Smart imaging from space for crops management

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Prof. Pierre Defourny is professor of geomatics, Earth remote sensing and land use planning at the Faculty of Bioscience Engineering of the Université catholique de Louvain. He is the founding president (2010-2015) of the UCL Earth and Life Institute gathering more than 300 researchers in Earth and biological sciences to address major challenges facing our planet (food production, biodiversity, climate, water). He leads a research lab in satellite remote sensing and GIS modelling for land applications, in particular for land cover, agriculture and forest ecosystem monitoring. As the co-lead of the global network for a Joint Experiment for Crop Assessment and Monitoring (JECAM), he is an executive committee member of the GEOGLAM initiative for global agriculture monitoring supported by the G20.

He is also an Earth Observation expert for space and UN agencies including the European Space Agency and the NASA where he worked as a visiting scientist for a year. Currently leading several flagship projects of the European Space Agency, his research team joint forces with many international partners to produce from multiple satellites the most precise time series of global annual land cover maps from 1992 to 2015 recently adopted by FAO, OEDC and some IPCC modelers. Similarly, the Sentinel-2 for Agriculture open source system capable to process massive volume of satellite observation for crop monitoring in near real time at 10 m resolution was designed and demonstrated in many countries around the world. Most recently, he is invited as expert to various committees related to the EU Common Agriculture Policy to support the DG-AGRI in the exploitation of the new Sentinel satellite fleet for the CAP reform post 2020.

INTRODUCTION

A tsunami of Earth Observations downloaded from space is changing the game for land surface monitoring in any place on Earth. For 40 years, the Earth Observation community has developed concepts, methods and algorithms using experimental or commercial satellites. Since a few years, the convergence of the performances of cloud computing infrastructures, the success of artificial intelligence and the new European Copernicus program have opened the avenue for the operational implementation of many new space applications supporting crop management, food traceability, and agriculture practices monitoring, amongst many others. Some are already mature applications currently implemented as operational services at full scale, while others correspond to emerging technologies that are often very promising but have still to be confirmed in an operational context.

AN INFORMATION TECHNOLOGY AND EARTH OBSERVATION (R)EVOLUTION

Satellite remote sensing is an undisputed source of regular land information for a vast range of users at all geographical scales with pixel size now varying from 30 cm to 10 -20m on the ground. After many years of satellite observation driven by NASA, the European Copernicus program has made a breakthrough for operational applications by committing to open, free, systematic and long term imaging capacities over the whole surface of the planet using a fleet of Sentinel satellites. Earth Observation is progressively becoming a common good, like meteorological observation with long-term policies and system redundancy.

Agricultural applications are directly supported by the new Sentinel-2 mission, including two satellites in near-polar sun-synchronous orbits, with a revisit cycle of 5 days over each location of any continent. They measure a very well calibrated surface reflectance in 13 different spectral bands (from 443 nm to 2190 nm) specifically designed for vegetation monitoring at 10 and 20 m resolution on the ground and for correcting atmospheric perturbations. The Sentinel-1 mission also consists of two satellites in orbit providing a revisit of 6 days at the equator (3 days over Northern Europe) and imaging of the land surface by sending a C-band signal (central frequency of 5.404 GHz) and recording the backscattered signal, regardless of cloudiness and environmental conditions. These all-weather and day-and-night radar imaging capabilities largely compensate the fact that the images recorded by these Synthetic Aperture Radar (SAR) instruments are much less familiar. The first one of these four satellites was launched in 2014 and the last one has been fully operational since July 2017, with the following Sentinel-2C and D spacecraft already under development. With the systematic coverage of the satellite constellation, the never-ending waterfall of Sentinel-2 images results ultimately into over 4 Terabytes of fresh products, published every day on the Copernicus portals. This represents a real challenge for the ground systems to cope with and likely also for users themselves to process in their applications. Only the fast development of cloud computing infrastructures like Amazon, Alibaba and Google Earth Engine allows the handling of such a considerable amount of observation time series over large areas in a timely manner.

MAPPING CULTIVATED AREAS THROUGHOUT THE SEASON AND MONITORING CROP DEVELOPMENT

Estimating planted areas at an early stage, detecting plant emergence date at field level and identifying crop type along the season are the current challenges that are being successfully tackled by some open source software such as the Sen2Agri system, which has been specifically developed to streamline the management of massive data volumes in a seamless way. Such a system automatically downloads the data from the satellite catalog and processes it as it arrives. Biophysical variables like the Leave Area Index (LAI), proportion of vegetation cover and fraction of the Absorbed Photosynthetically Active Radiation (fAPAR) are retrieved for each pixel of 10 x 10 meters from each cloud free image acquired over the country or the region of interest (figure 1).

The monitoring of these biophysical variables for a given crop is relevant for vegetation development assessment, field heterogeneity characterization and in the best case, yield forecasting. For instance, in a context of a food unsecure country like Mali, crop yield indicatorss for the main crops was related to the peak of LAI providing early crop production estimate one month before harvest. Current research activities try to depict disease impacts from the evolution of these EO-derived variables throughout the season in order to support the modelling of the spread of disease such as wheat rust or maize lethal necrosis.

In Belgium, several commercial applications are emerging for crop monitoring, sometimes led by the food industry (e.g. potato sector), to deliver satellite information to the industry for planning purposes or to the farmers for crop management.

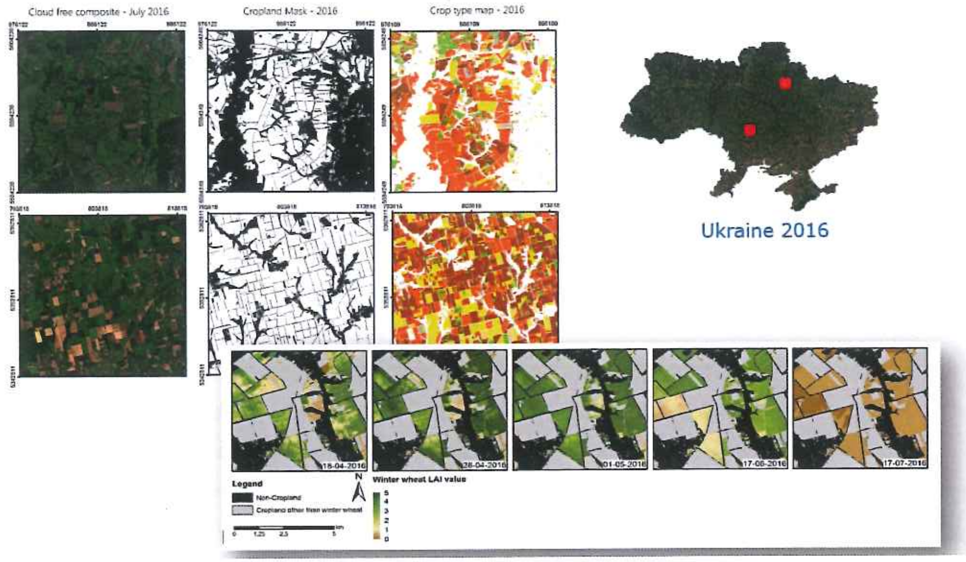

Figure 1 – First crop type map and Leaf Area Index (LAI) for the wheat fields produced at 10 m resolution from the Sentinel-2 mission in 2016 over Ukraine. This highlights the potential of near real time monitoring of each winter wheat field in Ukraine from the mid-season. The Leaf Area Index corresponds to a biophysical variable measuring the surface of all photosynthetically active leaves per ground unit and is closely correlated with the green biomass at early crop stages (Defourny et al., 2018).

SUPPORTING THE CROP MANAGEMENT

Exploiting the potential of the red-edge bands of Sentinel-2 has also led to the estimation of the crop canopy chlorophyll content from the images. Such information can be combined with eco-physiological knowledge to deliver the so-called Nitrogen Nutrition Index (NNI). In the context of the BELCAM platform supported by the STEREO program of the Belgian Science Office, this information is provided to farmers to deliver the current nitrogen plant status and advice on the fertilizer input (figure 2). In conventional, as in precision farming agriculture, the timeliness of such an information delivery is critical for fertilizer applications. The development of ecologically intensive agriculture could be directly related to such a capacity. Commercial services like Farmstar were initially developed many years ago with costly satellite images, but have become much more accessible today as they have been bought by fertilizer or seed companies.

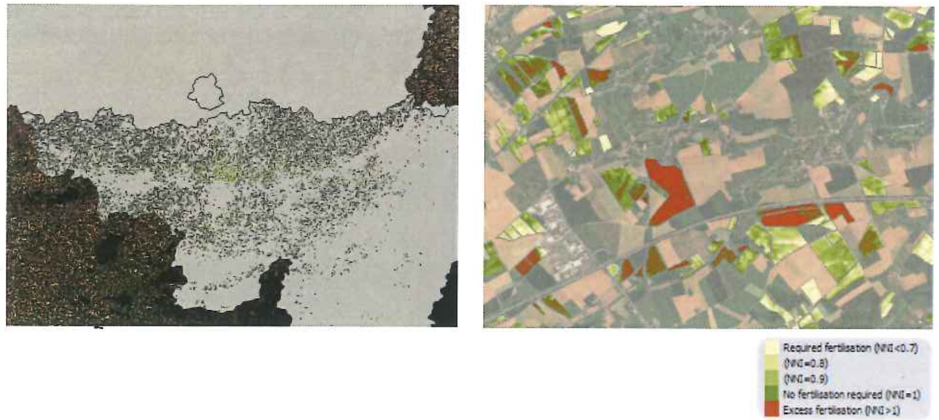

Figure 2 – First Nitrogen Nutrition Index map based on the canopy chlorophyll content measured for each 10 x 10 m pixel. The Nitrogen Nutrition Index measures the capacity of a plant to take advantage of additional Nitrogen input (Delloye et al., submitted in 2018).

DRIVING THE REFORM OF THE 2020+ COMMON AGRICULTURE POLICY

On the request of the EU Commissioner Phil Hogan, the forthcoming reform of the 2020+ Common Agriculture Policy will have to rely on the potential of the Sentinel satellites in order to simplify its implementation over the whole European Union. Monitoring agriculture practices along the season and their compliancy with regards to the new CAP regulations are expected to drive the new CAP paradigm voted by the European Parliament late May 2018, namely the Monitoring approach. This will allow the support of farmers in their crop management and the associated eligibility at field and at farm level. In this context, the Sen4CAP project, supervised by the European Space Agency and supported the European Commission, is currently investigating new methodological developments and the Paying Agencies protocols, in order to best take advantage of the various metrics derived from these satellite signals.

As illustrated in figure 3, the unprecedented density of satellite observation allows detecting crop management practices like tillage or no tillage, harvesting date, or green manure management. Similarly for grasslands, the detection of mowing dates by satellites should inform the farmer in due time about the management needed to improve its productivity in a sustainable perspective and to maintain its eligibility for subsidies. The overall 2020+ CAP objective is to move from a control perspective to a monitoring perspective, supporting the farmers in their crop and grassland management for ecologically intensive agriculture.

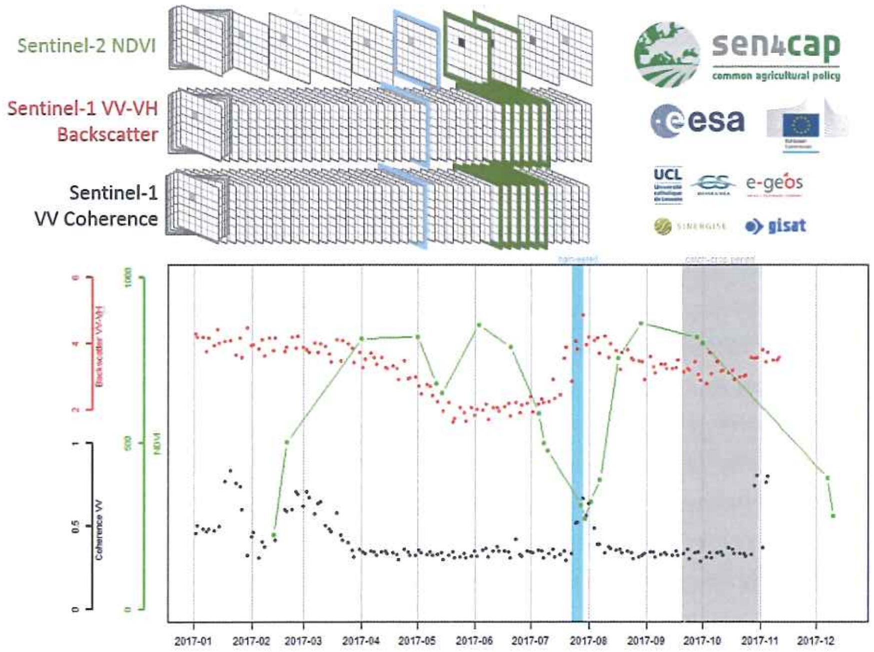

Figure 3 – Three different metrics respectively derived from Sentinel-1 and Sentinel-2 satellite constellations are computed from very dense time series of observations, in particular from the all-weather, day-and-night radar imaging system on board Sentinel-1 providing a useable image every 3 days over Belgium. The sharp coherence increase, matching the large drop of the vegetation index (NDVI) derived from Sentinel-2 depicts the harvest date of this field (source: Sen4CAP project, from GISAT – UCLouvain, 2018).

SHARING THE INFORMATION TO FARMERS AND TO THE GLOBAL LEVEL

The successful uptake of these new information sources is also much related to the communication tools for the information dissemination and its actual use by the targeted stakeholders. Numerous apps on smartphones, developed to display the field information along with meteorological forecasts, seems key to reach out to the farmer for crop management in near real time. Attractive web mapping interfaces are more required for analysts, who would prefer to browse a series of websites and to download fresh data in their own analytical tools. No standard is established yet and the innovation pace is currently particularly impressive. Beyond attractive and fancy interfaces, the service quality necessary to build user confidence will be key in the coming years as well as the integration of various services.

On the other hand, for international markets, the G20 request to enhance market transparency by widely sharing crop production estimates has been taken up by the GEOGLAM initiative, to derive such information partly from satellite imagery and crop modelling, in order to reduce food price volatility. More specifically the GEOGLAM crop monitor, compiling on a monthly basis all the available information from the main food producers, feeds the global, well-recognized Agriculture Market Information System hosted at FAO in Rome.

FURTHER PERSPECTIVES ON INFORMATION SOURCES

Next to the space agencies, Earth Observation by satellites and drones is also developing new low cost pathways. The Planets company currently claims to image the entire planet every day at 5 m resolution thanks to hundreds of nanosatellites built from cheap on-the-shelf components. Drones are sometimes introduced as robots to the farmers, imaging in an automated way all the fields of a farm whenever required. Last but not least, the Internet of Things linking drones, tractors, harvesters and satellites is another level of integration which is today tested at full scale. These big data flows have yet to be turned into relevant and timely information, which would have taken decades without the machine learning and artificial intelligence development. The societal challenge remains the same, making the best use of these information and communication technologies to move towards more sustainable healthy food production pathways.

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