Cropmark data

Guidance on using archaeological datasets in Precision Agriculture (PA) applications

Technical and conceptual notes to support data exchange via API platforms and Ecosystem Services Platforms (online GIS platforms)

Cropmarks are areas within a developing crop where local differences in greenness, development stage, height or leaf area are interpreted as indicating the presence of buried archaeological features. Cropmarks form because of local differences in soil properties such as available nutrients, compaction, moisture, temperature, or acidity, which result from the present of buried archaeological materials and human-modified soils. These interpretations are normally made visually by an expert interpreter, based on the shape of the area of plants which are developing differently from surrounding plants. Cropmarks are not persistent, form under specific combinations of conditions related to weather, soils and crop management, and may only be visible intermittently. Areas of land where cropmarks interpreted as representing archaeological features have been observed may be officially designated within a national or regional system for cultural heritage management.

Data Type

Images

Archaeological cropmarks are most commonly detected and documented in oblique or vertical aerial images. These photographs may be black and white or colour (RGB). Multispectral, hyperspectral and thermal imagery acquired from any platform (e.g. satellite, aircraft, UAV, kite) can also be used to detect and document cropmarks. In practice, these image types are less common and conventional photography remains dominant.

Vertical aerial imagery

Vertical aerial images documenting cropmarks will normally be georeferenced. The specific location of the cropmark feature within the image is not normally indicated.

Oblique aerial imagery

Oblique aerial images documenting cropmarks will normally be geolocated, but not georeferenced (stretched to an orthographic projection). The specific location of the cropmark feature within the image is not normally indicated.

Common Data Derivatives

- Interpretation vectors – Where oblique imagery is available, lines and polygonal shapes may be drawn over the features in the image in a graphics editor or GIS programme to characterise the shape and extent of the interpreted features. These vector features may be associated with attributes which describe the interpretation, which may make use of a controlled vocabulary. Vector drawings are typically georeferenced. These are typically available on a project, regional or national basis as a collection, rather than on a per site or area basis.
- Interpretation text – For either vertical or oblique imagery, a textual description of the interpretation may be associated with the image file(s) in the form of a report.
- Interpretation location – Where cropmarks have been identified in oblique imagery or in historic (pre-digital) imagery, a point location and description of a cropmark area may be provided without giving access to the associated imagery.

Identifiers

Unique identifiers for cropmarks are typically assigned to the collection of interpretations, images and metadata for a cropmark area. Individual appearances of a cropmark (detections) and individual images may be assigned their own unique identifiers. These UIDs are typically issued by a national or regional authority and are not persistent e.g. DOI identifiers.

An example UID on a site (cropmark area) basis is: https://canmore.org.uk/site/30923

An example UID on an image (item in a collection) basis is: https://canmore.org.uk/collection/397573

Unique identifiers may also be assigned to a location record and interpretation where no images are available directly from the source. An example locational UID is: https://archaeologydataservice.ac.uk/archsearch/record?titleId=1076034

Vocabulary

(Thematic tags, term lists, thesauri)
The following tags are recommended to provide compatibility across archaeological and agricultural vocabularies.

Getty AAT: Crop marks http://vocab.getty.edu/page/aat/300248611; landscape archaeology http://vocab.getty.edu/page/aat/300252459; Landscapes (environments) http://vocab.getty.edu/page/aat/300008626; aerial surveying http://vocab.getty.edu/page/aat/300226220

For UK collections: Evidence (England) CROPMARK ; Event Type (England) EVALUATION

AGROVOC: plant response http://aims.fao.org/aos/agrovoc/c_25446; crop monitoring http://aims.fao.org/aos/agrovoc/c_37838

GEMET: landscape alteration https://www.eionet.europa.eu/gemet/en/concept/4650; multiple use management area https://www.eionet.europa.eu/gemet/en/concept/5424

Vocabularies which describe the character of the archaeological remains vary widely. Original tags using these terms should be retained.

Data structure – cropmark area data

For any imagery submitted from a known cropmark area, regardless of the detection of a cropmark

Core attributes of data types (see above)

Critical information for inclusion

- Raw – original images
- Processed image data – a geolocated or georeferenced matrix of cell (pixel) rows and columns where each cell contains the numeric values with radiance / colour corrections and any desired band ratios applied; extent is defined by a bounding box in a WGS84 degrees or UTM metres

- Vector interpretation – archaeological features or areas of interest as represented by line or polygons each of which is linked to a database element or row which describes its essential attributes; extent is defined by a bounding box in a WGS84 degrees or UTM metres

Data Processing

For images or images in a collection:

- Raw – raster file with 1 or more bands
- Recommended processing:
    - georeferencing and rectification (vertical) OR geolocation (oblique)
    - Spectral calibration / colour correction to enhance contrast or balance radiance / brightness across an image collection
    - Band ratios e.g. NDRE, NDVI to increase visibility of potential cropmarks.

Note for videos:

- Raw file – video stream
- Recommended processing:
    - Extract representative frames as still images and process as for images
    - IF cropmark is visible through plant movement: trim video to minimum time where cropmark area is visible.

For interpreted vectors:

- No processing needed.

Metadata standard

For minimum metadata requirements, the INSPIRE geospatial standard is recommended (see Appendix xx for a list of mandatory metadata elements). In addition, IPAAST-CZO recommends the following core elements for inclusion with cropmark datasets:

Imagery Metadata		See Appendix 1 for full definition
(All data types)		
Duration/Collection date	Mandatory	Date (ISO 8601)
Imagery type	Mandatory	Character String (Free text)
Instrumentation details	Mandatory	Character String (Free text)
Area surveyed	Mandatory	Character String (Free text)
Bounding Box	Mandatory	Coordinates (WGS84, decimal degrees)
Nominal Spatial Resolution	Mandatory	Decimal / Numerical

Metadata for vector interpretations		
Scale of digitisation	Mandatory	Decimal / Numerical (e.g.1:5000)
Cropmark Cause	Optional	Character String (choice: anthropic inclusions in soils / improved soils / compacted soils / other)

Additional Metadata if known		
Survey Methodology (for raw datasets)		
Species of crop present (agrovoc vocab)	Optional	Character String (Free text)
Crop development cycle stage (agrovoc vocab)	Optional	Character String (Free text)

Date of most recent detection of cropmark	Optional	Date
Date of first detection	Optional	Date
Dates of any other detections	Optional	Character String (Free text)
Collection conditions (weather, recent weather history)	Optional	Character String (Free text)
Data processing (for processed datasets)		
Processing history list	Mandatory	Character String (Free text)
Archaeology (for Interpretation datasets)		
Monument type	Mandatory	Character String (Controlled List Value)
Monument period	Mandatory	Character String (Controlled List Value)
SM /Heritage List number	Mandatory	Decimal / Numerical

Scope Note

Applications of cropmark data in precision agricultural management decisions

The formation of cropmarks indicates areas where developing crops are reacting differently to local environmental factors, such as nutrient or moisture availability, soil salinity or subsoil compaction. The formation of cropmarks may provide an early indication of environmental stress across a wider local area. Consequently, observations of cropmarks may inform management decisions, e.g. variable rate applications of irrigation or fertiliser, both in years cropmarks form and in other years where the same crop is planted but cropmarks do not form. In areas with known cropmarks, their non-appearance over an extended period and under conditions where they would be expected to form (based on management and environmental conditions) may indicate erosion of topsoil. The regular appearance of cropmarks may inform management decisions, for example avoiding planting of crops with deep root systems, as part of an integrated programme of land management.

When using records of cropmark observations held by regional or national agencies, it is important to account for variable coverage and changing sampling strategies: coverage is not uniform each year and the focus of survey programmes will vary based on research and management priorities. A given organisation may not carry out flight campaigns in all areas in which cropmarks may be visible every year or may carry out the flight campaign on dates where specific cropmarks are not visible.

Scope Note

Precision agricultural data relevant to cropmark detection and monitoring

Images and image datasets of developing crops acquired using sensors employed in archaeology (RGB photography, thermal, multi – and hyper-spectral sensors) will be of direct relevance in archaeological applications. Increased frequency of image capture or image capture on different dates than those typical for archaeological aerial survey may be relevant for determining the length of the period(s) in which cropmarks appear in specific agricultural landscape contexts.

Sensors used in precision agriculture and not yet applied in archaeological applications can potentially produce relevant imagery or datasets in which cropmarks could be identified. Any precision agricultural instrument which maps differences in crop development could potentially be used to identify cropmarks. Relevant sensors include those that measure chlorophyll fluorescence, yield at harvest, biomass or leaf area index.

Micro-weather stations which report local weather, IoT sensors which provide high temporal resolution data on soil moisture and temperature, detailed reporting on agricultural practices e.g. sowing dates and crop type, and data on variable rate applications of irrigation or fertiliser provide relevant contextual information which may aid the interpretation of cropmark appearance or non-appearance in monitoring applications. These data are relevant because understanding the conditions under which cropmarks do and do not form. This improved understanding can better inform heritage management decisions in cropmark areas.

Schema

Related to -> **Ancillary explanatory factors data available:**

Treatments – irrigation (variable rate)

Treatments – fertiliser (variable rate)

Weather – cumulative rainfall

Weather – average temperature

Soil Moisture deficit – locally monitored or modelled

Crop – crop root depth range

Preservation potential – archaeological remains

Relevant Literature

Agapiou, A. (2020). Optimal Spatial Resolution for the Detection and Discrimination of Archaeological Proxies in Areas with Spectral Heterogeneity. *Remote Sensing*, *12*(1), 136. https://doi.org/10.3390/rs12010136

Corti, M., Marino Gallina, P., Cavalli, D., Ortuani, B., Cabassi, G., Cola, G., Vigoni, A., Degano, L., & Bregaglio, S. (2020). Evaluation of In-Season Management Zones from High-Resolution Soil and Plant Sensors. *Agronomy*, *10*, 1124. https://doi.org/10.3390/agronomy10081124

Czajlik, Z., Árvai, M., Mészáros, J., Nagy, B., Rupnik, L., & Pásztor, L. (2021). Cropmarks in Aerial Archaeology: New Lessons from an Old Story. *Remote Sensing*, *13*(6), 1126. https://doi.org/10.3390/rs13061126

Gojda, M., & Hejcman, M. (2012). Cropmarks in main field crops enable the identification of a wide spectrum of buried features on archaeological sites in Central Europe. *Journal of Archaeological Science*, *39*(6), 1655–1664. https://doi.org/10.1016/j.jas.2012.01.023

Hejcman, M., & Smrž, Z. (2010). Cropmarks in stands of cereals, legumes and winter rape indicate sub-soil archaeological features in the agricultural landscape of Central Europe. *Agriculture, Ecosystems & Environment*, *138*(3), 348–354. https://doi.org/10.1016/j.agee.2010.06.004

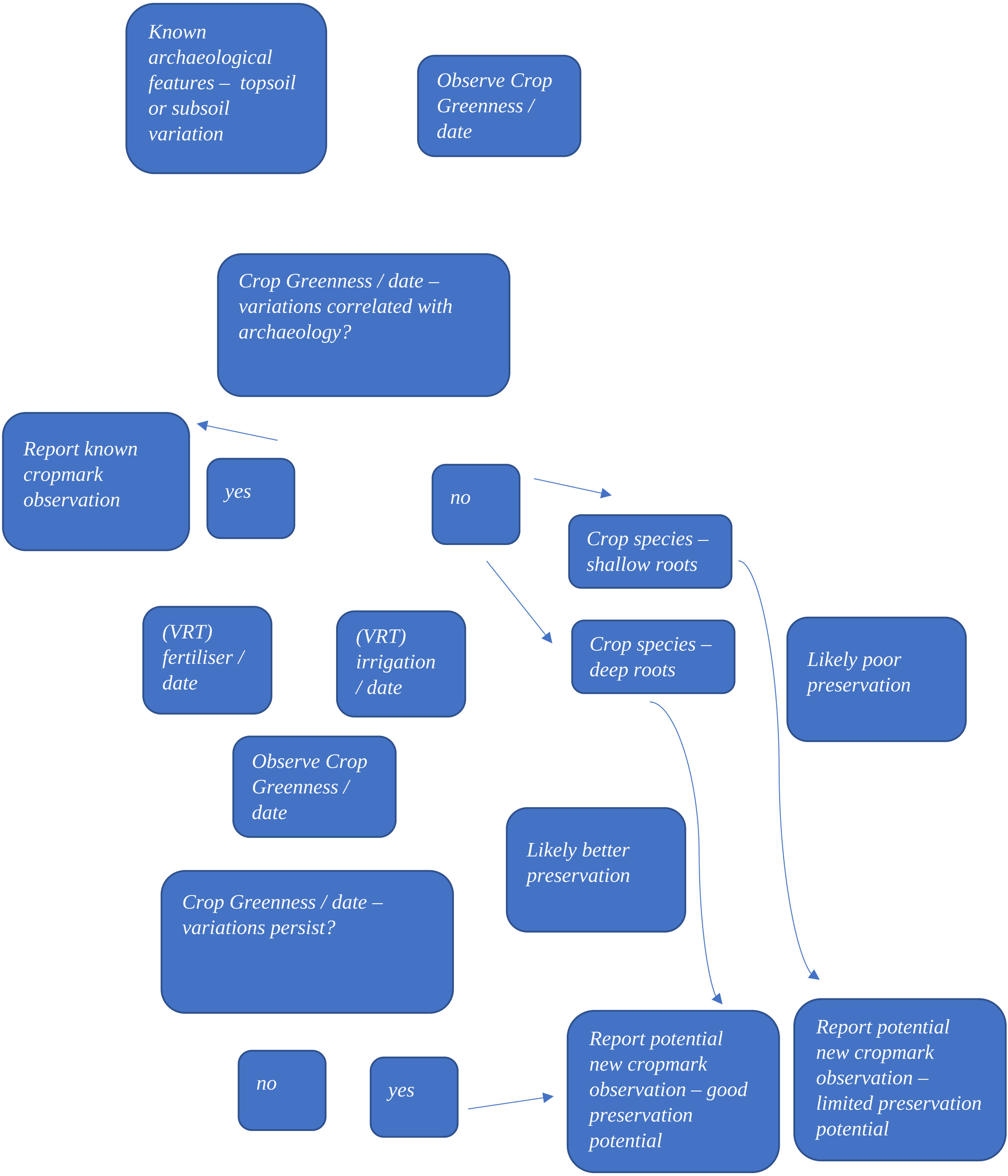
Hejcman, M., Součková, K., & Gojda, M. (2013). Prehistoric settlement activities changed soil pH, nutrient availability, and growth of contemporary crops in Central Europe. *Plant and Soil*, *369*(1), 131–140. https://doi.org/10.1007/s11104-012-1559-y

Kc, K., Zhao, K., Romanko, M., & Khanal, S. (2021). Assessment of the Spatial and Temporal Patterns of Cover Crops Using Remote Sensing. *Remote Sensing*, *13*(14), 2689. https://doi.org/10.3390/rs13142689

Khanal, S., Fulton, J., & Shearer, S. (2017). An overview of current and potential applications of thermal remote sensing in precision agriculture. *Computers and Electronics in Agriculture*, *139*, 22–32. https://doi.org/10.1016/j.compag.2017.05.001

Marino, S., & Alvino, A. (2019). Detection of Spatial and Temporal Variability of Wheat Cultivars by High-Resolution Vegetation Indices. *Agronomy*, *9*(5), 226. https://doi.org/10.3390/agronomy9050226

Example Application



Proposed Integrated modelling and interpretation space