Contents

Editorial 3
Chairpiece: by Steve Davis 7
Preliminary notice: AARG 2018, Venice 9
Student/young researchers’ scholarships for AARG 2018 10
AARG notices:
  Derrick Riley Bursary 11
  ISAP Fund
  Information for contributors
Pixels – So basic but so confusing by Geert Verhoeven 28
Sentinel-2 tools to improve field survey planning: Methods and first experiences by Jesús García Sánchez and Cristina Charro Lobato 34
Cropmarks 42
Books and papers of interest? 44
AARG: general information, membership, addresses, student scholarships 47
Sentinel-2 tools to improve field survey planning: Methods and first experiences.

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Abstract

This paper presents an innovative use of Sentinel-2 datasets to manage and organize archaeological surveys. Knowledge of the territory is customary for the process of organizing and carrying out fieldwalking surveys with excellent results. Good datasets will help to answer archaeological and historical questions present at the roots of any research project.

This method was tested in different survey projects carried out in three different countries (Italy, Portugal and Spain)³ during the late-winter and early spring of 2017 and 2018, a period in which cereal crops are in a crucial stage of its cycle and still differences in growth can be detected by means of examining the spectral footprint. This paper introduces some of the basic methodological questions while an in-depth study of results and its relationship with broader questions of visibility and survey is in preparation.

The method proposed is based on locating, prior to the fieldwork, the field plots that show a lower presence of vegetation cover, or preferably bare soil areas, in a straightforward way. In order to do so, we used multispectral images of the Sentinel-2 mission, whose temporal and spatial resolution, together with its free distribution, make it a good tool not only for the identification of archaeological elements, but also for the organization of field surveys.

Keywords

Sentinel-2, Remote sensing, Archaeological survey, Landscape Archaeology, Methodology, QGIS.

1. Introduction

This paper is focused on the territory of Urbel river valley (Burgos, Spain), an area subjected to a case-oriented survey implemented to understand the late Roman settlement pattern in this area of the Northern Plateau of the Iberian Peninsula (Figure 1). Landscape approaches are of major relevance to understand the occupation of larger areas of the countryside from the 3rd century AD onwards by aristocratic estates and their relations to urban centres and other possible farmsteads. Similar research has been applied elsewhere in the same region (Odra valley) combining non-invasive methods, landscape studies and intra-site oriented surveys.

Other relevant sites in the areas have been excavated in the recent present as La Olmeda, La Tejada (Palencia), Baños de Valdearados, Quintanadueñas (Burgos), etc., showing an unprecedented richness in commodities and in the extensive use of the countryside for both productive and otium purposes. The main scope of the survey projects implemented is to tackle issues such as appropriation of the countryside, the evolution of private property and its

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³ Landscapes of Early Roman Colonization survey in Venosa (Basilicata, Italy), Fronteira Landscape Project (Alentejo, Portugal) and Vegas Negras survey (Burgos, Spain).
reflection in the settlement pattern, and the final stage of these large residencies and their occupation by new Visigoth populations.

Remote sensing approaches are rather new in this research agenda. We have introduced this experimental programme in order to contribute to the development of survey methodology and to the broader framework of Landscape Archaeology in the region.

Our aim was to use Sentinel-2 to acquire a quick understanding of crop evolution and thus maximize our survey results. This approach has not been explored in Archaeology until now due to the lack of open access satellite imagery with an appropriate temporal and spatial resolution. This paper will illustrate an approach in the recent Vegas Negras survey project, Burgos (Figure 1).

2. The use of satellite imagery in planning regional fieldwork

Although there is no record of the use of satellite imagery as a tool to improve the planning of regional fieldwalking activities in methodological publications, in this regard its main usefulness is aimed at the definition and analysis of landscape units and the subsequent creation of priority maps that serve to guide the survey campaigns (Vicent, Chapa, Uriarte & Rodríguez, 1998). Thanks to these maps, it is possible to better plan the field campaigns with the exclusion, for example, of areas of high erosion and disappearance of soil horizons from the areas to visit, or the inclusion of areas of higher humidity in arid regions.

3. The use of Sentinel-2 images in the survey

The proportion of works where Sentinel-2 images are used in Archaeology are necessarily scarce due to its recent launch (Sentinel-2A in 2015 and Sentinel-2B in 2017). In our work, we applied the classification of the Sentinel-2A images to the organization of the archaeological field survey, as a methodological contribution. It is especially useful when
research teams are restricted in the execution of campaigns due to factors such as limited time and distance to the area of interest. In this case, a map of priorities of survey areas has been created according to the nature of the terrain, avoiding known problems in field practice determined by limiting factors such as visibility and accessibility to the terrain (Schiffer, Sullivan & Klinger, 1978). In forthcoming works we will explore how a Sentinel-2 classification could improve the usual mapping of ground visibility as well as provides better grasp in small changes in ground coverage which bias the documentation of pottery scatters.

4. Description of the area for Sentinel-2 classification and survey

As stated previously we focused the 2018 survey on a case-oriented survey in Burgos province, in the Urbel valley. At the time of survey (early April) the area was covered by cereal crops (wheat and barley). Different field plots have crops planted on different dates of the previous winter due to heavy rain and snow, several were planted very recently. In some cases, the talweg of a former river-bed is visible in earlier aerial pictures and on the ground because of the pebble soil-matrix, this is also visible in Near Infrared Images in appropriate periods of the year (i.e. PNOA NIR from 2009). Former field plot boundaries are also visible in occasions, as these existed in the whole region of Castilla y León until the 1960s, when a large programme of agricultural modernization and reorganization of the countryside was established by the authorities. A good insight into the pre-existing countryside organization can be seen in 1956 USAF flight over the Spanish territory (Pérez, Bascón & Charro, 2014).

5. Methods

For the present study, we chose a Sentinel-2 image pre-dating the beginning of the field survey, so as to produce a regional overview of which fields were available for surveying, and which ones would rather present visibility bias, and therefore would be better to avoid.

In order to work with the selected image, we used the Semi-Automatic Classification Plugin for QGIS 3.0, which is equipped with a set of tools for opening and managing bands and produce classifications and results in a systematic way. We also apply our belief in the use of open source tools for research and education.

5.1. Sentinel-2

In this work we decided to use Sentinel-2 images for several reasons. First, because they have been freely distributed through the ESA (European Space Agency) website (Koetz et al., 2017, Wulder & Coop, 2014) since its launch in June 2015. Images are downloaded geometrically corrected and with an assigned spatial reference system. In addition, in this portal they provide the user with all the information related to the mission, together with various image processing tools.

Secondly, there is its temporal resolution. Every 10 days –now every 5 days or even less if our area of interest coincides with the area of a complete contiguous image, taken at an earlier or later date - we can get a complete picture of the study area.

4 Sentinel 2 image ID: S2A_MSIL2A_20180328T110741_N0207_R137_T30TVN_20180328T183040
In addition, there is the spatial resolution of its 13 bands: 10 m for the most used bands (visible and Near Infrared colors = bands 2, 3, 4 and 8), and 20 m for the bands incorporated in this sensor (within the NIR wavelength = bands 5, 6, 7 and 8a).

In order to get as accurate a classification as possible, it is necessary to have an image taken very close to the survey date. Springtime is a tricky season due to the atmospheric variability so, although we reviewed the images in advance, we did not get a good one with a low cloud coverage until April 4th with the survey starting on April 7th. In that sense we were fortunate in terms of the date of the image as the survey area was luckily clear, considering the 63% of cloud coverage of the image.

5.2. Classification

One of the pursued objectives was to make the classification process as simple as possible. After several tests with unsupervised classifications in different software (PCI and ENVI), we chose to perform the classification with a satellite image processing plugin in QGIS, the Semi-Automatic Classification Plugin (SCP) (Congedo, 2016). This tool facilitates the work of classifying satellite images for non-specialists, since it can be applied from the download of the images and their prior processing (clipping and performing atmospheric corrections, among other possibilities) to the supervised classification of the images and other tools (e.g. raster calculator).

Our classification process involves a maximum of 2 working hours for an area of circa 20 square kilometers, including pre-processing of the images (atmospheric correction DOS 1, clipping of each band to adjust it to the work area), selection of training areas, review of separability between classes and different tests and adjustments. This time can be reduced if we do not apply corrections to check for the presence or absence of vegetation - and its degree of growth - in the various survey area plots, because they are not necessary for the objective of this classification.

We used additional information to the Sentinel-2 images, in particular several aerial images from different sources -Bing Aerial, Google Earth, and especially the PNOA orthophotography (Plan Nacional de Ortofotografía Aérea). General information on landuse was provided by CORINE LandCover, which despite having a small scale of detail is helpful in estimating different coverages and types of crops. Finally, the Normalized Difference Vegetation Index (NDVI) was the most meaningful (D’Odorico et al. 2013).

This information, together with the analysis of different band composites (Figure 2), helped us in selecting the classes used and the samples chosen for each one. We divided the set into 10 classes (C) or types, grouped into 5 functional macro classes (MC), a division according to the potential suitability for survey of each class represented (Table 1).
Figure 2. Cropped Sentinel-2 image of 3 x 5 km with some RGB color composites used, from left to right: 4-3-2 or Natural Color, 8-4-3 or False Color Infrared and 11-8-2. Background: PNOA 2017.

Table 1. Functional Classes and Macroclasses used in the classification of Sentinel-2 images.

<table>
<thead>
<tr>
<th>Macroclasses (MC)</th>
<th>Classes (C)</th>
<th>Observations regarding visibility and accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>0- Unclassified</td>
<td>-</td>
<td>Bounding box</td>
</tr>
<tr>
<td>1- Non-surveyable</td>
<td>1-Bush in shadows</td>
<td>Non-surveyable – Rough conditions and low visibility (if any)</td>
</tr>
<tr>
<td></td>
<td>2-Bush</td>
<td></td>
</tr>
<tr>
<td>2- Vegetation</td>
<td>3-Healthy grown</td>
<td>Low. Check visibility before discarding</td>
</tr>
<tr>
<td></td>
<td>4-Healthy growing</td>
<td>Medium. Prioritize</td>
</tr>
<tr>
<td></td>
<td>5-Healthy starting</td>
<td>Good</td>
</tr>
<tr>
<td>3- BUA</td>
<td>6-Metal roof</td>
<td>Non-surveyable – Mask applied</td>
</tr>
<tr>
<td></td>
<td>7-Tiled roof</td>
<td></td>
</tr>
<tr>
<td>4- Bare soil</td>
<td>8-Bare soil</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>9-Eroded soil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-Olive grove</td>
<td></td>
</tr>
</tbody>
</table>

Hence the areas that interested us are Macroclasses 2 and 4, which correspond to areas covered with vegetation and bare soil. Within Macroclass 2 we divided the coverages according to vegetation growth, establishing three stages: fully grown vegetation, growing vegetation, and initial growth. Thus, we can organize the fieldwork prioritizing the plots with average growth, and then initially discard those with fully grown vegetation. Macroclass 4 (bare soil) includes three subtypes: class 8 bare soil, 9 eroded soil and 10 olive groves. Obviously, inside an olive grove there are olive trees, but the intermediate space is bare ground and therefore surveyable, so it has been included within Macroclass 4 Bare soil. In the case of bare soil, recently sown fields may be included, but the vegetation has not yet begun to grow.
Figure 3. 2 x 2 km Images of the samples (ROIs) taken for classes 3 and 8 (right), and their appearance in Natural Color (left) and False Color Infrared (center) composites.

Figure 3 shows some example images of the samples taken (ROI or Regions of Interest) for each class, namely class 3 (vigorous vegetation) and class 8 (bare soil), where the NDVI was on average 0.9 for the first and 0.2 for the second. In addition, we can see their spectral signatures, which show a clear difference in reflectivity (Figure 4). We can note the different spectral responses of eroded soil, more pronounced in SWIR band 11, indicating areas of higher erosion, corresponding to these sample images of a plot extracted from the 11-8-2 composite (Figure 5).

Figure 4. Spectral signature of the defined classes: class 3 Healthy grown vegetation (MC2 Vegetation), class 8 Bare soil (MC4 Bare soil) and class 9 Eroded soil (MC4).

Figure 5 Images showing a plot with eroded soil. From left to right: 4-3-2 and 11-8-2 composites, and the same plot in an orthophoto (Bing Aerial 2017).

As a result, we obtained a map of landuse and coverages (as per Del Bosque et al., 2005) from the classifications of each area, one for classes and another for macroclasses, with an estimation of the area covered by each class and macroclass, which is helpful in estimating the time needed to survey each area.
6. Fieldwork observations

Since the project’s objective is to understand the ancient landscape and settlement pattern dynamics during the Late Antiquity the team aims to survey all the fields in any visibility conditions. However, those fields classified as Bushes (Classes 1 and 2) were nearly impossible to access as the ground was not visible at all. The rest of the area has an overall good visibility despite the differences in the state of the crops, whereas some fields had no crop at all (Bare soils) others had a Healthy growing or a Healthy starting crop, especially in the river valley. Some fields on top or closer to the limestone moorlands/ limestone Páramo Plateau have no crops, and in some cases erosion and thin shallow soils are visible. Some fields were prioritized for surveying before the visibility conditions turned much worse. In these cases, the usefulness of this approach is the effective characterization of the landscape before the field survey itself. Moreover, it is possible to gain extra information about small particularities of ground visibility (Figure 6).

Figure 6. Upper: differences of ground cover classification at the Urbel river area (Burgos, Spain), where cereal crops predominate; background PNOA 2017. Bottom: Examples of differential ground coverage.
Although the Sentinel-2 classification mostly focused on vegetation conditions, it also served to characterize geopedological information relating to crop growth and therefore to surface visibility.

Erosion is again a very acute factor where large areas on the edges of the limestone Páramo plateau calcarceous barrens have suffered heavy erosion. In such cases soil had almost totally disappeared.

7. Conclusions

Despite the relatively low complexity of our Sentinel-2 datasets, it should be acknowledged that critical use of satellite imagery will also improve the most basic aspects of an archaeological survey, such as its plan and time and team management. Monitoring crop health and soil erosion by means of satellite imagery can potentially become relevant aspect to other survey projects, not only in Mediterranean surveys, but also in any part of the globe covered by the Sentinel-2 programme.

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