Copernicus Sentinels missions and crowdsourcing as game changers for geospatial information in agriculture

by Flavio Lupia, Vyron Antoniou

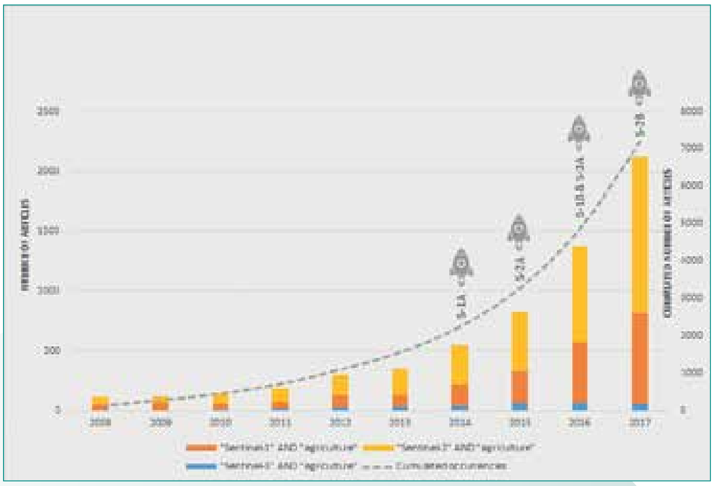

Fig. 1 - Yearly occurrences of papers indexed by Google Scholars containing the keywords: "Sentinel-1" AND "agriculture"; "Sentinel-2" AND "agriculture"; "Sentinel-3" AND "agriculture".

Today, new advances in science and technology and, above all, the open flow of rich datasets play a pivotal role when it comes to better manage territory and its resources. Agriculture is one of the relevant domains where data from Earth Observation and their integration with data from different sources (i.e. proximal and ground sensors and even in-situ data from human sensors) will provide many benefits. Such data-driven opportunities are the backdrop of the transition toward an innovative agriculture (see the concepts of smart farming, farming 2.0, precision farming/agriculture, digital agriculture, etc.). The following paragraphs describes briefly two new opportunities for the generation of data usable for agricultural application: remotely sensed data from the Copernicus programme and user generated data through crowdsourcing.

New options for mapping and monitoring agriculture remotely

Agricultural sector is getting ever more attention due to its role in feeding a growing world population by maximizing productivity and optimizing natural resources usage. At European level, agriculture has great economic relevance. According to 2013 Eurostat figures, 42.5 % of the area of EU-28 was occupied by agriculture and globally the EU-28's share was above the world average (37.9 %).

More accessible data and information can benefit the agricultural sector and the effective implementation of policies such as the Common Agricultural Policy (CAP). Though the current CAP (2014-2020) has contributed to agricultural sustainability, the future CAP (beyond 2020) will strive further to facilitate smart and resilient farming and actions to meet environmental EU targets and to improve the socio-economic tissue of rural areas. Achieving these goals requires a step up in research and innovation.

Copernicus, the programme for the establishment of a European capacity for Earth Observation (EO), is the chief example with its geospatial big data delivered with open data policy enacting a big leap in agricultural mapping and monitoring.

Copernicus is satellite-borne EO, in-situ data and services

such as the Copernicus Land Monitoring Service (https://land.copernicus.eu/) providing information on land cover/land use and variables for vegetation and water cycle monitoring for applications in several domains such as agriculture.
The Programme with its global coverage, powerful sensors, continuity of acquisition and open data policy is opening up new options to manage and control actions needed by CAP objectives for European agriculture.
Agricultural analysis can benefit from products delivered by the first three Copernicus Sentinels missions operating with twin satellites (A and B).
Sentinel-1 (S1), launched on 3 April 2014 (1A) and 25 April 2016 (1B), provides all-weather and day/night microwave acquisition (C-band Synthetic Aperture Radar) in four exclusive imaging modes with spatial resolutions down to 5 m and a swath width from 20 to 400 km.
Sentinel-2 (S2), launched on 23 June 2015 (2A) and on 7 March 2017 (2B), has a spatial resolution (10, 20 and 60 m) suitable for average size of parcels in Europe, a low revisit time (5 days at Equator), a multispectral sensor (visible, near-infrared and red-edge channels) and 290 km swath width. These features enable applications related to seasonal and within-season crop status analysis, yield prediction and determination of nutrient and irrigation needs. The integration of S1 and S2 allows to create very dense time series for agricultural studies. Moreover, S1 complements the multi-spectral information of S2 by acquiring under the clouds and trough vegetation canopy.
Sentinel-3 (S3), launched on 16 February 2016 (3A) and 25 April 2018 (3B), has near-daily acquisition at low resolution (300 m), two swath widths of 1270 and 1420 km, a sensor with high spectral quality with three high accuracy thermal bands usable for vegetation stress monitoring. Co-location of bands between S2 and S3 and the existence of bands devoted to atmospheric corrections ensure the full integration of the products generated.
As a whole, Sentinels will generate long term time series boosting several applications, including change detection of agricultural land, yield forecast and definition and calibration of agricultural models. Analytical possibilities will be much more powerful if integration with others EO open data is considered (e.g. Landsat missions).
The interests about Sentinels missions and their potential application in agriculture started well in advance their operational deployment, this is well depicted by the growing trend of the occurrences of the two terms "Sentinel-x" and "agriculture" within papers indexed by Google Scholar (Figure 1).
Among the relevant projects exploiting Sentinels data for agriculture, Sen4CAP (http://esa-sen4cap.org/) and Sen2-Agri (http://www.esa-sen2agri.org/) are two examples worth mentioning. Aimed at developing EO products and services with open source code, Sen4CAP is developed to increase efficiency, traceability and to reduce costs of the system managing the payments for farmers under the CAP. Sen2-Agri is designed to demonstrate, through a user-oriented approach, the usability of S2 time series for agricultural monitoring for a wide range of crops and farming practices. The main output is a free and open source processing system which delivers several near real time products (e.g. vegetation status map, monthly cropland masks, crop type maps).
Big geospatial data that is being generated by Sentinel's missions call for a shift in data management and analysis in order to effectively extract powerful information to support agricultural management. New technological solutions such as cloud-based platforms and multi-core processing systems are needed to effectively manage these huge datasets. The Thematic Exploitation Platform (https://tep.eo.esa.int/) and the Copernicus Data and Information Access Services (http://copernicus.eu/news/upcoming-copernicus-data-and-information-access-services-dias) are two interesting solutions.

Crowdsourcing: the option for bottom up data generation

In parallel with the authoritative initiatives for systematic EO and the collection of big geospatial data for further analysis, there are equally interesting developments at the other end of the spectrum: the citizens. The evolution of crowdsourcing, i.e. tapping the power of the crowd to achieve specific goals, usually through open and inclusive processes, has evolved into Volunteered Geographic Information (VGI) for the Geomatics domain. VGI, defined as the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals (Goodchild, 2007), has transformed the way that geographic information can be collected and maintained and today intertwines with Citizen Science (CS) which promotes the volunteer from the position of simple data provider to designer and practitioner of scientific work. These developments and efforts have not been left without support by the authorities. In EU, a number of projects has

been funded that aim to promote the engagement of citizens to scientific endeavours (see for example Horizon 2020 DITOS project - http://www.together-science.eu/ - or the funding of multiple projects through the COST Action Scheme).
In this context, and given the individual advantages of the authoritative data acquisition on the one hand and the bottom-up process of data collection on the other, a new challenge has appeared: how to combine the best of the two worlds in a way that will add value to the final products and services that reach the users. For example, effective exploitation of EO for terrestrial monitoring, and specifically for agriculture, cannot avoid the use of in-situ data necessary for calibration/validation of any derived product. Beyond the classical tools for collecting ground data, nowadays new opportunities derive from CS and VGI, where laypersons or interested stakeholders can actively or passively generate georeferenced information that can be merged with EO data. For example, both volunteers and farmers can provide relevant in-situ data on bio-geophysical properties of soils and crops. A recent study (Dehnen-Schmutz et. al., 2016) carried out in UK and France showed that farmers are confident in the use of apps and expressed interest to participate in CS projects especially for data collection and real-time monitoring. All these data can be collected and analysed with dedicated platforms so to deploy advisory services for farmers that will help them to improve crop management and production. Other examples can be found at the Spece4Agri (http://space4agri.irea.cnr.it/it), and the FOODIE (http://www.foodie-project.eu/index.php) projects which use VGI for agriculture or the LandSense (https://landsense.eu/) project that uses VGI for collecting Land Use and Land Cover (LULC) data. Space4Agri, developed a system for integrating remotely sensed, multi-source and heterogeneous data, authoritative datasets and in-situ data on crop development and agro-practices created by volunteer (agronomists, farmers and citizens) to support sustainable and precision agriculture (Bordogna et al. 2016). FOODIE is building a platform hub on the cloud where spatial and non-spatial data related to agricultural sector are available for agri-food stakeholders and can be integrated for supporting decision making process. Data are collected from different sources and made openly available (e.g. OpenStreetMap, voluntary collected data about market situation, crops yield, etc.). Finally, LandSense Citizen Observatory aggregates innovative EO technologies, mobile devices, community-based environmental monitoring, data collection, interpretation and information delivery systems in order to empower communities to monitor and report on their environment.
While there are enormous potentials from the synergy of authoritative and crowdsourced EO efforts, there are equally some important caveats that need to be addressed. Perhaps, the most important one is data quality. Quality issues can be analysed from different perspective and can affect heavily the results when are used for validating remotely sensed data or used for modelling applications in agriculture. Therefore, knowing these issues is relevant as quality can affect decisions making process from the farming level (i.e. precise management of the agricultural production process) to the policy level (good implementation and monitoring of economic and environmental measures). Quality evaluation of crowdsourced data owes to cover multiple facets of data at hand, facets that are usually not considered when dealing with authoritative data. Thus, apart from the well-defined spatial quality elements (ISO 2013) of completeness, logical consistency, positional accuracy, temporal accuracy, thematic accuracy and usability that need to be thoroughly evaluated, crowdsourced geographic information should be also examined against inherent biases. It is not uncommon for volunteered datasets to suffer from temporal biases, as volunteers might be able to contribute data only on weekends or after-work hours; positional biases, as it is easier for volunteers to reach and collect data from areas in their vicinity or wherever the access is not obstructed; or participation biases, as there are social imbalances regarding the people that volunteer (i.e. it usually requires for people to have enough free time and the means to acquire the needed equipment for data collection). All these factors need to be carefully considered and evaluated (e.g. by defining protocols for data collection (Minghini et al., 2017) before using crowdsourced geographic information with authoritative EO data.

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KEYWORDS

Crowdsourcing; geospatial; remote sensing; monitoring; mapping; agriculture; Copernicus sentinels

ABSTRACT

A big leap in the agricultural sector is expected thanks to the operational deployment of Copernicus data and services, the new Earth Observation program of the European Commission. The huge quantity of data delivered freely along with the good level of resolution (spatial, temporal and spectral) will open up new opportunities for achieving the well-known sustainability of agriculture. At the same time, the new trends of crowdsourcing and citizen science are delivering a great deal of geographical data collected by ordinary users with a bottom-up process. The two type of data and their integration will be the base for the future application in the agricultural sector, albeit management of big geospatial dataset and quality of user generated data are issues to be addressed.

AUTHOR

Flavio Lupia
flavio.lupia@crea.gov.it
Council for Agricultural Research and Economics (CREA)
Via Po, 14 00198 Roma, Italy

Vyron Antoniou
Multinational Geospatial Support Group
Frauenberger Str. 250, 53879, Euskirchen, Germany
v.antoniou@ucl.ac.uk