SUPER-G
SUSTAINABLE PERMANENT GRASSLAND

MEDITERRANEAN
BOREAL
ALPINE
PANNONIAN
CONTINENTAL
ATLANTIC

Remote sensing for grassland monitoring

- **AUTHORS:** Pilar Fernández Rebollo.

- **DESCRIPTION:** Remote sensing of grassland consists of acquiring information on the state and condition of grasslands without physically coming into contact with them. This procedure entails collecting data with sensors (cameras, scanners, radiometers, etc.) mounted on platforms (tractors, unmanned aerial vehicles (UAVs), aircraft and satellites). This data is recorded on a suitable media and processed with the help of mathematical algorithms to translate it into relevant information for grassland management. The method has had limited uptake and the benefits to the average farmer have not been clearly demonstrated, although it could potentially have considerable utility on larger farms and estates.

- **RATIONALE:** Decision support systems for grassland management require spatio-temporal information on sward development and condition. Destructive surveys are labour intensive, costly and do not provide adequate spatial and temporal coverage. Remote sensing overcomes these limitations and has been widely applied to vegetation monitoring and is a useful tool to make grassland farming better informed.

- **MECHANISM OF ACTION:** Information on grasslands features can be derived from spectral and non-spectral remote sensing data. The former is based on the specific and distinctive spectral absorption and reflection properties of grassland canopies, whereas the latter mostly provides information on canopy height and structure.

  The electromagnetic radiation incident on a grassland can be partially absorbed, transmitted or reflected. Grasslands also naturally emit radiation. The intensity and wavelengths of this reflected or emitted radiation are a function of the grassland characteristics and this spectral data can be recorded with the help of sensors. There is a wide variety of sensors that record reflected or emitted electromagnetic radiation with different spectral and radiometric resolution. Spectral resolution describes the ability of a sensor to define narrow wavelength bands while radiometric resolution refers to the ability to discriminate very slight differences in energy. Multispectral sensors record radiation in a small number of bands (e.g., Sentinel-2 from the Copernicus mission has 13 spectral bands) and hyperspectral sensors provide almost continuous very narrow bands (e.g., Hyperion provides 220 bands). Sensors can be placed in fixed location on the farm (e.g., digital cameras, phenocams) or, more commonly, mounted on a mobile platform: from ground vehicles or human operators to UAVs and satellites.

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 774124

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the European Commission can be held responsible for them.

SUPER-G
SUSTAINABLE PERMANENT GRASSLAND

MEDITERRANEAN
BOREAL
ALPINE
PANNONIAN
CONTINENTAL
ATLANTIC

Remote sensing for grassland monitoring

- **MECHANISM OF ACTION (cont.):**

The utility and application of spectral remote sensing at farm level depend also on the spatio-temporal resolution of the spectral data. On the one hand, some aspects of grassland management require a spatial resolution of below 10 m to capture spatial heterogeneity of grassland fields. Some satellite sensors have this spatial resolution. For example, Sentinel-2 provides four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. Other commercial sensors mounted on satellites such as Planet or Maxar provide spectral data at higher spatial resolution (<5m). Spatial resolutions of airborne or UAV-based sensors are much higher and range from centimetres to metres. On the other hand, grasslands change over time, so regular measurements are needed to support grassland management decisions. For instance, Sentinel-2 provides freely available data worldwide with a revisiting time of 5 days.

Typically, to examine multispectral data, vegetation indices (a combination of a few bands, e.g., Normalised Distance Vegetation Index- NDVI) are calculated and then related to specific grassland features by regression or using empirical or mechanistic modelling approaches. However, the focus is to use the entire spectrum rather than specific bands when working with hyperspectral data. Techniques like machine and deep learning are especially helpful for evaluating hyperspectral data.

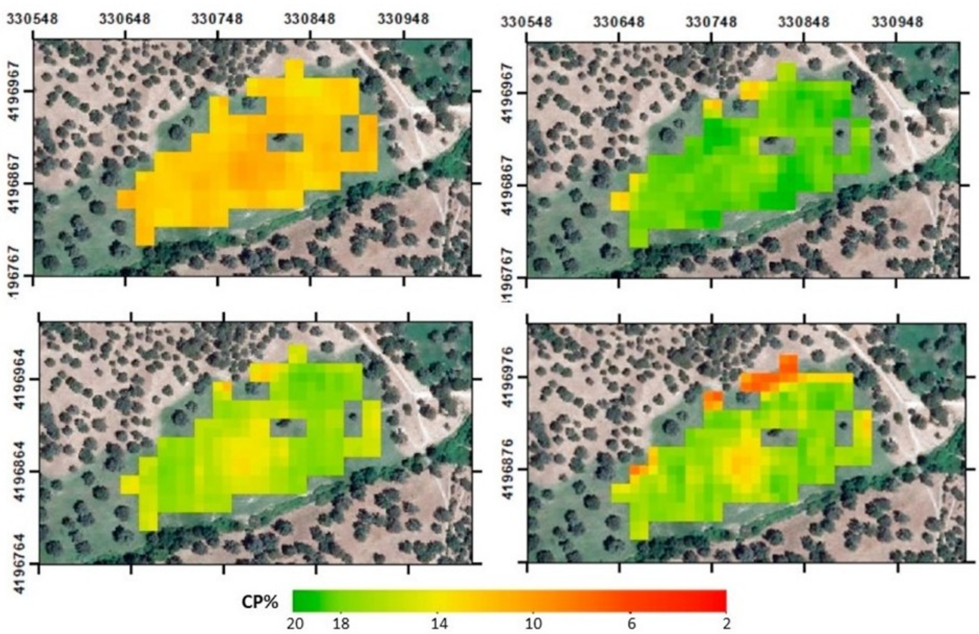

Fig.1: Spatial predictions of crude protein (CP) for four different dates in a field of irrigated grassland. Predictions made using a Partial least squares (PLS) model fitted with spectral field data and Sentinel-2 images for prediction. The background image is an aerial orthophotograph at 0.5 m resolution from July 2016. Source: Fernandez-Habas et al. (2021) https://doi.org/10.1016/j.scitotenv.2021.148101.

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 774124

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the European Commission can be held responsible for them.

- **MECHANISM OF ACTION (cont.):**

LiDAR (Light detection and ranging) scanning devices represent the most innovative technology for non-spectral data acquisition. These devices emit high frequency laser pulses (active remote sensing method) and record the reflected pulses to precisely represent the scanned grassland surface topography. The result is a 3D point cloud which can be used to estimate sward height. Most LiDAR systems can record several returns from a single laser pulse when it reaches an object with multiple layers, providing information for the whole vertical sward structure. LiDAR can be mounted on a UAV or operated from the ground (TLS, Terrestrial Laser Scanners, or novel handheld Simultaneous Location and Mapping SLAM). Radar (SAR) is another active remote sensing method that is also available from satellites. The sensor sends a microwave (radio) signal in the direction of the target and picks up the signal's backscattered component. The time delay between the sent and reflected signals establishes the distance to the target, and the strength of the backscattered signal is measured to distinguish between various targets. The advantage of SAR is that it can virtually always collect data regardless of the weather.

Spectral and non-spectral data have been used to estimate grassland properties such as: herbage growth rate, leaf area index (LAI), unwanted weed species, mowing events, phenological stage, type of grasslands, floristic gradients, plant diversity and crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents. TLS and UAV-LiDAR derived sward height has been successfully used to estimate standing biomass and SAR has been used for assessing spatial heterogeneity in grassland cover. The best way to develop reliable estimators of grassland attributes is to combine spectral and non-spectral data analysis techniques, which perform better on multi-temporal scales.

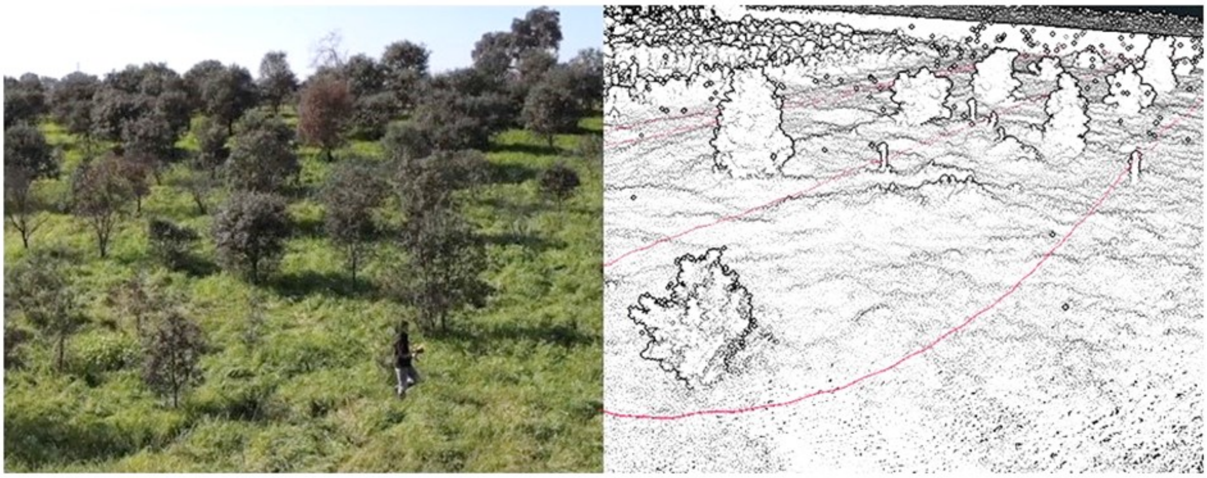

Fig.2: Operator scanning a grassland with a terrestrial laser scanning TLS (left) and a 3D point cloud generated (right). The 3D point cloud is used to generate a Grassland Surface Model (GSM). GIS (Geographical Information System) software can be used to subtract the Digital Terrain Model (DTM) from a GSM, resulting in plant height data, which can be used to estimate standing biomass.

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 774124

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Remote sensing for grassland monitoring

Potential for applying the management option

The collection and processing of remote sensing data requires considerable expertise and computer resources, making it necessary for most farmers who use this technology to have professional support. In the past decade, there has been an increase in research into the use of remote sensing to understand grassland dynamics along with the emergence of free and commercial services using this technology for grassland monitoring. Grassland commercial services that use remote sensing are developing and, although limited in number, there is a market for these services, which is expanding. However, in spite of its great potential, there is still little conclusive evidence on the benefit to farmers of using grassland remote sensing, in terms of increased yields or reduced input costs. Remote sensing of grassland could be used in all farming systems based on grassland and it can be implemented in any biogeographic region. However, currently, it is probably most applicable on large farms and estates that wish to monitor grass growth and quality over large areas.

Support

No incentives are needed for farmers to use services based on this technology. The option has the potential to increase farmers' knowledge of grassland attributes to optimise their use and management. The technology would be adopted by farmers if it can be shown to increase farm productivity, reduce production costs, or save time.

Practical considerations

Remote sensing based on satellite imagery with low spatial resolution (from hundreds of metres to metres) may be of limited use in grasslands with dense tree or shrub cover, as pure grassland pixels will be scarce. A similar situation may occur on farms of small size or with small fields, where an image pixel may contain more than a single field. In this situation, using drone images of higher spatial resolution (from tens of centimetres to centimetres) is an alternative.

The commercial services are cheapest when using free images from satellites and can be more expensive when using images from commercial satellites or from sensors mounted on aircraft. The service cost for drones is intermediate (lower compared to commercial satellites). Clouds limit the collection of spectral data. Drone flights may be hampered by wind. Prediction accuracy and model generalizability still need to be enhanced. Most of the services have not been fully tested in the heterogeneity of European grasslands, so solutions developed for one area might not give good results in another, and more work is needed.

Example of services

Some free and commercial services using remote sensing for grassland monitoring are listed below.

CropSAT is a tool for viewing maps of the biomass from Sentinel 2 data (based on NDVI). Maps of different date can be used to assess crop development during the season and to control N application. It is a free service. https://cropsat.com/

Pasture.io is a decision support system for grassland and grazing management. It uses commercial satellites, artificial intelligence, farm records and local weather data to give grazing recommendations several times a week. The service is charged. https://Pasture.io

Pasture From Space estimates green feed on offer (FOO) and pasture growth rates (PGRs) in Western Australia. Data from MODIS allows for the calculation of the normalised difference vegetation index to estimate FOO. The PGR uses weather information to determine the soil moisture and temperature plant growth indexes, which both indicate growth potential. The last input into the PGR is solar radiation. It is a free service. https://pasturesfromspace.dpird.wa.gov.au/#/map

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 774124

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the European Commission can be held responsible for them.