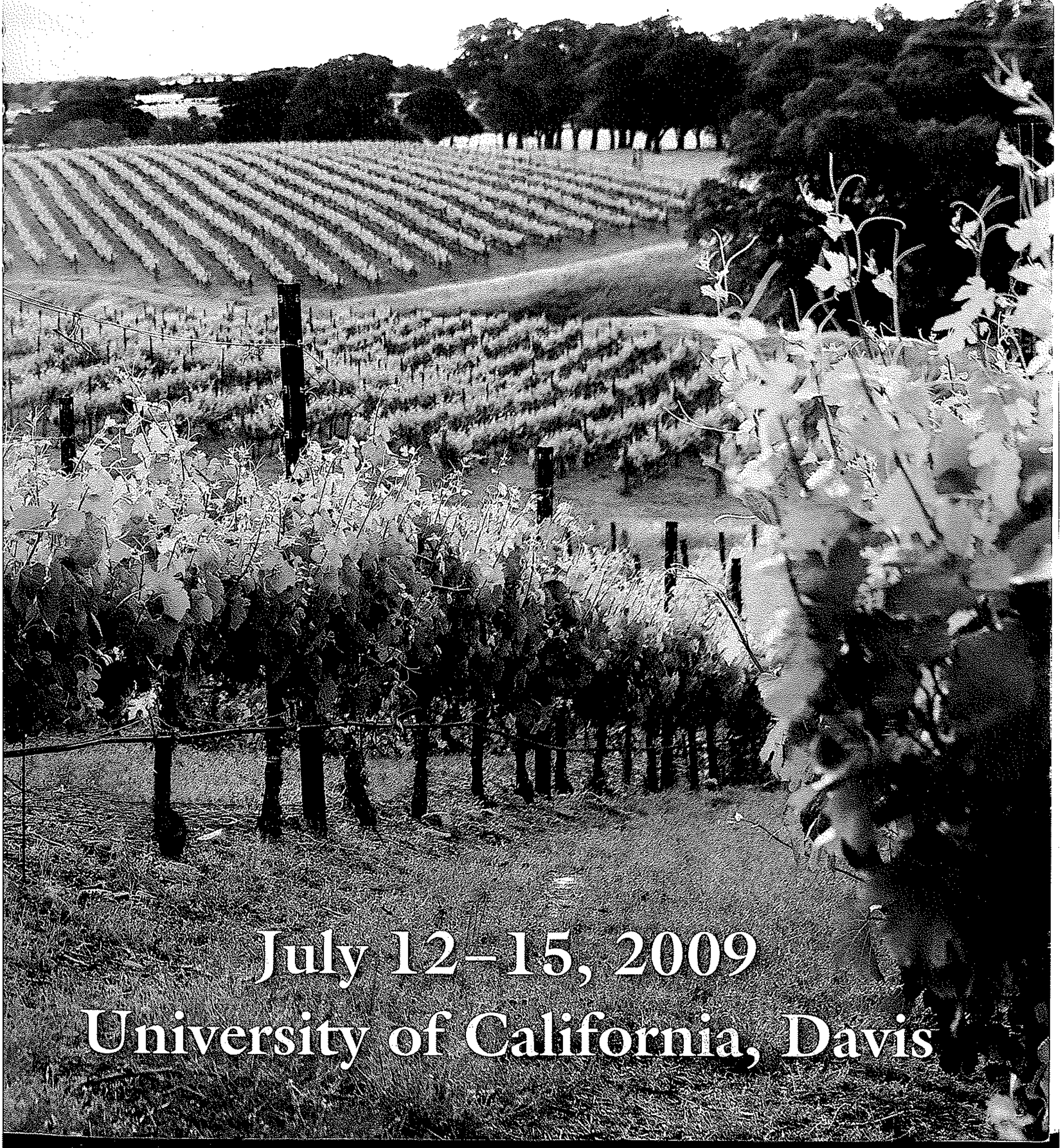
16th International GiESCO Symposium



July 12–15, 2009
University of California, Davis

AN INTEGRATED MULTI-SCALE MONITORING APPROACH TO UNDERSTAND THE RELATIONSHIPS BETWEEN CLIMATE, AGRICULTURAL PRACTICES ON GRAPES QUALITY

A. Matese [1], F. S. Di Gennaro [1], L. Genesio [1], F. P. Vaccari [1], A. Crisci1, A. Zaldei [1], P. Toscano [1], B. Gioli [1], E. Fiorillo [1], T. De Filippis [1], S. Di Blasi [2]

([1]) National Research Council - Institute of Biometeorology (CNR-IBIMET), Via G. Caproni 8, 50145 Firenze (Italy)
([2]) Consorzio Tuscania – P.zza Strozzi 1, 50123 Firenze (Italy)
Corresponding author: Alessandro Matese - e-mail: a.matese@ibimet.cnr.it

Abstract: Meteorological and micro-meteorological variables play an important role on the growth-yield response of grapevine and as a consequence on quality of productions.

Since growing regions are characterized by their climate, many authors have investigated the effects of weather related factors, such as temperature and pluviometry, on the best vintage definition. Moreover, they have found that the influence of management practices on grape quality, tends to be show a interannual varibility in function to the dymanic of seasonal weather pattern.

The purpose of the work is to investigate how specific the agronomical practices widely applied in canopy management (i,e. bud load, early leaf removal, bunch thinning) by farmers could have directly and indirectly an influence on the grape quality.

The research was carried out in four vineyards located in three different geographical areas of Tuscany. Randomized block field scheme has been adopted in homogeneous areas for vigour inside each vineyard. A local sensor network based on wireless technology (4 base station and 40 peripheral wireless nodes located in the vineyards) was developed and installed in order to acquire main micrometeorological parameters. Vineyard spectral vegetation indexes were analysed in different time steps along the growing season by high-resolution (30cm) airborne images in order to highlight variability in canopy development and to establish a correlation with management practices. Agrometeorological measurements and vegetation index calculated from airborne images, were compared with the analysis of the grape at harvest.

This study gives an overview of the technical solution adopted in the multi-scale monitoring approach and presents the preliminary results of the on-going research in four experimental vineyards.

Modern viticulture can be considered as a sort of precision agriculture, where different management among the different vineyards and within the vineyard is now recognized as a prerogative for a quality production. Precision viticulture, therefore, must necessarily take into account in order to manage the quality the interactions occuring in vineyard between plant physiology and the environmental factors. In modern environmental monitoring technology, has beeen developed several tools for land classification such as remote sensing storage and analysis of statistical data and Geographic Information Systems. Other technologies are useful for the weather parameters monitoring and for data transmission and storage,. Today is possible to achieve much information from farm system, and this one is can be used in an integrated way to offer at the grower a comprehensive view of the status of cultivations in order to lead a better management of interventions and to obtain the prefixed target in quality production, in respect of environment and its sustainability.

In particular, the knowledge of the qualitative and quantitive level of production before ripening provide a best plannig for harvest activity.

The novel WSN technology (Wireless Sensor Network) have shown its usefulness and it could be considered an efficient tool allowing a true real-time monitoring to optimize both the quality of production and the production processes (Pierce et al., 2007). The WSN is a network of nodes equipped with sensors.This ones transmit collected information using a radio connection to a mother node device called base station and its task consist in data storage. The NAV system (Vineyard Advanced Network) is a specific WSN device that could be installed in a vineyard. It is designed and realised by Institute of Biometeorology, CNR (Consiglio Nazionale delle Ricerche). The prototipal system has been realised for the aims of Consorzio Tuscania Project, with the task to monitor and collect agrometeorological parameters in order to study the effect of different management practices on grape quality.

Besides, we have coupled another innovative technology, installed on a airborne platform, for to achieve auxillary remote sensing measurements. Multispectral remote sensing is a tool widely used at local and global scale in land surveys (Dobrowski et al., 2002). It' well know that the continuous advances in processing of remote sensed data and the increasing number of sensors generally used, allows a more performing use of remote sensing for the most kind of spatial applications. Fore example DFR system (Duncan-Riegl-Flir) installed on a Sky-Arrow platform has been developed for the acquisition of high resolution multispectral images and in recent years is become as a powerful tool in precision farming, especially in viticulture. The application of satellite images in precision agriculture (Bramley, 2001) is limited both by the narrow spectral range than in time, while the high spatial and temporal resolution is a standard feature of DFR system. It ables to assess vine phenological stages and their status in vigory. The spatial resolution of the DFR (0.3 m to 8 m at the flight altitude of 4000 m) allows to discriminate small spatialdetails such as inter-row of a vineyard and the spectral resolution is more perfomant in respect to the traditional vegetation indices.

These technologies are able to produce a large set of information at different levels and different scales, which necessarily must be integrated. Obviously in operative context an integrated approach it is necessary to create and maintain a relational database.

Figure 1: Peripheral wireless nodes (Slave unit) located in the vineyard.

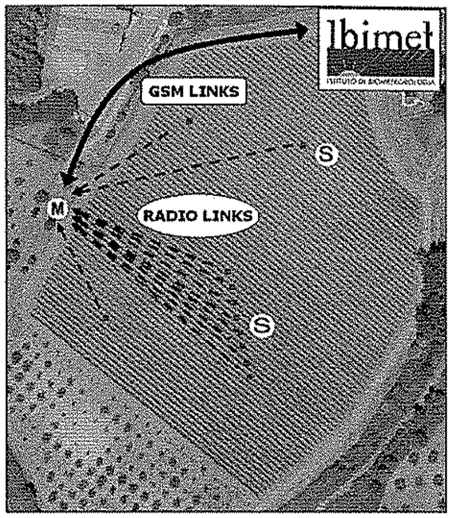


Figure 2: Transmission scheme between Master Unit, Slave Units and Remote Central Server (M=Master Unit; S=Slave Units).

MATERIALS AND METHODS

Experimental plot

The experimental plot (EP) was set up in three different areas of Tuscany: Chianti Classico, Monteregio di Massa Marittima and Bolgheri on four vineyards of Sangiovese and Cabernet Sauvignon, homogeneous for age, spacing of the vines and training system. The EP was designed using the results given by high resolution (30 cm) multispectral images processing. Homogeneous areas of high, medium and low vigor or photosynthetic efficiency have been yet identified using multispectral images thanks to a preliminary flights. Parcels have been designed within every blocks, where different canopy management were employed (bud load, defoliation, thinning). The combination of the three treatments provide 8 thesis be applied to each vigor block, 85 plants per thesis and 680 plants per block, for a total of 9520 plants on the experimental design.

Vineyard monitoring system

The NAV system was installed on 4 experimental vineyards.The system include a base agrometeorological station called Master, located outside the vineyard, and 40 sensor units called Slave devices (Fig. 1) placed as nodes within the 4 experimental vineyards. Every Slave units had monitored one of the 8 thesis of canopy management. The data collected from the units was acquired by the Slave and Master by radio connection, only to be sent trough GSM modem to the server Data Base which is located in Florence at the Institute of Biometeorology (Fig. 2).

The master manages up to 20 peripheral units per site, with a signal coverage of 200 m. This includes sensors for the measurement of the main agrometeorological parameters such as: air temperature, barometric pressure, humidity, speed and wind direction, global solar radiation and rainfall. The sensors follow the standards provided by the WMO reccomendations obtained by "Guide to Meteorological Instruments and Methods of Observation" World Meteorological Organization, 2008). The Slave units are designed to be compatible with the management practices of the vineyard, and to acquire supplemetary and useful micro-meteorological parameters such as: canopy infrared temperature, soil water matrix potential measured at two depths (0.3 m and 0.6 m), internal temperature of the bunch, air temperature and surface radiation of the bunch. These one are collected even in order to estimate the variability due to specific vineyard management practices as leaf removal, bunch thinning and bud load. Both base stations and devices are powered using a solar panel and a small battery to assure conitnuos energy alimentation. The NAV system is also equipped by a system managers software which allows to load the firmware and run the setup of the main functions. Moreover, the software was developed to allow a robust real-time monitoring of acquisition data.

Remote Sensing

The research activities have included the multi-scale monitoring through the acquisition of aerial imagery (Hall et al., 2002). Airborne remote sensing is performed with SKY ARROW 650 TC/TCNS airplane (Fig. 3). The aircraft is equipped with engine Rotax 100 HP. The flights can be made between 300 and 400 m a.s.l. depending on the type of application requested. The system is equipped with multispectral camera, thermal infrared camera, GPS and GPS / INS, laser altimeter. The images were acquired at a spatial resolution of 0.3 m and 0.6 m. Each sampling was radiometric and geometrically corrected. The radiometric correction converts the digital number of each pixel (brightness value) to a value of spectral radiance using the calibration parameters of the cameras. The GPS and GPS / INS aboard acquire data during flight at high frequency. The flight transect were planned in order to reduce the variation in solar radiation and the shadow effect on the ground, then agreeing to an acquisition under conditions of clear skies and high solar elevation. Airborne images are used to obtain Normalized Difference Vegetation Index (NDVI) maps. Spectral vegetation indexes reduce multi-spectral values of each pixel to a single numeric value (index), and have been developed to show vegetative condition changes (Wiegand *et al.*, 1991; Price e Bausch, 1995). NDVI is created by transforming each multi-spectral image pixel according to the relation:

$(R_{NIR} - R_{RED}) / (R_{NIR} + R_{RED})$

where R_{NIR} and R_{RED} are the reflectances in each band, respectively (Rouse *et al.*, 1973).

Figure 3: Sky Arrow 650 Tc/Tcns aircraft.

Geodatabase and geoportal (storage, management and data accessibility)

The geodatabase was designed to store, manage and transfer to the project partners all the geodata and related analytical data, collected during the research activities. Moreover the Geodatabase is the main component on which to develop web services and guide the application of a website that allows access to the geographic area in various type (summary tables, charts, graphs, bulletins, with reference to a geographical area).

The Geoportal is the entry point, on the Web, where all geodata information and services can be easily visualized and queried. It was composed by three areas

The Viewer: a web application for querying and accessing to GeoData

The GeoDB portal: an interface to manage the GeoDabase

The Catalogue: a research tool for browsing all data and metadata of the project

RESULTS AND DISCUSSION

The full set of components previously described can be considered an integrated system. The products of this system consist in a comprehensive framework provided by individual modules, where is possible to find different sources of information such as multispectral images, blocks images and experimental georeferenced plots, agrometeorological data acquired from weather stations of the NAV, vegetation indices calculated pixel by pixel, maps of soil surveys (electrical conductivity, texture and ability to field), maps of quality grapes and ecophysiological information. This integrated approach allows the extraction of information on many points within the vineyard through overlapping layers of geo-related information, both continuous variables (meteorological data) and environmental factors of vineyard (i.e. soil and topography). The system allows to carry out a multi-factorial analysis within each parcel of vineyard, with the aim of linking all the variables from the qualitative data verified for single parcel.

The integrated system could be also a useful tool for terroir characterization . The data acquired by the monitoring system on the ground, topography and soil analysis, along with human factors, contribute to a complete characterization of the vine vigor areas. The data derived from remote sensing and proximity sensing framework confirm the topografical definition of these areas linking to the definition of terroir (O.I.V.). This one affirm that the vine vigor areas can be defined geographic areas influenced by the interaction between physical environment (climate and soil), biological interactions and human activities (agricultural practices management).

The resultant of the combined effect of all these variables is

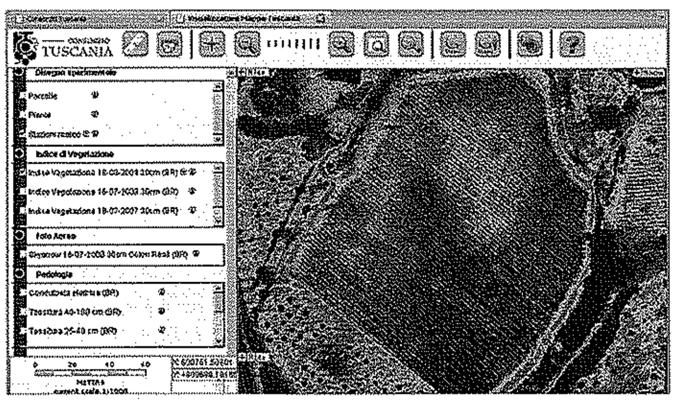


Figure 4: Geoportal for data management and access to geospatial information.

the quality level of the grape.

Therefore, the goal of NAV related surveys is to identify how the management practices are able to provide a best quality level in grapes and wine in the definition of terroir.

Preliminary results have confirmed these affirmations. The classification of homogeneous areas accordingly to vegetation is well correlated with NDVI profile values and have furnished a good indication of blocks location for experimental plot (high, medium and low vigor). The analysis also showed a marked variability intra-vineyard in terms of growth.

Other preliminary analysis based on the meteorological data were made to evaluated which kind of relations exists between a general vineyard climatic signature (land indicator) and other eventual proximal indicators, that have the task to give the feature of every potential microclimatical situation. The land indicator is useful to provide a comprehensive indication of vineyard climate characterization and can be used to compare the meteorological parameters of different vineyards. This indicator indexes are calculated using the meteorological data monitored by the Master station that is located outside the vineyard. The proximal indicator, instead, give a deep indication of the environmetal variability found in areas due essentially to vineyard canopy thanks to micrometeorological data monitored by the Slave units located inside the vineyard.

A climatic profile of land indicator is can be done by bioclimatic indices that are shown in Fig. 5. The Winkler index (Winkler *et al.*,1974), Huglin index (Huglin *et al.*,1978), SET index and Gladstone index (Gladstone, 1992) are calculated for the 4 experimental vineyards.

Another example of a land indicator has shown in the Fig. 6 where the temperature differences between Slave and Master highlight the land indicator and proximal indicator. The figure

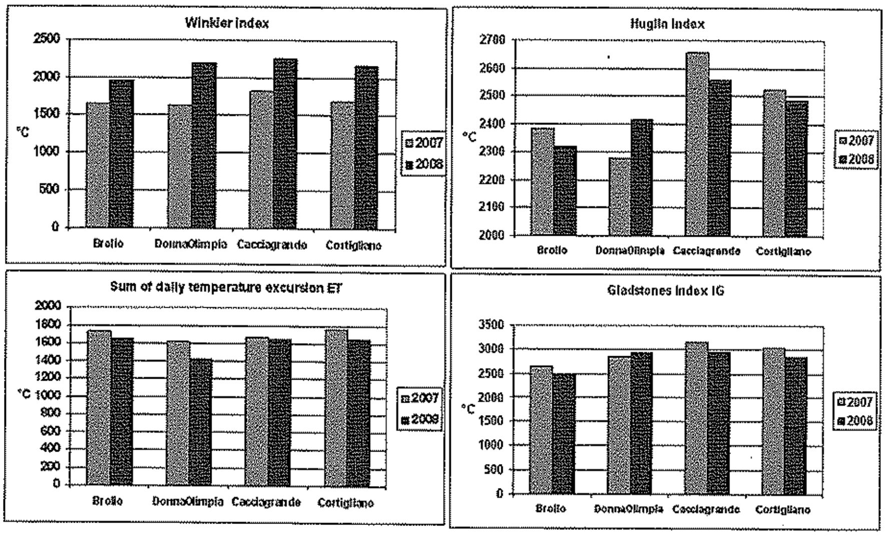


Figure 5: Main bioclimatic indexes calculated for the 4 experimental vineyards

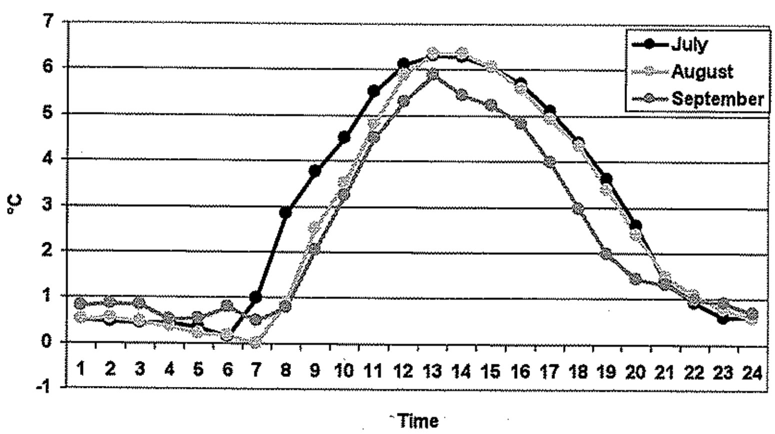


Figure 6 : Average diurnal courses of temperature between Slave units and Master calculated for three months.

6 shows the average diurnal courses of temperature calculated for three months (July, August and September) and point out the difference from Slave and Master temperature reach 6 °C in the central part of the day.

Concerning the analysis of the proximity indicator, the figures 7-8 show examples about the variability of micrometerological parameters within the vineyard and between agricultural practices management. The figure 7 shows the temperature differences between Slaves and Master, where every Slaves value is characteristic of a canopy management (thesis). While the figure 8 shows the bunch temperature of every Slave. In these figures show the micrometeorological variability is due by in areas with different treatment but located in the same vineyard and which is t he climatological difference between the Master (land indicator) and the Slave (proximal indicator).

These tests are still at a preliminary stage and will require further investigations for a better testing in the next years.

CONCLUSIONS

The integrated system responds in exhaustive way to the aim of the Tuscania project, but is also provide a complete multisource system characterized by its flexibility of design, installation and use. The real-time monitoring really allows the best suggestions for to fit the optimal choice in management strategies to obtain quality wines. The system also may allow to topographical identification of different areas in vineyard in terms of microclimate and, therefore, to plan a differentiated harvest. They can also be a source of information used by machinery in the case of fertilizing, processing and other operations specific to areas of the vineyard..

LITERATURE CITED

Bramley R.G.V., 2001. Progress in the Development of Precision Viticulture – Variation in yield, quality and soil properties in contrasting Australian vineyard. In: Currie L.D. and Loganthan P. (Eds). Precision tools for improving land management. Occasional Report No.14, Massey Univ., New Zealand;

Dobrowski S.Z., Ustin S.L. and Wolpert J.A., 2002. Remote Sensing estimation of vine canopy density in vertically shoot positioned vineyard; determining optimal vegetation index. Australian Journal of Grape and Wine Research, 8: 118-125;

Gladstone, J. 1992. Viticulture and Environment. 310pp. Winetitles, Adelaide.

Hall A., Lamb D.W., Holzapfel B. and Louis J., 2002. Optical Remote Sensing applications in viticulture: A review. Austr. J. Grape and Wine Res., 8: 36-47;

Huglin, P. 1978. Nouveau mode d'évaluation des possibilittés héliothermiques d'un milieu viticole. C.R. Acad. Agric. Fr. 64: 1117-1126.

Pierce, F.J., Elliot, T.V., 2007. Regional And On-Farm Wireless Sensor Networks For Agricultural Systems In Eastern Washington, Comput. Electron. Agri., doi:10.1016/J.Compag.2007.05.007.

Price J.C., Bausch W.C., 1995. Leaf area index estimation from visible and near-infrared reflectance data. Remote Sensing of Environment 52: 55-65.

Rouse J. W. Jr., Haas R. H., Schell J. A., Deering, D. W., 1973. Monitoring vegetation systems in the great plains with ERTS. The 3rd ERTS Symposium, NASA SP-351 1: 309-17.

Wiegand C.L., Richardson A.J., Escobar D.E., Gerbermann A.H., 1991. Vegetation indices in crop assessments. Remote Sensing of Environment 35: 105-19.

Winkler, A., Cook, J., Kliewer, W. and Lider, L., 1974. General Viticulture. 710 pp. University of California, Berkeley.

World Meteorological Organization, 2008. Guide to Meteorological Instruments and Methods of Observation, WMO-No. 8, Seventh edition, Geneva.

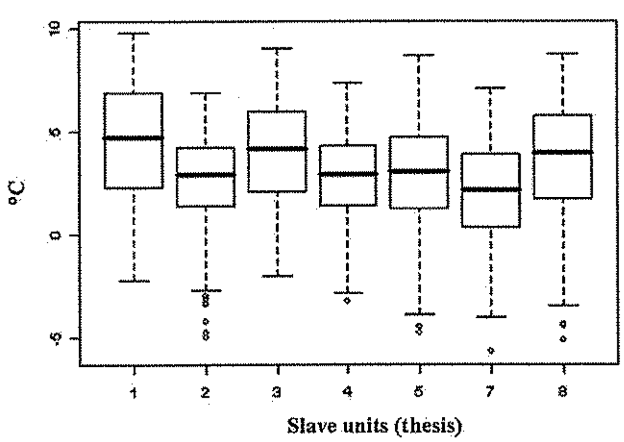


Figure 7. Box plot of temperature differences between Slaves and Master of every Slave units (thesis) for the ripening period.

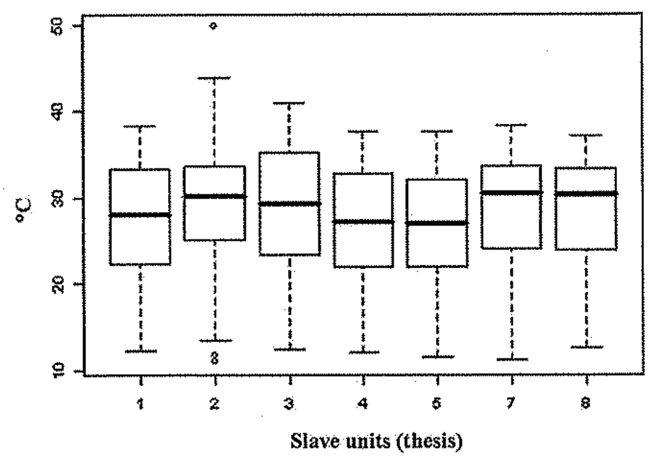


Figure 8: Box plot of bunch temperature of every Slave units (thesis) for the ripening period

SPONSORS

GiESCO

Groupe International d'Experts en Systèmes vitivinicoles pour la CoOpération

Group of International Experts of vitivinicultural Systems for CoOperation

RMI
Robert Mondavi Institute for Wine and Food Science
UCDAVIS

VITICULTURE & ENOLOGY
UNIVERSITY OF CALIFORNIA DAVIS

UCDAVIS
COLLEGE of AGRICULTURAL AND ENVIRONMENTAL SCIENCES

ACKNOWLEDGEMENTS

Napa Tour

Silverado Premium Properties, Napa
Beckstoffer Vineyards, Rutherford
Opus One, Oakville
Robert Mondavi Winery, Oakville

Lodi Tour

Lodi-Woodbridge Winegrape Commission

Thanks To:

Alison Byrum, Conferences and Events Services

Cover Photo: Berryessa Gap Winery, Winters, CA
David M. Davies, Photographer

Nancy Ottum and Jennie Resendez, Book Preparation

A Very Special Thanks To:

E&J Gallo Winery for Financial Support