INNPACTO project: A tool for scheduling irrigation using airborne high resolution thermal imagery

Bellvert J[1], Zarco-Tejada PJ[2], Girona J[1], Mata M[1], Bonastre N[1], Paris C[1], González-Dugo V[2], Romero R[2], Fereres E[2,3]

[1]Institute of Research, Technology, Food and Agriculture (IRTA), Water Use Efficiency programme, 25198 Lleida, Spain
[2] Institute for Sustanaible Agriculture (IAS), Consejo Superior de Investigaciones Científicas (CSIC), Córdoba, Spain
[3] Departament of Agronomy, University of Córdoba (UCO), Córdoba, Spain

Poster responsible e-mail:
joaquim.bellvert@irta.cat

9th European Conference on Precision Agriculture — Facing new challenges, providing new solutions — Lleida, Catalonia, Spain, July 7th-11th 2013

INNPACTO

Is a program aimed at enhancing the cooperation between research centers and private enterprises by developing joint R&D projects. In 2011, a project (IPT-2011-1786-060000), entitled: '**Commercial development of a tool to manage efficiently irrigation scheduling in parcels of different crops by using airborne high resolution thermal images**' was funded. The enterprises involved are Codorniu, S.A. and Sorigué, S.A., and the research centers are IRTA and IAS-CSIC. This project has been carried out for three years, until December 2014.

The goals of the project are: i) Development of Crop water stress index (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 leaf water potential (Ψ_L) maps, iii) Generate the optimal aerial platform, and establishing optimal flight 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.

Introduction

Adequate irrigation management is required for the efficient and profitable use of water in irrigation of agricultural crops. Spatial variability in water requirements across a field affects the efficient use of irrigation water. Therefore, identifying and mapping spatial variability based on plant water status (leaf water potential, Ψ_L) can be an effective tool for managing irrigation (Bellvert et al. 2012).

The increasing interest in remote sensing for water management applications has led to studying the possibility for its use in crop irrigation scheduling over large areas. The established method for detecting crop water status remotely is through the measurement of the crop's surface temperature. One approach for quantifying water stress is the `Crop water stress index´ (CWSI). Many studies have shown good correlations between CWSI and midday Ψ_L (e.g. Möller et al. 2007, Testi et al. 2008). Thus, Ψ_L maps extracted from estimations of CWSI obtained from airborne thermal imagery may be effective in assessing the spatial variability in water stress across fields and for scheduling irrigation.

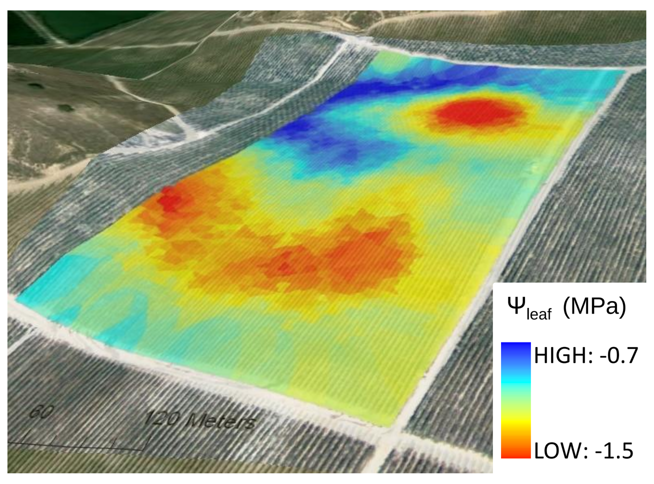

Figure 1. Vine water status variability of a 15-ha 'Pinot-noir' vineyard, obtained with midday leaf water potential (Ψ_L) measurements.

Figure 2. Leaf water potential measurements in the vineyard.

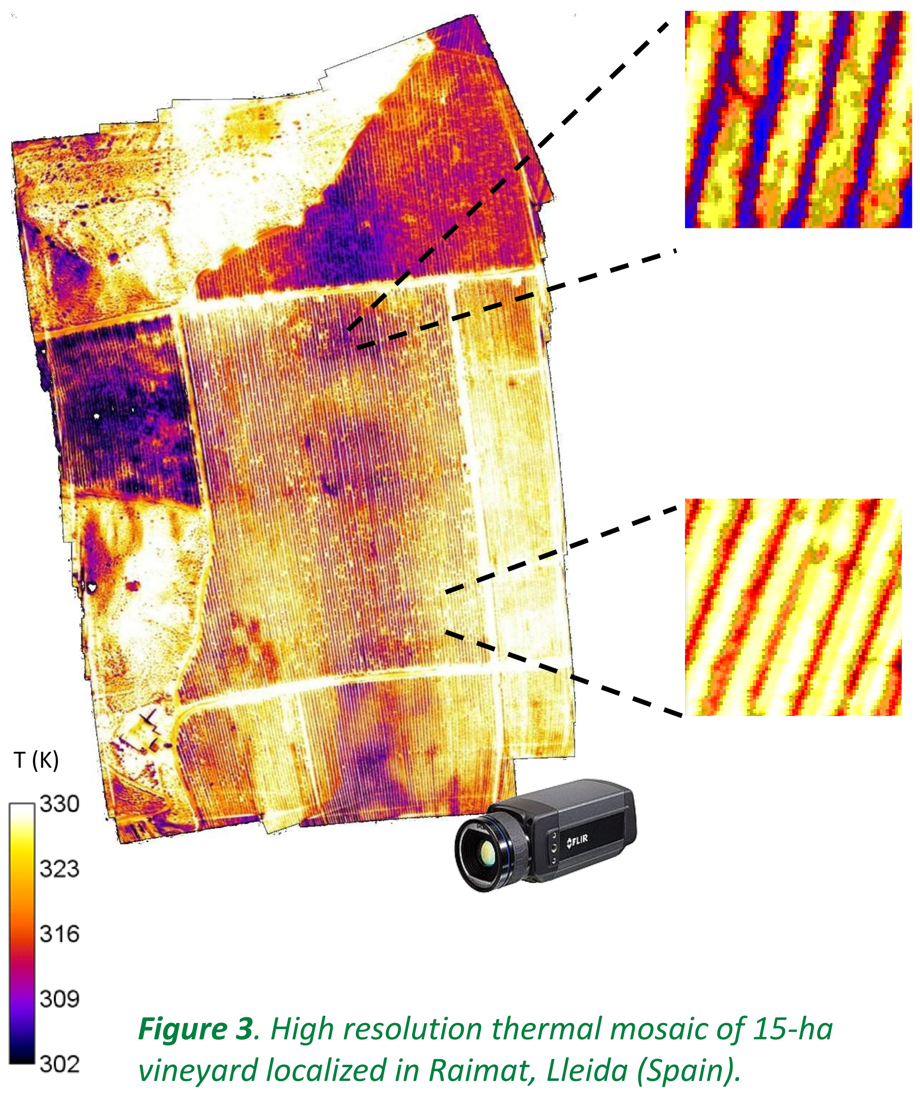

Figure 3. High resolution thermal mosaic of 15-ha vineyard localized in Raimat, Lleida (Spain).

Material and Methods

During the first year of the project, Crop Water Stress Index (CWSI) equations were obtained for different crops. Infrared temperature sensors were installed over well-watered trees transpiring at the potential rate. Canopy temperatures were continuously measured and recorded data was used to calculate the baselines of the CWSI. Midday leaf water potential was weekly measured in these well-watered trees and were used to validate the plant water status.

The empirical CWSI was calculated as (Idso et al. 1981):

$$CWSI = \frac{(T_c - T_a) - (T_c - T_a)_{LL}}{(T_c - T_a)_{UL} - (T_c - T_a)_{LL}}$$

where $(T_c\text{-}T_a)$ is measured canopy - air temperature difference; $(T_c\text{-}T_a)_{LL}$ lower limit of $(T_c\text{-}T_a)$ of a canopy which is transpiring at the potential rate, and $(T_c\text{-}T_a)_{UL}$ expected differential in the case of a non-transpiring canopy.

A high resolution thermal camera (FLIR SC655) was installed on an aircraft and flown six times during the season over fields of peach, nectarine, olive, apple trees and vineyards. Flights were conducted at 12:00 solar time (14:00 local time) at 150 m altitude above the ground level. Coincident to the flights, Ψ_L was measured in eighteen trees of each crop for ground truthing, by comparing the CWSI obtained from aerial thermal imagery with a ground-based stress indicator at different phenological stages.

a) b)

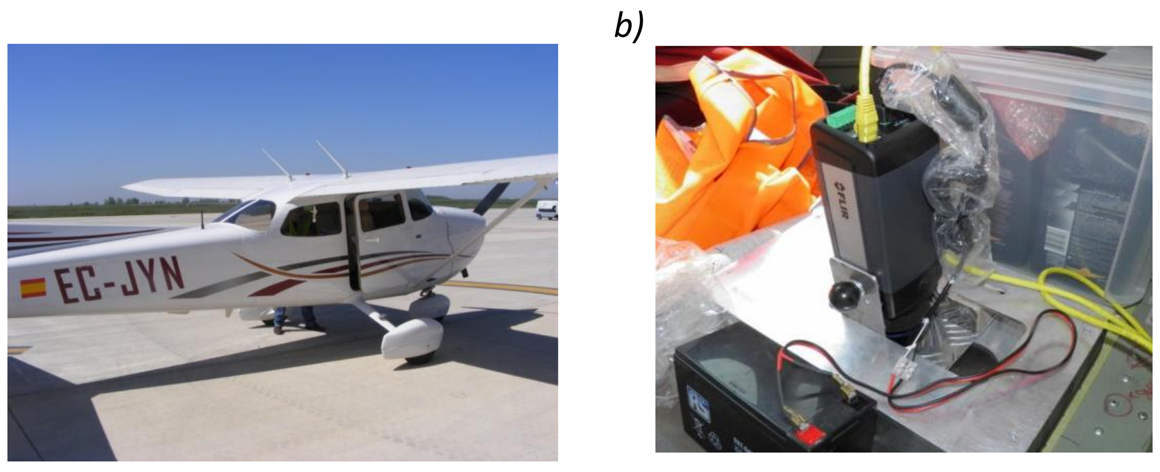

Figure 4. a) Aircraft used for thermal image acquisition and, b) Thermal camera installed on the aircraft and connected to a computer via USB 2.0 protocol.

Results

CWSI was successfully correlated with leaf water potential (Ψ_L) in all crops. As tree water stress increased, transpiration rate must have been reduced progressively until reaching its complete stomatal closure (CWSI=1). Relationships indicated differences between crops and phenological stages. Generally, for a specific CWSI value, midday Ψ_L decreased as crop developed. Moreover, in grapevines also a varietal effect was identified.

Irrigation scheduling of a 16-ha 'Chardonnay' vineyard was carried out solely on the basis of the Ψ_L maps obtained from airborne imagery throughout the season. Weekly airborne thermal images were collected over the farm to obtain Ψ_L maps. The irrigation system was divided into twelve regular sectors and irrigation decisions were taken individually for each irrigation sector based on the averaged Ψ_L. This method allowed the adoption of regulated deficit irrigation (RDI) strategies, leading to water savings of around 45% in some irrigation sectors without affecting yield.

a) b)

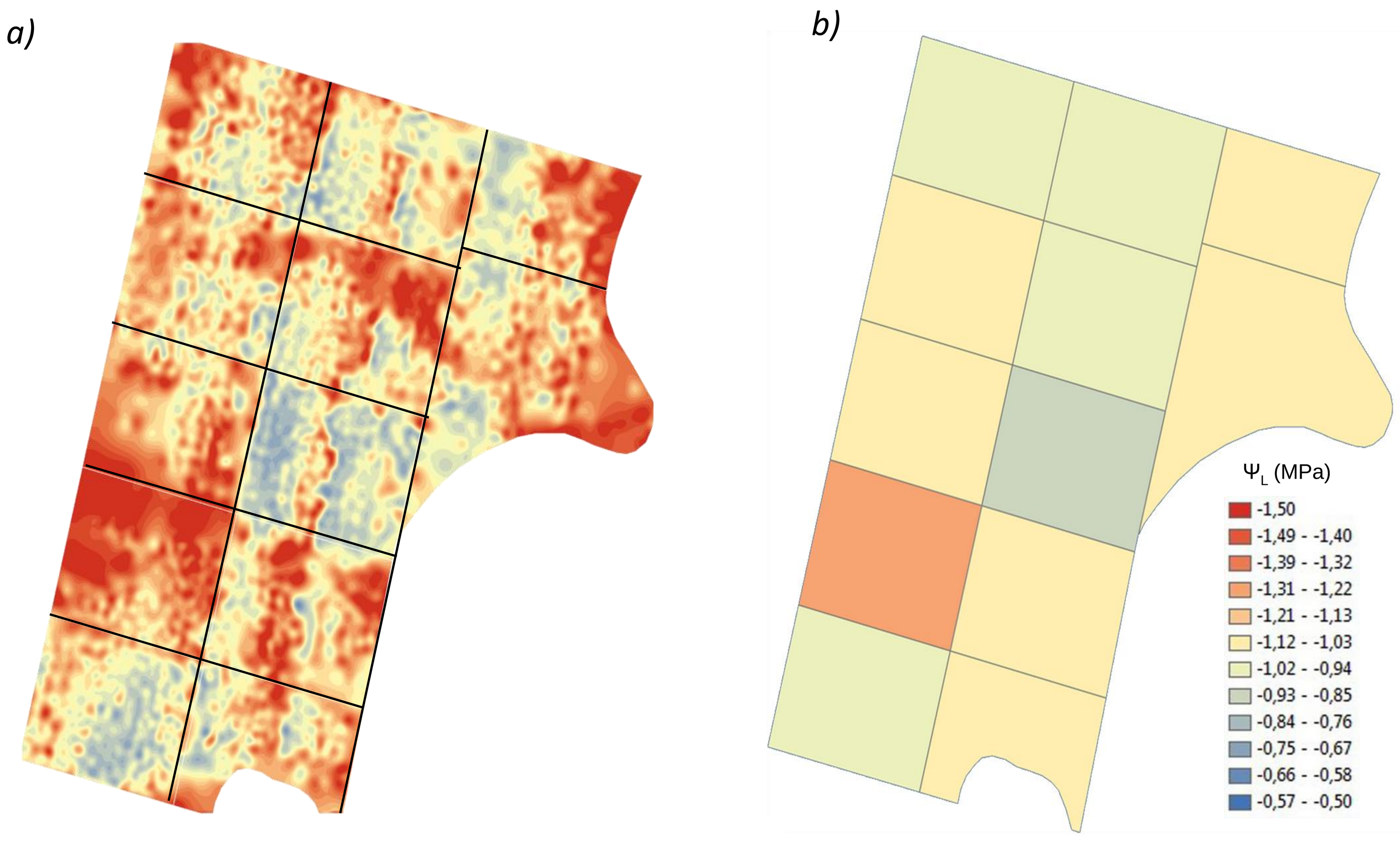

Figure 5. Vine water status variability of a 16-ha 'Chardonnay' vineyard. a) Estimated Ψ_L map obtained from thermal images, at vine scale. b) Averaged estimated Ψ_L at irrigation sector scale.

CONCLUSIONS

INNPACTO project has been demonstrating the reliability of using CWSI for detecting water stress in woody trees and grapevines. The study makes progress on the application of high resolution thermal remote sensing methods for mapping water status variability within-fields. It was confirmed that for monitoring efficiently CWSI, development of seasonal CWSI equations for each crop and relationships with Ψ_L are necessary.

A potential application in vine water status detection and irrigation scheduling based on weekly Ψ_L maps of a vineyard was successfully carried out throughout the season.

A commercial advisory service for farmers will begin in 2014.

References

Bellvert, J., Marsal, J., Mata, M., & Girona, J. (2012). Identifying irrigation zones across a 7.5-ha 'Pinot-noir' vineyard based on the variability of vine water status and multispectral images. Irrigation Science. 30, 499-509.

Idso, S.B., Jackson, R.D., Pinter, P.J., Reginato, R.J., & Hatfield, J.L. (1981). Normalizing the stress-degree day parameter for environmental variability. Agric.Meteorol. 24, 45-55.

Möller, M., Alchanatis, V., Cohen, Y., Meron, M., Tsipris, J., Naor, A., Ostrovsky, V., Sprintsin, M., & Cohen, S. (2007). Use of thermal and visible imagery for estimating crop water status of irrigated grapevine. J. Exp. Bot. 58, 827-838.

Testi, L., Goldhamer, D.A., Iniesta, F., Salinas, M., 2008. Crop water stress index is a sensitive water stress indicator in pistachio trees. Irrigation Science. 26, 395-405.

vCard

Remote sensing applications in precision agriculture