

A MESSAGE FROM THE EDITOR

NEW AG INTERNATIONAL



Courtesy of Tony Eason

Our online Chinese September
Edition is available at
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Registration to the
12th New Ag International
Conference and Exhibition,
to be held in Warsaw, Poland,
26-28 March 2014, is now open

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PRECISION AGRICULTURE: AT EVERY CORNER OF EVERY FARM INPUT TECHNOLOGY AND APPLICATION!

As I write these lines, hundreds of delegates from around the world are finalizing their arrangements to attend the Greensys scientific conference on Greenhouse Technology in South Korea or the ABIM congress on biocontrol in Switzerland. Others are starting to make plans to go to Austin, Texas to attend the annual Irrigation show and technical conference. Others, sometimes the same people, are "digesting" what they have heard and seen in Lleida, Catalonia in Spain where they attended the 9th European Conference on Precision Agriculture (ECPA) earlier in July. Finally, others are analyzing the benefits of their attendance to the China Water Soluble Fertilizer conference also held in July.

For all these events we have had or will have the pleasure of being the partner Agriculture Magazine, sometimes the co-organizer. They cover the main pillars of our editorial scope: plant nutrition, irrigation, biocontrol and greenhouse cropping.

In this issue of the magazine we are happy to report on the China event, with the release of so far totally unpublished figures about irrigation and fertigation products, thanks to the network that we have patiently built over many long years. Prior to the Irrigation show, and in the frame of a new constellation in the USA (no farm bill has been passed for the first time!) we are also pleased to bring you an exclusive interview with the President of the Irrigation Association.

However our biggest challenge for this issue of magazine was to bring you a report on Precision Agriculture that will show you (1) what is behind the concept, (2) where it can be useful and (3) whether any grower can put it in place. In Lleida, the keywords were sensors, monitoring, controlling, etc.. Certainly not drip tape, pivot, sprinkler, soluble fertilizers, etc.. Site specific crop management technology, Accuracy Assessment in the System of Site-Specific Base Fertilization, managing spatial and temporal variability in high value crops and design and implementation of farm management information systems, etc. have been the hot topics in this Precision Agriculture Conference.

I believe that the 16 pages of editorial allocated to the Lleida coverage, written by our Editor Patricio Trebilcock who came back from Catalonia completely enthusiastic, and going across most sections of the magazine (plant protection, products and trends, irrigation technology and agronomics), will catch your attention!

Last but not least, during the course of the summer we have had the great pleasure to meet for a chat with two "new generation" companies: Futureco of Spain, which is successfully pursuing its growth in the biopesticides and biostimulants businesses with its own spirit, ethics and values, and Pessl Instruments of Austria whose networks of weather, moisture, pest infection, fertility assessment, etc.. measurement stations make the various farm inputs talk together and efficiently at grower's gate in an increasing number of countries around the world.

We do believe, as I already wrote here not long ago, that the best synergies in emerging industries will come from discussions between powerful Research and data Centers and flexible, innovative and business minded SME's. Futureco and Pessl are wonderful examples that this approach works!

I wish you a good read!

Jean-Pierre Leymonie
Director

ADVANCES IN PESTICIDE DOSE ADJUSTMENT

Tree crops represent 4.4% of the cropland in the 27 European Union countries, but they represent 14% of the total pesticide consumption.

New regulations are increasingly restricting the excessive use of pesticides and appropriate application methods are crucial to fulfill the European pesticide reduction goals. During the European Precision Agriculture Congress (ECPA), held in Lleida, Catalonia, Spain, many new prototypes of spraying machines that adjust the application dose depending on the tree canopy were highlighted.

THE LOCAL TEAM THAT ORGANISED ECPA belongs to the Research Group on AgrolTC & Precision Agriculture, founded in 2004 bringing together researchers from four institutions (University of Lleida, Polytechnic University of Catalonia, Polytechnic University of Valencia and the Centre of Agricultural Mechanization of the Generalitat of Catalonia). Most of this group's research activities are directly linked to plant protection: electronic canopy characterization and weed detection; dose adjustment of plant protection products & decision support systems and variable-rate application of plant protection products in tree crops. It constitutes the reference group in

spray application techniques in Spain, with 11 patents and utility models in this area.

ELECTRONIC CANOPY CHARACTERIZATION

One of the most promising technologies for the geometric characterization of the canopies in the agricultural sphere is based on the use of LIDAR (Light Detection and Ranging) sensors. The use of this type of sensor is based on the measurement of the distance from a laser emitter to an object or surface. Its principal characteristics include, most notably, a fast meas-

uring speed and a high degree of accuracy. LIDAR systems can generate 3D digitalized models of crops with sufficient accuracy for most agricultural applications. A vast amount of information can be obtained from these models including height, width, volume, Leaf Area Index (LAI) and leaf area density.

"We have created a prototype based on these sensors mounted on a special vehicle that we use for research and teaching purposes. With this information we have been working along three lines. One is the development of a vari-

able rate application sprayer that turns nozzles on and off depending on the canopy's characteristics. It is mounted with a GPS, LIDAR and special electrovalves. We have also used this knowledge to create an online tool that helps farmers to determine the optimal dose of plant protection products. That is the DOSAFRUT project where we have incorporated our LAI estimations from this technology and we have also provided pictograms of referential types of orchards, so farmers can determine which are similar to their own condition, without using a sensor in their



fields. And now we are using this technology to find any difference withing fields that deserve future observations, such as changes in vigour", says Dr Alex Escolá (University of Lleida), the convener of ECPA.

DOSAFRUT: ADVANCES IN PESTICIDE DOSE ADJUSTEMENT IN TREE CROPS

In Europe tree crops receive more than three times the average quantity of pesticides used for arable crops. The lack of a universal method for determining suitable pesticide doses in real orchard situations is one of the most important constraints affecting the sustainability of pesticide use in tree crops, says Santiago Planas (Universitat de Lleida, Spain). In addition to the traditional pesticide dosing method, which is based on the pesticide concentration in the tank (g/100 l), other methods for determining recommended pesticide doses have appeared in the last two decades. These methods take into account structural parameters of orchards. They include the Pesticide Adjustment to the Crop Environment (PACE) method for fruit orchards (Walklate and Cross, 2005), the Canopy Height method and the Tree Row Volume (TRV) method, which was adapted to vineyards in Switzerland by Viret and Höhn (2008). More recently, the Leaf Wall Area (LWA) method has been proposed by the chemical industry (Wohlhauser, 2009).

However, LWA, which was evaluated by Walklate and Cross (2012) in narrow canopy orchards, is difficult to adopt successfully in regions where wide-canopy training systems are used (e.g. Southern Europe). This is because leafiness is a critical factor to be considered when determining dose recommendations. The Lleida group developed a method for estimating the Leaf Area Index. This methodology was then implemented in a decision support system (DOSAFRUT) and validated over four seasons, 2009-2012. DOSAFRUT is an online tool where users can adjust the volume application rate according to several factors: the specific dimensions and leaf density of the trees, the sprayer to be used, the type of product being applied, the pest or disease to be controlled and the weather conditions expected during the application period. The system is specially designed for apples and pears and a version

for stone fruits is being programmed. Based on the canopy characterization created with the LIDAR technology the system offer farmers different pictograms of canopy sizes and trellising systems, so farmers can choose the one which is closest to their reality.

During 2009-2011 the DOSAFRUT Method was validated through studies of pesticide deposits on targeted leaves and the biological efficacy of the applied pesticides for controlling *Psylla piri* (psylla), *Tetranychus urticae* (res spider mite), and *Frankliniella occidentalis* (trips) in comercial pear, apple and peach orchards. The orchard was divided into three blocks: untreated trees (control), tree sprayed using the standard spray volumen and tree sprayed using the recomended volumen determined using DOSAFRUT. The tank mix concentration remained constant for all the applications. DOSAFRUT provided adjusted

treatment doses, enabling savings of between 14% and 53% (volume reduction) as compared to the doses typically adopted by farmers and technical advisors (standard dose).

AUTOMATIC SELECTION OF VERTICAL SPRAY PATTERN

A group from the University of Torino (Italy), led by M. Tomagnone, presented an automatic system to easily adapt the vertical spray profile from orchard/vineyard sprayers to plant canopy characteristics (height and size). "Typically, the sprayer is adjusted to guarantee an adequate spray coverage on the most dense canopies present in the farm, but this setting is then excessive for other small or less dense plants", says Mr. Tomagnone. The prototype was developed in collaboration with Nobili spa and Arag srl companies. Activation of every single nozzle and feeding of each nozzle was made independent and it was managed through Arag Seletron® devices which allow spraying of every single nozzle to be stopped and are connected on a CAN-bus line. A conventional sprayer equipped with this innovative system was used successfully in 2012 in a 30 ha orchard farm in North Western Italy. The system developed allowed management of the vertical spray profile from an air-assisted sprayer in an easy way, adapting it to the vegetation characteristics. This system, if integrated with a GPS, could provide a fully automatic management of the spray application on the farm; the sprayer would automatically select the correct nozzle configuration depending on its position and therefore on the characteristics of the target plants.

CORNELL UNIVERSITY: VARIABLE SPRAYING MACHINE

A group from Cornell University, led by Jordi Llorens has developed a prototype of a variable rate

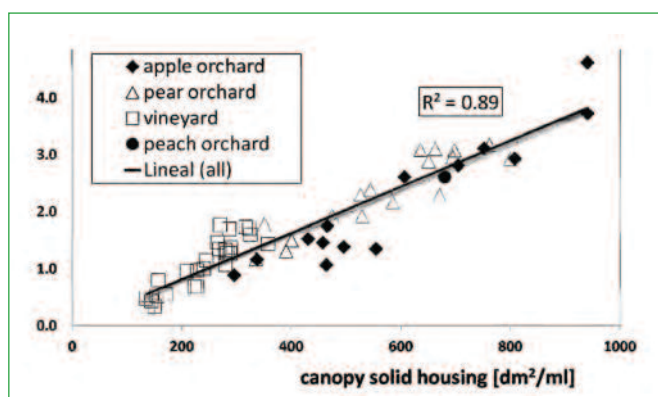


Figure 2: Correlation between orchard structure (obtained with the LIDAR sensor) and leaf area index for four tree crops.

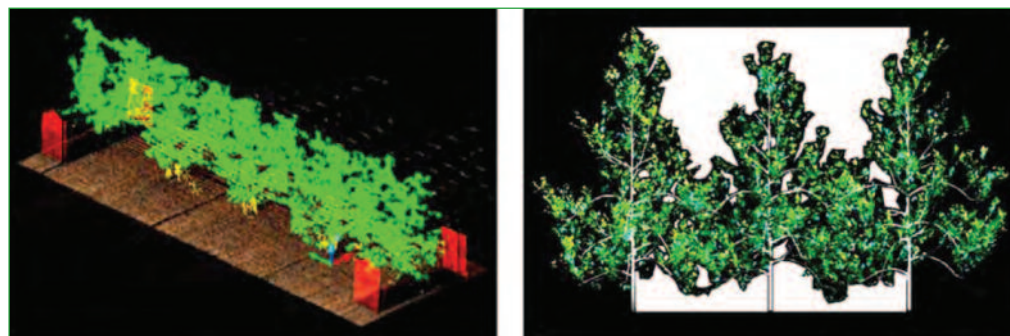


Figure 1: Digital apply orchard model obtained using a LIDAR sensor (left) and the related diagram used to estimate the proportion of gaps in the canopy. This image represents gaps totalling 39% of the row surface (right).

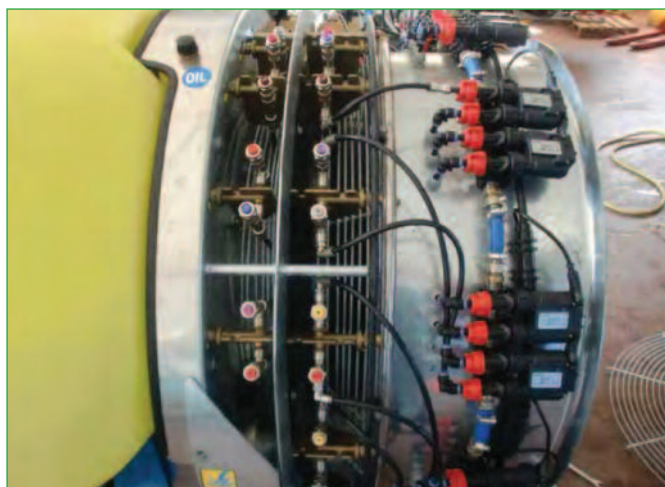


Figure 3: Detail of air outlets and nozzles of the air-assisted sprayer Nobili Geo 9DS UT.

spraying machine. The system makes one adjustment of liquid flow for an apple tree sprayer and one adjustment of air flow for a vineyard sprayer using the louvre system. In both cases the adjustment is made using the information provided by one sensing system for scanning the vegetation composed of a multiple array of ultrasonic sensors.

Two air assisted sprayers were used. One for fruit crop with one Lechler VarioSelect® system for proportional liquid application. The second sprayer is designed for vineyards and equipped with the louvre system for adjusting the outlet of air from the axial-fan.

For vegetation detection the sensing system proposed is based in on array of ultrasonic sensors that are capable of adapting to the both kinds of vegetation, in this case trees and grapevines.

To adjust the liquid flow rate in fruit spraying, the system uses a coefficient of application of 0.1275 L/m³. With this coefficient the system can calculate the total flow rate instantaneous that will apply the different nozzle configuration. For the adjustment of the air flow, the system is able to adjust the position of one electric actuator and in consequence the position of the louvre system designed by Cornell University. The preliminary results show that in both cases, air and liquid, the

application rate appropriate for each development stage of the crop can be correctly estimated, though it will be necessary to contrast the deposition results next season with field tests.

A NOVEL SPRAYING ROBOT: RHEA

A group from the University of Florence, Italy, led by Mr. D. Sarri presented the Rhea Project (Robot fleets Highly for Effective Agriculture and forestry management – www.rhea-project.eu), a new automatic generation of robotic systems to perform field operations. The prototype is a ground mobile unit (GMI): 4x4 wheel drive. The researchers presented a trial in olive trees, where different solutions about pesticide spraying and air vector devices management were investigated. After checking many configura-

tions, the selected one for woody perennial crops was a double side air blast sprayer (based on Nobili Oktopus air blast sprayer) with eight separate spraying modules on four vertical bands of the canopy. The prototype has a detection system composed of eight ultrasonic sensors, to detect data on canopy width in four vertical bands. To control flow rate, two solutions were developed: the first one consists of an intermittent spray nozzle driven by frequency and duty cycle electronically managed. The second one involves the use of double nozzles on each module with 70% and 30% of needed flow rate on each band, which are simultaneously open with full canopy. To manage the air blast flow rate, butterfly valves (step motor controlled) located on the main inlet manifold and in the fan calotte collector were designed. The expected pesticide dosage saving is about 50% of the conventional application rate maintaining, at the same time, the quality of the foliage deposition. ■



What's new in... Precision Agriculture?

Precision Agriculture (PA) is probably the area of the agriculture industry that is growing the fastest. In terms of sales it has grown exponentially in the last few years. Guidance systems alone account for more than US\$2 billion annually, and are already used by more than 80% of ag service providers in the US and in almost 90% of the Argentinean grain area. It is a growing and dynamic industry, but scattered, especially in Europe.

The industry has been very successful developing technology but now is time to put them together, creating common protocols and opening systems so different brands and users can get the best out of the data generated.

The European Precision Agriculture Conference, brilliantly organised by University of Lleida (Spain), was an ideal venue to highlight new technology and equipment but also to discuss new systems and crucial challenges, such as incorporating horticulture into this trend, making this technology available for small farmers and creating the space for future European Precision Ag Centres.

New Ag International's Editor, Patricio Trebilcock reports from Catalonia.



THE FIRST KEYNOTE lecture in Lleida was given by Dr. James M Lowenberg-DeBoer (see captioned picture), Associate Dean and Director of International Programs in Agriculture at Purdue University, USA. He is a pioneer in the use of spatial regression in analysis of crop sensor data, with published work in this area from the USA, Argentina and South Africa. He received the Precision Agriculture Legacy Award for his work on the profitability and adoption of site-specific crop management technology. During the first minutes of his lecture, he explained the difference between "information intensive" and "embodied knowledge" technologies. The "information-intensive" technologies require additional data and skill to use them, a clear example of this is



Integrated Pest Management. On the other hand, "embodied knowledge" technologies are information purchased in the form of an input. It requires minimal additional data or skill. Hybrid seeds are a clear example and GPS auto-guidance is another. In "embodied knowledge" technologies, users do not need to understand the science for the technology to be effective. Precision Agriculture will expand

worldwide if it develops embodied knowledge technologies," Lowenberg-DeBoer said.

PRECISION AGRICULTURE BOOMING WORLDWIDE, ESPECIALLY IN THE USA

Although it is difficult to have clear worldwide data for Precision Agriculture, the current figures are very promising. Lowenberg-DeBoer showed the results of the 2013 Purdue-Croplife Survey. The

main conclusion is that when it comes to the adoption of precision technology and the offering of precision services for dealerships, the more obvious the value or savings – either to the dealership itself or its customers – the faster and higher the adoption takes place. Based on this, The survey shows that GPS auto-guidance is becoming a standard practice in USA. 82% of US ag input dealers offer custom application with GPS guidance. Another trend is manual lightbar guidance being replaced by auto-guidance.



Dr James M Lowenberg-DeBoer

86% of all materials are custom applied with GPS guidance; 40% with auto-guidance. Sprayer booms are also growing fast in the US: both farmers and custom applicators adopting GPS guided sprayer boom control and planter shut offs. Purdue-CropLife survey indicates that ag input dealers using sprayer boom with section or nozzle controls jumped from 39% in 2011 to 53% in 2013.

According to the survey, dealerships adopting GPS-enabled boom control immediately realized savings from reduced input overlap, creating immediate economic value.

Another trend that generates industry interest is equipment-

mounted N sensors: Proof of this concept can be seen in the Yara N Sensor, N-Tech and Crop Circle which have led to a second generation of products including GreenSeeker by Trimble Navigation, OptRx by Ag Leader, CropSpec by TopCon, Isaria and MiniVeg by Fritzsche Umwelttechnik and Multiplex by FORCE-A.

According to the survey, 7% of US ag input dealers offered crop sensor driven N application in 2013, up from 4% in 2011. However, crop area managed with N sensors is still small in the USA.

In the USA, 70% of dealers offer Variable Rate Fertilizer Application: For variable-rate technology (VRT) used for application, single-nutrient fertilizer application is offered by more than 70% of respondents. Multiple-nutrient fertilizer and lime VRT applications are also

prevalent, both currently being offered by more than 60% of respondents. All of the VRT used for application saw significant increases from the 2011 survey results, especially multiple-nutrients that increased from 42% to 65%. Variable rate application of pesticides is currently offered by only 29% of dealers. But 45% of the dealer responders indicate they will be offering variable-rate pesticide application by 2016.

After years of slow growth, USA ag input dealers have doubled their offering of satellite/aerial imagery services. Crop area managed with imagery is still quite modest – 12.9% in 2011. There is a tremendous interest in UAVs and drones as military suppliers look for new clients.

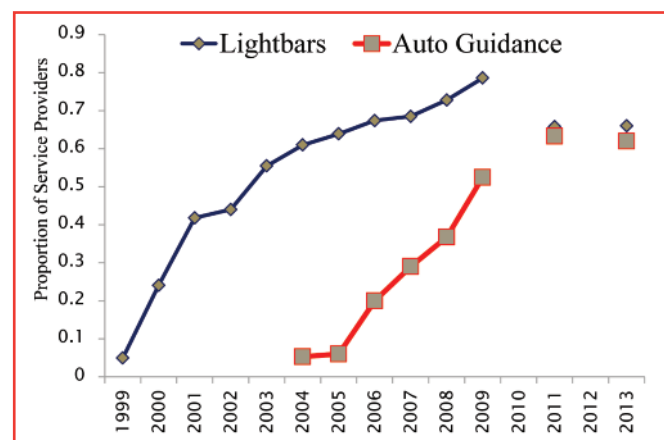
ADOPTION PROBLEMS? YES A FEW

51% of the ag dealers think that the toughest “hurdle” to adopting PA are the quick changes in equipment. Dealerships also expressed challenges in finding employees that can deliver the precision services (50% agreed or strongly agreed) and the fees that can be charged are not high enough to make precision services profitable (49% agreed or strongly agreed). Only 30% replied that un-compatibilities among different equipment was a problem.

A BIG INDUSTRY IN AUSTRALIA AND ARGENTINA

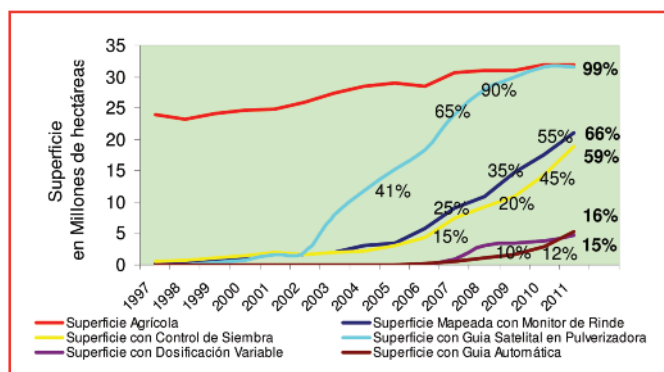
Precision Agriculture is also growing strong in Australia. Especially in sugar production, driven by economics and environmental concerns. There is also very active research in the use of Precision Ag technologies in wine production. GPS guidance is strong down under. “Australia led in use of GPS guidance, in part motivated by soil compaction and profitability of controlled traffic”, said Lowenberg-DeBoer.

In another paper written by Mario Bragachini from INTA Manfredi, Argentina, one can see the spectacular development of Precision Agriculture in the “Pampas”. Satellite lightbars have been installed in every sprayer and now they are used in 99% of the grain crop: 30 million ha. 30% of these devices are manufactured locally. In 2011, there were 15,101 seeding controllers in use (100% of them are locally manufactured). Yield monitors are also widely adopted (8,415 in use in 2011), covering 66% of the crop land. GPS and auto-steer are also increasingly popular, with 2,710 systems in use in 2011. Variable rate technology is also popular, although more recent, but already used on at least 5 million hectares.



Lightbars and Autoguidance Use by US Ground Based Ag Service Providers

All photos supplied by P. Trebilcock unless otherwise stated.



Evolution of Agricultural Land and % served by Precision Agriculture tools in Argentina

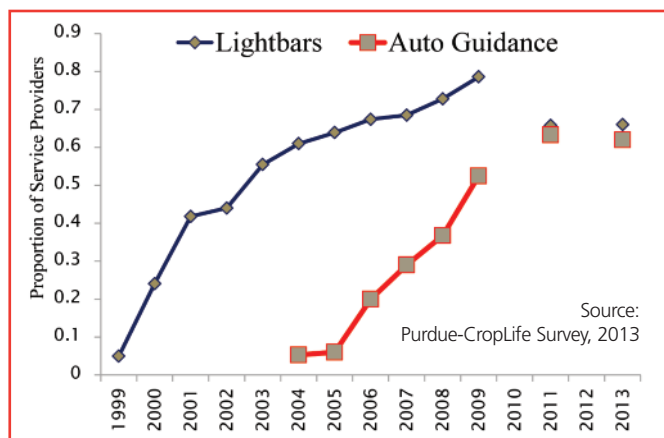
BRAZIL: STRONG IN THE SUGAR CANE INDUSTRY

During the Lleida Congress a Brazilian team (C. B. S. Cirani, M. A. F. D. de Moraes, and J. P. Molin) from University of Nove de Julho and University of Sao Paulo, presented a paper about the "adoption of precision agriculture technologies in the sugarcane industry in Brazil". Brazil is the largest sugarcane producer in the world. Sugarcane is grown in much of Brazil, but São Paulo state produces the most. It accounts for 60% of domestic production in the country and there are 205 processing plants. Over 50% of the companies have adopted some of these practices. Satellite imagery has one of the highest adoption rates, 76%. Among other techniques that deserve a special mention in terms of adoption rate are: automatic pilot (39%), geo-referenced soil sampling (31%) and use of fertilizers and soil ameliorants (lime) at a

variable-rate (29%). The main conclusions of this research suggest that the results for plants that have adopted PA technologies in São Paulo state, Brazil are positive, such as managerial improvements, higher sugar yields, lower costs and minimization of environmental impacts.

AFRICA: IMAGINATION NEEDED TO FOCUS ON SMALL FARMERS

In large farms in South Africa classic PA technology has been adopted, but adoption in traditional agriculture is very small. Rethinking of PA for small farmers is needed to solve problems such as counter top soil testing machines for fertilizer shops, using cell phones to communicate remote sensing and other sensor based pest management information. In a round table at the end of the Lleida Congress all of the keynote lecturers gave some ideas on how to use PA to benefit small farmers. Lowenberg-DeBoer has been very active working in Africa.



Percent of Ag Input Dealers Offering Satellite/Aerial Imagery Service

Field Demo: FORCE A



The Congress devoted one of the days for a Field Demo. There were 3 stations (precision viticulture, field crops & remote sensing, and canopy characterization and variable rate applications), located in a vineyard and farms in Raimat, 15 km from Lleida.

FORCE-A (Orsay, France) showed their sensors for precision viticulture. The "Multiplex" range of sensors are portable fluorimeters that allows performance in real-time with non-destructive measurements. This can be done in the laboratory or in the field, both pedestrian or mounted in tractors. It has an internal GPS used for cartography and the geolocalization of blocks. Its datalogger brings large capabilities for data acquisition and storage.

This optical sensor offers various applications, specifically used in ecophysiology. It can monitor fruit phenolic maturity, polyphenol antioxidant quantification of leaf and fruit epidermis. It can also measure the chlorophyll content of the sample and also the content of anthocyanins.

NEW PRODUCT FOR EARLY DETECTION OF DOWNY MILDEW

During the Congress, a French team lead by G. Latouche (University Paris-Sud) presented a poster about early detection of leaf downy mildew in vineyards with a new portable fluorescence sensor (Multiplex® 3, also by FORCE A). Excerpts of the paper:

Downy mildew is a major disease of grapevine caused by the oomycete *Plasmopara viticola* (PLASVI). In order to optimize these treatments and reduce their number, an early detection of the disease in the field is sought, preferably by non-destructive means for a precision agriculture approach. Stilbenes, the main phytoalexin of grapevine, are not present in healthy leaves. Their synthesis and accumulation is induced by PLASVI. They are fluorescent phenolic compounds, displaying violet-blue fluorescence (VBF). So, this fluorescence signal could potentially be used as a non-invasive proxy for the presence of downy mildew. A new portable sensor for stilbene VBF, Mx-330, was developed by the company FORCE-A based on the field fluorosensor Multiplex® 330. The aim of the present study was to verify whether this new sensor could be used in the vineyards to detect downy mildew. FORCE-A presents the first in vivo in-field non-invasive detection of a fungal disease. They also showed that PLASVI-induced stilbene VBF is a valuable signal to detect downy mildew in the vineyard. Thanks to its presence also on the adaxial leaf side, it is suitable for vehicle-mounted proximal sensing. Its specific diagnostic potential can be increased by the use of combined information provided by Mx-330 (VBF, GF_B) and Multiplex 330 (chlorophyll-dependent indices) to discriminate downy mildew from other biotic or abiotic stresses.



He and his team developed a crop storage bag for cowpeas. They have put strong emphasis on supply chain development. Currently six plants are manufacturing the storage bags and more than 2.5 million of them have been sold. The triple layer bags can keep any grain and have been of great aid to small African farmers.

PRECISION AGRICULTURE IN EUROPE: COOPERATION IS KEY

The focus of adoption research in Europe has been on classic PA, but adoption is modest and Germany leads the game. Use of on-the-go sensing for fertilizer application is probably the highest in the world because of relatively higher N prices, higher grain prices, environmental regulations limiting N use in some countries and also government support for N sensor use. There is interest in GPS guidance, growing especially in areas with relatively large farm

size such as the Eastern part of Germany.

Another extremely good keynote lecture was presented by Dr. Robbin Gebbers, from Germany (see captioned picture). He has been involved in research projects on low-cost remote sensing, site-specific fertilization and geo-electrical soil mapping before he started working at the Leibniz-Institute of Agricultural Engineer in Postdam, Germany. There he finished his PhD on "Accuracy Assessment in the System of Site-Specific Base Fertilization". He is now a senior scientist and the coordinator of research on "precision farming and precision livestock farming". The team comprises 20 scientists.



Robin Gebbers

NEW SENSORS FOR SOIL MAPPING

"In Europe, there are only a few sensors for soil mapping regularly used. Depending on their characteristics, sensors for soil mapping can be divided in mechanical, chemical, optical, electrical, radioactivity, acoustic and pneumatical sensors. In May 2013 we organized a Global Workshop on Proximal Soil Sensing. Soil spectroscopy and EC received most attention. More than 50% of the papers were about those sensors. Of great interest – and discussion – was gamma spectroscopy. We also discussed sensor fusion and calibration was another big issue. We have learnt that we have to calibrate every year." says Gebbers.

There were a few new sensors highlighted. At lab scale: THz and photo-acoustic spectroscopy. And at field level, two new ones: Geophilus and Capacitance (MPG by Geocarta). The German sensor Geophilus is a galvanic coupled resistivity sensor. It can measure 5 depths, it has different frequencies and a Gamma ray sensor. MPG from Geocarta is a capacitively coupled sensor that can measure three depths. A common problem with EC sensors, according to Gebbers is that they do not measure directly fertility parameters.

"That is why my favourite sensor in terms of measuring directly

parameters of agronomic interests are the pH sensors. In my institute we have developed for 3 years – together with universities – the Veris pH-Manager ionselective elektrodes sensors, based on anti-monometry elektrodes. It can be inserted directed into the field and it has a very good correlation with the standard German method for pH estimation. This is a very useful tool, but we have a strong need for sensors that can truly analyse nutrients. We also need physical soil condition sensors that can be used at tillage, for example", says Gebbers.

CROP SENSORS: COMBINING ONLINE AND ANCILLIARY DATA

There is a multiplicity of commercial crop sensors. Gebbers highlights the most popular:

- N-Sensor (YARA): hyperspectral VNIR, passive.
- N-Sensor ALS (YARA) multispectral VNIR (54), active.
- CropSpec (TOPCON), 2 WVB, active (laser).
- Miniveg (Fritzmeier), fluorescence, active (laser).
- Isaria (Fitzmeier), 5 WVB, active.
- Cropmeter (Claas, agrocom), mechanical, passive.
- Multiplex (Force A), induced fluorescence (3), active (LED).
- GreenSeeker (N-Tech, Trimble), 2WVB, active.
- P3 (Agri Con), ultrasonic, active. (A new German product)

"We had a meeting in Germany last year and there are lots of farmers who are using these sensors. But the problem is that they

Remote Farming: HUMAN OPERATOR, ROBOT IN THE FIELD

A cooperation project between the University of Applied Science Osnabrück and the private companies Robert Bosch GmbH and Amazonen-Werke has created the Coala field robot, "BoniRob". "Maybe this is the most mature project designing a field robot" says Gebbers. The robot is a crop scout that is operated remotely from an office and can "manually" remove weeds in the field. It



has a phenotyping sensor system and localization devices. This is the beginning of remote farming.



Photo courtesy of Michel Dabas. Geocarta

An Interview with...

Dr. Alexandre Escolá, Universitat de Lleida, Chairman of the ECPA Congress



ALEX ESCOLÁ

What are the main numbers at this event?

We are very pleased. 301 people attended the Congress. There were 100 oral lectures and all of them have been incorporated into a book. We had 56 posters, which were compiled on a CD where people can see the abstract of each poster and also a complete picture of it. Our website was visited by 12,000 unique visitors from all over the world. We think that it was a great success.

Pretty amazing attendance, taking into account that Precision Ag is a very specific topic?

Yes, it is very specific but at the

same time it is transversal. We had scientists that work in soil science, satellites, fruit experts, robotics, irrigation specialists, experts in the economics of precision agriculture. In fact, it was a very broad audience. We had 9 different sessions. And there were people more devoted to "philosophical" aspects of these technologies and on the other hand there were also farm advisors, people that work daily in the farms. You have to bear in mind that the International Precision Agriculture Society was only founded three years ago. This is fairly new.

How broad is precision agriculture currently and could possibly be in the future?

Well, any agriculture that is efficient and respects the environment is precision agriculture. As someone pointed out, a farmer does not wake up and says, "yes today I am going to do precision agriculture". He is going to simply farm the land the most efficient way he can. So if we allow agriculture to use all of these technologies and be efficient and sustainable, maybe in the end what we do today will be simply considered

as normal farming. We might disappear as a specific discipline, and this will be a sign that we have been successful.

What were the best moments of this Congress?

In terms of audience, there were always three sessions that were constantly full. These are the ones that originated precision agriculture: all of the technology to assess the health of soil and plants. It could be based on either remote or local sensors. However the main interest is to develop sensors that can be reliable and give quick results.

Which Precision Ag technologies are consolidating?

Some are becoming standard such as those sensors that measure electrical conductivity in the soil. One can estimate soil humidity based on them. The other technologies that are growing are those that estimate plant water status based on airborne NIR images. Now we have spectral, multispectral and hyperspectral cameras that can measure the radiation reflected by the crops in a very precise way. Many radio-

metric indexes are emerging from those technologies and scientists are relating them to real crop parameters.

What is your own team currently researching in the Catalonia labs?

As you know our team was originally focused on plant protection. We wanted to develop systems that would enhance the efficiency of pesticides applications. We work in various directions. One is canopy characterization, based on LIDAR sensors. We can estimate the Leaf Area Index with the technology, thus enhancing application efficiency. We have also developed a prototype, a variable rate spraying machine – one of the very few developed for fruit crops in the world - that uses this technology and applies the specific amount of pesticides for each canopy condition. But as this prototype is expensive, we also created a web based decision support system, DOSAFRUT, that allows farmers to determine the correct application program. And we are currently using other sensors to characterize the orchards in more precise ways and study other aspects beyond plant protection.

have to apply nitrogen earlier every year due to climate change", he said. Thus, it becomes urgent to combine

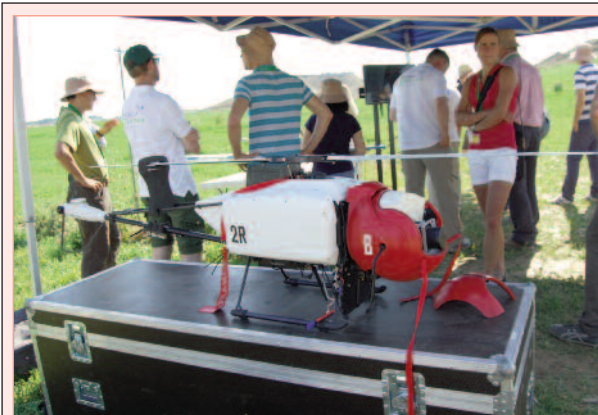
online measurements (provided by these sensors) with ancillary data, such as soil maps. A lot of research in Germany is moving in

that direction.

Yield maps were out of fashion for a while but they are coming back. Claas, a German company, reports

an increase in sales of yield monitors.

In summary, the main concepts regarding Crop sensors are: there



Field Demo: FIELDCOPTER

Unmanned Aerial Systems (UAS) are an up and coming method in providing farmers with near real time sensing information for precision agriculture applications such as water stress monitoring, detection of nutrient deficiencies and crop diseases. The EU funded project FieldCopter provides state of the art multi-spectral cameras on UAS. Two research institutions and four companies participate in this research project, from Belgium, Spain and The Netherlands. The aim is to validate it and probably create a spin-off company. What are the advantages over cameras in aeroplanes? They can be more local, operate even with cloudy conditions as they fly in lower altitude and provide higher resolution images. In terms of prices they are still more expensive than plane based systems, estimates are in the range of 50 euros/ha for the complete service.

Field Demo: AGROPIXEL



The Spanish company Agropixel uses aerial images to enhance vineyard management. First they identify spatial variability using aerial multispectral images. Then they identify the "Smart points" where field samples should be taken. Based on this information they can characterize the fields and create differential management zones. Many actions derive from this analysis: differential management, re-designing irrigation sectors and very important: differential harvest. "Here a B quality grape is paid at €800/MT and a C quality grape is paid at €500/MT. So, identifying where are the best grapes and then harvesting them in a differentiated manner is very profitable. It is not easy as this varies from year to year and also because there are more differences between the grapes within a block than within blocks. Using thermal images we are launching a new service for irrigation management Agropixel said.

is a need for a combination of on-line and off-line approaches. Researchers should help farmers to discriminate stress factors such as N, water and pests.

In crop protection, we are still waiting for the sensors that monitor weeds, infections and pests. And not to be forgotten is yield mapping, worth analysing and using.

CELLULAR PHONES: THE NEW FRONTIER?

One can do a lot with cellular phones. They are packed with sensors: gyroscope, accelerometers, GPS, radio receiver, etc. There are some applications already available.

Yara (Norway) has created the YARA ImageIT app, for the determination of N- requirements of rape seed in spring. The farmer takes a picture of the crop and transmits it to a central server and then he/she gets an N recommendation for that position: "Your oilseed rape crop has currently taken up 30 kg N/ha. The green fresh matter is about 5.4 t/ha.

Yara recommends a total N-application of 210 kg N/ha."

Spectrum Technologies (USA) has launched the "FieldScout GreenIndex", which is a cellular app with a comparison board, for the determination of N requirements of corn.

UNMANNED AERIAL VEHICLES: HUNDREDS OF PROJECTS

Another trendy topic is the use of Unmanned Aerial Vehicles (UAVs) in precision agriculture. These small devices are low cost. It could require less than 3,000 Euros to build a system. A project is being conducted in Germany that could generate mosaics and ortho-photos of good resolution with cheap cameras mounted on UAVs. It combines RGB pictures with NIR images, combining them in an NDVI map, process them and give a Nitrogen recommendation.

UAVs are a challenge to traditional remote sensing. There are many applications: crop protection, N-management, cattle management, fish ponds and meteorolo-

gy. There must be hundreds of projects working on this currently in Europe. Limitations? Well, some batteries problems and there will be new laws that will restrict the use of UAVs in Europe.

DECISION MAKING: FROM PRECISION AGRICULTURE TO SMART FARMING

The term "Smart Farming" became very popular at Agritechnica 2011. The concept is to make the decision making process more automatic than current precision agriculture. The idea is that a network of location-based services will send recommendations to the farmer, sharing information.

A very interesting project, i-Green (4 years, 14 million Euros) was developed in Germany from 2009-2013. The aim was to create a network of location based services and knowledge, integrating various public and private information sources based on semantic technologies (the data set is coming in and the software will "know" what to do). And mobile decision assistant systems will facilitate the cooperative production processes. 24 partners participated in this project, including 12 private companies such as SAP AG, John Deere, CLAAS, Krone, Amazonen-Werke, etc.

Results so far? A Machine Connector: which facilitates communication of machines from different brands, and a GeoBox & MapChat, which supply geo data services for ag service providers. "There is growing demand for smart services. In Germany farmers are asking for this and also for web based services and mobile applications. And companies are generating products that match that demand. But there are big challenges ahead: one is integrating and developing Precision Agriculture to support algorithms, the other, the lack of agronomic knowledge to match data and algorithms. The other challenge is to combine this smart system,

where everything is automatic and provided, with constant research in the field. And last but not least, data privacy and ownership will be some of the things to sort out.

TOWARDS EUROPEAN PRECISION AGRICULTURE CENTRES?

According to Gebbers the European Precision Agriculture researchers and professionals should work in order to improve research by focusing on cooperation.

Germany is a good example of industry cooperation. The Agricultural Industry Electronics Foundation (AEF) was founded in 2008 and it already has 140 members. The aim is to provide resources and know-how for the increased use of electronic and electrical systems in farming. They started with ISOBUS standardization. ISOBUS is the universal protocol for electronic communication between implements, tractors and computers. AEF created the ISOBUS Test Centre at the University of Osnabrück. And they are also implementing standardisation of agricultural applications in general, such as farm management information systems, electric drive camera systems, among others.

One of the "off-springs" of this is the Competence Centre ISOBUS, founded in 2009 by AMAZON, GRIMME, KRONE, KUHN, LEMKEN and RAUCH. They are developing together ISOBUS components. For example the ISOBUS-Terminal CCI 100/200 is common and comes with different brands but is the same. This centre also supplies information about ISOBUS for service suppliers, dealers and students.

Another interesting initiative is John Deere's European Technology and Innovation Centre, opened in 2010 in Kaiserslautern, Germany. There are currently 90 researchers there and the plan is to have 200 researchers. The focus is on intelligent solutions, integrating elec-

tronics into tractors and harvesting equipment and technologies that help to automate machine operation, reduce operator fatigue and increase machine productivity in the field. John Deere has recently become a shareholder in the German Research Centre for Artificial Intelligence. "John Deere is going to offer Smart Farming in the future".

But the best example of cooperation in research is the COALA experience in Germany. It is an outreach centre of the University of Applied Sciences Osnabrück, located in the heart of Germany's "Agrotech Valley", where most of the agricultural machinery companies are located. These guys are showing how networking works! COALA gathers research institutions, universities, start-ups, established companies and funding institutions and the centre develops new solutions. One example is the BoniRob robot. Another is the KOMOBAR apps, which are decision support and communication structures for mobile machinery. They have also created a phenotyping system. Named Breed Vision, this system can monitor every plant outdoor, ideal for breeding programs.

THE KEY TO SUCCESS: MAKE IT EASY TO USE

Cooperation can promote precision ag and this is very important

in Europe, where everything is scattered. Cooperation is possible, even with competing companies. "I wanted to show you all of these examples from Germany, because some are leading the way and we can take these examples in order to move forward towards European Precision Ag Centres. It takes time to get results and it needs favourable conditions such as people, infrastructure and money. But it makes sense", concludes Gebbers. The future will tell. In the meantime maybe the key statement of the conference was "Precision agriculture must be easy to use to succeed"

According to Lowenberg-DeBoer, the author of the above statement, just above, the most widely adopted ag technology of the 20th century is embodied knowledge tech. No wonder, the most widely adopted PA technologies are those with embodied knowledge in them such as GPS guidance. Quickly adopted PA technologies are those that are easy to use and show short term & visible benefits. Widely adopted technologies usually initially respond to some specific local need. For instance in the case of Argentina – yield monitors provide professional farm managers with new information. In Australia GPS guidance facilitates controlled traffic and in Western

Europe N Sensors help farmers deal with N regulation.

The future? In most of the world VRT will achieve widespread adoption only when it becomes an embodied knowledge technol-

ogy – probably as equipment mounted on-the-go sensing.

Nanotechnology will provide small and cheaper sensor and Ag robotics will entail a dramatic rethinking of mechanization. ■

Field Demo: AGCO LAUNCHES FUSE TECHNOLOGIES

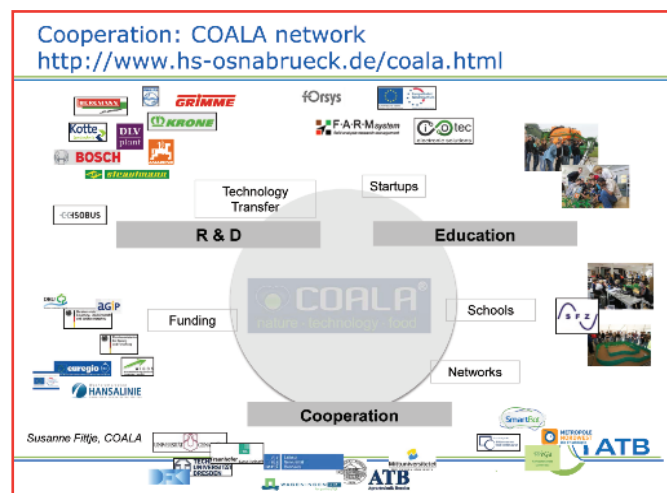


AGCO (USA) is a manufacturer and distributor of agricultural equipment and infrastructure, with popular brands such as Challenger, Fendt, Mazze Ferguson, Valtra and More. Launched during EPCA, a new global corporate initiative that addresses all aspects of precision farming technology and how farmers can optimize their operations through AGCO products and new services. The new strategy is called Fuse™ Technologies and it will provide professional growers seamless integration and connectivity across all their farm assets – regardless of brand.

"There are three pillars in this new strategy: the first one is optimizing the use of current machines. In any piece of tech today, whether it is your computer, tractor or a combination, more often there is more capabilities in it that your customer is utilizing. So the big opportunity is making sure the machine is doing the maximum productive job it can do. And helping customers ensuring that the machine is never down. The second pillar is optimizing a system of machines working together. Optimizing those logistics and making sure machines communicate across the farm and makes those flow nicely. And the third pillar is having data work nicely across the whole cycle. From the time they harvest through fall, tillage, planting and spraying. We want data to flow around the cycle of farming", Eric Hansotia, Senior Vice President, Global Harvesting and Advanced Technology Solutions at AGCO, told New Ag International.

"25% of our investment in Fuse™ will be in training capabilities and customer support and the remaining 75% will be devoted to infrastructure and engineering. We have 50 new professionals devoted exclusively to this project. The adoption of Precision Agriculture has grown exponentially and also the use of smartphones in agriculture. In North America most tractors over 200 HP are going to have some Precision Ag guidance on board, whether lightbar or autoguidance in different levels of accuracy. We have a unique opportunity to get things right. If you think about it, customers see more value in what the hardware can do rather than in the hardware itself. It is the application that we are looking for", says Matt Rushing, AGCO Vice President of Product Management, ATS and Electronics Functional Group.

Fuse™ new technologies will be used by all AGCO brands and it will be an open approach to technology, facilitating the flow of data among different brands. "Precision Agriculture has created nice pieces, now is time to get them together", summarized Hansotia.



The Coala Network, a good example of research cooperation in Precision Agriculture

PRECISION IRRIGATION: FROM LEAF TO AIRBORNE

Measuring plant water status is crucial for appropriate irrigation scheduling. And if this is done manually in a farm using a Schollander Chamber and at the same time those results correlate with those taken at the same time by a NASA sensor mounted on a aeroplane 8,200 metres above, irrigation enters a new era. Welcome to Precision Irrigation, as presented by many researchers during the European Precision Agriculture Conference, recently held in Spain. Patricio Trebilcock, New Ag International Editor, reports from Lleida.

UC DAVIS-NASA: VINE WATER STATUS FROM AIRBORNE

A group from UC Davis (USA) led by M.M. Alsina investigated the suitability of airborne spectral reflectance for detection of plant canopy water status and its potential use as a tool for precision irrigation management of table grapes. During EPCA, Dr. Davis Smart presented the results on behalf of their team. The experiment took place in 2011 and 2012 in a table grape vineyard in Delano, California. Two deficit irrigation treatments were established, one per year, and compared to the grower's usual irrigation schedule. In spring and summer of 2011 and in summer 2012, an airborne platform equipped with NASA's MODIS/ASTER Airborne Simulator (MASTER) sensor overflew the vineyard. Coinciding with the flights, the leaf water potential,

leaf specific water content and leaf area index were measured at field level, and crop evapotranspiration was measured using the surface renewal approach. "Our results demonstrate that when the changes in vine water status caused by deficit irrigation treatments were measureable at the field level, they could also be detected from the airborne platform. Therefore, both methods have similar potential for irrigation scheduling", said Dr. Smart. Remote sensing techniques represent one tool for improved water management through rapid and large-area detection of crop status. Band-ratio indices from multispectral images are commonly used for estimating vegetation leaf and canopy properties, including canopy water content. The normalized difference infrared index (NDII) has been shown to be a good indi-

cator of canopy water status in a number of relevant studies.

The experiment was carried out in 2011 and 2012 in a commercial Crimson Seedless 32 ha vineyard in Delano, California. Two irrigation treatments were compared each year, a full irrigated treatment (F) and a deficit irrigated treatment, which was different between years. The F treatment corresponded to the regular, owner-defined, irrigation management in the vineyard. In 2011, the irrigation was stopped 10 days before each airborne flight (F-10 treatment). In 2012 the irrigation was decreased by 0.5× full irrigation (F×0.5) from the beginning of the season.

On May 20th and June 30th of 2011 and on June 27th of 2012, an airborne platform equipped with NASA's MASTER sensor overflew the experimental vineyard twice a day at 10:00 a.m. and 2:00 p.m.



Concurrent with the two daily image acquisitions in 2011 and 2012, leaf water potential (LWP), canopy water content (CWC) and crop evapotranspiration (ETc) were measured.

MEASURING FROM 8,200 METERS

The MASTER instrument was mounted on a NASA ER-2 aircraft flying at an altitude of 8,200 m on May 20, 2011 and on a NASA DC-8 aircraft flying at 4,100 m on June 30. This instrument collects reflectance (0.4-2.5 μm) and thermal (3.0, 13 μm) data in 50 channels. It samples 716 pixels per scan line in cross-track direction with a total field of view of 85.92° and an instantaneous field of view of 2.5 mrad. The leaf water potential was measured using a Schollander Chamber. According to Dr. Smart, the water stress induced by irrigation deficit in table grape vineyards

was clearly seen at the airborne level using remotely sensed data. The airborne instrument was able to detect the same trend of change in vegetation water content and plant water status in response to variations in irrigation treatment as ground measurements did. Therefore, the MASTER NDII might be successfully used as an indicator of water status in vineyard and potential decision tools for irrigation.

SPAIN: USE OF AIRBORNE THERMAL IMAGES

A Spanish group, led by J. Bellvert (IRTA, Lleida) conducted their research on the use of thermal images on irrigation scheduling of wine grapes. Crop water stress index (CWSI) has been used as a tool for mapping spatial variability in water requirements of vineyards. Crop water stress index (CWSI), based on measuring canopy temperature is a good indicator of plant water status. The basic assumption was that water stress induces stomatal closure, transpiration is reduced and therefore, the temperature of leaves increase. In recent years, the possibility of measuring canopy temperature by high-resolution remote sensing has increased the interest to adopt irri-

gation strategies at field scale. Recent studies successfully related CWSI with leaf water potential in vineyards. But it has been shown that there are differences between varieties and also at different phenological stages.

During 2009-2011, CWSI seasonal equations were obtained for varieties 'Pinot-noir', 'Chardonnay', 'Tempranillo' and 'Syrah' by using infrared temperature sensors and high resolution airborne thermal imagery. Leaf water potential (Ψ_L) measurements were used to validate the proposed methodology. In 2012, irrigation scheduling of a 16 ha 'Chardonnay' plot was carried out solely on the basis of remotely sensed Ψ_L obtained throughout the season.

Irrigation scheduling on the basis of Ψ_L maps was successfully achieved. Figure 1 shows an example of Ψ_L map obtained on 4 July (stage II) from high resolution thermal images. Spatial variability of vine water status ranged from Ψ_L between -0.5 to -1.6 MPa. For instance, averaged Ψ_L for irrigation sectors 3 ($\Psi_L = -1.4$ MPa) and 4 ($\Psi_L = -1.6$ MPa) were more negative than in others. Thus, irrigation scheduling during that week consisted in applying more irrigation water in these irrigation sectors. On

the other hand, irrigation sectors with higher Ψ_L values (i.e. 5, 8 and 10) were not irrigated during that week.

Irrigation water applied through the season was different between irrigation sectors, ranging from 150 to 300 mm. Non significant differences were found in yield, number of clusters and berry fresh weight between irrigation sectors. Therefore, this method allowed adoption of regulated deficit irrigation strategies, leading to water savings of 50% in some irrigation sectors without affecting yield. This study demonstrated the possibility of using high resolution thermal imagery in creating Ψ_L maps. CWSI has been successfully related to Ψ_L in all varieties, with this relationship being different at different phenological stages. This implied that the determination of vine water status would depend on variety and phenological stage and the appropriate CWSI equation should be applied in each case. This group is currently developing an R&D Project called INNFACTO in collaboration with local wine companies such as Codorniu. This project will be carried out during three years, until December 2014. The goals of the project are: i) Development of CWSI equations for mapping water stress in grapevine, peach, nectarine, olive and apple trees, ii) Development of automatic procedures to convert thermal imagery information to Ψ_L maps, iii) Generate the optimal aerial platform, and establishing optimal flying altitudes and the necessary thermal image resolution for each crop, iv) Determination of the seasonal relationships between Ψ_L and CWSI, v) Set up a commercial advisory service for farmers that enables efficient irrigation schedules.

MULTISPECTRAL IMAGES: COULD THE DIFFERENCES BE CAUSED BY VARIABILITY OF DRIP IRRIGATION?

A very interesting study was presented by B. Tisseyre and A. Ducanhez from Montpellier SupAgro/Cemagref, France. In large

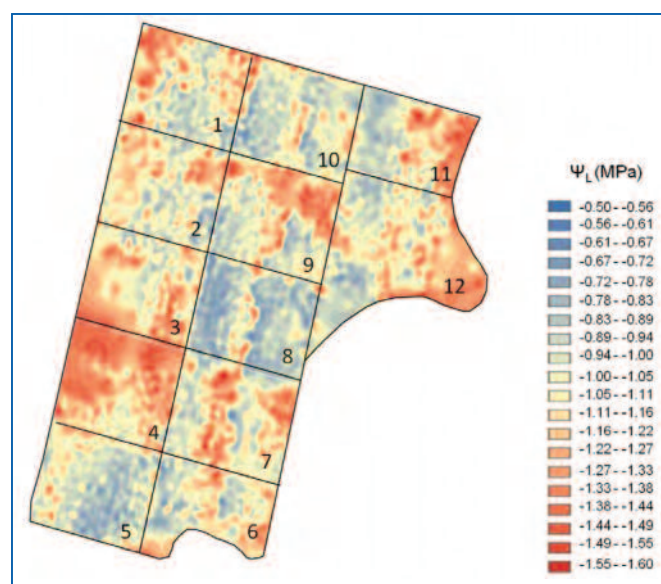


Figure 1. Leaf water potential map of 16 ha of "Chardonnay" vineyard, obtained from high resolution thermal images. Estimated Ψ_L values were obtained from relationship between CWSI and Ψ_L in stage II.

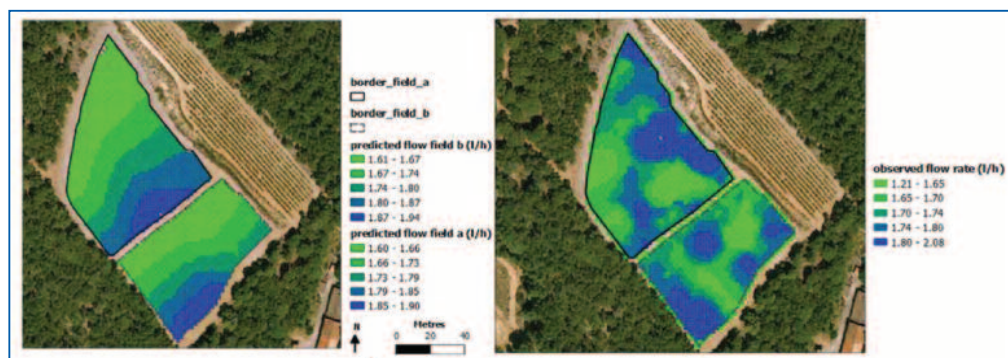


Figure 2: Map of (a) estimated flow rate and (b) measured flow rate.

fields, recent studies have shown that the within-field variability of drip irrigation can induce significant differences in vine vigor. This problem questions the use of multispectral images. Indeed, the origin of the variability observed by remote sensing remains uncertain as it can be linked either to stable parameters of the environment or to heterogeneous irrigation. In fact, many farmers tend to assume that irrigation is very even, following manufacturers information. Hornbuckle et al. (2012) showed that in large fields of South Australia, the within-field variability of irrigation can be organized spatially. This can induce zones with very different vigor which is expected to impact drastically the within-

field variability of both yield and harvest quality. This problem questions the use of multispectral images to define within-field management zones. Indeed, whatever the origin of the observed variability, in regions where water is the limiting factor, vine vigor zones observed by remote sensing will mainly correspond to zones of different water restrictions (Acevedo et al., 2008). However, the origin of the variability remains uncertain as it can be linked either to stable parameters of the environment (soil water availability) or to heterogeneous irrigation. In the long term, decisions to be taken to control (reduce) the variability may be drastically different depending on the

circumstances encountered. Indeed, if the observed variability is caused by differences in water supply, then corrective actions should focus on improvement of the irrigation system. In contrast, if the observed variability is caused by stable factors of the environment, then corrective actions may relate to other practices (grassing modulation, pruning modulation, irrigation modulation, etc.).

IRRIGATION VARIABILITY STRONGLY DEPENDENT ON THE ELEVATION

"Given the diversity of situations that may be encountered in a region as vast as the south of France, it is difficult to extrapolate the results obtained on two fields",

says B. Tysseire. "The results of this study showed that on small fields with a medium slope and an irrigation system similar to that studied in our work, water supply may be considered uniform. For larger vine fields or steeper slopes, spatial uniformity of irrigation may be questioned. The model approach proposed in the study shows that irrigation variability may be strongly dependent on the elevation. Therefore, the study shows that the combination of spatial information like a vegetation index which is strongly affected by water availability in Mediterranean conditions and the elevation could be a relevant decision support to identify potential problems of irrigation heterogeneities.

EFFIDRIP: AN AUTOMATIC IRRIGATION AND FERTIGATION SCHEDULER

The European Project Effdrip (www.effdrip.eu) was presented by A. Torres from CRIC, Spain. EFFIDRIP is an R&D project funded by the EU program FP7-SME. Its overall objective is to offer a cost-effective tool that provides the end-users (farmers or technicians) effortless irrigation and fertilization management, as well as easy and reliable supervision of the state of the irrigation system. EFFIDRIP aims at relieving farmers from most of the tasks involved in acquiring data, re-scheduling, reprogramming and supervising the application of efficient irrigation. The activities in the EFFIDRIP project include the design, implementation and validation of an ICT based platform including a wireless sensor network in the field as well as the server software and the web interface, all driven by open standards.

The EFFIDRIP system complements the functionalities of current irrigation and fertigation control equipment by making them part of a higher level system based on ICT. The irrigation controller remains as a key component for the execution of irrigation and fertigation schedules with some autonomy. What

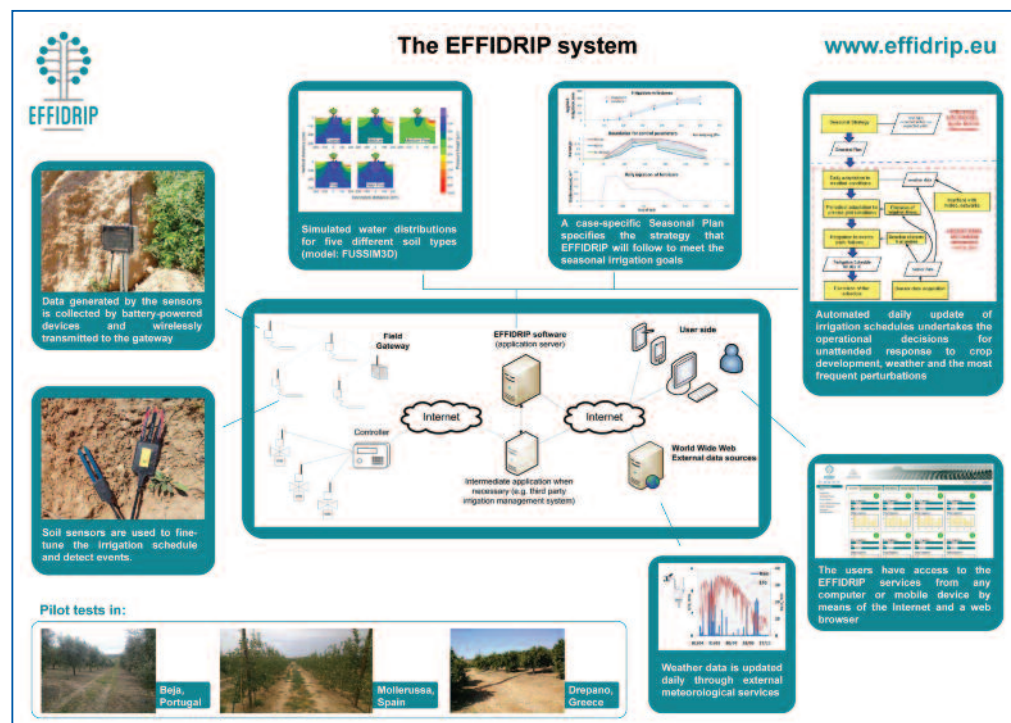


Figure 3: The EFFIDRIP SYSTEM

really makes the difference is that those schedules will be updated remotely once a day for each irrigation sector. For each subsequent application, the precise crop water and fertilizer needs will be estimated as function of weather conditions, the soil and crop water status, as assessed by sensors, as well as to the productive and environmental goals by the farmer. The performance of the system is being evaluated at three test sites, in Portugal, Greece and Spain.

PIVOTS: A NOVEL SOIL MOISTURE SENSOR SYSTEM

G. Vellidis from the University of Georgia (USA) introduced a soil moisture sensor-based variable rate irrigation (VRI) control system. The control system consists of a wireless soil moisture sensing array with a high density of sensor nodes, a VRI enabled center pivot irrigation system, and a web-based user interface with an integrated irrigation scheduling decision support system.

The University of Georgia smart sensor array (UGA SSA) consists of smart sensor nodes and a gateway. A 'smart sensor node' is defined as the combination of electronics and sensors installed at each location in the field. A UGA SSA node consists of a circuit board, a radio frequency (RF) transmitter, soil moisture sensors and temperature sensors. Each sensor node accommodates up to 3 Watermark® soil moisture sensors and 2 thermocouples for measuring temperature. The RF transmitter is a postage stamp-

sized intelligent low-cost, low-power, 2.4 GHz radio module capable of acquiring, analyzing and transmitting sensor data. Data from all the nodes are routed to a centrally located node known as the gateway at 5 minute intervals. At the gateway, data are stored on a solar-powered net-book computer and transmitted via cellular modem to an FTP server hourly.

One unique characteristic of the UGA SSA is that it uses wireless mesh networks to communicate between irrigation sensor nodes. If any of the nodes in the network stop transmitting or receiving or if signal pathways become blocked, the operating software re-configures signal routes in order to maintain data acquisition from the network.

An important characteristic of the system is its affordable cost – a 12-node system can be installed for a one time cost of USD 5200.

In parallel the researchers are developing a web-based irrigation scheduling tool called the Flint Irrigation Scheduling Tool (FIST) which will allow farmers to remotely check soil moisture of fields but will also provide irrigation scheduling recommendations. ■

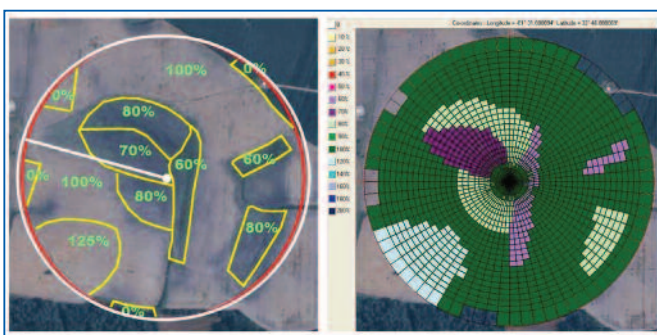


Figure 4. Irrigation application rates assigned to different areas under a 48 ha center pivot irrigation system (left) and variable rate irrigation implementation of the application map (right)

Precision Horticulture: A continent to explore

Horticultural crops use three times more pesticides per hectare than broad acre crops. Apple trees are sprayed at least 16 times a year in some regions. Fundamental problems such as annual bearing are not understood fully. Orchards are complex, different from one another, farmers use different varieties and different planting densities. And plots are small. So, it is much easier to sell millions of Precision Agriculture (PA) machines for corn than for apples. However, on the other hand, horticulture is a huge industry worldwide. And big opportunities arise for smaller PA product manufacturers who can target their "niche" products to global users. Dr. Spyros Fountas (Greece) gave a very inspiring keynote lecture in Lleida about the current trends in Precision Horticulture.



Dr. Spyros Fountas

SPECIFICITIES IN PRECISION HORTICULTURE

Precision horticulture has some very clear specifics. First of all, the most of the operations are manual, especially at harvest. And as most of the produce goes directly to the consumer, quality control of the products is a very important issue. Quality is important for table fruits and vegetables and quantity is important for processing crops (same as arable crops). As the majority deals with perennial crops (orchards), temporal stability is very important. There is huge diversity of crops and varieties within crops which make Precision Agriculture complex. For instance, there are many trellising systems and also planting densities, which forces growers to tailor machinery and pesticide application equipment. And to make things more complex, fields are in general small in size.

The European horticultural market is very big. In 2010 the fruit and vegetable markets had total revenues of 124 billion euros. The annual growth rate of this sector was 3.4% for the period spanning 2006-2010. And the annual growth rate is expected to be 5.2% for the period 2011-2015, reaching 160 billion euros. Europe is the world's second largest producer of fruits and vegetables. But in spite of this, it has a deficit in

Dr. Spyros Fountas, Assistant Professor at the University of Thessaly (Greece), has participated in a number of national and European Projects related to Precision Agriculture such as FP7 Future Farm, ICT-Agri I RoboFarm and ICT-Agri II User-PA. He was the co-organizer of the 6th ECPA in Skiathos, Greece in 2007.



Picture 1: Mechanical Harvest of citrus



Picture 2: Vacuum Apple Harvester

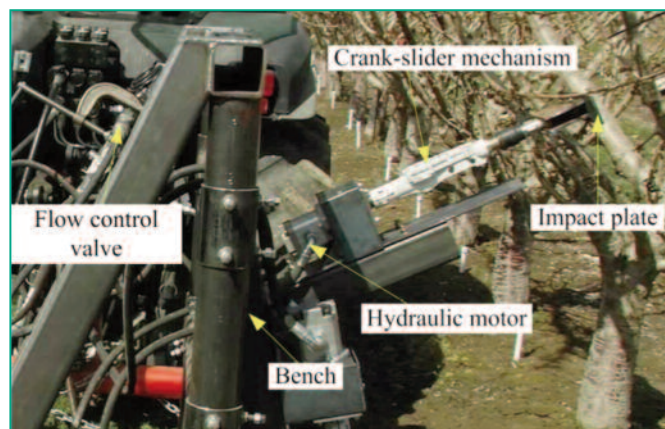
fruit and vegetables (8 billion euros).

AN EMERGING TREND: SPECIFIC MACHINERY

In the United States, there are many emerging mechanical harvesters for fruit crops. The company OXBO has created a fruit mechanical harvester (Picture 1) that is very advanced. Currently this machine is only in use with USA.

The company Phil Brown Welding has created a vacuum apple harvester (Picture 2). It sucks the apples and distributes them to bins. And it is not fully automatic, it still needs operators. Washington State University

(USA) has very active programs enhancing cherry orchard's productivity. They have developed prototypes of mechanical harvesters for sweet cherries with actuators that shake the tree (picture 3). These prototypes are custom made for stem-free cherries. Maybe olive production is among the most technified crops in some areas of the world. There are several harvesting machines, especially suited for "super-intensive" orchards. California State University has developed a fully automatic harvester targeted to use almost zero labour at harvest (Picture 4). There are many challenges in mechanical harvesting. The main



Picture 3: Mechanical Harvester of Sweet Cherry

one is finding the correct interaction between the orchard system (orchard densities, plan formation) and the machine system. The other important constraint for the development of mechanical harvesting is that fruits are not mature at the same time. There is also the need for crop load uniformity. This being said, with so many orchard configurations and different varieties, the market size for these machines is a niche one-

not very big and highly segmented. However, this could be an opportunity for small companies.

TECHNOLOGIES: FROM THINNING TO POLLINATION

There are also very interesting technologies for Precision Agriculture in fruit production. Washington State University has developed a smart monitoring tool, a 3D vision machine for improved apple crop load estimation.



Picture 4: Mechanical Harvest of Olives



Picture 5: PollenPlus Quad Duster

In New Zealand kiwi pollination is a complex task. Kiwi is a crop that uses pollinators, and farmers sometimes prefer exogenous pollen. The PollenPlus™ Quad-Duster is a portable pollen sprayer widely used in many orchards in the country (Picture 5).

Thinning is another activity that could be radically enhanced with these technologies. Dr. Robbin Gebbers (Leibniz-Institute of Agriculture Engineer, Postdam, Germany) presented some slides about a project that has just come to completion and created a prototype for tree specific thinning of blossoms. The ultimate goal is to regulate alternate bearing. In apples, for instance, alternate bearing results in biannual cycle of yields with many small apples and few big apples every other year. This is an alternation between many and few flowers. And this is different from tree to tree. Thinning of flowers can regulate alternate bearing. The prototype is called OPTI THIN and is based on: positioning sensors, optical sensors and on board computer with data base and algorithms and an actuator (Picture 6). The results have been very promising.

MONITORING LABOUR PRODUCTIVITY

Ampatzidis et al (2009) developed a yield mapping machine based on RFID tags and in 2012 using the same principles developed a labour monitoring system. Each

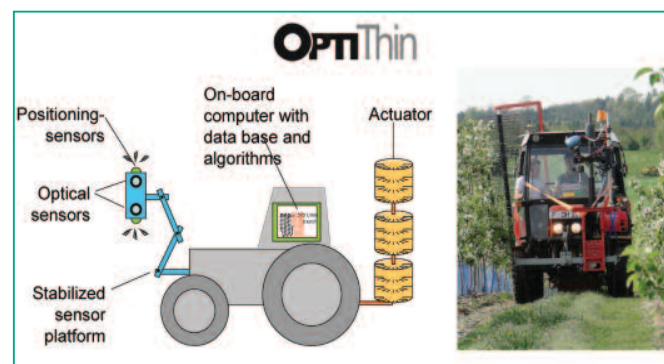
worker wears an RFID tag (as a bracelet) and in this way the system can keep track of how many kilograms each worker harvests per day (Picture 7).

ON THE GO CANOPY VOLUME ESTIMATION

The University of Florida (USA) is another pole of research of PA in fruit trees, especially in citrus. They have developed many interesting equipment such as the use of digital photography for canopy vigour estimation; ultrasonic canopy volume estimation, yield mapping systems and automatic colour image acquisition, from a pick up truck. This research group has also developed multispectral NIR cameras for estimating stress in citrus (Picture 8).

JAPAN: GPS NAVIGATION IN ORCHARDS

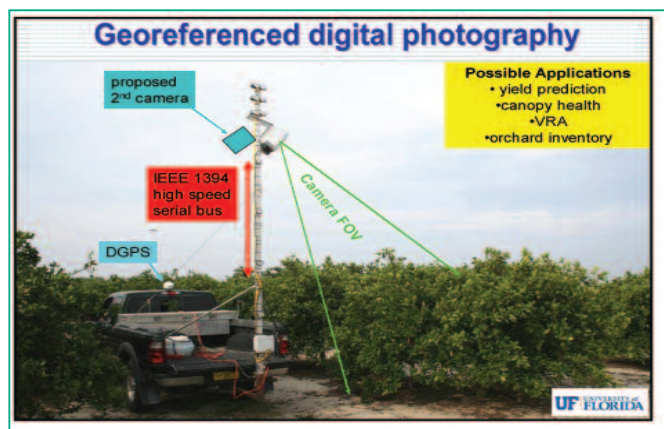
Current GPS cannot be used at any time or in any place. Sometimes GPS do not work well under the canopy. A group at Hokkaido University in Japan have solved this problem using the Quasi-Zenith Satellites System (QZSS). This system uses multiple satellites that have the same orbital period as geostationary satellites with some orbital inclinations (their orbits are known as "Quasi-Zenith orbits"). The system makes it possible to provide high accuracy satellite positioning service covering close to 100% of Japan, and also Australia. GZSS enhances GPS services in the fol-



Picture 6: OPTI THIN, blossom thinning machine



Picture 7: Labour Monitoring System bracelet



Picture 8: Georeferenced digital photography (U. of Florida)

lowing ways:

- 1) Availability enhancement (improving the availability of GPS signals).
- 2) Performance enhancement (increasing the accuracy and reliability of GPS signals).

The Hokkaido University team have developed a robot tractor with a QZSS receiver. The travel accuracy of this system compared

to traditional Base-Station is superior, with an accuracy up to 3 cm (Picture 9).

CHILE: YIELD FORECASTING FOR FRUIT EXPORTERS

Dr. Dvorlai Wulfsohn has implemented a service in Chile of yield forecasting at block scale in apples, olives, kiwis, cherries, wine grapes and cucumber seeds. They

also evaluate in-time pruning for labour recruiting and quality control. The Pronofrut forecast system has become increasingly popular, with a forecast error on average of less than 4%.

ISRAEL: REMOTE SENSING FOR PRECISION HORTICULTURE

The Volcani Center (Israel) is also very active in this field. Dr. Fountas showed some trials with the use of cameras (FLIR + RGB or AOTF) and a Tether interface. It is a remote controlled, in the field system (up to 24 meters above the crop).

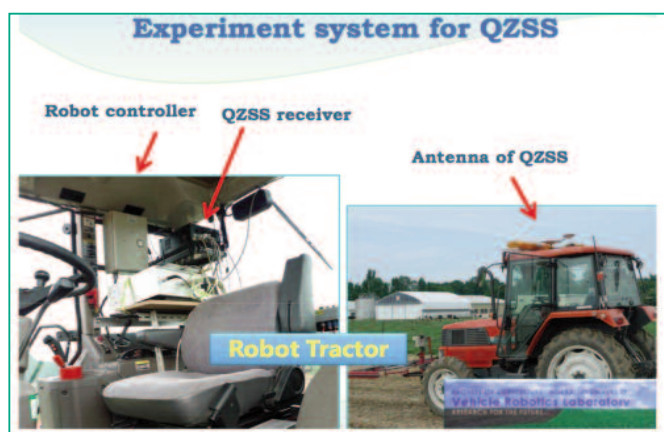
SPATIAL MANAGEMENT FOR ORCHARDS IN SMALL FIELDS

Dr. Fountas and his colleagues have been working for 8 years in different regions of Greece in spatial management in small fields. And, surprising enough, variability is also huge in small fields. They have done yield mapping in plots smaller than 1 ha. They have demonstrated the consistency in yield across the years in annual bearing orchards (olives) (Picture 10). Differences in P and K are also big in small plots and the team have been using PA technologies to convince farmers to fertilise less. But obviously one thing is to assess a problem and the other one is action: applying variable rate fertilizers in one hectare apple orchard is not simple. The solution was very simple: drawing contour lines and dividing

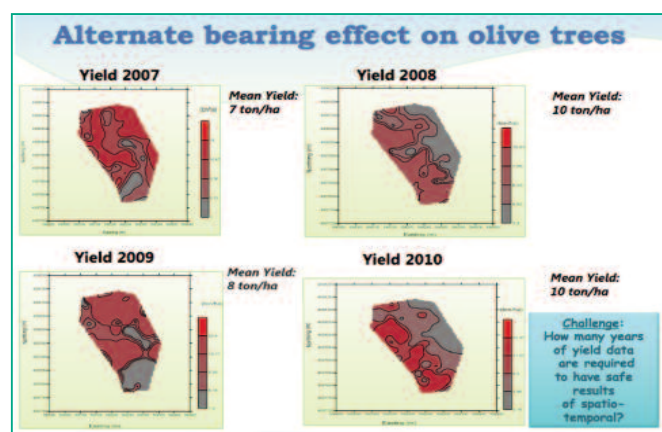
the orchard in two application zones. There are many uses of PA in small orchards, as shown by Mr. Fountas, yield mapping, measurement of flowers, determining the quality of apples, NDVI maps, EC soil zoning, etc. The "take away" message was that not only PA prescriptions should be site specific, but also engineering for PA should be site specific. It is continuous work with the local conditions. But it pays off very well.

The majority of fruit and vegetable operations will continue to be done by hand due to limited technology available. Some operations are closer to "automation" such as spraying with on/off machines. And there are still many agronomic challenges ahead. One is understanding annual bearing: "many years of yield and data are needed to explore the alternate bearing effect and generate management strategies". The other one is generating quality mapping linked to post harvest operations. In a more philosophical way, precision horticulture is not only about technology, it is about putting the available resources in order to do things right.

Precision horticulture has a great future! ■



Picture 9: Enhancing GPS navigation



Picture 10: Annual bearing in olive orchard