Metrology applied to agrometeorology and forecasting models for agro-food sciences technologies

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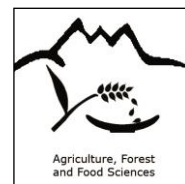
TRIENNIAL FINAL REPORT
CYCLE XXX

Ph.D DEGREE IN
AGRICULTURE, FOREST AND FOOD SCIENCES

Metrology applied to agrometeorology and forecasting models for agro-food sciences technologies

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Years:

2014; 2015; 2016; 2017

Objectives of the Ph.D work

Meteorological data have many applications in the prevention of natural adversities of climate origin, in programming and addressing the human activities, in the use of resources and in territorial planning. Local agrometeorological stations provide useful data in forecasting models to support management decisions, to contain costs and to reduce the impact of farming activities on environment. Agrometeorology can also play a significant role in reducing the negative impacts caused by pests and diseases. An appropriate, preferably integrated, pest management system using meteorological and microclimatological information can reduce pre and post-harvest losses appreciably.

Despite the considerable improvement of technologies and instrumentations, the analytical methodologies need a robust metrological assessment for the measurements of meteorological parameters in agricultural and food science field. Metrology, for instance, can be usefully applied in support of epidemiological forecasting models for vineyard diseases, such as grapevine downy mildew (*Plasmopara viticola*), one of the most important disease affecting viticulture strictly depending by temperature, humidity and rain. In order to relate the meteorological quantities with the biological cycle of the pathogen, several forecasting models have been developed. These provide information on progress and evolution of the infections, on the best time to make or not treatment in the field, all depending on the meteorological data. However, these models do not consider the quality of input data, usually collected from sensors not calibrated or calibrated without traceability and without inclusion of measurement uncertainties.

The success of any investigation or study depends upon the availability of reliable data. Meteorological data should be collected under standard conditions in accordance with established practices, both for observations and for the exposure of instruments. There is a need for testing various types of sensors, their calibration and to evaluate the measurement uncertainty related the meteorological quantities gathered from automatic weather stations (AWS), in order to improve cultivation disease predictions and reduce the use of chemicals in agriculture.

The main objectives of this research were to achieve a metrological systemic approach applied to agrometeorological studies to implement the traceability of weather measurements. In the first part of the PhD work, both non-calibrated and calibrated AWS were installed in a vineyard, evaluating the uncertainty in meteorological measurements and improving epidemiological forecasting models, to optimize the use of pesticides with a positive impact on the environment, health and crops management.

This research activity also concerned the quality of table tomatoes cultivated in tunnels, given the characteristics of health benefits of the crop and the strategic role of the cultivation in the Italian and world economy. Currently, accurate measurements of meteorological parameters in protected cultivation are neither unavailable, and the measurement uncertainties of environmental parameters that can be resolved in percentage uncertainties on the variability of the product are unknown.

Solar radiation and microclimate measurements, using calibrated instruments and traceable data, within different cultivation environments were evaluated. The radiometric properties of the films used as covering material and the identification of the morphological processes of culture in response to the type of film adopted were also analysed in order to study the evolution of the filtering capacity during film life time and the response of the crop based on meteorological parameters observations.

First year experimental work (2014/2015)

Two AWS were installed in a vineyard located in Monferrato (North-western of Italy), selected to be representative of vine-growing area, cultivar, position, slope, solar exposure and proximity of trees. The instruments were calibrated with traceability to national reference standard. Moreover, the different position in field were analysed with statistical tests, in order to evaluate the effect of the sensors' position and calibration on sloping hills, in terms of the influence on meteorological measurements.

Results

Meteorological data gathered from the two AWSs were used as input values of an epidemiological forecasting model in order to improve vineyard disease predictions and to reduce the use of chemicals in agriculture. The presence of trees affects both humidity and temperature measurements; the effect of the positioning of the sensors on sloped hills were evaluated, in terms of the influence mainly on air temperature and relative humidity measurements.

The inclusion of the calibration curve and uncertainty in the input data and the positioning contribution affects the disease prediction up to 5 days. Related to solar radiation, statistical differences were observed; this can be explained by the effect of the vine canopy spatial arrangement that tends to alter the vineyard's microclimate.

Second year experimental work (2015/2016)

An experimental measurement site was selected in the research area of Turin. The following structure and instruments were installed:

- No. 2 adjacent tunnels of equal size and different covering materials with opposite filtering properties in respect of UV-B solar radiation (the first type diffusive and filtering the UV-B radiation, the other one transmissive).
- No. 2 AWS, one per each tunnel, including sensors for the detection of air temperature, relative humidity, solar radiation for UV-B, solar radiation as PAR (Photosynthetically Active Radiation) and soil moisture;
- No. 1 AWS outside the tunnels including sensors for the detection of air temperature, relative humidity, solar radiation for UV-B, global solar radiation, wind speed, and precipitation.

The instruments used followed calibration procedures defined *ad hoc*.

About 150 seeds of Saint Pierre tomato cultivar were sowed in a microclimate-controlled greenhouse on April, two weeks later about 80 seedlings were transplanted in seedling plug trays and maintained under the same conditions until May. Then, 46 tomato plants were then selected, transplanted in pots individually and moved in the experimental site (20 per each tunnel and 6 outside). A drip irrigation system was installed to monitor the soil water content.

During the growing period of the plants phenological and morphological aspects were recorded: plant height, internode length, leaf area index (LAI), anthesis and fruit set. Meteorological data were evaluated and compared.

Results

The absence of UV-B radiation affected both the growth and the LAI of the tomatoes, while the presence of UV-B radiation, on the other hand, affected temperature and relative humidity. Even though, the temperature values gathered from calibrated sensors were higher than the ones gathered from non-calibrated sensors, vice versa for relative humidity values.

Third year experimental work (2016/2017)

Based on the experience acquired during the Ph.D. activity of the second year, the experiment on the measurements of meteorological parameters in protected cultivation**s** was replicated.

The same experimental measurement site located in the Research Area of the CNR of Turin and the same structure and instruments of the previous year were used and installed.

During the month of May, 46 seedlings of Saint Pierre tomato cultivar, previously sowed in a microclimate-controlled greenhouse, were selected, transplanted in individual pots and moved into the site (20 per tunnel and 6 outside). During the growing period of the plants the following phenological features were recorded: plant height, leaf area index, anthesis and fruit set.

Results

The meteorological sensors for the measurement of microclimate conditions were recalibrated and evaluated for the dynamic and stability. Specifically, in order to cover the whole calibration's range for atmospheric measurements, new selected set points were used for temperature sensors and for the evaluation of the hysteresis of the relative humidity sensors.

Data obtained from thermo-hygrometers sensors, calibrated and non-calibrated, were compared. In general, the temperature values obtained from the data to which the calibration curves were applied and associated with the calibration uncertainty, were higher than the values obtained from data without application of the curve and the uncertainty, vice versa for relative humidity values.

The ageing and radiometric properties of the films used as covering material due to their exposure to the sun and their deterioration were evaluated. The high temperature recorded in the last ten-days of June and in first ten-days of July, over than 40 °C, changed the transmissive feature of the covering material. Consequently, the phenological characteristics of tomatoes changed, specifically, their growth, anthesis, LAI and fruit setting trends.

Research study abroad

Francesca Sanna undertook a period of study as a visiting researcher at Maynooth University (Ireland), from October 2016 to February 2017.

The study concerned the meteorological parameters that influences one of the most important diseases affecting potatoes (Potato Light Bligh – PLB), and the evaluation of forecasting models for the prompt detection with focus on the calibration of sensor used as sources of the input data.

She also coordinated a group of MSc. students involved in digitising Potato Late Blight historical, documentary, records held by the national meteorological service, Met Éireann. This work involved

digitising, scanning and evaluating the compiled student-digitised records and developing a procedure for implementing this in a classroom setting.

During this period, Francesca participated in an MSc/PhD level module, entitled 'Climate Data, Analysis and Modelling'. This module provides a basic introduction to processes of accessing, analysis and modelling, with a specific emphasis on large climate data sets. As part of this module, Francesca undertook regional climate simulations for Ireland with the Weather and Research Forecasting (WRF) regional climate model.

A key focus involved also an extensive evaluation of methods and approaches to calculate potential evapotranspiration (PE) in Ireland, based on available station level data. As evapotranspiration is only measured at a few locations in Ireland, it is currently only estimated for unmeasured locations. However, to date, an extensive evaluation of techniques to estimate PE has not been undertaken. This work, which directly contributes to on-going land-atmosphere coupling research here, will be published once completed.

Educative activities and conferences:

Conference organizer

MMC-2016– Metrology for Meteorology and Climate – 2016, held in Madrid, Spain on from 26 to 29/09/2016; organizer and scientific committees.

ENV58 MeteoMet2 International meetings. Scientific sessions and round table held at the Collegio Carlo Alberto in Moncalieri (TO), Italy; Scientific visits to Alpine sites (meteorology observing site at the Bessanese glacier and permafrost monitoring site at the Colle del Sommeiller) from 11 to 15/09/2017; organizer and scientific committees.

Training course:

- *Climate Data, Analysis and Modelling,* organized by Maynooth University, held in Maynooth Co. Kildare (Ireland), from 26/10/16 to 14/12/2016 for a total of 24 hours;

- *Writing skills for PhDs,* organized by Scuole di dottorato UniTO held in Turin on 22/04/2016 with a release of Certificate of attendance, for a total of 3 hours;

- *PhD Excellence Course in Metrology*, organized by INRiM and Politecnico di Torino, held in Turin, from 09 to 11/03/16 for a total of 12 hours;

- *Site measurement experiment,* organized by INRiM, held in Turin on 06/10/15 with a release of Certificate of attendance, for a total of 8 hours;

- *Statistical methodology for Agricultural Science. Statistical models and error handling* organized by SIA – Società Italiana di Agronomia, held in Turin from 9 to 11/02/2015, with a release of Certificate of attendance, for a total of 24 hours;

Seminar/workshop:

- *Metrology for High Mountains and Climate Observational Issues*, organized by INRiM, held in Moncalieri on 22/02/2017 for a total of 7 hours;

- *Giornata dedicate alla valorizzazione delle competenze dei dottori di ricerca e postdoc,* organized by Scuole di Dottorato dell'Università di Torino, held in Torino on 04/10/2016 for a total of 8 hours;

- *Soil moisture measurement – challenges in calibration and metrological traceability-* satellite event of the International conference MMC2016, held in Madrid, Spain, on 28/09/2016 for a total of 7 hours;

- *Limiti fisici ed economici della crescita*, organized by Seralmente CulturaNet held in Grugliasco on 19/04/2016 for a total of 3 hours;

- *Come cambia il clima dopo la COP21,* organized by Società Meteorologica Italiana, held in Castiglione Torinese, TO on 06/02/2016 for a total of 8 hours;

- *International year soil,* organized by Istituto per le Piante da Legno-CNR e l'Ambiente, held in Turin on 04/12/2015 for a total of 8 hours;

- *XIII Convegno AISSA*, organized by Associazione Italiana Societa' Scientifiche Agrarie, held in Turin from 26 to 28/11/2015 for a total of 16 hours;

- *Food Metrology,* organized by Istituto per le Protezione Sostenibile delle Piante-CNR and INRiM, held in Milan on 09/10/2015 for a total of 8 hours;

- *Metrology for Meteorology International Workshop* held in Turin on 23/04/2015, organized by INRiM in the framework of the European Project "MeteoMet – Metrology for Meteorology" for a total of 8 hours.

Publications

Sanna F., Fealy R. 2017. *An analysis of different methods to calculate potential evapotranspiration for a mid-latitude location* (submitted).

Sanna F., Deboli R., Calvo A. 2017. *Variability of tomato in protected environment in response to meteorological parameters* Plant, Soil and Environment (in press).

Merlone A., Sanna F., Bell S., Beges G., *et al.*, (2017): The MeteoMet2 Project– Highlights and Results. Measurement Science and Technologies 29 025802 17pp. DOI: 10.1088/1361-6501/aa99fc

Sanna F., Calvo A., Deboli R., Merlone A. 2017. Vineyard diseases detection: a case study on the influence of weather instruments calibration and positioning. Meteorological Applications, (*published on line*). DOI: 10.1002/met.1685

Merlone A., Lopardo G., Sanna F. Bell S., Benyon R., *et al.,* 2015. The MeteoMet project – Metrology for Meteorology: challenges and results. Meteorological Applications, 22 (S1): 820-829. DOI: 10.1002/met.1528

Merlone A., Musacchio C., Sanna F. 2015. The Metrology for Meteorology Conference: MMC 2014. Foreword on Meteorological Applications, 22 (S1): 817-819. DOI: 10.1002/met.1548

Sanna F., Cossu Q.A., Bellagarda S., Roggero G., Merlone A. 2014. Evaluation of EPI forecasting model with inclusion of uncertainty in input value and traceable calibration, Italian Journal of Agrometeorology, 12(3): 33-44

Conferences:

Oral:

- <u>Sanna F.</u>, Coppa G., Merlone A. *Involvement of INRiM in MeteoMet2 project*. International meetings ENV58 MeteoMet, held in Moncalieri (TO), Italy, from 11 to 15/09/2017

- <u>Pavlasek P.</u>, Merlone A., Sanna F., Coppa G., Duris S. *Performance of AWS and permafrost sensors with emphasis on their dynamic and self-heating*, International meetings ENV58 MeteoMet, held in Moncalieri (TO), Italy, from 11 to 15/09/2017

- <u>Sanna F.</u> and P. Miao. *Calibration and measurement uncertainty for soil moisture instruments in agriculture field and survey results*, Workshop on Soil moisture - international conference MMC2016, held in Madrid, Spain, on 28/09/2016

- <u>A. Merlone</u>, Coppa, G. Musacchio C., Sanna F., *et al. Metrology for Climate observation*, 16th international conference EMS_ECAC, held in Trieste, Italy, from 12 to 13/09/2016

- <u>Merlone A.</u>, Coppa G., Musacchio C., Sanna F., Paro L., Pogliotti P., Chiarle M., Nigrelli G., A. Viola, Vitale V. *Temperature metrology for the cryosphere*, International conference Tempmeko 2016, held in Zakopane (Poland), from 27/06 to 01/07/2016

- <u>Sanna F.</u>, Merlone A. *Metrology for meteorology*, International Meeting WP2 MeteoMet, held in Vilanova i la Geltru (Spain), from 02 to 04/05/2016

- <u>Sanna F.</u>, Coppa G., Merlone A. *Water thermal pollution metrology for biomarker detection*, International EMPIR international conference EMPIR Call2016,held in Torino, Italy, on 01/12/2015

- <u>Sanna F.</u>, Bellagarda S., Roggero G., Merlone A., 2014. *A metrological approach to evaluate epidemiological forecasting models* in 1st IMEKOFOODS 2014 Metrology Promoting Objective and Measurable Food Quality and Safety, Roma, 12-15 October 2014

Poster:

- Sanna F., Deboli R., Coppa G., Calvo A., *Experimental site for the meteorological measurements in protected cultivation of a tomato cultivar*. International conference Agriculture and Climate Change, held in Sitges, Spain, from 25 to 26/03/2017

- Sanna F., Deboli R., Calvo A., Merlone A. *Weather instruments calibration as influence on diseases prediction in viticulture*. International conference Agriculture and Climate Change, held in Sitges, Spain, from 25 to 26/03/2017

- Sanna F., Deboli R., Coppa G., Calvo A., Merlone A. *Experimental site for the measurement of meteorological parameters in protected cultivation*, International conference Metrology for Meteorology and Climate-2016, held in Madrid, Spain, from 26 to 29/09/2016

- A. Merlone, G. Coppa, G. Lopardo, C. Musacchio, A. Piccato, F. Sanna, *et al. Metrology for Climate observation*, international conference GCOS 2016, held in Amsterdam, from 02 to 05/03/2016

- Sanna F., Calvo A., Merlone A. *Mutual influences on meteorological measurements due to the weather stations positioning*. XVIII National Congress AIAM 2015, Agrometeorologia per Nutrire il pianeta, acqua, aria, suolo, piante, animali, San Michele all'Adige (TN) 9-11 June 2015