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RESULTS PACK

Precision Farming: Sowing the seeds of a new agricultural revolution

EDITORIAL

PRECISION FARMING: SOWING THE SEEDS OF A NEW AGRICULTURAL REVOLUTION

The adoption of precision farming techniques is allowing the EU to increase its agricultural output whilst ensuring the sustainability of the European agri-food sector. Consequently, the EU has been supporting cutting-edge research and innovation into a number of exciting solutions that will truly harness all of the opportunities from what promises to be a truly 21st-century agricultural revolution.

Precision farming has the potential to contribute to the wider goal of meeting the increasing demand for food whilst ensuring the sustainability of primary production, based on a more precise and resource-efficient approach to production management – in essence 'producing more with less'. With the explosion in the digital revolution, technologies focused on, for example, Big Data and 'the Internet of Things' have also opened numerous doors for the advancement of precision farming techniques. With 70 to 80 % of new farm equipment having some form of precision farming component within them, precision farming technologies are now present in all four stages of the crop growth cycle (soil preparation, seeding, crop management and harvesting). However, it is not just crop and fruit farming that has benefited – farmers engaged in livestock rearing are also experiencing the positive benefits derived from precision farming technologies.

Economic and Environmental Benefits

The European Commission has been extremely keen on fostering precision farming techniques, providing funding for new investments through both the FP7 and Horizon 2020 programmes. This is to guarantee that farmers are not only able to effectively reduce costs without cutting production but also to offer the possibility of substantially increased yields, thus providing an even stronger boost to local economies.

Alongside economic considerations, precision farming also promises substantial environmental benefits, being seen as a means to make Europe's agri-food sector more sustainable in the long term, particularly in the drive to reduce the sector's use of agro-chemicals, such as pesticides. Such environmental benefits will also feed into the EU's much larger environmental ambitions, such as the tough targets envisioned in the Paris climate change agreement.

This CORDIS Results Pack introduces you to 13 EU-funded projects that have been at the forefront of the precision farming revolution.

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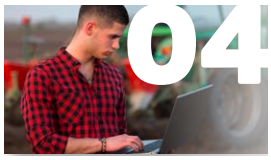

Higher quality, more efficient farming through open standards

The EU-funded AGROIT project implemented an open platform based on open standards in order to facilitate a higher-quality, more efficient way of farming.

Over the course of the last two decades, farming in Europe has witnessed two simultaneous changes. On the one hand, increasing EU and national regulations, such as cow registries, have placed new administrative demands on farmers. At the same time, the sector has seen the deployment of a range of sophisticated technologies in the area of machinery and automation.

To help European farmers better manage these administrative demands while taking full advantage of new technological opportunities, the EU-funded AGROIT project has implemented an innovative open platform based on open standards. 'The premise of this project is our belief that the deployment of ICT is the next step forward that will change farming and enable the transition to higher-quality and more efficient agricultural sector,' says project coordinator Rok Rupnik.

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By using these applications, farmers can significantly increase the efficiency of their activities and save on resources – including time.

Apps and data

The project's objective was to build an open-standard based AGROIT platform to deliver applications and services to farmers, local communities, state and EU institutions and agriculture-related consultants. With these applications, farmers have the ability to simply and easily input data during the execution of their daily activities – even with dirty hands or in rough conditions. 'Based on our existing prototypes, we implemented a scenario-oriented user interface to enable farmers to have a sequenced order of daily activities,' explains Rupnik. 'By using these applications, farmers can significantly increase the efficiency of their activities and save on resources – including time.'

In addition to the applications, the project also developed integrated monitoring systems that enable the collection of data from sensors and other devices via wireless technology. 'Historically, farming has been an opaque business because of the difficulty in obtaining solid datasets, making it irrational to expect a farmer to fill out forms after a day in the field,' adds Rupnik. 'But data collected from sensors and machines brings new possibilities for analyses and data-driven decision making.'

AGROIT integrated all of these features into a platform. 'Here, standards and integration examples have been published under public domain or creative commons licenses to allow collaboration and support within the agriculture industries and communities,' explains Rupnik.

Rupnik notes that there are several advantages of using an open platform. For instance, it allows users to integrate multiple systems in order to provide more robust and more easily accessible information. By facilitating collaboration between developers, open platforms also lead to better, more tailored solutions.

Putting it into practice

So what does this all look like in practice? As an example, let's take the routine agricultural task of preparing a field for planting. Thanks to the use of GPS, AGROIT's mobile app will know that the farmer is working in a particular field and thus can provide them with an overview of what areas have been cut and which areas still need tending to.

Or let's say a fruit farmer notices a problem with one of her plum trees. By opening a consultancy case via the mobile application, she simply snaps some photos of the tree and makes a phone call to a consultant to discuss a solution. After the call, the consultant checks the farmer's operational data (e.g. field shapes, hybrids, past treatments, etc.) and inserts treatment specifics into the consultancy case for the farmer to implement in the field.

The AGROIT app can even help veterinarians providing care to farm animals. 'In many rural areas, veterinarians are few and far between,' says Rupnik. 'But now, thanks to the AGROIT app, a farmer can consult with a vet remotely and exchange documents or certificates electronically.'

Project	**AGROIT: Increasing the efficiency of farming through on open standards based AgroIT platform**
Coordinated by	DATALAB TEHNOLOGIJE DD (Slovenia)
Funded under	CIP
Project website	https://www.agroit.eu/SitePages/Home.aspx

Enabling precision farming across Europe through GNSS

Researchers within the EU-funded AUDITOR project have developed a ground-based GNSS augmentation system capable of delivering high-performance and cost-efficient services and applications to farmers across Europe.

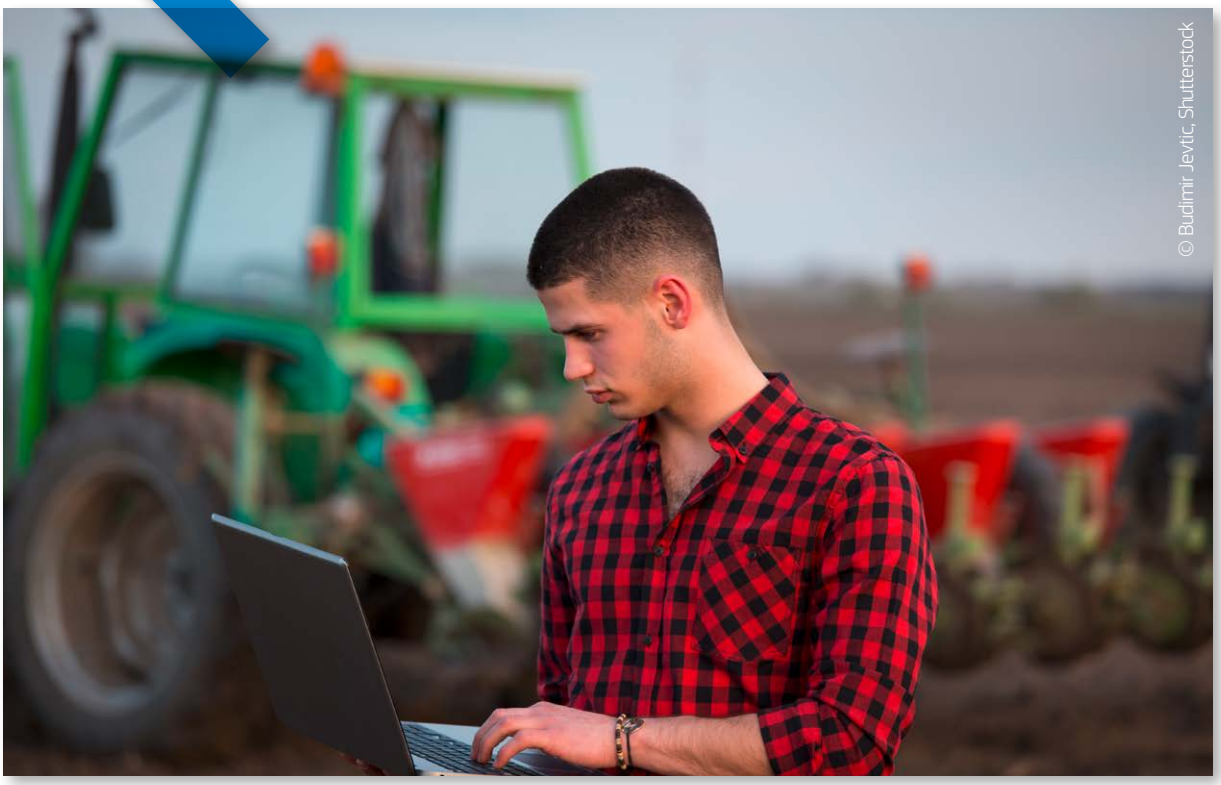
The costs associated with agriculture are on the rise and environmental demands are gaining ground by the day – meaning efficient and sustainable farming solutions are needed more than ever. One such solution is precision agriculture.

From automatic steering to farm machinery guidance, variable rate application, yield and soil monitoring and livestock tracking, all precision agriculture applications depend on the precise positioning provided by GNSS. However, in order to get the level of precision that these types of farming applications demand, GNSS signals must be augmented. In Europe, this augmentation is provided by EGNOS, Europe's regional satellite-based augmentation system that is used to improve the performance of GNSS. The problem is that agriculture is a rural endeavour, meaning some farms are located in areas where EGNOS coverage is poor.

To help improve the performance of EGNOS, the EU-funded AUDITOR project is developing a ground-based GNSS augmentation system that will deliver high-performance and cost-efficient services and applications for the agriculture industry. 'The purpose of this project is to develop an improved GNSS ground-based augmentation system using modern and proven algorithms in highly configurable, cost-effect receivers,' says Project Coordinator Esther Lopez. 'As a result, AUDITOR will enable cost-effective precision agriculture services to farmers, especially for those with small and mid-sized farms in areas where EGNOS availability is limited.'

The AUDITOR architecture

AUDITOR's architecture is based on a RF dual-band multi-constellation GNSS front-end and an embedded digital processing platform. The front-end receiver acquires the GNSS signals and embeds all analogue and digital hardware required to convert the RF signal to digital samples. The digital processing platform then



converts and customises the signals for the AUDITOR systems. The system then serves as a basis for providing higher-level services for the end user via cloud-based web and/or mobile applications.

The future of farming

AUDITOR is set to enable a range of precision agriculture applications. For example, with AUDITOR applications, farmers can accurately measure spatial variability in soils and crops. This information, expressed in the form of yield maps, allows the farmer to precisely apply fertiliser, water and pesticides – thus reducing production costs and the farm's environmental impact. The high-accuracy positioning it provides also enables the use of autonomous mobile robotic units, used for identifying weeds, pests and diseases.

'The making of soil and crop maps, as well as the spatially varying application of fertiliser that these maps enable, is completely dependent on the availability of a high-quality GNSS signal,' says Lopez. 'Now, thanks to AUDITOR, even areas in Eastern and Southern Europe that once were unable to get this required GNSS signal can reap the benefits of precision agriculture.'

With the ever-increasing requirement for augmented yield and profitability and energy and cost savings, the future of farming is precision agriculture. By focusing on providing the augmentation needed to enable existing precision agriculture applications in Europe alone, Lopez is confident that AUDITOR is well-positioned to compete in a market with an estimated EUR 180 million value.

AUDITOR will enable cost-effective precision agriculture services to farmers, especially for those with small and mid-sized farms in areas where EGNOS availability is limited.

Project	**AUDITOR: Advanced Multi-Constellation EGNSS Augmentation and Monitoring Network and its Application in Precision Agriculture**
Coordinated by	ACORDE TECHNOLOGIES SA (Spain)
Funded under	Horizon 2020-LEIT-SPACE
Project website	http://www.auditor-project.eu/euproject.html

A Robotic revolution is coming in precision farming

Two pioneering pilot projects have demonstrated how automated precision agriculture can reduce input costs and the environmental impact of heavy machinery, while achieving significant production efficiencies.

The EU-funded ECHORD++ project is pioneering demand-driven technological innovation by encouraging novel robotic solutions to pressing social and environmental issues. This is being achieved through funding a number of application-oriented research projects called 'experiments', of which some are focused on the topic of precision agriculture. Two of these sub-projects underline the potential of robotics in achieving food production fit for the 21st century.

Selective robotic harvesting

The first of these sub-projects, GAROTICS, has developed a robotic system for selective green asparagus harvesting. Asparagus must be selectively picked when the crop reaches the desired height, a process that favours manual harvesting in order to leave younger, smaller stalks undamaged. This is a challenging and labour-intensive process, which means that agricultural operators are vulnerable to labour supply shortages and high processing costs.

In order to address this, GAROTICS built a robotic harvesting machine with a camera viewing the asparagus dam and two harvesting tools. Each of these tools has two blades at the bottom, which are positioned to work like scissors. The objective was to increase the robot's vision capability to reliably and robustly identify asparagus stalks that are ready for harvesting, and to increase the harvesting productivity by vision-driven multi-tools harvesting mechanism.

'Performed field tests demonstrated reliable robotic selective harvesting,' says GAROTICS team member Dr Holger Raffel from the University of Bremen, Germany. 'We found that several harvesting tools could be mounted on the machine, which can then work in different environmental conditions, which is important bearing in mind the short seasonal harvesting time.' The project was able to show that with automated harvesting speed-up of cost-effective, accurate asparagus harvesting is possible.

Cooperative farming robots

A second precision farming pilot, called MARS, has developed small streamlined mobile agricultural robot units designed to work together to achieve production efficiencies. Three key objectives were identified: optimising precision farming in order to reduce the input of seeds, fertilizer and pesticides; reducing the environmental impact and energy consumption of heavy machinery; and using automation to anticipate challenges arising from climate change and possible skill shortages.

We predict that the future of farming will look differently than just big machinery, as a fleet of robots can be much better handled and scaled.

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Another key objective of the MARS project was to simplify current robot prototypes used in precision agriculture. This was achieved by minimising the use of on-board sensors.

'We made control algorithms and process optimisation tools available on the cloud and used precise GPS-based technology,' explains MARS project partner Prof Christian Schlegel from Hochschule Ulm, Germany. 'All these measures are intended to lead to a significant cost reduction of the overall system, paving the way towards robots as a true alternative in the agricultural domain.'

The robots cooperate as a group, and a key advantage of this technology is the radical reduction in weight and size compared to conventional farming equipment. Using robots to carry out agricultural tasks also increases safety. 'We predict that the future of farming will look differently than just big machinery, as a fleet of robots can be much better handled and scaled,' adds Schlegel.

The MARS experiment focused on the seeding process for corn, which was performed by two robots. The project was able to show that a fleet of robots was capable of performing such a task and able to match all relevant key performance indicators. 'I think it is important to note that this is not just a robotics solution, but one that is fully integrated into the workflow of a farmer and the needs of farming,' concludes Schlegel.

Project	**ECHORD++: European Clearing House for Open Robotics Development Plus Plus**
Coordinated by	TECHNISCHE UNIVERSITAET MUENCHEN (Germany)
Funded under	FP7-ICT
Project website	http://echord.eu/ http://echord.eu/garotics/ http://echord.eu/mars/

Spy in the cowshed aids farmers

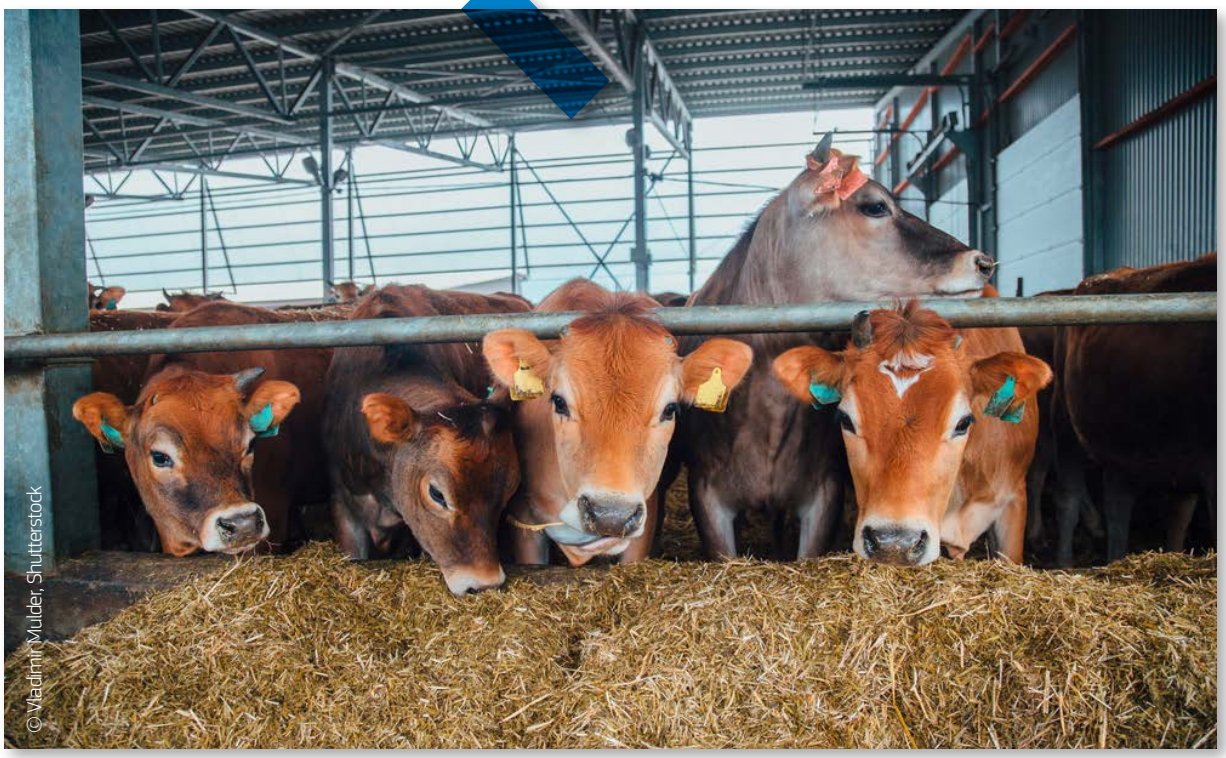
A growing global appetite for meat has led to farms becoming bigger than ever before. Automatic round-the-clock monitoring of livestock using surveillance technology can help busy farmers better manage their animals, improve the food chain and save money.

Farmers struggle to cope with the increased size of their herds and flocks and have less time to keep an eye on the health and welfare of individual animals. The result is rising concern among consumers who demand safe but affordable milk, meat and eggs produced under clean, sustainable and animal-friendly conditions.

Precision Livestock Farming (PLF) offers a solution to overworked farmers by employing sensors, cameras and microphones using sophisticated algorithms to continuously monitor every single animal. The EU-funded EU-PLF (Bright farm by precision livestock farming) project was established to realise the full potential of PLF tools by developing them into commercial products and services for use on dairy, fattening pigs and poultry farms.

Blueprint for success

'The main objective was to install PLF technology in commercial farms across Europe and analyse how it is used by farmers and creates value for them' explains project coordinator Dr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Daniel Berckmans. To achieve their objectives, project partners created a draft blueprint for farmers, high-tech small and medium-sized enterprises (SMEs), and other key actors who wished to design and develop PLF tools.

The blueprint was a valuable resource for advising farmers how to choose and install suitable PLF technology and identify which problems needed to be addressed. An online PLF e-Course for students, scientists and researchers was also produced, providing an important platform for the further development of knowledge and sharing experiences relating to the technology.

We have shown that automated monitoring every second day and night is far more effective than human observers checking a livestock shed once a year.

Listening in on livestock

The consortium developed better algorithms for the camera and microphone systems to give a more detailed understanding of factors affecting livestock behaviour and health. 'It was shown that the camera system can now predict more than 90 % of all problems, such as blocked feeder and drinking lines, and light and climate issues by continuous image analysis of broiler behaviour,' says Dr Berckmans.

Furthermore, project partners found that continuous analyses of the sound produced by fattening pigs can detect an infected animal two to 10 days before the farmer or the veterinarian notice it. Hence, PLF technology could reduce the use of antibiotics and enable farmers to respond more quickly in cases of infection, thereby decreasing production losses and thus saving money.

'Before the project many doubted this approach would work, believing it was unrealistic, but people's attitudes towards PLF have now completely changed, claims Dr Berckmans. 'We have shown that automated monitoring every second day and night is far more effective than human observers checking a livestock shed once a year.'

Farm data - a valuable resource

Researchers used new modelling tools and identified areas where different PLF applications could be of social and economic value on the farm and in supply chains. This valuable data, taken from farm measurements, can help unlock economic potential by improving the effectiveness of the food supply chain (feed-animal-food) and providing social and economic incentives for the adoption of PLF.

According to Dr Berckmans: 'Many different stakeholders have yet to discover what type of information they can select from all this data and more algorithms will be developed.' However, there has been a growth in interest shown by a range of sectors, including the pharmaceutical and animal feed industries, technology companies, veterinarians, slaughterhouses and meat retailers. During the project four new high-tech PLF companies were started.

EU-PLF will reduce stress in farmers by enabling them to act more effectively and achieve a better work/life balance, while gaining greater recognition for their efforts. Benefits include healthier, happier animals and an improved economic performance for farms.

Project	**EU-PLF: Bright Farm by Precision Livestock Farming**
Coordinated by	KATHOLIEKE UNIVERSITEIT LEUVEN (Belgium)
Funded under	FP7-KBBE
Project website	http://www.eu-plf.eu/

A smarter, more precise irrigation system

To help promote sustainable farming, EU-funded researchers working within the FIGARO project have developed an innovative, high-tech irrigation platform capable of accurately managing the quantity of water used.

The efficient and effective use of water in irrigation systems is of critical importance for sustainable agricultural development, food security and overall economic growth. This is particularly true in light of global population growth, climate change and the competing demand for water from other economic sectors.

In addressing this challenge, the EU-funded FIGARO project turned to precision irrigation. Precision irrigation is a technique that applies a precise amount of water to crops at precise times in order to optimise crop yield and water productivity.

With FIGARO, the farmer knows the exact irrigation volume required, the number of times to irrigate and the right irrigation timing to optimise water use and energy consumption.

Taking out the guesswork

'Aimed at providing farmers with the necessary tools to make the right decision on irrigation and thereby increasing their productivity and decreasing their use of water, the FIGARO irrigation management platform combines an existing software platform, hardware and sensors with a newly developed DSS (decision support system) module,' says project coordinator Lior Doron. 'Together, the system gives the user the best irrigation recommendations at the farm level.' Features include a sophisticated decision support programme, built-in crop growth model, plant and soil sensors, satellite-based data analysis and forecasting algorithms.

Information is captured by soil, water, and plant sensors placed around the field at critical locations. This information is combined with local weather measurements from meteorological stations, remote satellite images, weather forecast services and crop and hydraulic models. The system then analyses the data in order to provide the farmer with accurate, precise and reliable recommendations for how much and when they should irrigate their crops. 'With FIGARO, the farmer knows the exact irrigation volume required, the number of times to irrigate and the right

irrigation timing to optimise water use and energy consumption,' says Doron.

Built in flexibility

The FIGARO platform's structure was designed to be able to integrate any type of sensing technique and management model, which allows the user to expand and tailor its functions to their unique needs. As a result, the platform can utilise both a model's sensing systems and networks calibrated to local conditions and best practices.

Furthermore, emerging technologies such as robotic and mechatronic sensors can all be easily integrated into subsequent versions of the platform.

Widespread uptake

In addition to benefiting farmers, FIGARO also provides policymakers with an effective tool for monitoring and managing irrigation and to better regulate the use of water for agricultural purposes. Likewise, food-related companies who depend on the produce grown using the FIGARO system will see their environmental footprint decrease, making it easier for them to comply with environmental regulations.

'The platform's flexibility, ease of use and minimal maintenance ensures its widespread uptake and use,' says Doron. 'Not only is FIGARO helping farmers reduce water and fertiliser use and optimise their energy consumption, it's also helping the European farming industry adapt to the new realities of climate change and evolve into a sustainable sector.'

Project	**FIGARO: Flexible and PrecIse IrriGation PlAtform to Improve FaRm Scale Water PrOductivity**
Coordinated by	NETAFIM LTD (Israel)
Funded under	FP7-KBBE
Project website	http://www.figaro-irrigation.net/

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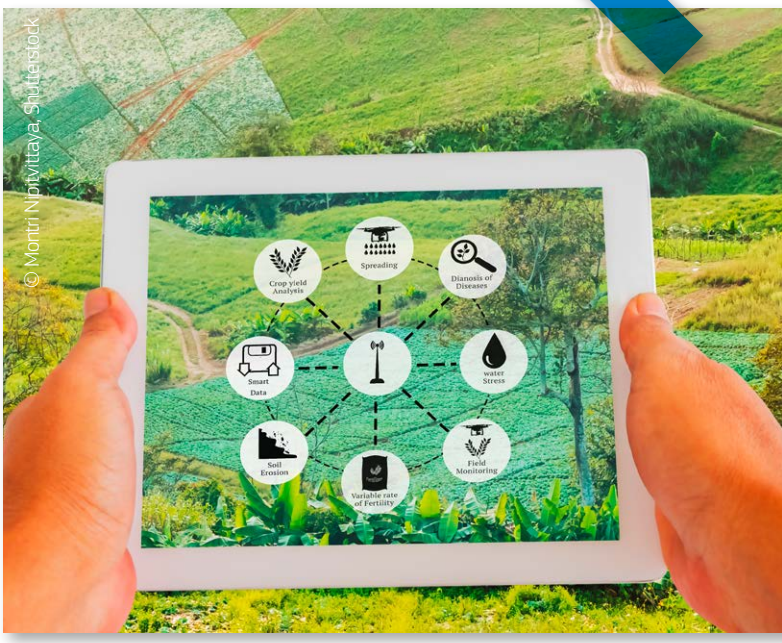
Powering the next generation of farming with data

To help European farmers better manage and use data, the EU-funded FOODIE project has developed a cloud-based platform to host both spatial and non-spatial agricultural data.

As agriculture continues to shift away from the family farm and towards being a data-driven business, today's farmers and agri-food operators must manage many different and heterogeneous sources of information. As a result, in addition to traditional agricultural equipment such as tractors, essential farm equipment now includes technology for collecting, storing, sharing and analysing diverse and large quantities of spatially and non-spatially referenced data.

The availability of this data is both a blessing and a curse. On the one hand, it enables precision agriculture. On the other hand, this data also poses a barrier to the adoption of precision agriculture. This is because the multitude of data models, formats, interfaces and reference systems currently in use create incompatibilities that require specialised technical knowledge to integrate and interpret all the available sources of information.

To help European farmers better manage – and use – this data, the FOODIE project created a cloud-based platform hub to host spatial and non-spatial agricultural data and related open data sources. 'FOODIE established an open and interoperable cloud services platform that provides advanced and added value services for different stakeholders in the agriculture domain, with a particular focus on supporting the improvement of a farmer's daily activities,' says project coordinator Miguel Ángel Esbrí. 'The FOODIE services platform also provides a set of open and standards-based APIs, allowing external parties to access its services and datasets and enabling them to build new services and applications on top of it.'



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Specialised applications

The core outcomes of the project include the FOODIE Data Model, where information is kept and shared, and the FOODIE Cloud Platform. From the Cloud Platform, users can access a range of specialised applications developed specifically for farmers. For example, the Marketplace application provides a virtual space to connect consumers and producers of agricultural data and applications. 'The Marketplace enables customers to find and consume relevant resources in the agri-food domain, including datasets, services, applications, and training materials,' says Esbrí. 'Similarly, producers can publish their own datasets, services and applications.'

Other features include a Geoportal for advanced search and metadata visualisation and a Developers' Corner.

FOODIE established an open and interoperable cloud services platform that provides advanced and added value services for different stakeholders in the agriculture domain, with a particular focus on supporting the improvement of a farmer's daily activities.

A practical toolbox

One of FOODIE's key features is its toolbox for farmers. 'These are a set of advanced and added-value farmer-specific tools built on top of the FOODIE cloud infrastructure and services and geared towards supporting the daily activities of farmers,' explains Esbrí.

For example, SmartV is a web-based tool that provides advisory services in different aspects related to winegrowing, such as disease prevention, production estimation and harvesting scheduling. Its user-friendly design allows winegrowers to apply precision viticulture techniques to manage the variability of the vineyard. It also stores historical information about the status of the vineyard. 'We provide a unique solution for farmers where they can get all the functionalities needed for the proper management of the vineyard,' says Esbrí.

Other applications within this toolbox include a comprehensive machinery tracking, route and fuel optimisation system for tractors, a crop yield potential calculator and a pest early warning advisor.

'The FOODIE cloud platform and all of its related tools and applications are well-positioned to help usher in a new generation of cloud-based agricultural products capable of lowering the cost of production and maintenance,' adds Esbrí.

Project	**FOODIE: Food-Oriented Open Data in Europe**
Coordinated by	ATOS SPAIN SA (Spain)
Funded under	CIP
Project website	http://www.foodie-project.eu/

Innovative FIWARE-based apps for more productive farming

The EU-funded FRACTALS project provided EUR 5.52 million in funding to 46 SMEs, who collectively produced a portfolio of disruptive FIWARE-based applications for agriculture.

Introducing state-of-the-art technology into traditional industries can be an effective means of boosting productivity and ensuring competitiveness. With this in mind, the EU-funded FRACTALS project set out to encourage the development of innovative technologies focused on increasing agricultural productivity. To do so, it provided funding of up to EUR 150 000 to web entrepreneurs developing FIWARE-based applications for the agricultural sector.

The EU-funded FRACTALS project provided EUR 5.52 million in funding to 46 SMEs, who collectively produced a portfolio of disruptive FIWARE-based applications for agriculture.

FIWARE is an open, public and royalty-free architecture and set of open specifications for digital applications. Applied to the agriculture sector, FIWARE can be used to create crop sensors that tell farmers when they need more nutrients or ground sensors that instruct sprinklers to dispense the exact amount of water needed. 'These types of applications create Smart Fields that have the potential of making food production much more sustainable and helping reduce both waste and costs,' says project coordinator Goran Hodoba.

Levelling the playing field

According to Hodoba, FRACTALS focused on agriculture due to a recognised need for technological innovation in the area. 'Less than a quarter of European farmers use ICT in their daily work,' says Hodoba. 'This is significantly lower than in the US, where technologically-enabled American farmers operate more

efficiently, increasing communication along the supply chain and thus achieving better margins.'

To help level the playing field, FRACTALS funded and nourished the creation of 43 innovative, market-ready FIWARE-based applications that address concrete problems and agriculture needs in 12 different countries. In addition to the funding, the project also provided developers with ongoing technical and entrepreneurial support and training. The project also established new models of communication and collaboration between ICT industry and agriculture by involving end-users in testing and validating the applications via a Living Lab environment and by organising demo days and matchmaking opportunities.

One example of the type of applications coming out of the project is AgriSens, a back-end system that helps farmers make decisions about their crops by leveraging remote sensing and drone technology. AgriSens products and services are used by large agricultural producers, individual farmers, researchers, seed producers, insurance companies and banks in order to gain valuable insights into the field and, when necessary, take quick corrective action. Today, AgriSens applications are being used by more than 200 users in over 30 countries.

Positioning Europe

In total, FRACTALS invested EUR 5.52 million into 46 SMEs, which produced a portfolio of disruptive FIWARE-based applications for agriculture, all of which are currently benefiting farms in 26 European countries. But the project's impact is much bigger than this immediate benefit.

FRACTALS funded and nourished the creation of 43 innovative, market-ready FIWARE-based applications that address concrete problems and agriculture needs in 12 different countries

For Europe to catch up with global competitors, it is critical to invest in a smart way and to combine priorities in order to maximise impact. 'This combination is what made FRACTALS a smart investment for European taxpayers,' says Hodoba. 'It simultaneously helped the South Eastern Europe/Balkan region to bridge the gap with the rest of Europe through implementing FIWARE technologies whilst, at the same time, contributing to safe and adequate food for future generations of Europeans.'

Project	**FRACTALS: Future Internet Enabled Agricultural Applications**
Coordinated by	RAZVOJNI FOND AUTONOMNE POKRAJINE VOJVODINE D.O.O. NOVI SAD (Serbia)
Funded under	FP7-ICT
Project website	http://fractals-fp7.com/index.php/about/project

Building the high-tech farm of tomorrow

To ensure the competitiveness of European agriculture, the EU-funded ICT-AGRI 2 project worked to enhance and improve farming's use of ICT and robotics.

According to the EU-funded ICT-AGRI 2 project, high technology is the future of farming. 'We believe that modern agricultural engineering tools are needed to enable a sustainable agricultural sector capable of providing for the growing need for food, feed and bio-based products while simultaneously reducing its overall environmental footprint,' says project coordinator Niels Gøtke. In this light, the ICT-AGRI 2 project set out to develop eco/resource-efficient and competitive agriculture through an enhanced and improved use of ICT and robotics.

Our overall goal is to strengthen European research within the diverse area of precision farming and develop and fund a common European research agenda concerning ICT and robotics in agriculture.

Funding the future of farming

'Our overall goal is to strengthen European research within the diverse area of precision farming and develop and fund a common European research agenda concerning ICT and robotics in agriculture,' explains Gøtke. 'In other words, we pooled fragmented human and financial resources as a means of improving both the efficiency and effectiveness of Europe's research efforts.'

At the outset, the project underwent an intensive mapping exercise where it reviewed all existing ERA-NET projects pertaining to ICT and robotics for agriculture, citing the key players from both industry and research and identifying future needs. From here, researchers developed multiple instruments and procedures for transnational funding activities, as well as a strategic transnational research agenda and programmes. Next, the project established and maintained a network of international collaborations within the realm of sustainable agriculture and conducted an array of workshops to promote the initiative and subsequent calls.

Based on its Strategic Research Agenda, the project issued three calls for innovation. For example, the Enabling Precision Farming

Call focused on the development and implementation of complete solutions for the adoption of precision farming. Seventeen proposals were considered for funding, including the Happy Cow project, which developed hardware and software for a cloud-based oestrus detection system for dairy cows, and 3D Mosaic, an advanced monitoring system of tree crops for optimised orchard management. The other two calls covered the topics of Applications for Smart Agriculture and Farm Management Systems for Precision Farming.

Provided that sufficient infrastructures are in place, digital technologies can bring new opportunities to rural areas that are likely to raise their attractiveness and viability.

A huge impact

Digital technologies and robotics are some of the most important recent innovations for all actors in the agri-food value chain, and advances in precision agriculture are helping to address the global challenge of increasing productivity in a more sustainable manner. Beyond assisting in primary production, digital technologies have immense potential for supporting many elements of the rural economy – from food supply chain management to innovative new business models. 'Provided that sufficient infrastructures are in place, digital technologies can bring new opportunities to rural areas that are likely to raise their attractiveness and viability,' says Gøtke. 'I believe that ICT-AGRI 2 has had a huge impact on bringing attention to these opportunities.'

According to Gøtke, ICT-AGRI 2's strength was its ability to set the agenda for digital farming by bringing together different research communities from ICT, agriculture and the environment. From the outset, the project took a cross-thematic approach with a focus on open-source development. 'New technologies are rapidly emerging and will soon be capable of revolutionising farming,' says Gøtke. 'ICT-AGRI 2 successfully supported the development and implementation of these new technologies for a competitive, sustainable and environmentally-friendly agriculture.'

Project	**ICT-AGRI 2: Information and Communication Technologies and Robotics for Sustainable Agriculture**
Coordinated by	STYRELSEN FOR FORSKNING OG UDDANNELSE (Denmark)
Funded under	FP7-KBBE
Project website	http://www.ict-agri.eu/

Using GNSS Reflectometry to map soil moisture

EU-funded researchers have designed a lightweight airborne system which uses satellite signals to measure how moist soil is. It could allow farmers to save water through smart irrigation as well as helping water managers deal with extreme weather events such as flooding.

Researchers from the EU-funded MISTRALE project have designed a system which can measure soil moisture from a drone flying at low altitude using GNSS Reflectometry. The system, still a prototype, can produce high-resolution maps of soil moisture by harnessing signals from either the Galileo or GPS global satellite systems. It could help farmers make better decisions about when and where to irrigate and help water managers understand weather events such as flooding and water logging.

GNSS Reflectometry, or GNSS-R, is a remote sensing technique which uses satellite signals bounced off the earth's surface to learn about natural phenomena. In this case, the MISTRALE team

The MISTRALE team have designed a system which measures direct GNSS signals coming from satellites above, and indirect signals reflected from the ground below and compares the two to learn about soil moisture.

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The team have also designed a GNSS-R sensor and antennas capable of tracking the satellite signals whilst on the move and fitted these to a small unmanned aircraft or drone.

Developing something that was compact and lightweight was a challenge. 'The whole system-sensor, antennas, CPU — has to weigh less than 2 kg and be as small as possible,' says César Roda, project manager of MISTRALE and based at M3 Systems in Belgium.

Futureproof device

The researchers chose to make the sensor multi-frequency — it can handle signals on GPS's L1 and Galileo's E1 bands but also Galileo's E5 — as a way of future-proofing the device. 'Having a multi-frequency, multi-constellation receiver is very state-of-the-art', says Dr Roda. 'Applying this to GNSS-R is going to open up a lot of possibilities and allow researchers to use it for new applications.'

The first test flight, which took place over the Camargue nature reserve in Southern France in August 2015, collected 22 gigabytes of data. This has been used to finetune the processing algorithms. Additional flights over potato fields in the Netherlands, vineyards in France and an open pit mine in Spain are planned for this summer and autumn.

The MISTRALE researchers are now optimising the system and expect to complete a working prototype, which can produce soil moisture maps to a resolution of 50m x 50m, by the time the project ends in late 2017. The drone, a long distance unmanned aircraft designed for research purposes, can fly for 1 000 km in a straight line or eight hours without stopping at low speed and altitude.

Smart farming and flood prevention

The main beneficiaries of MISTRALE are expected to be farmers who could use the information to do smart irrigation and save water. It could also be used to map flooded areas in the event of a natural disaster. Unlike earth monitoring systems, 'we can measure the surface covered by water even through vegetation, so we can see through trees to the land underneath,' comments Dr Roda.

Water managers in charge of flood prevention could also put the MISTRALE technique to use as 'if you know how wet the soil is, this can help inform decisions about flood prevention measures,' concludes Dr Roda.

Project	**MISTRALE: Monitoring of Soil moiSture and wateR-flooded Areas for agricuLture and Environment**
Coordinated by	M3 SYSTEMS BELGIUM SPRL (Belgium)
Funded under	Horizon 2020- LEIT-SPACE
Project website	http://www.mistrale.eu/

New and innovative mobile apps help farming to get smarter

The EU-funded SMARTAGRIFOOD2 project has boosted innovative ideas for smarter agriculture by supporting entrepreneurs to set up successful businesses

From sensors that can detect whether cattle are ready to breed, to soil quality detectors, the 'Internet of Things' is making inroads in agriculture.

One EU-funded project is aiming to accelerate its uptake by using a cloud-based computing architecture and supporting smart farming ideas. SMARTAGRIFOOD2 provided technical support and funding to small enterprises and web entrepreneurs to transform their innovative ideas into new applications and business services that help farmers.

'Between January and September 2016, the businesses we supported generated a total turnover of EUR 2.5 million and created 41 new jobs,' says George Beers, SMARTAGRIFOOD2 project coordinator.

The project builds on an earlier EU-funded project – SMARTAGRIFOOD – which built cloud – based FIWARE architecture specifically tailored to the needs of the agriculture sector. SMARTAGRIFOOD2 then opened a call for innovative ideas and selected 50 companies out of 158 applicants to develop their mobile applications. Halfway through the project, 17 were selected for the next phase – with three of them identified as 'high flyers' receiving extra support. All 17 projects used FIWARE to turn their ideas into reality.

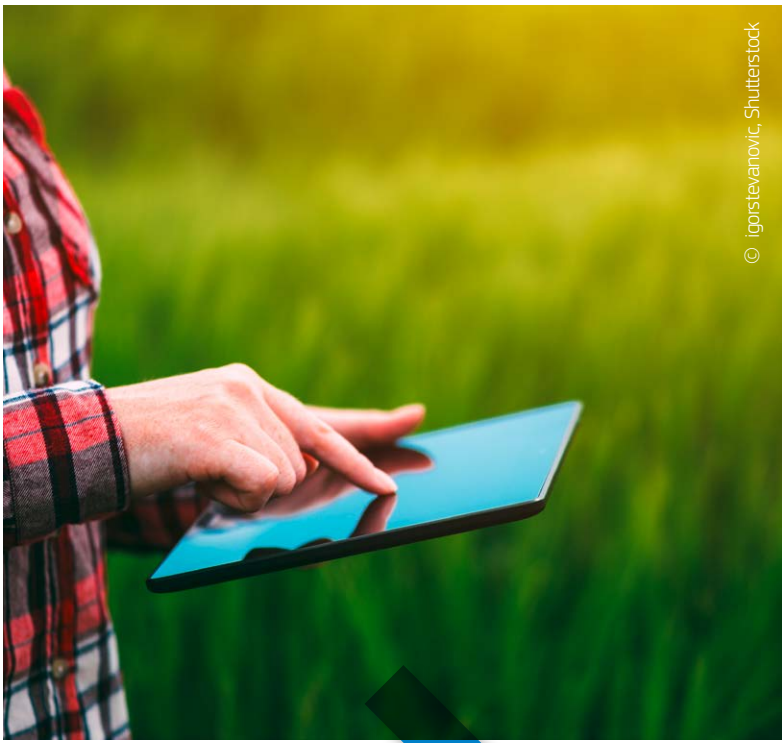
The successful projects included a farm financial analysis app that provides simple and affordable financial management and analysis solutions for small and medium-sized farms. Another company developed sensors that track the flow of nitrates in soil helping farmers to reduce fertiliser use by detecting only where fertiliser application is necessary.

One of the other successful recipient projects developed a mobile app which allows beekeepers to carry out inspections and record live beehive data such as population and diseases, whilst another developed an irrigation advice app that provides farmers with information on when and how much water their crops need, helping farmers to reduce irrigation costs by up to 30 %.

Other successful ideas included an app that provides farmers with fast information on plant pests and diseases, and an app that helps goat and sheep farmers make management planning decisions.

Many of the apps can be used by farmers via their smartphones when they are close to their crops or animals, allowing them to make informed in-the-field decisions.

The "ecosystem" that resulted from the project can be used in the further digitalisation of the agri-food sector as an initial connection has been made between agri-food businesses and smart internet appliances.



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Shifting to precision farming

All of these projects are designed to meet the broader goal of increasing the quantity and quality of agricultural production through 'precision farming' that provides much more detailed information on the amount of inputs needed, such as fuel and fertiliser, faster tracking of animal and plant health and other information, all of which can help meet environmental sustainability, animal welfare and food safety goals as well as improve the farm business.

With the project now over, Beers hopes its legacy will live continue to live on. 'The "ecosystem" that resulted from the project can be used in the further digitalisation of the agri-food sector as an initial connection has been made between agri-food businesses and smart internet appliances,' he says.

Moreover, some of the project partners have continued their cooperation as part of an on-going, large-scale Horizon 2020 pilot project for the 'Internet of Things' called IOF2020, which began in February 2017 and is due to run until December 2020. This project has received nearly EUR 30 million in EU funding and will be taking forward many of the processes and innovations initially conceived within SMARTAGRIFOOD2.

The EU-funded SMARTAGRIFOOD2 project has boosted innovative ideas for smarter agriculture by supporting entrepreneurs to set up successful businesses.

Project	**SMARTAGRIFOOD2: SmartAgriFood2 is a a phase 3 FI-PPP project supporting SMEs in the development of smart services and applications for the agri-food sector based on the validation and use of results from the SmartAgriFood (Phase 1) and FI-Space (Phase 2) FI PPP projects**
Coordinated by	STICHTING WAGENINGEN RESEARCH (the Netherlands)
Funded under	FP7-ICT
Project website	http://smartagrifood.com/

Pepper robot harvester edges closer to commercialisation

The EU-funded SWEEPER project has made huge leaps in the development of robotic pepper harvesting technology, incorporating the entire production chain, and hopes to take its technology soon to the mass market.

Picking vegetables in greenhouses under humid and high temperature conditions can be a tough, uncomfortable and repetitive task – all factors behind the current decline in availability of farm workers to pick vegetables such as peppers. Today, many farmers are looking to overcome this problem and reduce their costs by automating labour.

Technology – such as robotic pepper harvesters - has been developed but it is still not market-ready. EU-funded project SWEEPER aims to bridge the gap between the laboratory and the market by ironing out the problems in current prototype harvesters. The project then hopes to get harvesting robots for the greenhouse onto the market for the first time, helping to secure Europe's role as a global leader in agricultural robotics.

Overcoming challenges to reach the market

'The reduction in the labour force has put major pressure on the competitiveness of the European greenhouse sector. We

hope to develop the technology that will prevent greenhouse food production from migrating out of Europe due to the 40 % expected rise in labour costs over the coming decade,' says SWEEPER project coordinator Jos Balendonck from Wageningen University in the Netherlands.

So far, robotic harvesting systems have not been commercialised. Obstacles holding them back include the slow pace of current technology, which has a success rate of around 33 % and takes an average of 94 seconds to harvest one fruit or vegetable. Moreover, today's robot harvesters are not robust enough, are difficult to control, and are not well enough integrated into post-harvest logistics.

Building on past innovation

SWEEPER itself builds on a previous EU-funded project, CROPS. CROPS researchers developed a prototype sweet pepper harvester and patented a gripper that can grip and cut peppers. The system can also do several different tasks including harvesting apples and grapes, and spraying.

Over the 2016-2017 winter period, SWEEPER improved on CROPS' pepper harvester technology by building in sensors and advancing algorithms to improve the localisation of fruit and the detection of fruit maturity. The robot can now detect obstacles and can calculate a collision-free path to the fruit, allowing maximum free space to grip and cut off the fruit.

The project team also improved the software used to control the harvesting system and have made plans to automate post-harvest fruit and vegetable packing logistics.

SWEEPER is now finalising a second prototype harvester which will be tested in the summer of 2017. Balendonck hopes that for the 2018 growing season, the system will be much improved, taking it closer to commercialisation.

Meanwhile, SWEEPER is also considering factors such as technology acceptance by growers. It has formed a European grower advisory board so that farmers can give feedback.

The project has also studied the different types of greenhouse cultivation systems and has found that single row cultivation systems are best suited to automated picking since they boost fruit visibility and accessibility.

SWEEPER is designed for peppers – a high-value European crop which has an estimated European yield of 1 900 000 000 kg per year. However, the technology can be easily modified and transferred to other crops. Meanwhile, Balendonck envisages making even more improvements, such as adding sensors that can detect vitamin content, levels of sweetness, expected shelf life of the fruit, and the ability to provide advanced crop disease warnings.

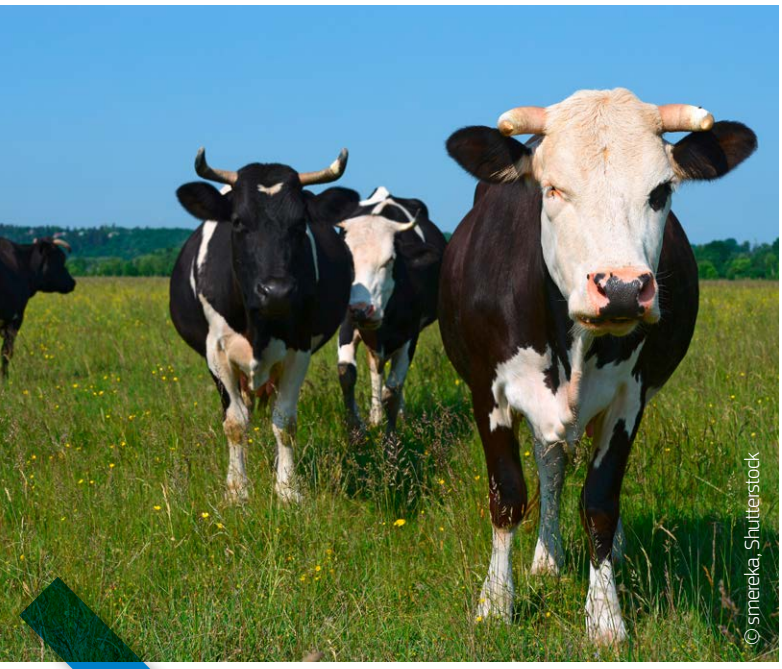
© SWEEPER

Project	**SWEEPER: Sweet Pepper Harvesting Robot**
Coordinated by	FONDAZIONE BRUNO KESSLER (Italy)
Funded under	FP7-ICT
Project website	http://www.sweeper-robot.eu/

The project then hopes to get harvesting robots for the greenhouse onto the market for the first time, helping to secure Europe's role as a global leader in agricultural robotics.

Swifter on-site detection of toxins in milk reduces waste

EU-funded scientists have developed a kit to swiftly detect toxins in milk, eliminating the need for expensive and time-consuming off-site laboratory tests.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Much fresh farm produce has to be discarded due to contamination. In the dairy industry, waste and the cost to the farmer can be reduced by better detection of contaminants such as aflatoxins.

Animal feed contaminated by aflatoxin mould and consumed by cows can be passed on in milk as Aflatoxin M1 — a potent carcinogen in humans that is heat — resistant and cannot be controlled by pasteurisation. With dairy ingredients present in a multitude of foods and drinks, early detection and protection from contamination is crucial for both the food industry and human health.

Now EU-funded researchers working on SYMPHONY have developed a desktop system that incorporates sample preparation and the functions of a small laboratory to detect even very low concentrations of aflatoxins in milk and dairy products.

'The system developed by the consortium brings testing into the dairy. Aflatoxin detection methods currently in use are not very friendly to the dairy — samples must be sent to external laboratories for final confirmation of the analysis,' says project coordinator Leandro Lorenzelli, head of microsystems technology research at the Bruno Kessler Foundation's Centre for Materials and Microsystems in Italy.

Traditional tests for aflatoxins in milk take two hours to obtain a result, but the method is not accurate and gives many false positives. With strict EU limits on aflatoxins, testing needs to be more reliable. 'If you want high accuracy you have to assign the test to external laboratories and then you get the answer after several days, which is totally unacceptable for the fresh milk market,' notes Dr Lorenzelli. It is also expensive as it requires specialist personnel, he adds.

Swifter results

'Currently SYMPHONY has demonstrated a result in half an hour. The aim is to reach a time of ten minutes,' Dr Lorenzelli says.

Over the three and a half years of the project, the consortium developed a three-stage process of sample preparation to extract the soluble aflatoxin from the milk, then produced a concentrate that can be analysed, followed by sensing to detect the amount of toxin. Two of the processes developed by the team have been patented.

The main purpose of the sample-preparation stage is to clean the milk sample of unwanted components such as fats, which may interfere with the following stages and cause clogging of the system, and to concentrate and make the toxin available for detection.

The system developed by the consortium brings testing into the dairy. Aflatoxin detection methods currently in use are not very friendly to the dairy — samples must be sent to external laboratories for final confirmation of the analysis.

The concentrated liquid containing the toxin is then passed over a photonic sensor on a silicon chip coated with antigen receptors to detect and quantify the aflatoxin. 'Concentrated liquid sticks to the receptors which affects the light travelling through the sensor, and this phase shift is measured. The degree of phase shift relates to the amount of toxin present,' explains Dr Lorenzelli.

Multiple detection

The targeted cost of the overall system should be some EUR 2 000–3 000 for the hardware, he says, and the cost of each test is estimated at around EUR 5.

The system can be useful beyond the dairy industry as an array of sensors can be set up to measure different toxins or target substances. 'In principle you can expand the system for multiple analyses. The sensor is particularly suited to detect many different molecules at the same time,' Dr Lorenzelli concludes.

Project	**SYMPHONY: Integrated SYsteM based on PHOtonic Microresonators and Microfluidic Components for rapid detectioN of toxins in milk and dairY products**
Coordinated by	SOCIETA COOPERATIVA AGRICOLA (Italy)
Funded under	FP7-ICT
Project website	http://www.symphony-project.eu/

A wheeled robot to monitor grape growth

Just as great wine needs time, great grapes require continuous attention and reliable assessment tools. Noting the absence of a convincing alternative to manual sampling and analysis, an EU-funded consortium has developed VINEROBOT, an 'Unmanned ground vehicle' (UGV) equipped with non-invasive sensor technology.

Today, assessing the readiness of vine grapes for harvesting requires growers to sample hundreds of berries, with their eyes as the only tool they can rely on.

With VINEROBOT's (VINEyardROBOT) technology, they can now look forward to the day when this tiresome work will be facilitated by a robot able to estimate future grape yield and monitor plant growth, as well as assess water status and berry composition, with all that information being made available on their smartphone or tablet.

Now, with its second prototype, the VINEROBOT team has recently been granted a six-month project extension to complete its work. Dr Javier Tardaguila, coordinator of the project, discusses the benefits of this technology and his hopes for great success within the wine grower community.

Our goal is to optimise vineyard management, as well as improve grape composition and wine quality.

What are the benefits of VINEROBOT's approach compared to alternatives?

Recently, various remote sensing solutions from aerial platforms or satellites have been enhanced with simultaneous acquisition of spectral information in the visible and infrared ranges, allowing for the assessment of grapevine vigour and water status. But the small spatial resolution of multispectral devices, the discrete architecture of grapevine cultivation in rows rather than bulk crop, limited weather flexibility and the elevated cost of aerial monitoring, are major drawbacks which have forced small and medium-sized European vineyards to discard remote sensing altogether.

VINEROBOT is a promising alternative: It will provide reliable information using proximal sensors on-the-go in a non-invasive way, in different types of soils, and in a more cost-effective process that can be used across a wide range of vineyards.

What would you say are the most innovative aspects of VINEROBOT's UGV?

Rational decision-making in sustainable viticulture requires objective and continuous key parameter monitoring by means of advanced technologies and sensors in the field. But currently there are no commercial products that can simultaneously map key parameters such as agronomical, physiological and fruit composition on-the-go. Data sampling is being carried out manually, which implies high costs and low resolution, and is usually influenced by the interpretation of the person involved.

By designing, developing and deploying an agricultural robot in the shape of a UGV, and equipping this robot with several non-invasive sensing technologies to monitor the likes of grapevines' vegetative growth, nutritional status and grape composition, VINEROBOT aims to bridge this gap. Our goal is to optimise vineyard management, as well as improve grape composition and wine quality.

What tasks can this robot perform?

The VINEROBOT is equipped with non-invasive advanced sensors and artificial intelligence systems, to provide reliable, fast and objective information on the state of the vineyards to grape growers. Thanks to these technologies, VINEROBOT will be able to work — that is, retrieving agronomical and physiological data from the grapevines — autonomously and safely over long periods of time under the uncertain environmental conditions typically found in vineyards.

The first version of the VINEROBOT incorporates a fluorescence-based sensor to assess nitrogen content in leaves. The measurement is performed on-the-go and provides information about the heterogeneity and state of the vineyard.

The other sensor included in the VINEROBOT measures the anthocyanin content in grapes. This sensor is a fusion between a fluorescence sensor and a fine vision system: It gathers information about the composition of grape berries.

A second version of the VINEROBOT is already foreseen. It is expected to include two additional sensors: one for yield assessment and one to control vineyard water status.

What has been the sector's feedback so far?

Grape growers who have seen the VINEROBOT have shown a high level of interest, especially young grape growers (younger than 45 years of age), because they are often more open-minded regarding new technologies.

However, in the long term it is expected that older viticulturists will also consider using our robot, once they witness the good results achieved in other vineyards.

What can they expect in terms of concrete benefits?

The VINEROBOT works alone, without the need for any human presence. Moreover, working speed can be adjusted depending on the size of the vineyard, so that the robot can obtain information about the whole vineyard easily and in a short period of time, whilst providing useful maps to vine growers.

These maps of wine parameters can help them with how to best treat the crop. For example, they can plan for a more precise mechanical harvesting or fertilisation, which will have a huge influence on the yield and the wine's quality.

When do you expect your solutions to be commercialised?

We are still developing and completing the VINEROBOT, improving its latest version. We don't really know when it will be ready, but we expect that the product could be commercialised next year.

Project	**VINEROBOT: VINEyardROBOT**
Coordinated by	UNIVERSIDAD DE LA RIOJA (Spain)
Funded under	FP7-ICT
Project website	http://www.vinerobot.eu/

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RESULTS PACK

Published by
The Community Research and Development Information Service (CORDIS)
managed by the Publications Office of the European Union
2, rue Mercier
2985 Luxembourg
LUXEMBOURG

cordis@publications.europa.eu

Editorial coordination

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The research*eu Results Packs are published by the Community Research and Development Information Service (CORDIS) and managed by the Publications Office of the European Union. Content is prepared using information featured on the CORDIS website, as well as original material collected specifically for this publication.

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ISBN 978-92-78-41484-9 (printed version)
ISBN 978-92-78-41486-3 (ePUB)
ISBN 978-92-78-41485-6 (PDF)

ISSN 2529-3265 (printed version)
ISSN 2529-2919 (ePUB)
ISSN 2529-2919 (PDF)

doi:10.2830/731671 (printed version)
doi:10.2830/873814 (ePUB)
doi:10.2830/094402 (PDF)

ZZ-AD-17-008-EN-N

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