Remote sensing for archaeological studies and territory management: case study of the roman city of *Lucus Asturum* (Asturias, Spain)

Otilia Requejo Pagés
Department of Cultural Heritage. Principality of Asturias. Spain
Javier F. Calleja
Department of Physics. University of Oviedo. Spain
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**Objective**
To demonstrate the capability of spaceborne sensors to detect archaeological remains.

1. Study area: Geography and History
2. Selection of the sensor
3. World View 2 features
4. Algorithms applied to the WV2 data
5. Conclusions and future work
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Study area: Geography

The area of study (Llanera, Principality of Asturias, Spain) is located in the central western part of the Cantabrian coast in the north of the Iberian peninsula.
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Due to its geographic situation it forms part of the Asturian depression bordering the sea, a horizontal band which runs from east to west across the Asturian territory and which topographically is a sunken flattened surface in between two lines of low summits.

The geomorphology mainly reflects the action of fluvial processes being the course of the Nora river, which stands out, both in length and extension, as one of the fluvial meadows which constitute the most significant element in the landscape of Llanera at its southern limit. To the north, the plain of Llanera is bordered by hills and medium-sized slopes which do not surpass altitudes of 500 meters and which separate this valley/coalfield from the coastal area.
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Study area: History

Lucus Asturum is one of three known and documented centers of population during the Roman period in Asturias. It is cited for the first time in the middle of the second century A.D by the Greek geographer Claudio Ptolomeo, where it is mentioned alongside the names of cities and villages of the Astures.
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Study area: History

The center of this site is located on a surrounding area of flat ground of the parish church of Santa Maria de Lugo de Llanera, in the Eria de la Castañera, the central part of the territory of Llanera. The archaeological excavations undertaken in the area around the temple confirm material evidence of Roman occupation beginning in the middle of the first century A.D. The archaeological remains identified formed part of a *vicus viari*, a habitat or built-up area of secondary type composed of various separate constructions or forming small groups with unoccupied medium-sized spaces. The area occupied by the entire complex would have been approximately 50 hectares.
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Selection of the sensor

Radar ruled out: Lack of the required expertise, Vegetated humid ground

Optical range (VNIR). Working hypothesis: buried remains have an impact on vegetation

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Figure taken from:
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Selection of the sensor

- **Spatial resolution**
  - Size of the searched patterns:
    - 0.1 m – 10 m

- **Spectral resolution**
  - Detection of vegetation changes:
    - Visible, NIR

- **Temporal resolution**
  - Not important. Study area has not changed much for years
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**World View 2**

**Spatial resolution**
- Panchromatic: 0.5 m
- Multispectral: 2 m

**Spectral resolution**
- Acquistion date: 11 October, 2011
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**Algorithms**

### Real color

- $R = \text{Band 5}$
- $G = \text{Band 3}$
- $B = \text{Band 2}$

### NDVI

$$NDVI = \frac{NIR - R}{NIR + R}$$

- $R = \text{Band 5}$
- $NIR = \text{Band 7}$

### Principal components

- PC 1
- PC 2

### Crop – Veg – Soil *

- **Crop**
  $$Crop = -0.38\rho_{\text{blue}} - 0.71\rho_{\text{green}} + 0.20\rho_{\text{red}} - 0.56\rho_{\text{NIR}}$$

- **Veg**
  $$Veg = -0.37\rho_{\text{blue}} - 0.39\rho_{\text{green}} - 0.67\rho_{\text{red}} + 0.52\rho_{\text{NIR}}$$

- **Soil**
  $$Soil = 0.09\rho_{\text{blue}} + 0.27\rho_{\text{green}} - 0.71\rho_{\text{red}} - 0.65\rho_{\text{NIR}}$$

- **Blue** = Band 1
- **Green** = Band 3
- **Red** = Band 5
- **NIR** = Band 6

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Real color RGB composite of the WV2 image
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Real color RGB composite of the study area
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Areas with special features/patterns will be marked in a red circle

When no special features/patterns are observed, the area will be marked in a yellow circle

In this work we focus our attention on three areas inside the study area
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Real color RGB composite

- **YES**
  - Special features/patterns observed

NDVI

- **NO**
  - No features/patterns observed
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**Graphs:**

- **NDVI vs Crop Band**
  - $R^2 = 0.0068$

- **NDVI vs Veg Band**
  - $R^2 = 0.9083$
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Kun adaptive filter on Crop Component
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**Conclusions and future work**

1.- We have proven the capability of WV2 to detect regular patterns and features in vegetated areas.

2.- Different features are highlighted using different algorithms: Principal components analysis seems to highlight any vegetation special feature. *NDVI* and *Veg component* are highly correlated, and they provide similar information. *Crop component* provides information not contained in the NDVI.

3.- Results are compared with *Lidar* results: Some features can be related to topography.

4.- Features detected by different algorithms might have different origins. Some of them could be related to buried archaeological remains.

5.- The results are consistent with the morphology of the site, archaeologically characterized as a *vicus viari*: a secondary and dispersed agglomeration developed around communications crossings.

5.- The results will contribute to an effective planning of the archaeological work on site as well as facilitate the implementation of preventive and corrective measures in the urban management of this territory.

**Future work:** DN conversion to TOA reflectance, atmospheric correction. Identification of the origin of the features. In-situ validation.
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