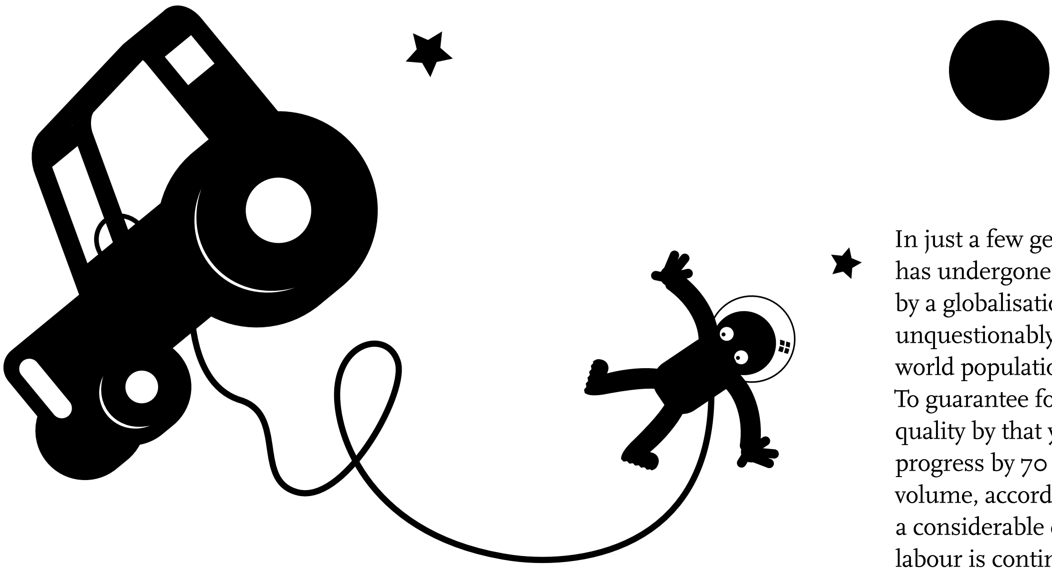
FOOD SECURITY

FOCUS ON AGRICULTURE

The agricultural sector lies at the centre of major challenges such as food security, respect for the environment and socioeconomic expansion. From a planetary level right down to the plot, remote sensing is used for the development of ever-more efficient monitoring and forecasting tools.



In just a few generations, the agricultural sector has undergone profound changes accompanied by a globalisation of its stakes. The first one is unquestionably food security for everyone. The world population will reach 9.6 billion by 2050. To guarantee food in sufficient quantity and quality by that year, global food production must progress by 70 % compared with the current volume, according to FAO forecasts! This is a considerable challenge knowing that rural labour is continuously in decline. Furthermore, agricultural production depends on climate conditions, which are subject to growing variability and increasingly common extreme weather conditions.

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The GLOBAM, EVA-3M, ADASCIS, MOCA, SOC-3D, SENSAR and HYPERMIX projects have been financed by Stereo II, the Belgian science policy (BELSPO) research programme for Earth observation.
More information: eoedu.belspo.be > teacher's corner ; eo.belspo.be > Directory > Projects

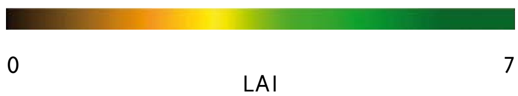
One of the goals of the Global Earth Observation System of Systems (GEOSS) is to strengthen the global agricultural monitoring to improve food security.

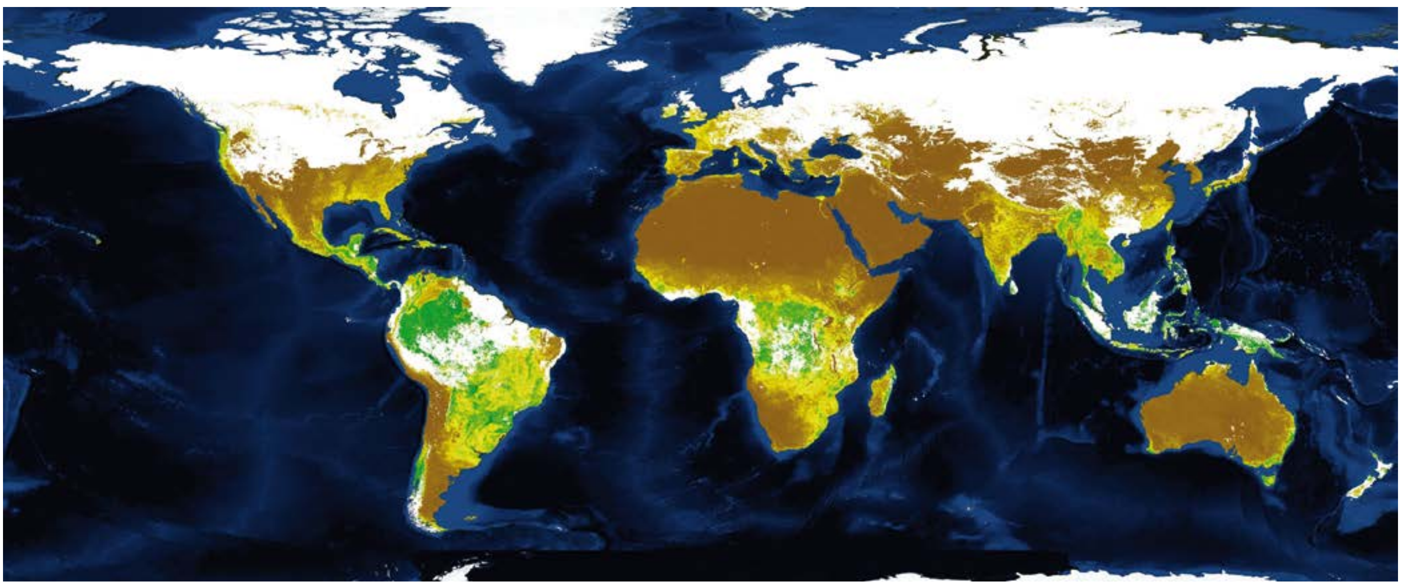
Secondly, farming practices lie at the heart of environmental issues. They have a direct impact on soil, air and water quality, but also on landscape and the habitats necessary for the preservation of biodiversity. And finally, agricultural produce is a leading economic tool, the volume of which is even the subject of speculation in financial markets.

To meet all these stakes, it is essential to improve farming practice monitoring tools and production forecasting tools. These tools were developed at the time remote sensing began to expand. Since the launch in 1972 of Landsat-1, the first civil satellite dedicated to the observation of terrestrial resources, many useful farming applications have seen the light of day. They provide information on the state of plants, allow cultivated surfaces to be mapped, help with the estimation of future yields or the assessment of damage after extreme events (drought, flooding, frost, storms, etc.). The constant improvement of the sensors' spatial and spectral resolution also benefits precision agriculture. This consists of adjusting the supply of water, fertilisers or other input according to the plot's actual needs. A 'precise' approach that optimises quality and yield while limiting the environmental impact.

Today, research projects are supported by a growing number of observation instruments that offer a great variety of scales, spectral ranges and acquisition frequencies. The volume of archived data is also considerable. For instance, we have more than 40 years of Landsat (resolution of 30 metres) and SPOT HR images (20 to 2.5 metres), 36 years of global daily images from the NOAA-AVHRR satellite (1 kilometre), 16 years of VEGETATION images (1 kilometre to 300 metres), almost 15 years of data from the MODIS sensor (1 kilometre to 250 metres) and 10 years from the MERIS sensor (approximately 300 metres).
By exploring the specific benefits of the different sensors and the most productive way to combine them, researchers have extended their possibilities and their sources of information in order to help the agricultural monitoring, from a global level (thanks to worldwide agrometeorological models), to the level of the farms themselves.

The Leaf Area Index (LAI) is derived from the global data of the VEGETATION sensor. Issued every ten days, it is one of the parameters to establish estimation maps of worldwide agricultural production.





FEEDING NINE BILLION HUMANS IN 2050

Faced with global demographic pressure and the absolute necessity of an increased agricultural supply, the variability in production and yields has become a major concern. In order to ensure food safety, authorities have joined forces on a local and global level to create monitoring systems. In 1988, the European Commission founded the MARS programme, aimed at making the link between the Earth's new observation capacities and agricultural forecasting techniques. It was followed by the GEO initiative (Group on Earth Observations), which works on building a global public observation service called GEOSS (Global Earth Observation System of Systems). These efforts are assisted by space agencies, major international organisations (World Food Programme, FAO, World Bank, etc.) and by a community of national and regional authorities that provide farmers with help and information.

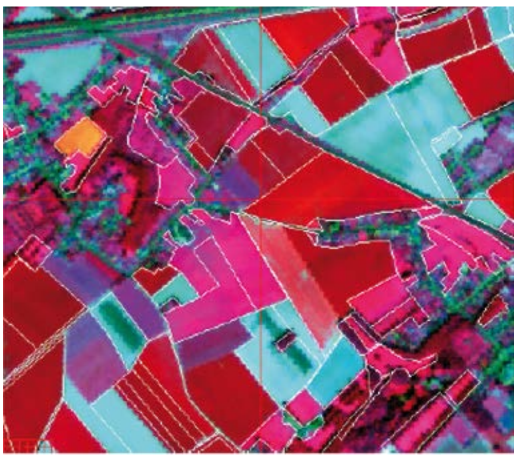
Within this context, it is rather surprising to note that while technological progress in the domain of Earth observations has been remarkable since the end of the 1990s, operational monitoring systems haven't significantly evolved. Leading-edge scientific advances integrating remote sensing have indeed been made, especially in the modelling of crop growth, but they are underused. The aim of these models is to generate detailed information on a regional, continental and global level. For this purpose, they must be provided with precise and reliable data, which relates to proper time slots, covering vast geographical stretches with very different conditions. Within this context, the **GLOBAM** project combined local crop monitoring by Earth observation with the global growth models to best estimate farming production at all levels.

WHICH SENSORS FOR WHICH RESULTS?

The study concerned three sites measuring 300 x 300 km each – Northern Europe (including almost the entirety of Belgium), Asia (China) and Africa (Ethiopia) – in order to cover three radically different agro-ecological contexts. The growth seasons of winter wheat and corn were observed using field measurements and data from different types of satellite sensors and different spatial resolutions.
The properties and advantages of these different sensors were explored and combined in order to provide material for the global monitoring methods that take into account local particularities. Since field sampling is impossible on such a vast scale, the study chose to combine variables derived from remote sensing with various growth models, calibrated specifically to each of the sites.

The results of the project have opened up a series of methodological possibilities that will help improve the forecasting and monitoring of crop growth. For instance, the data from the SAR radar, whose active signal crosses the cloud layer, is very useful in places where the sky is often covered. If these images are acquired on a regular basis, they can be used to complete the information provided by the optical images. By innovatively correlating these two sources, the research has improved the extraction of the Leaf Area Index, an important parameter since it concerns the surface of green foliage per unit of ground surface. An even more surprising result was the confirmation of the valuable contribution of the geostationary satellites.
These satellites, which orbit at approximately 36,000 kilometres from Earth, are traditionally used for meteorological observations.
Data from the MSG (Meteosat Second

What is the resolution needed to identify plots in a given agricultural landscape? The GLOBAM project used data from low, medium and high resolution sensors. Here you see the same agricultural landscape seen by SPOT 5's HRV sensor (10 m) and the MODIS sensor (250 m).



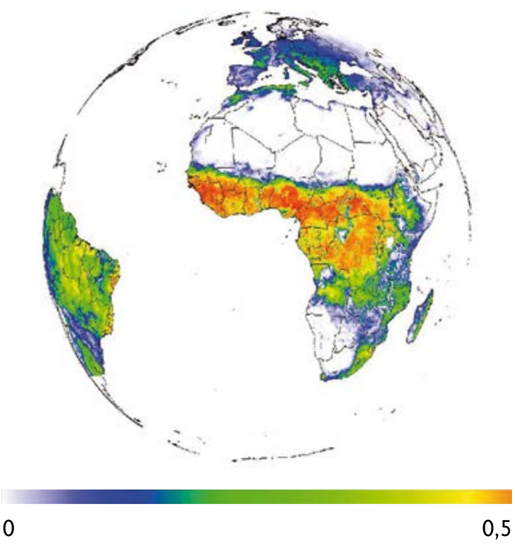
Generation) satellites, however, can also be used to estimate the evapotranspiration for a precise type of crop. This parameter gives information on the plants' (and the soil's) water deficit and on its level of vulnerability, which influences its development and therefore the expected yield. Assimilated in growth models, evapotranspiration is valuable for the monitoring of plant growth.

MORE ROBUST METHODS

Towards the end of the project, two studies showed what the necessary evolutions should be for satellite images and extraction methods in order to meet future challenges, especially in terms of the spatial resolution required for several types of agricultural landscape representative of global diversity. In Ethiopia, for example, very high resolution observation data is recommended in order to perceive the mountainous area in sufficient detail as well as the network of small plots often containing mixed crops of two or three species.

The robustness of the methods to be developed is also highlighted. Indeed, it is not simply a question of elaborating monitoring techniques applicable to all geographic regions, but also in unstable meteorological and climate conditions. To face the planetary challenge of food safety, it is now essential to have higher performance monitoring and forecasting tools integrating this variability.

Another project, EVA-3M, is endeavouring to develop a generic method in order to quantify the evapotranspiration process for different types of land use and different climate zones. The spatial and temporal resolutions must be sufficient to meet the needs of the agricultural sector: to estimate water needs, establish irrigation plans, better anticipate drought alerts or fine tune yield forecasts. The project therefore studies how best to exploit, on a regional or sub-regional level, the evapotranspiration maps produced from the MSG geostationary satellites data. While the frequency of their observations is very high (every 15 minutes), the spatial resolution, on the other hand, is only three kilometres. The researchers are therefore trying to compensate this lack of spatial precision by combining this high temporal resolution data with polar satellite data, offering a spatial resolution of 300 metres.



Evapotranspiration (ET), the sum of evaporation from land and sea surfaces and plant transpiration, is an essential component of the water cycle. Global maps of ET are produced every 30 minutes by means of Meteosat data.

ORGANIC CARBON

The hailstorm that hit the country in June 2014 caused extensive damage to crops as well as infrastructure.
If it is recognized as a natural disaster, the affected farmers will be eligible for compensation from the Disaster Fund.

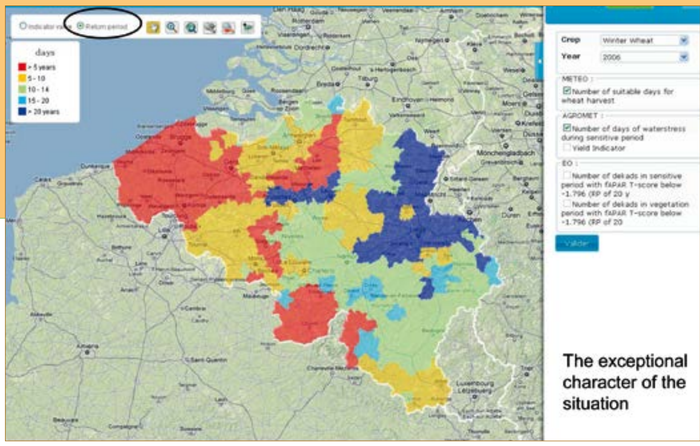
Crop insurance: from remote sensing to practical application

Every year, farmers in our regions face growing instability with regard to their income. On the one hand, they are confronted with fluctuations in market prices and a gradual reduction in the European Union's compensation mechanisms; on the other hand, they are faced with unpredictable weather conditions and increasing extreme meteorological events (drought, heatwaves, heavy rain, storms). For the agricultural sector, better management of natural risk is therefore sometimes a crucial necessity.
In Belgium, agricultural losses due to a disaster are covered by the Fund against Natural Disasters. The services responsible for managing the fund are seeking to make the damage assessment process and follow-up of the damage more reactive and more efficient. The ADASCIS project has therefore studied how to support the decision support system on the basis of reliable and objective information.

The project began with a selection of relevant indices that take into account the damage suffered by the crops. These indices are derived from meteorological data, agrometeorological models and observations from low and medium resolution satellite sensors. The index values are then compared to reference values established on the basis of historical data.
On a regional and community level, the calculation of indices has enabled the identification of areas with a recurring problem (late growth, low yield, low soil moisture) or at high risk of crop damage. At the level of the plots, a detailed study, using very high resolution satellite images and SAR images, was carried out at two particular sites in order to validate the results obtained thanks to the medium resolution data.

A pre-operational web application was developed to allow users to visualise and analyse their various damage and risk indices in the form of maps and graphs. The application was tested during the 2011 growth season to assess the extent and the intensity of the spring drought.
The tool developed allows the competent authorities to identify a disaster zone and to make a decision concerning the eligibility of the claims.

The project also concerns the evolution of crop insurance. Since 2006, extended cover against unpredictable weather conditions is recommended by the European authorities. In case of a disaster, the amount of European compensation paid out to farmers is directly linked to the insurance policy they have taken out. The project analysed the crop insurance systems in use in other countries and defined a procedure adapted to Belgium. For the regional farming authorities, the tool created can thus serve as an information base on nature and the frequency of the risks incurred. The composition of the project's steering committee reflects all these stakes; besides FPS Economy, it includes farming groups, representatives from the Flemish and Walloon Regions and stakeholders from the insurance sector (Assuralia).



With the web application developed by the ADASCIS project user can visualise the exceptional nature of a situation. For example, the number of favorable days for wheat harvest compared to a reference year.

AT THE HEART OF MAJOR CHALLENGES

The extraction of an intact soil core of about 1 m long is done with a percussion gauge The vertical distribution of the carbon is then analyzed.

The soil organic carbon (SOC) is an essential factor in agricultural productivity. It fulfils a series of fundamental biological, physical and chemical functions which have an impact on the fertility, quality and stability of farmland but also on biodiversity or the toxicity of pollutants. It also plays a key role in carbon balance. Indeed, soil offers a significant carbon sequestration capacity. It has been shown that the implementation of certain farming practices optimises the amount of carbon captured in the soil, thus reducing the concentration of CO_2 in the atmosphere. The new Common Agricultural Policy programme (2014-2020) includes the protection of soil rich in organic carbon among its priorities and defines the reduction of organic matter as one of the main threats to soil resources.

Luxembourg was one of the first countries to take the initiative to systematically measure SOC concentrations in its farmland. The SOC estimation can be used directly for the implementation of the carbon credit granting mechanisms. It is also an indicator of the compliance with the "good agricultural and environmental conditions" established by the European Union. These conditions set out all the rules and practices to be followed in order to benefit from community aid (maintenance of land and grassland, controlling irrigation, diversified cropping systems, etc.).

The MOCA project studied how to develop an efficient and operational analysis and mapping method for SOC concentrations. The researchers endeavoured to determine whether the precision obtained was sufficient to allow farmers to assess the impact of new farming practices on these concentrations. Since obtaining the field data necessary for such an inventory using traditional sampling techniques is expensive and fastidious, airborne hyperspectral sensors are an ideal alternative. However, the researchers had to find a way to reduce the negative impact of factors that disrupt the signal, such as the level of humidity or shadows linked to the land's ruggedness. In the area studied in Luxembourg, characterised by different soil types and a high variability in SOC concentrations, five hyperspectral images captured by the AHS-160 sensor were processed, analysed and compared with field measurements. In the majority of cases, the models developed provided sufficiently precise SOC estimations to meet the needs of extensive farming. The project's methodological advances directly benefit end users, such as the Luxembourg-based company Convis, which uses the results to establish fertilisation plans and soil quality reports.

Both types of freshly plowed soil can serve as standards for organic carbon concentrations: the right one has an average carbon content, the left one scores rather low.

CARBON’S 3RD DIMENSION

Continuing this research, the **SOC3D** project studied how to improve the estimation of the carbon stock by integrating its vertical distribution in the first metre of arable land into the spatial representation of the SOC.

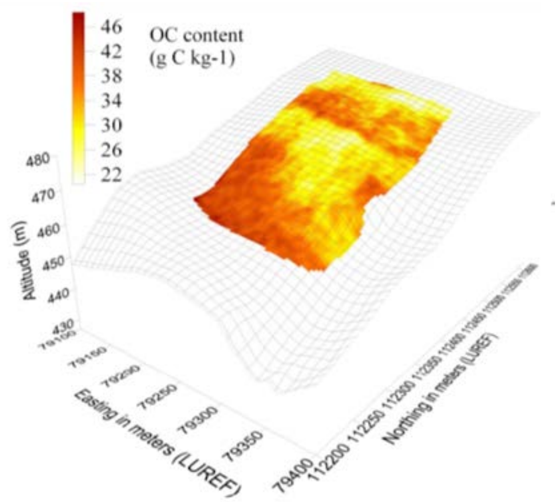
Regarding surface concentration, the APEX (Airborne Prism Experiment) hyperspectral sensor flew over a perimeter of 860 km^2 in Luxembourg. Its data was validated and compared with more than 150 soil samples taken from the study area. For the contents in the first metre of soil, core samples were extracted using a percussion gauge and every 10-centimetre intact layer was scanned by a laboratory spectrometer. The purpose of the experiments carried out on this “third dimension” is to obtain estimations of SOC concentrations that are closer to reality and to be able to extrapolate the carbon stock of the entire the perimeter studied.

For the estimation of surface concentrations, the best results were obtained by combining the hyperspectral data and geomorphological variables (slope, curvature). The maps obtained provide a good overview of within-plot variation and clearly show that the SOC content depends on the soil type and the geomorphological variables.

By putting these results in a Google Earth application, the user can very easily observe the spatial distribution of the SOC. This often reflects changes in farming practices that have occurred over the years or differences in the level of erosion.

These detailed maps are useful on two levels: on the one hand, they inform farmers about the organic matter content in their fields, which allows them to take the appropriate conservation measures; on the other hand, they provide material for the national SOC inventories, which lie at the heart of the concerns and the new regulations of the Common Agricultural Policy.

Google Earth image of the southern Grand Duchy of Luxembourg, which was projected onto a map of the organic carbon content of plowed soil.

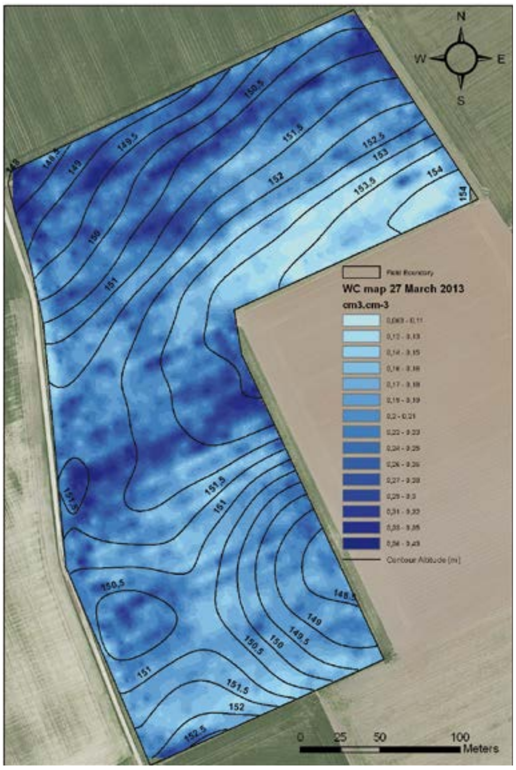


One of the factors that change the soil carbon content within a parcel is topography.

WATER, AT THE SOURCE OF EVERYTHING

Soil moisture is, of course, another essential parameter in plant growth, but it also plays a major role in numerous processes of the water cycle (infiltration, runoff, absorption by roots,

High-resolution soil moisture map of an agricultural parcel in Gentinnes, compiled using data from ground-penetrating radar and draped over the contours. The darker the blue, the higher the water content.



evaporation), in energy exchanges with the atmosphere and, therefore, also in the climate system. Thanks to airborne or satellite remote sensing instruments, in particular radars, its estimation has become widespread at all levels, from the field to the drainage basin. However, soil moisture is by nature highly variable in time and space, and it is difficult to obtain sufficient field data to effectively calibrate and validate processing methods for Synthetic Aperture Radar (SAR) data.

To reduce the continuing high level of uncertainty of these methods, the **SENSAR** project is seeking to integrate the contribution of a new type of radar, the Ground Penetrating Radar (GPR). This could indeed help to overcome the continuing difference in scale between remote sensing and traditional field samples. The perfecting of the SAR data processing methods will ultimately lead to the production of soil moisture maps that are more faithful to local variability.

The project is examining several study zones located in Belgium with different types of soil and topography, with the aim of establishing maps that can be directly used by Belgian or international public services, or by private organisations such as insurance companies or farming associations.

HYPERSPECTRAL AND HYPERSPATIAL

The **HYPERMIX** project focused on a fundamental problem of remote sensing: when the engineers design a satellite sensor, they have to make a compromise between the spatial resolution and the spectral resolution, by optimising the signal-to-noise ratio (signal = useful information; noise = irrelevant data), which indicates the quality of the recording. For instance, the Hyperion satellite sensor currently offers the highest spectral resolution from space (220 spectral bands), but its spatial resolution is only 30 metres. On the other hand, sensors such as Pleiades, Quickbird or WorldView-2 offer a very high spatial resolution (approximately 50 centimetres in panchromatic and 2 metres in multispectral), but their spectral resolution is much lower (4 to 8 spectral bands). As for airborne hyperspectral sensors, such as APEX, they often combine the benefits of an unequalled spectral resolution and a very good spatial resolution (0.5 to 7 metres), but the field of vision is reduced.

Many applications, such as detailed land cover mapping, the study of the dynamics of vegetation or the assessment of its condition require spatially and spectrally precise information. The research team has therefore developed methods to merge the hyperspectral and hyperspatial data, in order to generate a product that combines

Citrus orchard in the area of Valencia, Spain, overflown by a UAV equipped with a hyperspectral sensor.

their respective qualities. The test was carried out on citrus fruit orchards located in the region of Valencia in Spain and in Loksbergen in Limburg. An image with 215 spectral bands and two metres of resolution provided by the APEX sensor, and an image with three spectral bands and 20 centimetres of resolution provided by a microdrone were merged to generate an image with 215 spectral bands and 20 centimetres of resolution.

Thanks to this merged product, it was possible to extract more precise estimations from certain biophysical parameters (chlorophyll concentrations, water content, etc.) of fruit trees. It was possible to precisely map the water stress level of trees, a parameter that directly influences the quality of the fruit. Tests were also done on a virtual orchard located in an environment with simulated conditions. The methodological advances produced were made available to the community of remote sensing researchers.

High spatial resolution + High spectral resolution = High spatial and spectral resolution

The photochemical reflectance index (PRI) reflects the plant health variability between and within parcels, and helps for example to accurately determine water needs within each plot.