FELLOWSHIP SUMMARY REPORT

OECD Co-Operative Research Programme

Sustainable Agricultural and Food Systems

Development of a web-based framework for integrated water management in agriculture based on data assimilation and machine learning techniques.

Fellow: Silvio J. Gumiere
Host institution: Civil, Environmental and Architectural Engineering, University of Padova
Host Collaborator: Matteo Camporese
Fellowship Dates: 6 September 2021 to 24 January 2022

Consent Statement: I give consent for the posting of this report on the Cooperative Research Programme's website.

1. What were the objectives of the research project? Why is the research project important?

The main objective of this project is to provide a web-based framework for implementing data assimilation and machine learning techniques into hydrological models for agricultural water management. Such a web-based framework will help to predict the soil hydric status for irrigation and water management purposes. The specific objectives of this project are (i) to develop a machine learning (ML) framework for predicting soil hydric status in croplands, (ii) to compare the performance of ML and data assimilation in predicting soil hydric status for irrigation management, and (iii) to develop a web-based irrigation and water use platform.

Agriculture uses approximately 80% of water resources. Therefore, it is essential to use precision management practices and develop sustainable technologies and approaches to continually improve water management practices. Increasing agricultural biomass needs in response to population growth require the development of new agricultural practices as well as new predictive technologies for soil moisture status. Precision agriculture relies on the use of data from real-time sensors that provide information on weather, geographical positioning, yields, water status, soil fertility, and plant water stress, which is then integrated into predictive numerical models. The dynamics of water in a heterogeneous soil profile cannot be expressed as an average of the hydraulic properties of the soils. In the unsaturated soil zone, the dynamics of water are governed by a strongly nonlinear relationship between the matrix potential and hydraulic conductivity. In soils with heterogeneous profiles, this nonlinear dynamic of water is due to the instability caused by the different properties of the flow domains comprised of soil pores of various sizes, and this dynamic often deviates from the classic model based on Richard's equation. For a soil profile with high contrasts between two horizons, the difference in hydrodynamic parameters results in two subdomains that have completely different or even partially disconnected water flow dynamics.

2. Were the objectives of the fellowship achieved?

The first objective has been achieved, and the last two are partially achieved. More simulations are needed to fully test the performance of both ML-based and physics-based soil water dynamic models (objective ii). Additionally, when calibrating the physics-based model, the calibrated parameters have shown a strong dependence on the length of the dataset, and we are currently exploring this avenue. The web-based irrigation platform (objective iii) is online, and the forecasting module is partially working. We have experienced some connectivity problems with weather forecast websites. Work to correct this issue is in progress.

3. What were the major achievements of the fellowship? (up to three)

- **(i)** Development of an algorithm to predict soil matric potential at root zone of potato and cranberry crops.
- **(ii)** Development of a web-based irrigation management platform based on real-time soil matric potential measurements.

4. Will there be any follow-up work?

The follow-up work will consist of (i) finishing two publications submitted to scientific journals (Agricultural Water Management and Computers & Geosciences). One publication is about the calibration and validation of the developed model. The other publication presents the functionalities of the web-based platform. Both publications are intended to be submitted by September 2022.

This will likely be the start of collaboration between Laval University and the University of Padova beyond the activities associated with this fellowship. A new project about the ecohydrology of agricultural systems has been submitted in collaboration with the two universities.

5. How might the results of your research project be important for helping develop regional, national or international agro-food, fisheries or forestry policies and, or practices, or be beneficial for society?

Increasing agricultural biomass needs in response to population growth require the development of new agricultural practices and predictive technologies for soil moisture status. Precision agriculture relies on the use of data from real-time sensors that provide information on weather, geographical positioning, yields, water status, soil fertility, and plant water stress, which is then integrated into predictive numerical models. The dynamics of water in a heterogeneous soil profile cannot be expressed as an average of the hydraulic properties of the soils. Web-based integrated platforms can help growers manage irrigation more intelligently, limiting the impacts on the environment.

6. How was this research relevant to:

The objectives of the CRP: This research will strengthen the scientific knowledge and process models required for precision irrigation and water management in agricultural watersheds, helping producers, irrigation cooperatives, and policy-makers assess soil water status using a web-based platform.

The CRP research theme: The research focused on developing and improving soil water models that are useful for evaluating precision irrigation strategies to optimize agricultural water use for sustainable water management.

7. Satisfaction

Did your fellowship conform to your expectations: Yes, the fellowship exceeded my expectations.
Will the OECD Cooperative Research Programme fellowship directly or indirectly increase your career opportunities? Yes, the program has increased my career opportunities. It allowed for me to work with scientists in similar and complementary disciplines, share experiences on modelling approaches, and use the newest algorithms to solve real-life problems in agricultural water management.

Did you encounter any practical problems?
I did not encounter any problems at all.

8. Advertising the Cooperative Research Programme

How did you learn about the Cooperative Research Programme: I learned of the programme through a colleague and via the website.
What would you suggest to make it more "visible": I believe that the programme already has great visibility.
Are there any issues you would like to record: None.