Portable Hyperspectral Imaging (pHI) for the enhanced recording of archaeological features and deposits

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Dans **ArcheoSciences** **2025/1 n° 49-1**, pages 493 à 496
Éditions **Presses universitaires de Rennes**

ISSN 1960-1360

Portable Hyperspectral Imaging (pHI) for the enhanced recording of archaeological features and deposits

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Highlights: pHI has the potential to improve classification of archaeological soils/sediments, It could replicate results of time-consuming geoarchaeological lab analysis, This would enhance efficiency in archaeological research

Keywords: Hyperspectral imaging, geoarchaeology, remote sensing, non-destructive analysis

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This research was supported by Bournemouth University QR funding.

Introduction

The way in which the physical attributes of archaeological soils and sediments are recorded is primarily through subjective description (e.g. colour, texture, and composition), digital photography, and 2-dimensional illustration. More labour-intensive laboratory analysis (e.g. particle size analysis, loss-on-ignition), geophysical (magnetic susceptibility) and geochemical (portable X-Ray fluorescence (pXRF)) measurements of archaeological features and deposits can yield deeper insights into past-human activity but are difficult to implement at large scales. The provision of portable Hyperspectral Imaging (pHI) offers a possible 'non-destructive' solution to this but the capability of this has yet to be fully realised. This research presents some initial results from a case study where this technique has been applied and highlights the potential contribution that portable hyperspectral sensors can make to the recording of archaeological features and deposits.

Hyperspectral imaging is a non-destructive technique that captures rich spectral information of a scene or target. Unlike conventional cameras, or multispectral sensors that cover a small number of narrow or broad wavelength regions, hyperspectral sensors collect data across hundreds of contiguous spectral bands. The result is a 3D 'data cube', composed of stacked images at adjacent wavelengths, where each pixel represents a unique spectrum of intensity information from those wavelengths. As the proportions of reflected, absorbed, and transmitted energy vary in certain wavelengths according to the physical and chemical properties different materials, the provision of 'spectra' for every pixel in an image can enable the classification and characterisation of different materials (Bhargava *et al.*, 2024). Whilst hyperspectral imaging has been used to establish indicators of past human-activity contained within soils and sediments (e.g. geochemical, moisture content, and organic matter and variations (Linderholm *et al.*, 2019 ; Haburaj *et al.*, 2020 ; Sciuto *et al.*, 2022)), this has been hampered by a lack of sensors that can be used in the field. With the development of rugged, handheld hyperspectral cameras, however, it is now possible to collect this data 'in-situ' and this research is focussed on assessing whether it can provide an enhanced understanding of the formation of archaeological features and deposits.

Methods

Hyperspectral imagery was collected at the Bournemouth University Field School at Winterborne Kingston, UK. This site forms the focus of the Durotriges Project, which investigates Late prehistoric and Roman societies of central southwestern Britain. It is situated on Chalk geology and comprises a range of settlement and funerary features (e.g. ditches, large storage pits, human and animal burials), many of which comprise a complex stratigraphy and evidence for ritual, industrial and agricultural activity.

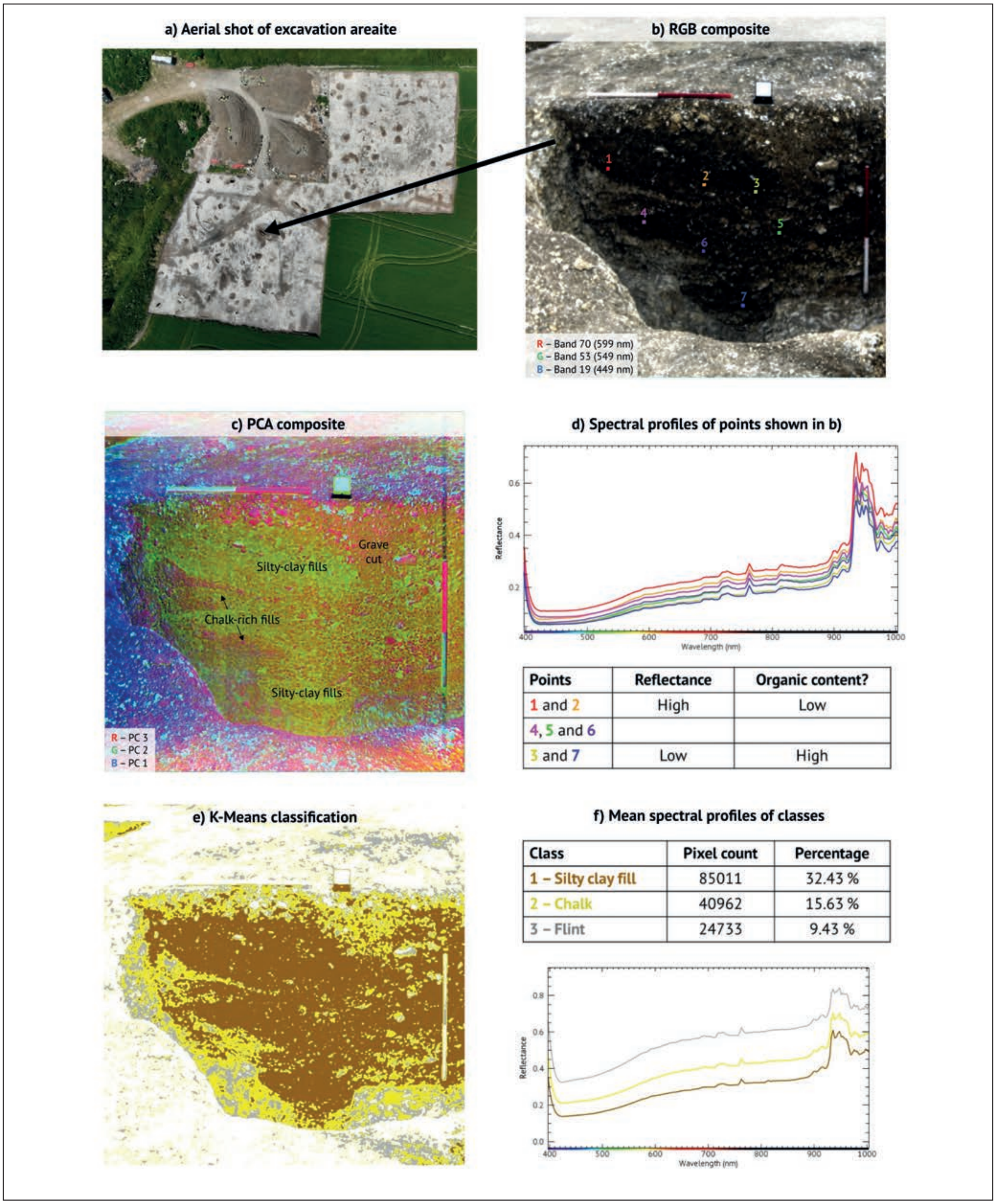

Figure 1: Results of pHI at Winterborne Kingston, Dorset focussing on a large extraction pit with a) and aerial shot indicating the location of the feature, b) an RGB composite, c) PCA composite, d) Spectral profiles derived form points shown in RGB composite, e) K-Means classification of the hyperspectral data, and f) Mean spectral profiles of classes used in K-Means classification.

The pHI data was captured using a Specim IQ, which is a fully portable, battery-operated hyperspectral camera with basic data pre-processing routines implemented within the camera software. The wavelength range is 400-1000 nm, comprising a push-broom (line scan) sensor, whereby data are collected as a series of lines. This provides images comprised of 512x512 pixels, the resolution of which is dependent on the distance from the target. At 1 m away from the target the camera provides a field of view (FOV) of 0.55 x 0.55 m. In the spectral dimension, the number of recorded spectral bands is 204, which range between 2 and 3 nm wide. To correct for different light conditions, a spectralon white reference panel to calibrate each image. The data were then analsyed using ENVI, which enabled 'spectral profiles' to be visualised and other image processes to be performed. This included a Principal Components Analysis (PCA) to reduce data dimensionality and summarise the variance contained within the 3D data cube. A K-Means (unsupervised) classification was also applied to the original hyperspectral data to 'classify' all pixels in hyperspectral image.

Results

An example of a hyperspectral image is provided for a single excavated feature from Winterborne Kingston (Figure 1a). This details a large extraction pit, which was filled with silty-clay and chalk eroding from the sides and a later (Roman) human burial. A 'true-colour' (RGB) composite was produced Red (599 nm), Green (549 nm) and Blue (449 nm) bands, which shows a poor contrast for deposits contained in the feature (Figure 1b). The PCA composite image, comprising the first three-component bands, helped to distinguish the chalk-rich and silty clay material more clearly, whilst also being more representative of the entire hyperspectral data cube (Figure 1c). Within this image, it is slightly easier to identify the later Roman 'grave cut' in the upper part of the section, as well as different materials within the fills such as flint and chalk inclusions. However, the result of this is a somewhat garish and over colourful image, which can be difficult to interpret. Despite this, the K-Means classification was arguably more successful at aiding interpretation.

The K-mean classified image shown in Figure 1e represents a categorisation of different materials based on their spectral properties. The spectral profiles of classes pertaining to silty-clay, chalk and flint material are shown in Figure 1f and these classes were converted to vectors. This can then be used to provide a quantification of different materials contained within the exposed section of the feature. Whilst such classifications are undoubtedly very useful it does not significantly further our understanding of more subtle differences across these deposits. By looking at the spectral profiles from a single type of material, however, it is possible to make more specific inferences.

The image shown in Figure 1b shows the position of different points and their corresponding spectral profiles (Figure 1d). Whilst the profiles are very similar in overall shape, the reflectance values do vary within each material 'class'. For example, Points 1 and 2 are characterised by a higher reflectance, whereas Points 3 and 7 are notably lower. Various factors can cause this, including variable geochemistry, moisture content, or organic content. In this case the lower levels of reflectance encountered at points 3 and 7 were interpreted as being indicative of a higher organic content. This illustrates how pHI can enable the observation of subtle differences in the composition of archaeological deposits that may not be directly observed by the human eye.

Discussion & Conclusion

The data presented here demonstrate the potential of pHI for the recording of archaeological features and deposits. It suggests that some enhanced definition of materials can be achieved through image processing and classification methods (e.g., PCA and K-means clustering), but analysis of individual spectral profiles is required to elucidate more subtle differences in the composition of these materials. Whilst these spectral differences likely relate to variations in organic content, it is not currently clear whether other parameters (e.g. geochemistry) also contribute to this. Thus, further comparison with other laboratory and field-based methods is required to verify the validity of these results. Thus, the continued exploration of 'portable' techniques such as pHI is highly desirable as there is enormous potential to facilitate a deeper understanding of past-human activity '"at the trowel's edge".

References

Bhargava, A., Sachdeva, A., Sharma, K., Alsharif, M. H., Uthansakul, P., Uthansakul, M., 2024. Hyperspectral imaging and its applications: A review. *Heliyon*, 10, 12: e33208. DOI : 10.1016/j.heliyon.2024.e33208.

Haburaj, V., Japp, S., Gerlach, I., Hoelzmann, P., Schütt, B., 2020. Coupling spectral imaging and laboratory analyses to digitally map sediment parameters and stratigraphic layers in Yeha, Ethiopia. *PLOS ONE*, 15, 9: e0238894. DOI : 10.1371/journal.pone.0238894.

Linderholm, J., Geladi, P., Gorretta, N., Bendoula, R., Gobrecht, A., 2019. Near infrared and hyperspectral studies of archaeological stratigraphy and statistical considerations. *Geoarchaeology*, 34, 3: 311-321. DOI : 10.1002/gea.21731.

Sciuto, C., Cantini, F., Chapoulie, R., Cou, C., De la Codre, H., Gattiglia, G., Granier, X., Mounier, A., Palleschi, V., Sorrentino, G., Raneri, S., 2022. What Lies Beyond Sight? Applications of Ultraportable Hyperspectral Imaging (VIS-NIR) for Archaeological Fieldwork. *Journal of Field Archaeology*, 47, 8: 522-535. DOI : 10.1080/00934690.2022.2135066.