerris* and

*Fagus sylvatica* become predominant. In the natural communities, canopy is characterised by different coverage degrees and different distribution and abundance of deciduous species.

### Remote sensing data and image processing techniques

In this study two hyperspectral MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) images acquired on September 22<sup>nd</sup>, 2000 at 11:22 a.m. (5000 m) and at 12.11 a.m (2000 m) were processed and analysed. Image pixel resolutions are respectively 10m/pixel and 4m/pixel. MIVIS is a modular hyperspectral imaging system that collects the reflected solar radiation into 102 spectral channels: 20 channels in the VIS-NIR wavelength range (0.43-0.83  $\mu\text{m}$ ), 8 channels in the near-infrared (1.15-155  $\mu\text{m}$ ), 64 channels in the mid-infrared (1.98-2.47  $\mu\text{m}$ ) and 10 in the thermal infrared (8.18-12.7  $\mu\text{m}$ ).

During MIVIS overflight, a radiometric field survey was carried out in order to radiometrically calibrate airborne images. Field data were collected by a FieldSpec FR portable spectrometer that operates in the 350-2500 nm wavelength interval. MIVIS images were calibrated into reflectance using the empirical-line method [Moran et al., 2001].

In order to prevent smoothing of pixel value during resampling procedures, no geometric correction of the images were carried out. Furthermore, because of the low S/N ratio in the infrared channels, only the images related to the first spectrometer and to channel 28 (1.525  $\mu\text{m}$ ) were processed.

The *Spectral Angle Mapper* classification method [Yahas et al., 1992] was applied to MIVIS reflectance data by making use of spectral endmembers derived automatically from the image itself, to test the ability of unsupervised classification to detect all landscape units. To identify image-derived endmember, *Minimum Noise Factor* (MNF) and *Pixel Purity Index* (PPI) algorithms [Green et al., 1988; Boardman and Huntington, 1997] were performed on the MIVIS data sets; these spectra were associated to specific landscape units as listed in Table 1 and used to perform the *Spectral Angle Mapper* classification.

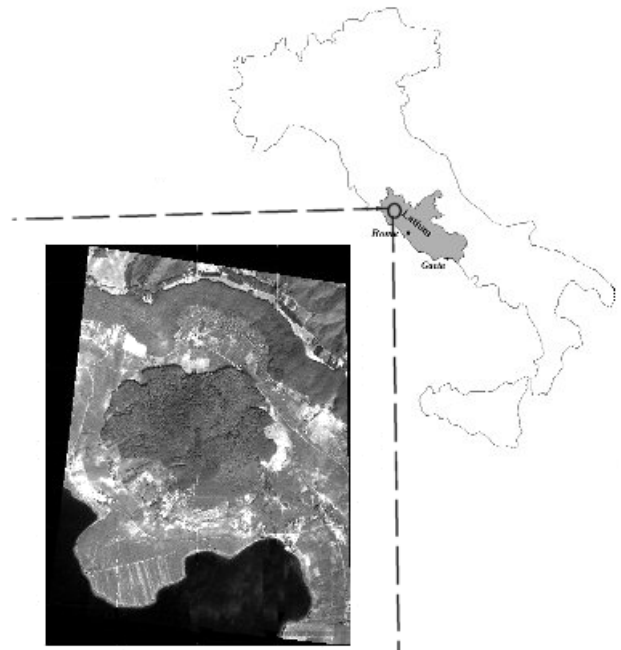


Figure 1. Location of the study area: MIVIS image of the northern area of Vico Lake.

**Table 1. Landscape units description**

Landscape units	Description	Spectral classes
Forest vegetation	<i>Fagus sylvatica</i> wood with a different coverage degree	<i>Fagus sylvatica</i> wood (coverage $\geq$ 80%) <i>Fagus sylvatica</i> wood (coverage 60- 70%)
	<i>Castanea sativa</i> wood	<i>Castanea sativa</i> wood
	<i>Quercus cerris</i> wood with a different coverage degree	<i>Quercus cerris</i> wood (coverage $\geq$ 80%) <i>Quercus cerris</i> wood (coverage 60- 70%)
Erbaceous vegetation	Meadows and open areas to recent coppice-with-standards	Meadows Recent coppice
Agricultural area	<i>Corylus avellana</i> cultivation	Hazel-grow cultivation
Soil		Soil
Marsh vegetation	<i>Phragmites australis</i> vegetation	Reed bed

*Maximum Likelihood* classification was performed using the same set of MIVIS channels after training sets selection. These areas were selected according to field data; some of them were used to classify the images and some to estimate classification accuracy. The accuracy of both classifications was verified by the error matrices, K coefficients [Congalton, 1991] and field observations.

## Results and discussion

The comparison between accuracy and K coefficients (Table 2) concerning the classification techniques performed onto data at different spatial resolution reveal that in the study area ML provides a better distinction among different vegetation units. However, visual inspection of the classified images showed that a different spatial distributions of forest formations depend on image spatial resolution.

**Table 2. Comparison of overall accuracy and K coefficient for SAM and ML classifications.**

	Image 2000 m		Image 5000 m	
	<i>overall accuracy</i>	<i>K coefficient</i>	<i>overall accuracy</i>	<i>K coefficient</i>
<b>SAM</b>	69%	0.65	84%	0.81
<b>ML</b>	99.4%	0.99	99.6%	0.99

In the SAM classification the higher omission and commission errors are mainly related to forest vegetation classes. In fact the image-derived endmembers cannot carefully describe all different forest vegetation classes; this is due to the fact that in the study area pure pixel are poorly represented, because of the high heterogeneity of deciduous woods. This methodology produces high “salt and pepper” pixel distribution and the cartographic boundaries of forest formations are difficult to map; such situation is evident from a “looks good” approach, that is the most useful accuracy assessment [Foody, 2002].

The results of the ML classification show a better landscape units distribution, even though the spatial distributions of pixel classified at 2000 m and 5000 m do not exactly overlap. The spectral signature of each landscape unit is not only function of the specific plant species but also depends on the surface morphology: these parameters become most important as target-sensor distance decrease. In fact the spectral signatures of forest vegetation differ in images acquired at 2000 m with respect to those at 5000 m. The same trend is not evident in non-vegetated landscape units (soil) as shown by the spectral signatures of the principal landscape units (figure 2): in the visible range reflectance values derived from images at 5000 m are higher than those measured at 2000 m; in fact as pixel resolution increases, the percentage of leaf layers in the pixel area increases, producing higher reflectance values.

The standard deviation is statistically significant only in near-infrared region; however spectral signature related to *Corylus avellana* cultivations shows high standard deviation in the range between 0.8 e 1.2  $\mu\text{m}$ . This trend is related to the regular spatial model distribution of trees [Pielou, 1960]; in fact the regular interaction among plant-soil-plant homogeneously influences canopy reflectance, although pixel size increases.

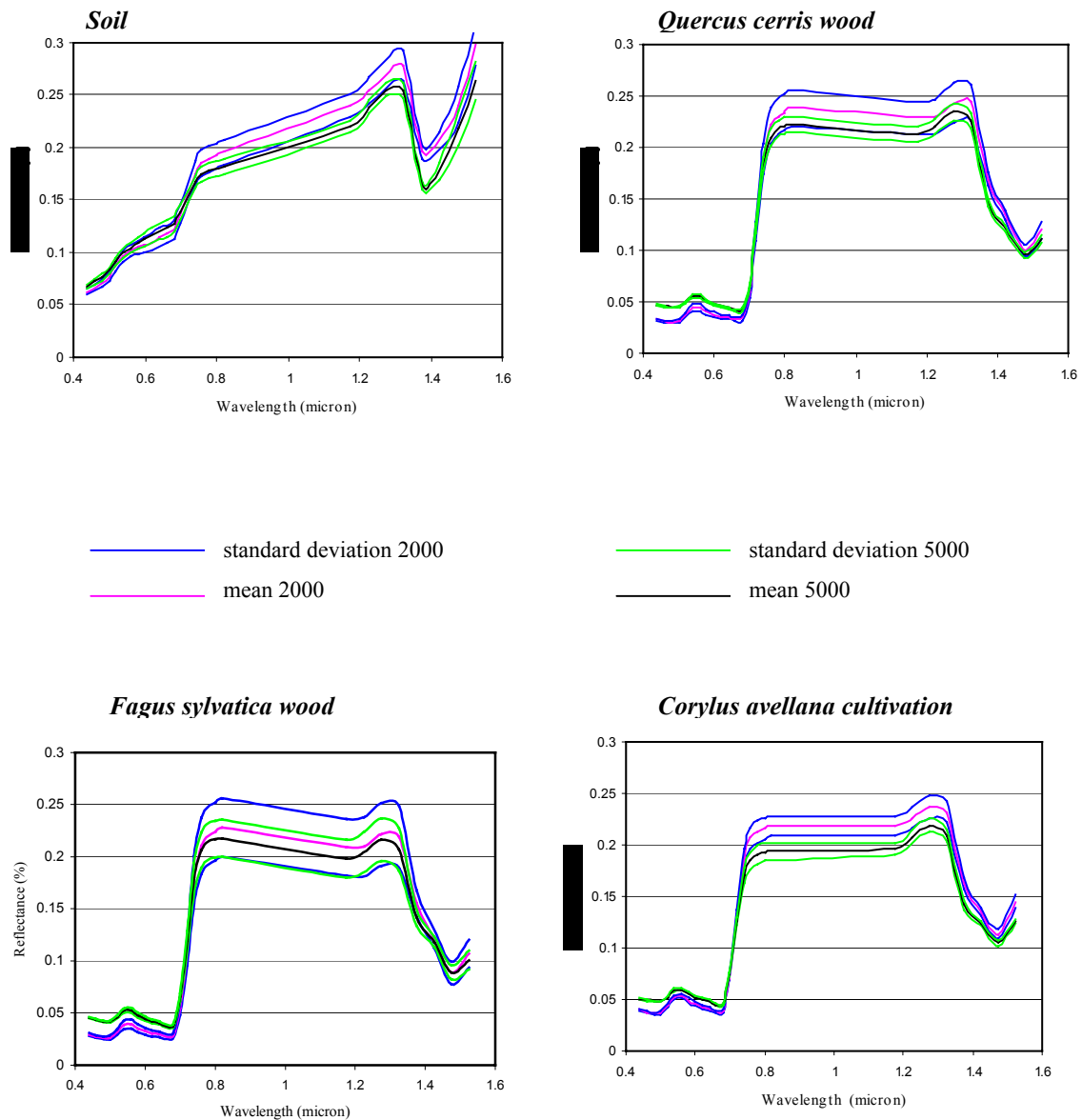


Figure 2. Spectral signatures extracted by MIVIS images acquired at different altitudes.

According to the field surveys carried out to verify the reliability of the classification methods, it resulted that the image acquired at 2000 m allows to evaluate the level of fragmentation and biodiversity, while that at 5000 m allow to discriminate the vegetation communities at landscape level with a high accuracy.

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