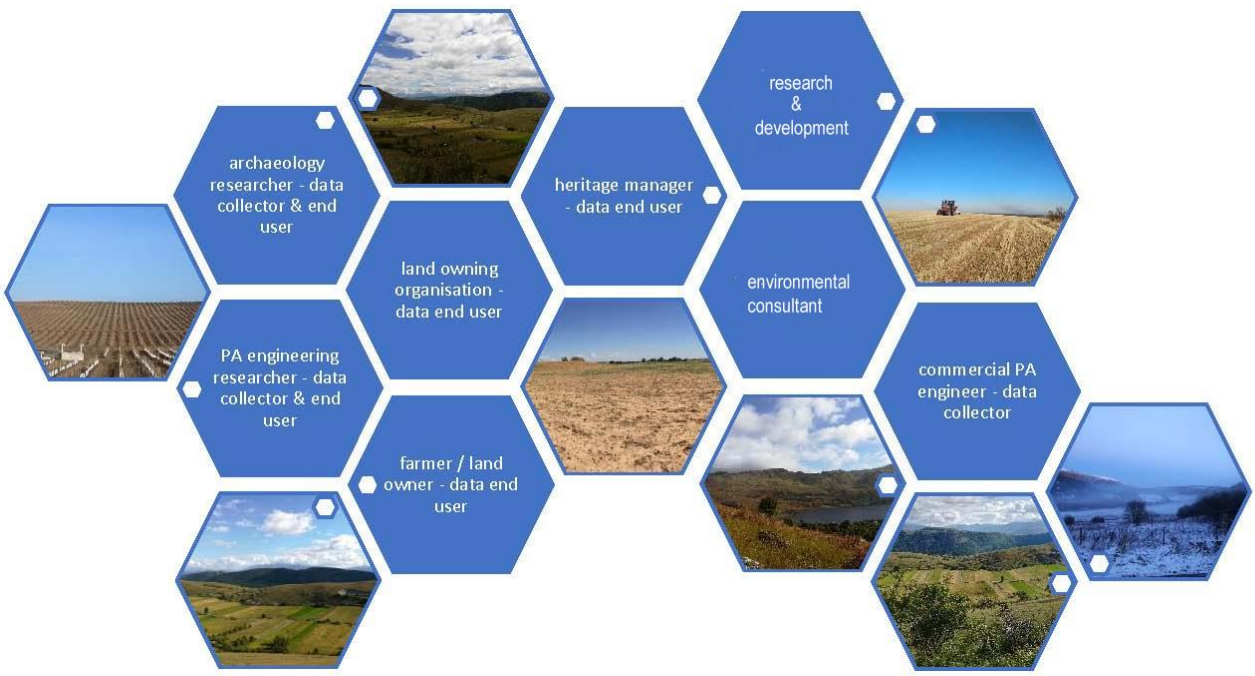
ipaast project report: second workshop on connecting remote and near surface sensing across archaeology and precision agriculture (PA) – exploring crop connections

14th September 2021 – Report prepared by Eamonn Baldwin and Rachel Opitz

Workshop focus: Crop development monitoring in PA and cropmark detection/monitoring in Archaeology

This workshop aimed to:

- introduce stakeholders from archaeology and precision agriculture to one another
- consider what data can be assembled to understand the interactions between developing crops, soils and buried archaeological remains. This workshop emphasised data gathered using aerial and satellite methods, used for monitoring and detection work over large landscape areas.
- understand how data, analytical approaches, and models used in different domains can be connected to provide information that would be useful to different stakeholders



Perspectives represented at the 14 September 2021 workshop, which brought together stakeholders from industry, academia and third-sector organisations in archaeology and agriculture.

Participants: Carolina Perna (University of Florence), Kirsty Millican and Richard Haewood (Historic Environment Scotland), Paul Scholefield (UK Centre for Ecology and Hydrology), Keith Challis (National Trust), Nick Wilson (York University), Daniel Kindred (ADAS Consultancy) Victorino Mayoral Herrera (CSIC, Research Council of Spain), Antonio Rubio Loscertales (Spectral Geo), Carlos Tarragona (Spectral Geo), Dominic Powlesland (Landscape Research Centre), Athos Agapiou (Cyprus University of Technology), Simon Crutchley (Historic England), Rachel Opitz and Eamonn Baldwin (University of Glasgow)

(left) Dag Endresen, (right) J. Dassié – crop development monitoring and crop marks side by side

Workshop activities included presentations from all participants which introduced their work, followed by full group discussions concerning connections between crop development monitoring in PA and cropmark detection/monitoring in Archaeology.

We asked – What information could archaeological cropmarks provide to professionals working in precision agriculture, farmers, and land managers?

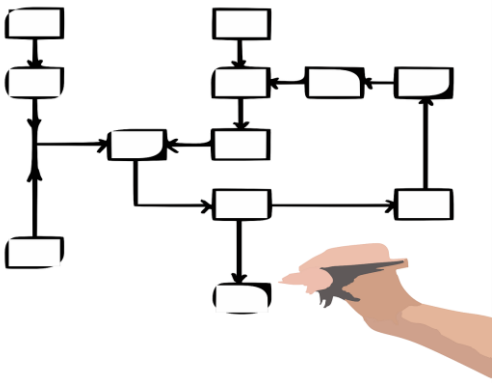
What data, information, or insights about cropmarks could be useful in PA?

Participant responses:

- Cropmarks could be used as a local indicator of conditions in a wider area. For example, their presence or absence could be used to infer general conclusions about local soil moisture levels. This information could be used as an indicator of conditions across the surrounding area. To use cropmarks as local indicators or benchmark sites, a systematic research programme would be needed to establish correlations between the conditions on cropmark sites and those in their surrounding areas.
    - This systematic research programme would need to improve our understanding of the variability of cropmark formation over time. There are many factors which contribute to the detectable (visible) presence or absence of a cropmark at any given time.
    - This research would need to go beyond an analysis of relationships between climate, weather, soils and other environmental factors because variations in cropmark formation also reflect the impacts of agricultural practices such as ploughing over time.
    - Determining optimal monitoring windows, periods and timings for cropmark detection would be an important first step in using cropmarks as local indicators of wider crop development conditions.
        - We must assess the overlaps between the possible periods in which we can detect cropmarks and the periods in a crop's development when PA applications could make use of the data provided.

    - Determining the appropriate spectral resolution of the data and identifying useful band combinations and derived indices would likewise be an important early step in research about using cropmarks to indicate wider crop development conditions.

- Most cropmarks are identified and monitored using RGB or RGB-IR data. Thermal data over cropmark sites could potentially provide further information useful in PA, beyond that from RGB-IR data. For example, thermal data could provide information on water content, which would be relevant to early detection of crop stress.



Images: Creative Commons – Wikimedia Commons. What is needed to bring cropmark data into workflows?

What would support and encourage practitioners in PA to incorporate archaeological data into their workflows?

Participant responses:

- Diverse types of data are important as they may provide complimentary or contextual information. Integrating them is therefore useful, especially as more sensors and data continue to become available.
- Access to data, especially raw data would encourage the uptake of archaeological data in PA workflows.
- Data collected for Archaeology is generally collected at a higher resolution than data collected for PA. Archaeology's high-resolution data may be useful for some specific PA applications. PA practices that typically require high resolution data include eradicating weeds, monitoring vineyards, and estimating yield in some crops. For example, to estimate yield in a watermelon crop, growers count individual fruits. High resolution data may also be useful for calibrating and validating treatment plans.
- It would be interesting to know what cropmarks can reveal about compaction, carbon stored in the soil, and biodiversity.
    - Of these, being able to improve carbon inventories at a large scale is a current priority. If archaeological cropmarks can be used to improve the accuracy of these inventories or contribute to monitoring changes in carbon inventories at a large scale, this would incentivise their use in PA.
    - Beyond large area monitoring, detailed insights into specific areas such as field margins might encourage uptake in PA. These areas may already be manged differently to support biodiversity or other environmental needs. Additional information on the carbon stores or heritage value of these areas could be integrated into their management plans.
- The funding landscape is important. Innovator projects with business models which include future revenues from datasets would provide good incentives for uptake of archaeological data in PA.

What changes to archaeological practice could make these data more useful in PA?

Participant responses:

- A more systematic approach to the mapping of cropmarks would be helpful, possibly assisted by machine learning, to provide fuller coverage.
- Systematic features extraction from lidar data, again possibly assisted by machine learning, could provide fuller coverage. Example applications include identifying historic field boundaries.
- Updates to the cropmark record which reveal the current condition at past cropmark sites would be helpful. Multi-temporal monitoring rather than singe-shot detection data seems more useful for PA.
- Archaeological data from land use areas other than the conventionally targeted arable crops could be useful in PA. For example, data which helps assess conditions in long-term unimproved grasslands is worth considering.
- Improved understanding of cropmark formation in other non-cereal crops could increases the value of these data to PA. For example, alfalfa has been shown to reveal buried remains in the near-infrared part of the spectrum but does not show cropmarks in the visible spectrum. A better understanding of what this tells us about how the plant is affected by variations in soil conditions could be useful.
- Some data might be more useful if collected at a different time of year. For example lidar data is normally collected 'leaf off' for topographic mapping. Leaf on collection is more useful for some PA applications.

Images: Creative Commons. When data is collected (leaf on or off) and over what crop and land cover types (alfalfa) requires coordination.

We asked – What are the potential uses of crop development monitoring data to identify cropmarks and support archaeological research and heritage management?

What data, information, or insights from PA could be useful in cropmark detection and monitoring?

Participant responses:

- Many factors involved in cropmark formation are relatively constant; it could be the less predictable factors such as weather (temperature, rainfall, moisture) which are crucial to understanding variability in cropmark formation. Many farms maintain weather stations and could provide localised weather data.
- Information on the presence of specific elements/minerals in the soil could lead to the better characterisation of archaeological features. For example, previous studies have suggested a link between phosphorus levels and graves in at some archaeological cemeteries. This information could be useful in interpreting what kinds of archaeological features are represented by cropmarks.

In my perspective archaeological prospection and precision agriculture have a lot in common. It's not only about the data sets, and we do have a lot of common data sets. It's also about the processing chain and how to process your data. I think in archaeology we have a lot to learn from precision agriculture, including about theoretical models that have not been developed in archaeology. - Athos Agapiou

Summing up – we asked about:

Low hanging fruit: What has the greatest potential for a coordinated approach?

Participant responses:

- Field trials to research crop development and better understand what's driving and what's limiting crop growth has great potential? Can crop development over cropmarks be investigated in a controlled field experiment using trickle irrigation or fertilisation? Can we compare growth in a trial area without archaeological features to growth over a buried archaeological feature under the same management conditions? Does controlling specific factors, such as moisture or nutrients, at microscale eliminate or reduce variations in crop growth?
- Further research to identify non-crop plants which are indicators of specific compounds and elements in the soil, which are by-products of activity of archaeological interest, has high potential. For example, the correlation between metal-tolerant plants growing in the field margins and archaeological remains could be investigated.

Images: Creative Commons – Wikimedia Commons and EGU. Plant tissue and soil mineralisation data are underexplored in cropmark studies.

Potentially interesting items: What don't we know that needs more research?

Participant responses:

- Can the insights from plant tissue analysis be used to better understand crop development within cropmarks? It would be a very good starting point if it meant you can identify the driving and limiting factors of plant growth, even if only controlled conditions (laboratory or field trial).
    - Detailed investigations such as performing a series of tissue analyses on samples gathered on a transect across a cropmark could help explain slight variations in growth related to the buried archaeological features and their effects on soils conditions.
    - There are limitations on this idea. The analysis works best on harvested plant which is more consistent than growing plant. Further, there will be difficultly untangling agricultural signals from the archaeological signals.
- When thinking about soil composition, artifact surface survey is also useful as historical manuring practices can result in high concentration of pot sherds in the soil, changing its composition. How might this information be translated into PA?

- Research to provide a better understanding of the causes of mineralisation and nutrient retention in the soil, accounting for archaeological components as well as the soil biome, would be interesting.
- When combining data from sensors with different spectral resolutions, careful statistical analysis has been able to enhance buried structures within mixed vegetation environment. Pilot projects on the analytical methods needed to combine data at different spectral resolutions to produce relevant insights are needed.

What obstacles do you see to applying outcomes of this research?

Participant responses:

- Does PA need high spatial resolution data and detailed insights? For applications like variable rate fertilising, irrigation and crop spraying, this seems unnecessary and wouldn't be supported by the current economics of agriculture.
- From an archaeological perspective, again spatial resolution is the biggest stumbling block. Current approaches to analysing spectral data and imagery require very high spatial resolutions because identifying small features is seen as essential for basic detection and characterisation, which are the main tasks in heritage management.

What specific questions should we be asking the community?

Participant responses:

- How should a large and diverse collection of data from across PA and archaeology be stored?
- How would you want to be able to access diverse data from across PA and archaeology?
- How would you analyse data collections from across PA and archaeology?
- Are there existing platforms and services into which you would expect these data to be integrated?

Image: The Noun Project - Creative Commons