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Integration of airborne optical and thermal imagery for archaeological subsurface structures detection: the Arpi case study (Italy)

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The application of Remote Sensing data for detecting subsurface structures is becoming a remarkable tool for the archaeological observations to be combined with the near surface geophysics [1, 2]. As matter of fact, different satellite and airborne sensors have been used for archaeological applications, such as the identification of spectral anomalies (i.e. marks) related to the buried remnants within archaeological sites, and the management and protection of archaeological sites [3, 5].

The dominant factors that affect the spectral detectability of marks related to manmade archaeological structures are: (1) the spectral contrast between the target and background materials, (2) the proportion of the target on the surface (relative to the background), (3) the imaging system characteristics being used (i.e. bands, instrument noise and pixel size), and (4) the conditions under which the surface is being imaged (i.e. illumination and atmospheric conditions) [4].

In this context, just few airborne hyperspectral sensors were applied for cultural heritage studies, among them the AVIRIS (Airborne Visible/Infrared Imaging Spectrometer), the CASI (Compact Airborne Spectrographic Imager), the HyMAP (Hyperspectral MAPping) and the MIVIS (Multispectral Infrared and Visible Imaging Spectrometer). Therefore, the application of high spatial/spectral resolution imagery arise the question on which is the trade off between high spectral and spatial resolution imagery for archaeological applications and which spectral region is optimal for the detection of subsurface structures.

This paper points out the most suitable spectral information useful to evaluate the image capability in terms of spectral anomaly detection of subsurface archaeological structures in different land cover contexts.

In this study, we assess the capability of MIVIS and CASI reflectances and of ATM and MIVIS emissivities (Table 1) for subsurface archaeological prospection in different sites of the Arpi archaeological area (southern Italy). We identify, for the selected sites, three main land cover overlying the buried structures: (a) photosynthetic (i.e. green low vegetation), (b) non-photosynthetic vegetation (i.e. yellow, dry low vegetation), and (c) dry bare soil. Afterwards, we analyse the spectral regions showing an inherent potential for the archaeological detection as a function of the land cover characteristics. The classified land cover units have been used in a spectral mixture analysis to assess the land cover fractional abundance surfacing the buried structures (i.e. mark-background system).

The classification and unmixing results for the CASI, MIVIS and ATM remote sensing data processing showed a good accordance both in the land cover units and in the subsurface structures identification. The integrated analysis of the unmixing results for the three sensors allowed us to establish that for the land cover characterized by green and dry vegetation (occurrence higher than 75%), the visible and near infrared (VNIR) spectral regions better enhance the buried man-made structures. In particular, if the structures are covered by more than 75% of vegetation the two most promising wavelengths for their detection are the chlorophyll peak at 0.56μm (Visible region) and the red edge region (0.67 to 0.72μm; NIR region). This result confirms that the variation induced by the subsurface structures (e.g., stone walls, tile concentrations, pavements near the surface, road networks) to the natural vegetation growth and/or colour (i.e., for different stress factors) is primarily detectable by the chlorophyll peak and the red edge region applied for the vegetation stress detection. Whereas, if dry soils cover the structures (occurrence higher than 75%), both the VNIR and thermal infrared (TIR) regions are suitable to detect the subsurface structures.

This work demonstrates that airborne reflectances and emissivities data, even though at different spatial/spectral resolutions and acquisition time represent an effective and rapid tool to detect subsurface structures within different land cover contexts. As concluding results, this study reveals that the airborne multi/hyperspectral image processing can be an effective and cost-efficient tool to perform a preliminary analysis of those areas where large cultural heritage assets prioritising and localizing the sites where to apply near surface geophysics surveys.

	Spectral Region	**Spectral Resolution (μm)**	**Spectral Range (μm)**	**Spatial Resolution (m)**	**IFOV (deg)**
ATM	VIS-NIR SWIR-TIR (tot 12 ch)	variable from 24 to 3100	0.42 - 1150	2	0.143
CASI	VNIR (48 ch.)	0.01	0.40-0.94	2	0.115
MIVIS	VNIR (28ch.)	0.02 (VIS) 0.05 (NIR)	0.43-0.83 (VIS) 1.15-1.55 (NIR)	6 - 7	0.115
	SWIR (64ch.)	0.09	1.983-2.478		
	TIR (10ch.)	0.34-0.54	8.180-12.700		

Table 1. Characteristics of airborne sensors used for the Arpi test area.

1 References

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