PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XL cycle, 2024-27)

Project draft

1.Field of interest

AGR-08

2.Project title

Precision Irrigation in Viticulture: Multisource Data Processing for the development of a Decision Support System.

3.Tutor: Arianna Facchi

Co-tutor/s: -

4.Relevance of the topic and state of the art:

Most climate projections predict that climate change will significantly affect the hydrological cycle leading, in many agricultural areas of the planet, to more frequent droughts and heat waves, to alteration of the spatial and temporal patterns of precipitation, to an increase in crop evapotranspiration, and to a general reduction of the available water for agriculture [1]. In this scenario it is therefore essential that research could focus on the development of 'water saving' technologies and techniques, with the ambitious goal to produce more with less ('more crop per drop', [2]). Also the UN Agenda 2030, with its 17 sustainable development goals, stresses the need of solutions to increase the sustainability and resilience of agricultural systems to climate change (Objective 2, Target 2.4) and of achieving higher water use efficiencies in every productive sector, including agriculture (Objective 6, Target 6.4) [3]. Moreover, at the European level, the Water Framework Directive (2000/60/EC), offering a legislative framework for policies and practices aimed at the protection and sustainable use of water resources, encourages the agricultural sector to find real solutions for an increasingly efficient use of water.

As for the other agronomic inputs, also for water the conventional management is based on the application of a homogeneous input over the field, considered as a uniform spatial unit [4]. This is also often valid when considering different fields, where the irrigation amount and frequency of application is usually constant and a result of established farmer customs or of the advice provided by irrigation system installers (in the case of pressure irrigation). However, the spatial heterogeneity of soil characteristics, topography, microclimate, as well as of crop development can result in a non-uniform irrigation requirement. This is why a homogeneous irrigation application inevitably leads to areas constantly over-irrigated or under-irrigated with respect to optimal needs [5].

Viticulture is a sector where the application of Precision Irrigation (PI) techniques could lead to significant benefits not only in terms of sustainability in the use of water but, above all, in terms of improvement of yields, grape quality and organoleptic characteristics [6]. As the vine is a perennial and particularly profitable crop, any investments in technologies for the site-specific management of inputs and/or crop operations are more economically sustainable in the medium to long term with respect to other crops. Grapes and wine are the expression of the concept of terroir, central in enology, which encompasses the effects that pedological, climatic, topographical, biological, cultural and agricultural factors have on the final product. Among the environmental factors that mostly influence the vine physiology, the yield and the quality of grapes, water is one of the most important [6; 7].

In Viticulture, data coming from ground, drone, and satellite surveys could be used to define different homogeneous management zones to optimize site-specific inputs [7; 8]. Moreover, agro-hydrological models integrated with weather forecasting could be used to support precise irrigation decisions maintaining or enhancing yield quantity and quality [6].

Although several papers can be found in the literature illustrating the performance of sensors to monitor the water status of soils or vines installed in vineyards or mounted on different platforms, and some effort has been made to estimate the hydrological balance and predict the irrigation needs of vines using agro-hydrological models, nowadays there is the need to organize all the information produced in a workflow to propose effective (suitable /advantageous) procedures and digital instruments that can be used by single or group of winegrowers to modernize their approach to irrigation in in wine-growing areas.

5.Layout of the project (draft)

5.1. Materials & Methods:

LANDSCAPE SCALE

The experimental activity will first focus on the collection of spatial data for 2 large wine-growing areas in northern Italy (Franciacorta, Colli Morenici del Garda). Among the data, the following are crucial: time series of current agro-meteorological data and climate change scenarios, soils and their hydrological characteristics, land use, water supply sources and irrigation methods adopted (if any).

A physically-based agro-hydrological model with a GIS interface will be developed to simulate the irrigation requirements of individual vineyards in the area under the current climatic conditions and considering medium-term climate change scenarios.

The system will then be complemented by the possibility of reading short-term (7-day) climate forecast data, in order to estimate irrigation requirements in real time. The system results will be available through a WEB interface to make them more accessible.

The results obtained can be used to support the irrigation planning and management of the considered districts (by the Irrigation Consortia and/or by wine-growers irrigating using private of wells).

VINEYARD SCALE

At the vineyard scale (3 vineyards in Franciacorta) the experimental activity will focus on the development of procedures, tools and protocols for optimising irrigation management in the individual vineyard plot. This objective involves, on the one hand, the development of

procedures for investigating the spatial variability of the main factors influencing the dynamics of water in the soil-crop system and, on the other hand, the selection of tools and protocols for an irrigation management modulated according to the actual irrigation needs of the vine.

The monitoring carried out in the 3 vineyards using traditional techniques (physical-chemical characteristics), sensors in the soil and on the vine (soil water status, vigour and vine water status), proximal sensors (Electro-Magnetic Induction sensor - EMI) and remotely (UAV with multispectral and thermal camera) will be used to implement and verify the estimates made with the agro-hydrological model using 7-day weather forecasts. The model completed with with sensors (DSS) will be used to optimize irrigation management in the 3 vineyards.

The activity at the farm scale will be carried out in collaboration with POLIMI, which, as part of a PhD programme activated with Agritech funds, is working on the identification of the best UAV indices for monitoring the water status of vines.

The PhD student's research activity will be supported by the knowledge and tools developed by the AGR/08 research group in the field of Precision Irrigation in vineyards in recent years [7-10].

5.2. Schedule and major steps (3 years):

1st YEAR

- Bibliographic analysis;
- Building of the geographical database for the 2 areas under investigation (Franciacorta, Colli Morenici del Garda);
- Installation of instrumentation of 2 vineyards (the 3rd is already instrumented) and acquisition of experimental data;
- Implementation of the agro-hydrological model for the three pilot vineyards.

2nd YEAR

- Simulations with the agro-hydrological model of the irrigation management in the 3 pilot vineyards, also implementing the 7-day agro-weather forecast;
- Implementation of the model for the entire territorial extension of Franciacorta and Colli Morenici;
- Writing of 1 paper.

3rd YEAR

- Critical analysis of the results obtained in the simulations and possible adjustments, with the objective of developing a DSS for the vineyard irrigation management in the two district areas, and irrigation protocols for the vineyard scale.
- Writing of the PhD thesis and 1 paper.

6. Available funds (to support research): (*source and amount*)

Progetto EU iCOSHELLs (4 anni, data di inizio giugno 2024, 131875 euro)

7. Co-Financing (to support the bourse): (*amount and UGOV code of the fund/s*)

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8. Literature: (*max 10 citations)*

[1] Wada, Y.; Floerke, M.; Hanasaki, N.; Eisner, S.; Fischer, G.; Tramberend, S.; Satoh, Y.; van Vliet, M.T.H.; Yillia, P.; Ringler, C.; et al. Modeling global water use for the 21st century: the Water Futures and Solutions (WFaS) initiative and its approaches. *GEOSCIENTIFIC MODEL DEVELOPMENT* **2016**, *9*, 175–222.

[2] Unesco; World Water Assessment Programme *Nature-based solutions for water*; 2018; ISBN 978-92-3-100264-9.

[3] United Nations, Department of Economic and Social Affairs, Population Division World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248. 2017.

[4] Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R.; Church, J.A.; Clarke, L.; Dahe, Q.; Dasgupta, P.; et al. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Pachauri, R.K., Meyer, L., Eds.; IPCC: Geneva, Switzerland, 2014.

[5] Food and Agriculture Organization of the United Nations (FAO) Water for Sustainable Food and Agriculture. A report produced for the G20 Presidency of Germany; Rome, 2017; ISBN 978-92-5-109977-3.

[6] Bonfante, A.; Basile, A.; Langella, G.; Manna, P.; Terribile, F. A physically oriented approach to analysis and mapping of terroirs. GEODERMA 2011, 167–68, 103–117.

[7] Ortuani B., Facchi A., Mayer A., Bianchi D., Bianchi A., Brancadoro L. (2019) Assessing the effectiveness of variable-rate drip irrigation on water use efficiency in a vineyard in northern Italy. Water, 11, 1964; doi:10.3390/w11101964.

[8] Ortuani B., Sona G., Ronchetti G., Mayer A., Facchi A. (2019) Integrating Geophysical and Multispectral Data to Delineate Homogeneous Management Zones within a Vineyard in Northern Italy. Sensors, 19, 3974; doi:10.3390/s19183974.

[9] Ronchetti G., Mayer A., Facchi A., Ortuani B., Sona G. (2020) Crop row detection through UAV surveys to optimize on-farm irrigation management. Remote Sensing, 12(12), 1967; https://doi.org/10.3390/rs12121967.

[10] Ortuani, B.; Mayer, A.; Bianchi, D.; Sona, G.; Crema, A.; Modina, D.; Bolognini, M.; Brancadoro, L.; Boschetti, M.; Facchi, A. Effectiveness of Management Zones Delineated from UAV and Sentinel-2 Data for Precision Viticulture Applications. Remote Sens. 2024, 16, 635. https://doi.org/10.3390/rs16040635.