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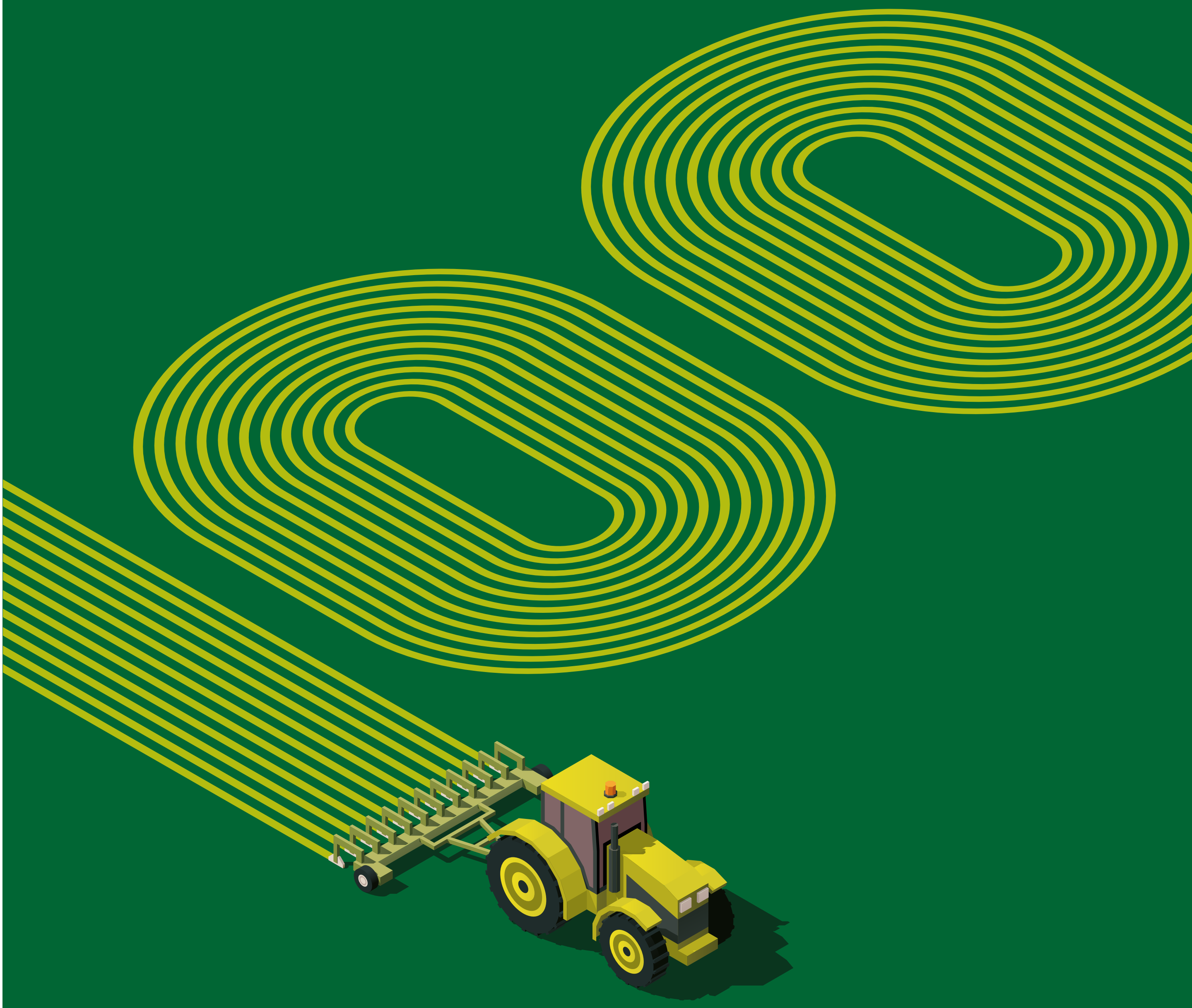

Research and knowledge transfer in the agrifood, forestry and fishery sector in Catalonia

Generalitat de Catalunya
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EMERGING TECHNOLOGIES APPLIED TO THE AGRIFOOD SECTOR

Robot for automatic harvesting of garden produce depending on its ripeness, developed as part of the SWEEPER project funded by the European Union's Horizon 2020 programme. Photo: www.sweeper-robot.eu

01. Introduction

The sustainable development goals proposed by the 2030 Agenda include: putting an end to hunger, achieving food security, improving nutrition and promoting sustainable agriculture. Many different initiatives will be required to meet these challenges, but they undoubtedly require the application of the latest scientific and technological breakthroughs to transform a sector that is strategic for our society.

The report *Eating the future: for a productive, sustainable, resilient, healthy, responsible and universal food system in Catalonia*, produced by the Advisory Board for Sustainable Development, makes several recommendations: it emphasises that research into the most environmentally friendly production techniques must be enhanced, that research and innovation in precision farming and information and communication technology (ICT) must be encouraged to ensure the optimum management of resources, and that tools and instruments for transfer and advice for the production sector must also be strengthened to improve efficiency in the management of inputs (water, energy and fertilisers).

It is therefore necessary to continue research in the fields of biotechnology and plant genetics in order to obtain more resilient plants, which make better use of nutrients, consume less water and fewer phytosanitary products, and which are more efficient in capturing and transforming energy. However, we also need to determine how to apply technologies that have been developed in other sectors in order to improve productivity, or simply to use innovation to introduce new ways of making manual tasks easier.

We are approaching an emerging agricultural management model called the Smart Farm, which is based on an intensive use of ICT and automatic systems, and therefore increases the quality and quantity of production and reduces the human effort involved. In this article, we will focus on the technological aspects which can lead to the most disruptive changes when applied to the agrifood sector.

02. Remote sensing systems

One of the most widespread applications in agriculture today is the use of satellite remote sensing systems in combination with the use of remotely piloted aircraft systems (RPAS, also known as drones).

The European Space Agency's (ESA) *Sentinel-2* Earth Observation mission is one of the most widely used systems in agriculture. It consists of two satellites in a low orbit at an altitude of 786 kilometres, which provides global coverage of the entire world in five days. The satellites are equipped with a 13-band multispectral cameras in the visible, near infrared and short-wave infrared bands of the spectrum, which provide a resolution of 10, 20 and 60 metres respectively, in a scan area of the Earth's surface 290 kilometres wide.

Other satellites, such as *Satellite Imaging Corporation*'s Pleiades, can provide daily imaging at optical resolutions of 0.5 metres, and multispectral images at a resolution of 2 metres. By processing these images, which can be complemented with those obtained from drones flying at low altitudes, it is possible to calculate the Normalized Difference Vegetation Index (NDVI) and other similar parameters, which can be used to estimate the development, quality and quantity of vegetation and crop stress.

This makes it possible to perform a careful diagnosis of the state of the crop, and consequently to determine the measures that need to be applied on a precise and localised basis. The result is an optimisation of the resources applied and an improvement in the crop's efficiency as a result. This gives rise to what is known as precision agriculture.

Remote sensing systems can be used to visible and infrared images which when they are properly processed, can show various parameters of the state of the soil, crops and vegetation.

03. Precision agriculture

This is based on the combined use of geographic information systems (GIS), which provide highly accurate information about the terrain, and a satellite navigation system (GPS, Galileo or Glonass). It is possible to precisely determine the geographical point where an inputs treatment needs to be applied using the results of the analysis of the terrain provided by remote sensing systems.

This treatment (phytosanitary, nutrients or irrigation), can be applied semi-automatically using a manual guide for the tractor, with the help of a satellite navigator, and the treatment is dispensed at the place instructed beforehand; or it can be done completely automatically using autonomous vehicles, both on land and in the air, which are guided by these GPS systems and go to the specific place where the programmed treatment needs to be applied. Several manufacturers of agricultural machinery incorporate integrated navigation systems in their vehicles, or they can be fitted to automate these tasks.

These navigation systems also often contain other types of sensors (such as infrared and ultrasonic distance meters, gyroscopes and inclinometers) which when combined with contact sensors and vision systems, make it possible to determine the condition and unevenness of the terrain, and the presence of unexpected obstacles or other unforeseen problems. They can therefore create alarms and apply the appropriate remedial measures. These vehicles may include sensors that measure the NDVI index directly, or use laser diode reflectivity to determine the chlorophyll content of plants, and calculate and dispense the treatment which needs to be applied on the spot.

There are some benefits to using drones for phytosanitary applications, but there are also some limitations. They can reach areas or places that are difficult to access, which makes it easier to apply specific pesticides or equivalent products when taking precise measures against a particular pest; flying over the crop also means that the phytosanitary treatment can be applied more precisely to the specific area of the plant that needs it. Their limitation is the product's load and dispensation capacity (which ranges from 5 to 15 litres, with a maximum aircraft weight of 25 kg). Their autonomy is around 25 minutes flying time, and they have a maximum speed of approximately 8 m/s. However, because they are remotely piloted aircraft systems (RPAS), according to Spanish legislation, they must be piloted by a drone operator authorised by the*Spanish Air Safety Agency* (AESA), who must meet all the relevant legal safety requirements.

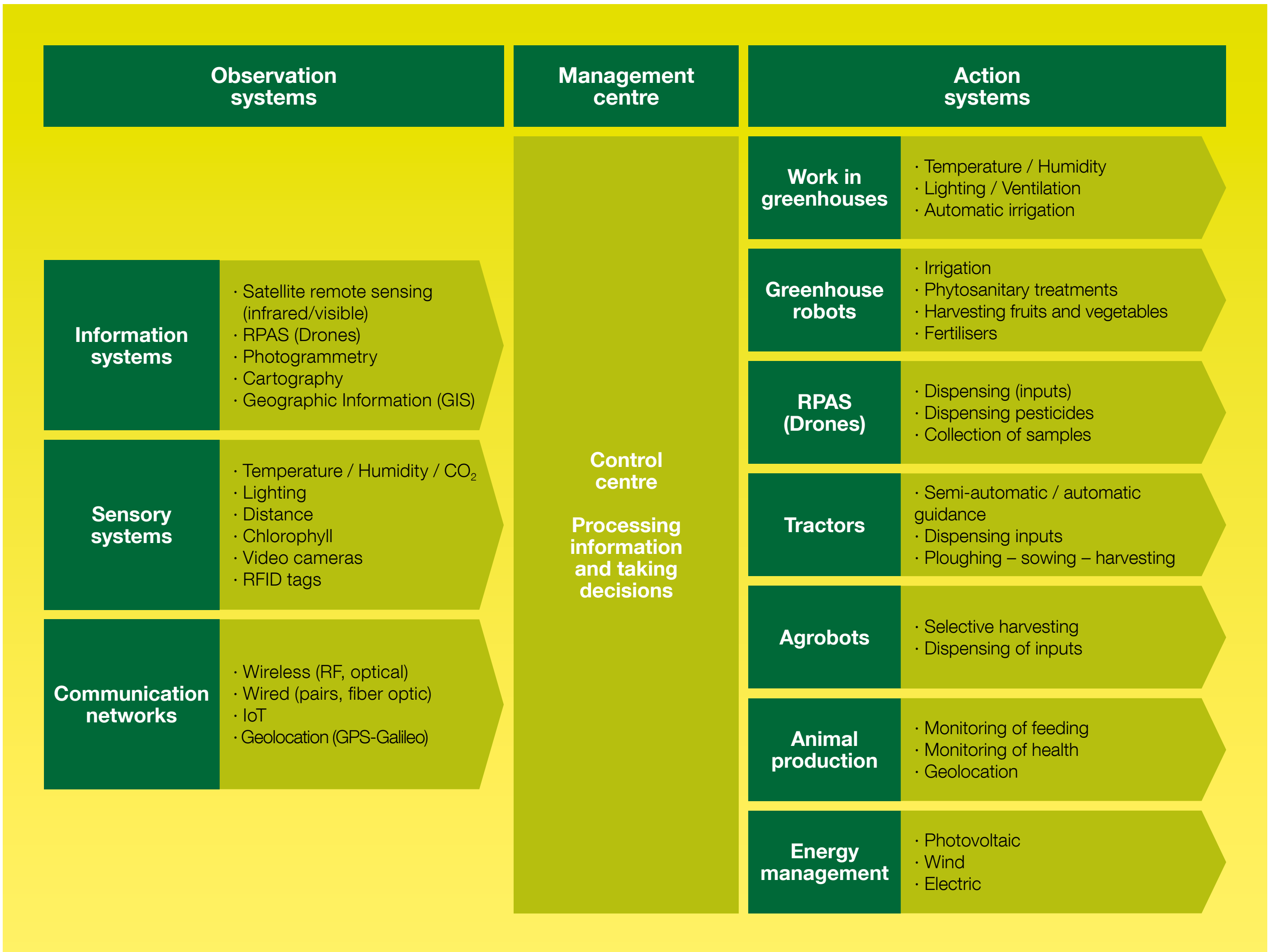

Figure 1: *Diagram of the various technologies for observation and action in agriculture and livestock farming. Source: Jordi Berenguer.*

The Agricultural Mechanisation Unit (UMA) at the UPC is participating in the European *Optimised Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables* (OPTIMA) project, which aims to develop smart phytosanitary application equipment enabling products to be used safely, in smaller quantities and with lower risks of environmental pollution, and to improve the quality of the food produced.

The same group at the UPC has also developed the mobile application DOSAVIÑA, for use by wine producers, which calculates the optimum amount of the phytosanitary product and the appropriate volume to be distributed in espalier vines. It contains a practical guide for selecting the appropriate working parameters (forward speed, working pressure, type and number of nozzles, etc.) based on the structural characteristics of the plantation and the type of machinery used, and the amount of phytosanitary product used on the plants can be adjusted to reduce the risk of pollution.

04. Robotics and automatic systems

One of the areas where technology can be most disruptive is in the application of robotics and its systems associated with agricultural tasks, both outdoors and in greenhouses. For example, the combination of image processing techniques and artificial intelligence means that robots capable of detecting the optimum degree of ripeness of fruit and vegetables and collecting them automatically can be designed.

One of the first benchmark projects was the CROPS project, funded by the European Union between 2010 and 2014, as part of the 7th Framework Programme. This consisted of the development of a robotic platform for use in both fumigation and selective harvesting of fruits, based on identifying their ripeness. This project continued with the SWEEPER programme (photo p. 74), which was also funded by the EU (2015-2018), as part of the Horizon 2020 Programme to develop an autonomous robot able to pick vegetables in greenhouses under conditions with high temperatures and humidity levels, and it is expected to be marketed in the near future.

Panasonic has also developed a robot to harvest tomatoes grown in greenhouses. The robot moves along a track located between the rows of tomatoes, and uses an image recognition camera to detect the tomato. It determines whether it is ripe by analysing the colour, and then makes the decision whether to harvest it or not.

The Industrial Equipment Design Center (CDEI) at the UPC designed a leaf stripper to mechanise the process involved in cleaning wheat during the harvesting process a few years ago. It is made of stainless steel, and is equipped with a system of vulcanised rubber-coated rollers which separate the leaves surrounding the grain with the help of a small motor. The clean cobs are placed in a container, ready for the next step in the management, storage and distribution process. The equipment increases productivity by 150%, as it increases the rate from 6-8 manually stripped cobs per minute to the 18-20 that the machine can process in the same time.

05. Sensor networks and facility monitoring

Information from satellite and drone remote sensing systems can be supplemented by information obtained from sensors on the farm itself. These sensors are based on the Internet of Things (IoT), and provide a networked connection and remote access, making it possible to continuously monitor buildings, greenhouses and crops based on the measurement of physical parameters (temperature, humidity, brightness, etc.) and chemical parameters (concentrations of CO_2, nutrients, etc.). Analysing and processing the data obtained provides an accurate diagnosis of the crop or the agricultural or livestock farm, and consequently helps in decision-making processes. These systems are complemented by a set of actuators that regulate the ventilation, irrigation, lighting and heating of the facilities remotely, manually or automatically, so that they are always kept under optimum conditions for production.

The amount of robotic application systems and equipment will increase both in greenhouses and outdoors in the coming years, and they will make intensive cultivation and automatic harvesting of fruit and vegetables possible by day and by night.

The RFID system brings traceability to the entire food chain:
it identifies the animal from its source until it reaches the end consumer.

It contains all the information which can be used to provide all the guarantees that food health regulations require.

06. Identification and traceability systems

RFID (*Radio Frequency IDentification*) systems are smart tags that can be read remotely by a reader antenna. They were designed to replace bar codes printed on paper. They are available in different formats and capacities. Some are completely passive, with a very low cost and do not need any power supply; these tags can be used for remote reading of stored code. Others can store information which can be updated and modified, and may even incorporate a type of temperature or humidity sensor, as well as a GPS receiver (a battery power system must be incorporated in these cases).

These systems are widely used in livestock farming, as they enable animal to be identified individually and remotely. For meat production, each individual is assigned a unique RFID-tagged code, so that for example, the amount of feed to be dispensed can be individually controlled when the animal approaches the trough. If the tag is active (battery-powered), it can incorporate body temperature sensors that can automatically generate veterinary alerts if the animal becomes ill, and administer the appropriate drug treatment in time. If they also have motion sensors or GPS systems, it is possible to determine the animal's movements in semi-wild conditions, or its location when it is released in mountain pasturelands.

These systems also provide traceability in the entire food chain: they identify the animal from its source until it reaches the end consumer. They therefore incorporate all the information about their growth process as far as the abattoir, including processing, storage and distribution, which means that it is possible to provide all the guarantees required by food health regulations.

As an example, in April 2018 the French INRA (*Institut National de la Recherche Agronòmique*) introduced a new RFID-based heat sensing device for sheep, which allowed farmers to monitor reproduction in their herds and avoid hormone treatments.

Finally, Figure 1 shows the various technologies for observation and action applied to agriculture and livestock production.

07. Agriculture 4.0

The new concept of Industry 4.0 is taking root as a connected model of industry, involving an intensive use of the IoT, Big Data, and the application of algorithms and artificial intelligence to process data and make decisions. The aim is to make better use of resources, and to adapt better to production needs. The same concept could be transferred to the agricultural and livestock sector to define Agriculture 4.0, which would include precision agriculture and Smart Farming, as well as other key areas including meteorology and remote sensing. If in addition to all the above we consider how Big Data is used to process historical data series (for climate, environmental, population, supply and demand, etc.) which are then used to create predictive models for behaviour of supply and demand, and real-time data about that supply and demand, it is possible to describe the agrifood sector as a complex global system and to manage it as such. This would indirectly help us to fight food wastage, based on more efficient production and the application of dynamic distribution logistics, which can be adapted to the demand from the market. This would therefore lead to an optimal management of food, which is an essential resource for our society.

08. Conclusion

The Polytechnic University of Catalonia is renowned for its research and technology transfer work in the fields of information and communication technology, artificial intelligence, robotics and mechanics, energy and materials, chemistry and agriculture, aeronautics, infrastructure and building. While these research activities took place in their respective vertical fields not so long ago, the current trend is towards cross-disciplinary work in the application of these technologies to other fields, such as agriculture, where their application can create more disruptive changes. The UPC aims to contribute with technology to the transformation of the agrifood sector that Catalonia needs.

Further reading

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ADVISORY COUNCIL FOR SUSTAINABLE DEVELOPMENT. *Eating in the future: for a productive, sustainable, resilient, healthy, responsible and universal food system in Catalonia.* First edition. ISBN 9788439397588l

Intelligent sensing and manipulation for sustainable production and harvesting of high value crops, clever robots for crops. http://crops.sweeper-robot.eu/

Sweet Pepper Harvesting Robot. http://www.sweeper-robot.eu/

"Introducing AI-equipped Tomato Harvesting Robots to Farms May Help to Create Jobs" https://news.panasonic.com/global/stories/2018/57801.html

Optimised Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables. https://cordis.europa.eu/project/rcn/214745/factsheet/en

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Un nouveau dispositif de détection des chaleurs chez les brebis. http://www.inra.fr/Entreprises-Monde-agricole/Resultats-innovation-transfert/Tous-les-magazines/RFID-Chaleurs-brebis

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