

## USE AND PROCESSING OF MULTISPECTRAL IMAGES IN PROXIMITY REMOTE SENSING

### 1. INTRODUCTION

The paper presented the result of tests concerning the acquisition of multispectral images from UAV and the processing of multispectral indices for archaeological purposes. From a technical point of view the frames were captured with a Sentera 6X multiband sensor equipped with 5 cameras at 3.2 mpx for the spectral bands of Blue, Green, Red, Red Edge and Near Infrared (from now on NIR) and a 20 mpx RGB camera, with brightness sensor and built-in GPS. Furthermore, radiometric calibration of the images was achieved with the reflectance panel and the parameters provided by the producer. Multispectral camera was integrated with a DJI Phantom 4 drone, according to a setup not foreseen by the producer which allowed for an easy-to-use system (for technical specifications on the integration see EBANISTA, JAIA, POMPILI 2021; EBANISTA, JAIA in press a).

### 2. STATE OF THE ART

The tests described are part of a modern line of research concerning the application in the archaeological field of these vegetation indices developed and codified in the predictive research in agrotechnical field, but responding, from a point of view of compatibility of marks genesis, to the cropmarks of classical archaeological photointerpretation (on the question of photointerpretation in the archaeological field: PICCARRETA, CERAUDO 2000; for the botanical question: PIROLA *et al.* 1982; for the genesis of the indices: DEERING *et al.* 1974). The reference scientific literature is now sufficiently extensive, considering the relatively low cost of equipment and the ease of use of data processing software (among many: AGAPIOU *et al.* 2012a, 2012b; URIBE *et al.* 2015; FIORINI, MATERAZZI 2017; CHIVASA *et al.* 2020). To date, however, the great limit remains a still extensive methodological vacuum due, in my opinion, to the lack of a necessary comparison of the indices processed from multiband data with panchromatic images. Almost all the scientific literature presents marks, sometimes of exceptional reading, in the NDVI without however declaring whether the same marks are also visible in the panchromatic and to what extent. This does not allow us to understand whether there are marks visible only in the processed indices, or in the case of marks already visible in the panchromatic whether there is a quantifiable increase in the data. Furthermore, even a modest number of bands, such as the one presented in

this paper based on the sensor in use, allows the extraction of multiple indices, comparable in order to understand which the best performers are considering the different purposes of the research.

### 3. COMPARISON OF VEGETATION INDICES WITH PANCHROMATIC IMAGES

The comparative analysis of the same flight in panchromatic and multispectral has often highlighted how the NDVI index, the most responsive in the archaeological field by affinity with cropmarks, shows marks that are already visible in the panchromatic (EBANISTA, JAIA in press a). The goal of the experiments carried out by the author of this paper is to codify a coherent method line in order to understand the cases in which it is possible to trace the presence of buried structures only through the processed indices that use the near infrared bands.

In the case studies here presented mark reading is absolutely, or almost, prerogative of vegetation indices. These are two tests (Anzio, Villa Adele and Villa Imperiale) in which the excavation data demonstrated very recent soil filling with notable modern inclusions. It seems possible to hypothesize that the reduction in fertility of these soils is perceptible only in the elaboration of the vegetative indices, more sensitive even at low ranges of chlorophyll values. Furthermore, tests that compare flights in different areas analyze through the comparison of six vegetation indices how the reading of lithic elements (*basoli* or blocks) covered by the vegetation or dry foliage can be clear and defined compared to the panchromatic. Finally, the comparison of six different indices allowed us to evaluate how the use of processed indices based on NIR interpolation allows us to eliminate the covering effect of the shadows generated by the walls on the turf.

#### 3.1 Anzio, Villa Adele

As part of the excavation campaign carried out in September 2023 at Villa Adele in Anzio (RM) under the direction of A.M. Jaia, a series of galleries at a depth of 7 m of the modern floor and accessible to date only through a Roman well were highlighted. First identified in 2000, then inspected by specialized speleologists in 2022, they were brought to light through a pedestrian entrance, used until very recently, as evidenced by the internal finds and by conoid of collapsed soil at the bottom of one of the rooms. The NDVI processed by the images acquired before the opening of the excavation trench shows a mark not appreciable in the panchromatic. This is a dark mark of irregular shape that, according to the values setting in black and white, indicates the areas where vegetative growth is inhibited (Fig. 1). The area identified by the mark corresponds to the sector which, according to the results of the excavation, corresponds to a significant backfill of thousands of cubic meters

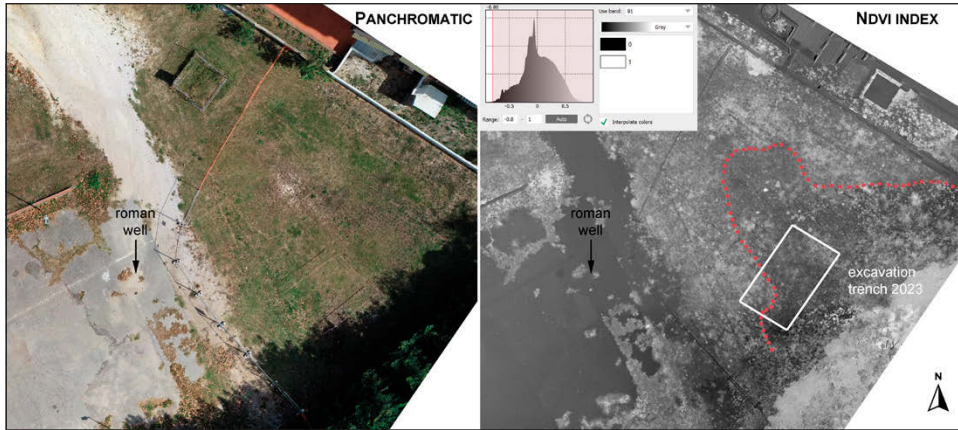


Fig. 1 – Anzio (RM), Villa Adele. Comparison of the panchromatic image and the NDVI index.

which obliterated the natural slope from which the ancient structures were accessed in the middle of the last century (for detailed excavation report: JAIA, EBANISTA in press b). Considering that in the different layers that make up the backfill abundant recent building materials were found, it can be hypothesized that the presence of these kind of inclusions in the soil determines a lower fertility that produces as an effect a lower vigor of the turf that generates a clear response in the NIR, thus giving a good response in the index used.

### 3.2 Anzio, Villa Imperiale

A similar situation was found in the case of flights carried out in October 2023 at the Villa Imperiale of Anzio. As part of the redefinition of the phases of the villa codified in the 70s by Santa Maria Scrinari, Jaia reduced the building phases to just two major interventions (SANTAMARIA SCRINARI, MORRICONE MATINI 1975; JAIA 2008). The second phase, referring to the late Antonine and Severian age, includes the regularization of the structures along two orientations: the one to the S at the large curvilinear structure of the first phase (Fig. 2a) and the one that is set parallel to the W coastline and includes the thermal area and the promontory of the so-called Arco Muto (Fig. 2b). This sector constituted a vacuum of knowledge, presenting as an area excavated first in 1889 (Boccanera excavation) and then in 1929-32 when the Podestà of Anzio, as part of the tourist promotion of the town, built a sports field around the Arco Muto. Based on the discovery of detailed planimetry carried out by G. Gatti from 1931 and unpublished until a few years ago, it was possible to relocate the plans of the northernmost structures of the villa area with extreme precision, with further confirmation of positioning given by

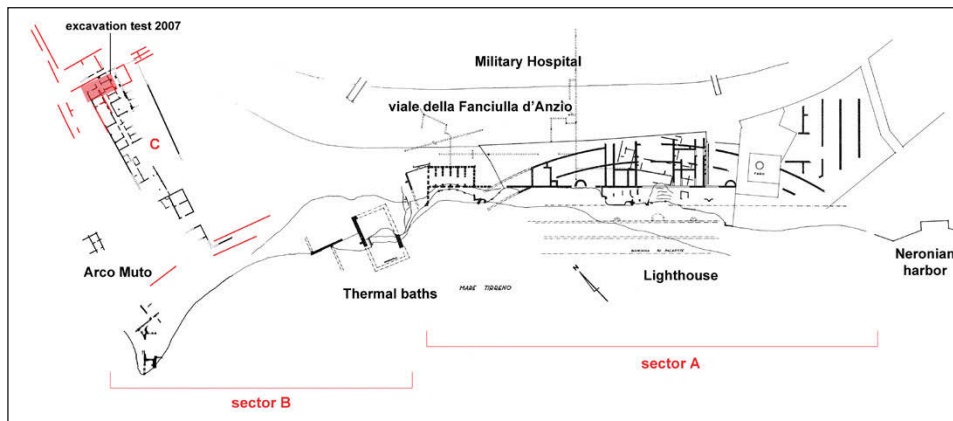


Fig. 2 – Anzio (RM), Villa Imperiale. Plan of the known structure with the addition of the structures identified based on the NDVI marks in 2023 (processed by JAIA 2008, 76).



Fig. 3 – Anzio (RM), Villa Imperiale. Comparison between the panchromatic image and the NDVI index.

an excavation carried out in 2007 using the only off-axis wall as a reference (Fig. 2c). The comparison between the panchromatic image and the NDVI index clearly shows that only in the latter in the sector N of the modern entrance to the archaeological area marks with NW-SE orientation are visible (Fig. 3). Superimposing the NDVI marks to the Gatti planimetry the increase in knowledge in N direction is evident (Fig. 2, in red). The genesis of the marks



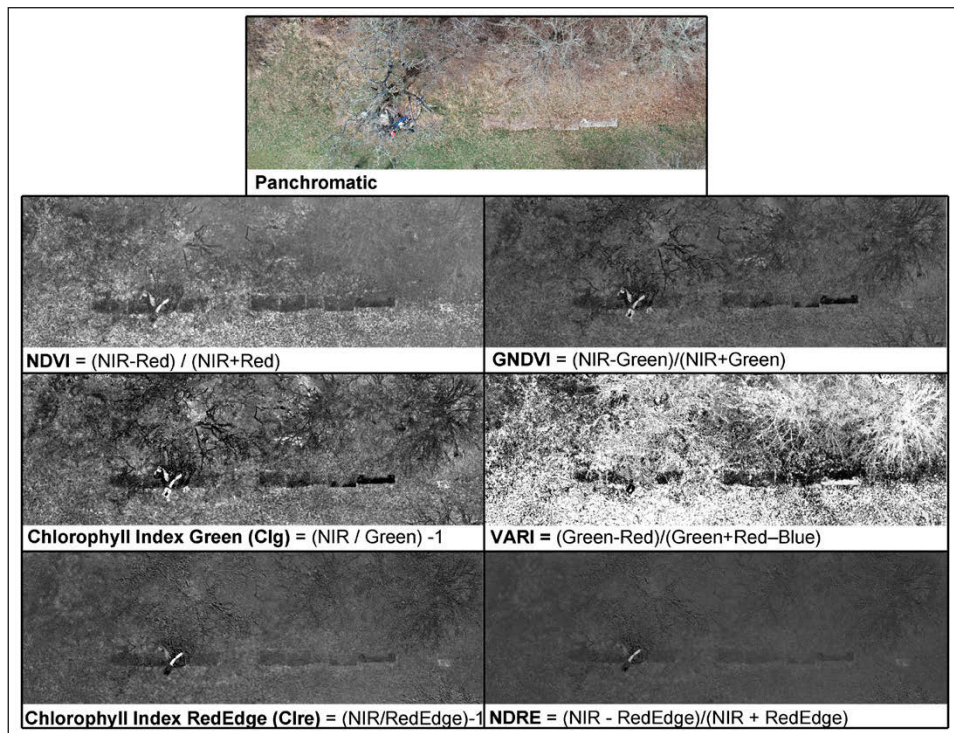


Fig. 4 – *Nersae*, Pescorocchiano (RI). Comparison between the panchromatic image and six vegetation indices.

is like these of Villa Adele, as also in this case it is a recent filling, probably carried out with inconsistent material. There is therefore a good chance of identifying archaeological marks in conditions of land carryovers, more or less recent, but with considerable inclusions that decrease the fertility of the soil, reducing the vegetative vigor of the turf. This is significantly sensitive to NIR so as to appear only in the chosen index but is not appreciable in the visible spectrum. This is basically the method used in predictive agrotechnical analyses with respect to the degree of greenness appreciable in the visible as it responds to minimum chlorophyll concentration intervals.

### 3.3 Visibility of blocks and basoli, comparison of six vegetation index

Another performing capability of multispectral images interpolated via indexes that make use of NIR is to make visible blocks or *basoli* covered by vegetation that often remain almost completely invisible in panchromatic images. In a detail of a larger flight carried out in *Nersae*, the ancient capital of the

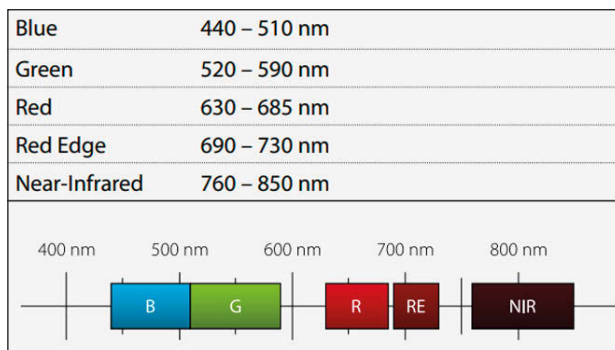


Fig. 5 – Spectral Bands (from [https://www.geosoluciones.cl/documentos/rapideye/RE\\_Red\\_Edge\\_Band\\_White\\_Paper.pdf](https://www.geosoluciones.cl/documentos/rapideye/RE_Red_Edge_Band_White_Paper.pdf)).

*Equicoli* located in the Salto valley, in the panchromatic image the presence of a row of blocks, partially covered by foliage, is only intuitable. The comparison of six vegetation indices (Fig. 4), processed considering the five bands acquired by the sensor used, shows that the few regrowth of turf between block and block are exalted in the contrast between a good vegetative vigor and the value below zero determined by the presence of the lithic material. It is evident that the NDVI, the GNDVI and the Chlorophyll Index Green show satisfactory results, with an excellent increase of knowledge. The response of the VARI is also good, but the marks in the Chlorophyll Index Red-Edge and NDRE (Red-Edge NDVI) indexes are less clear. These are the two indexes that interpolate the Red-Edge band. This, located at about 700/750 nm in the spectrum of the visible, represents the inflection point of the reflectance curve of the vegetation that separates the reflectance in the visible from the NIR reflectance (Fig. 5). NIR, instead, corresponds to the maximum peak of the reflectance values reaching 1300 nm. In the context, however, it must be considered that the reflectance in the Red Edge band, being more influenced by chlorophyll rather than by the presence of biomass, allows to evaluate the vigor of the plants even in the most advanced stages of their growth, unlike the NDVI which is less effective as the plant develops. The analysis of the type of turf therefore becomes fundamental: sown and therefore subjected to the cyclic anthropogenic action, uncultivated or constantly cut.

In a detail of the previous flight at the Imperial Villa of Anzio the turf is clearly irregular, partly dry with sporadic regrowth which however corresponds to a deep root layer. In fact, it is not uprooted or sowed, but only periodic mowed; so, the roots certainly intercepted the buried structures, however not extremely deep, resulting in the genesis of cropmarks. In this case the extraction of six vegetation indices (Fig. 6) significantly emphasized

the paved road (repositioned in modern times) to NE for the phenomenon already described, in addition to make visible the marks of the paving of the republican *domus* recognizable as oriented differently from the imperial plant (Fig. 7). Marks are not appreciable in the panchromatic but are instead extremely clear in the NDVI.

### 3.4 Shadows visibility in processed indices

It is interesting, however, to note that from the comparison in Fig. 6 there are differences in relation to the effect of the shadows which defines a visibility disturbance in the panchromatic and VARI index. Instead in the other indexes shadows are less evident, and in some cases totally disappear, revealing the image covered by the black chromia. The phenomenon occurs because these indices use the infrared radiation that is also present in the shadowed areas, nullifying the covering effect of the phenomenon. The black shadow that appears in the panchromatic image is the dark area projected

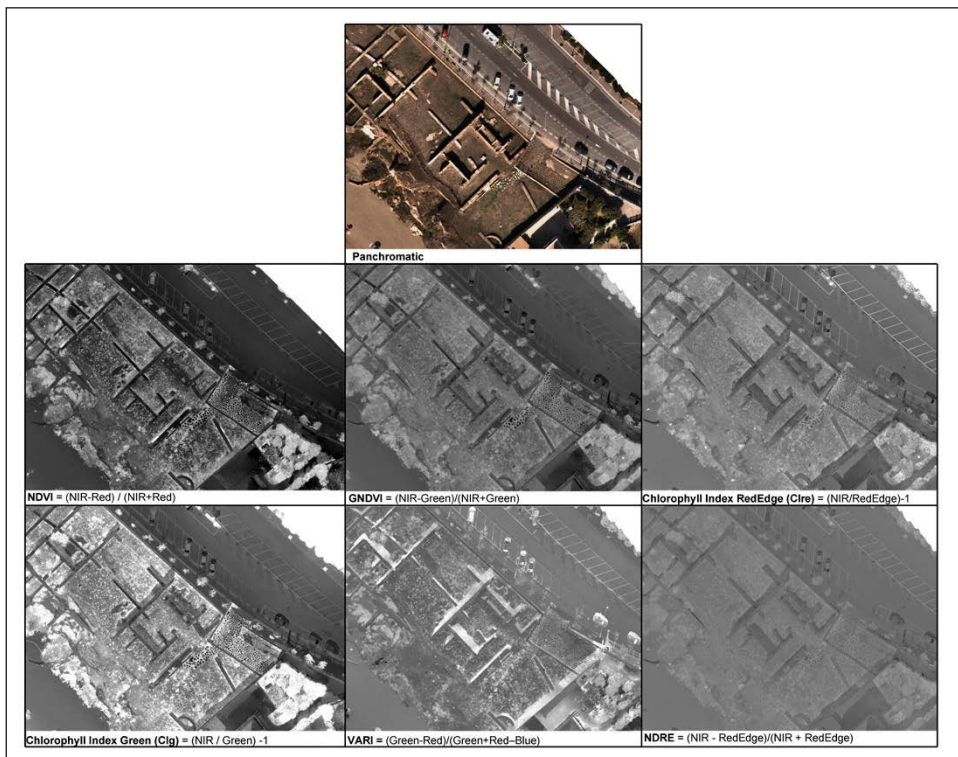


Fig. 6 – Anzio (RM), Villa Imperiale. Comparison between the panchromatic image and six vegetation indices.

on a surface, in this case the turf, with high walls that, intervening between the surface itself and the sun light source, prevent the passage of visible light, but not of infrared radiation.

The NDVI index shown in the slide is in this case of excellent readability, as it completely cancels out the effect of shady coverage. At this point, the observation of this phenomenon and the optimal response of the NDVI index (also good for other indices, Fig. 6) to the problem of shadow coverage becomes fundamental in cases in which even with the correct acquisition of flights in the central times of the day it is not possible to avoid the phenomenon for the presence of walls of modest height. In this way, a part of the image, that would otherwise been totally lost, can be recovered.

### 3.5 Conclusion

This contribution, despite its preliminary structure in the dynamics of a large and ongoing research, demonstrates the importance of the comparison between the various vegetation indices that can be processed, based on the specific sensor used, and the panchromatic images. An important methodological gap in the scientific bibliography of reference is, in my opinion, the almost always absent comparison of marks visible in processed vegetation indices with the same image acquired in panchromatic at the same time and with the same vegetative conditions of the vegetation cover.



Fig. 7 – Anzio (RM), Villa Imperiale. NDVI index.



Very often in fact, the marks (comparable with those of classical photointerpretation, mainly cropmarks) are already visible in panchromatic images, but the comparison with vegetation indices, such as NDVI, demonstrates in many cases an increase in the degree of visibility which can be estimated as a percentage (for *Lavinium* test at Santa Maria delle Vigne villa see EBANISTA, JAIA in press a). The choice in this paper to analyze only the cases in which the marks are visible only and exclusively in the indexes processed paves the way for further evaluations. The tests have demonstrated how inconsistent and very recent backfills are a prototypical case of marks reading only in the processed indexes that make use of the NIR band (and partially and with less satisfactory results in the Red Edge). A further intuition, which will be appropriately developed through further tests in multiple contexts, is that relating to overcoming the obstacle of shadows in reading images.

Laura EBANISTA

Sapienza Università di Roma  
laura.ebanista@uniroma1.it

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#### ABSTRACT

The contribution presents the results of a research that involves the use of data acquired by a multispectral camera transported by a UAV and their analysis and interpretation in the context of archaeological diagnostics. The experimentation expected the acquisition of multispectral images and the extraction of all the possible vegetation indexes on the basis of the spectral bands of the specific camera used (Sentera 6X). The tests, carried out in different contexts (*Antium*, *Nersae*), analyze the readability of the index data extracted from multispectral images in comparison with the marks visible in the panchromatic images, especially considering cases in which the marks are visible only in processed indices that interpolate the NIR band.