

# 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 0.5x full irrigation (Fx0.5) 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  $\mu\text{m}$ ) and thermal (3.0, 13  $\mu\text{m}$ ) 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-

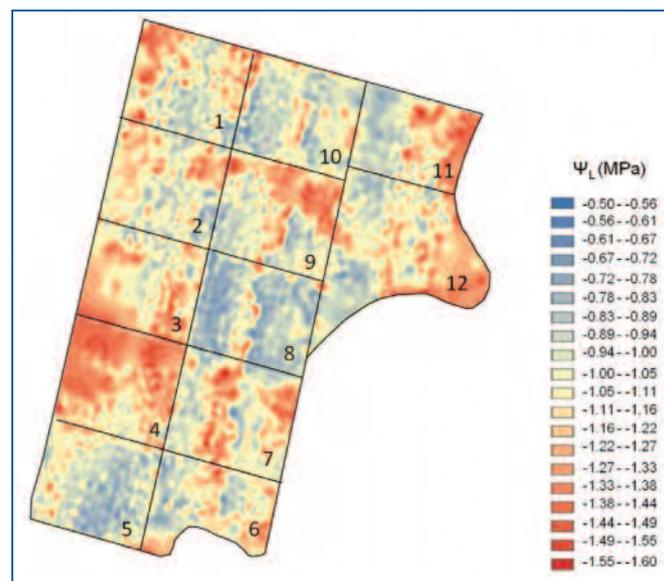
gation strategies at field scale. Recent studies successfully related CWSI with leaf water potential in vineyards. But it has been shown that there are differences between varieties and also at different phenological stages.

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 ( $\Psi_L$ ) 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  $\Psi_L$  obtained throughout the season.

Irrigation scheduling on the basis of  $\Psi_L$  maps was successfully achieved. Figure 1 shows an example of  $\Psi_L$  map obtained on 4 July (stage II) from high resolution thermal images. Spatial variability of vine water status ranged from  $\Psi_L$  between -0.5 to -1.6 MPa. For instance, averaged  $\Psi_L$  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  $\Psi_L$  values (i.e. 5, 8 and 10) were not irrigated during that week.

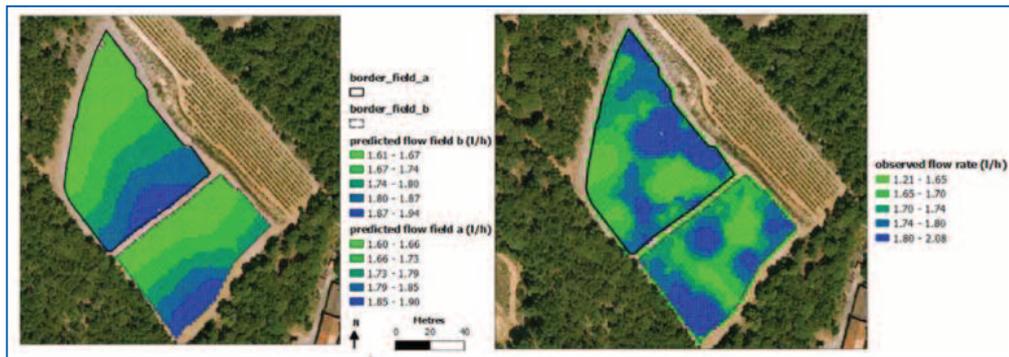
Irrigation water applied through the season was different between irrigation sectors, ranging from 150 to 300 mm. Non significant differences were found in yield, number of clusters and berry fresh weight between irrigation sectors. Therefore, this method allowed adoption of regulated deficit irrigation 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  $\Psi_L$  maps. CWSI has been successfully related to  $\Psi_L$  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  $\Psi_L$  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  $\Psi_L$  and CWSI, v) Set up a commercial advisory service for farmers that enables efficient irrigation schedules.



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

### 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 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**

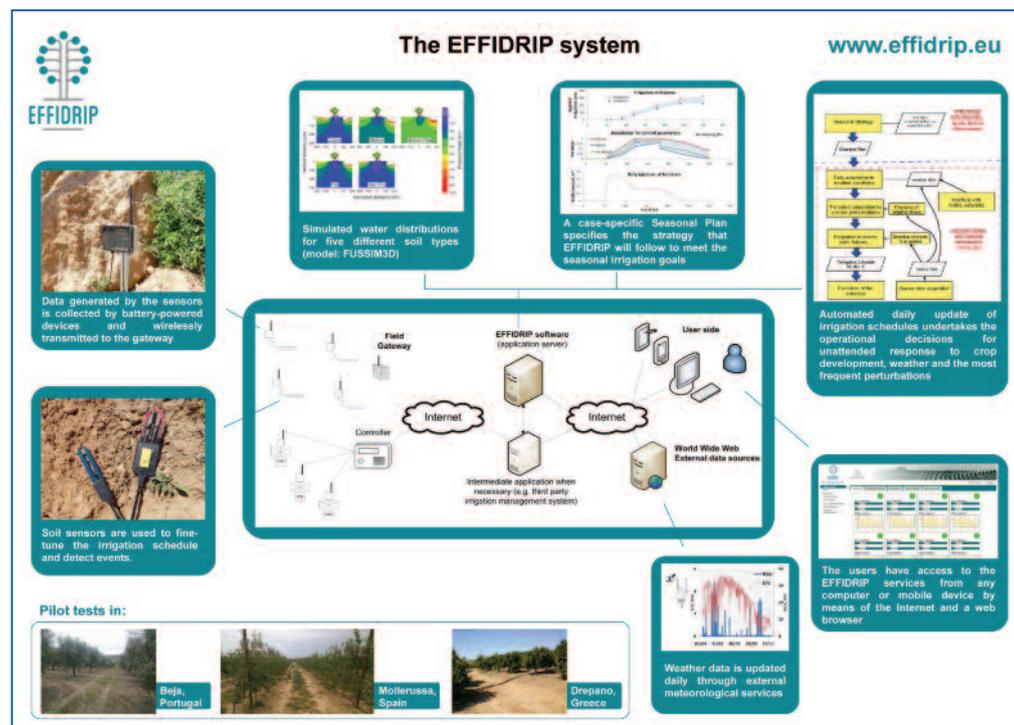
“Given the diversity of situations that may be encountered in a region as vast as the south of France, it is difficult to extrapolate the results obtained on two fields”,

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.

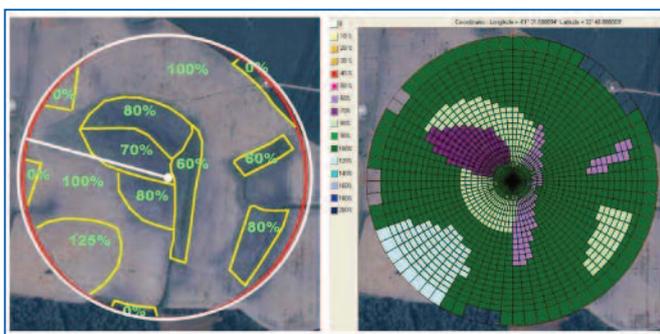
The University of Georgia smart sensor array (UGA SSA) consists of smart sensor nodes and a gateway. A 'smart sensor node' is defined as the combination of electronics and sensors installed at each location in the field. A UGA SSA node consists of a circuit board, a radio frequency (RF) transmitter, 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)**