proceedings

Abstract

From Gas Sensors to Artificial Neural Networks: A New Precision Farming Approach for Crop Coefficient Determination †

Francesco Tralli [1,*], Barbara Fabbri [1], Matteo Valt [2], Alessandro Drago [1] and Vincenzo Guidi [1]

1 Department of Physics and Earth Sciences, University of Ferrara, Via Saragat 1, 44122 Ferrara, Italy; barbara.fabbri@unife.it (B.F.); alessandro.drago@unife.it (A.D.); vincenzo.guidi@unife.it (V.G.)
2 MNF—Micro Nano Facility, Sensors and Devices Center, Bruno Kessler Foundation, Via Sommarive 18, 38123 Trento, Italy; mvalt@fbk.eu
* Correspondence: francesco.tralli@unife.it
† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: This study aims to utilize gaseous emissions from cultivation to predict the crop coefficient, an indirect measure of plant water stress. An array of chemiresistive gas sensors was used to collect the data, which were then processed by a simple artificial neural network algorithm. The results highlighted that the gas emissions from tomato crops can be used as a reliable indicator for determining the crop coefficient, allowing for more efficient and effective irrigation management. This research offers a potential solution to the growing issue of water scarcity in agriculture by providing a cost-effective and practical method for monitoring crop water status.

Keywords: crop coefficient; gas sensors; artificial neural network; water management

Citation: Tralli, F.; Fabbri, B.; Valt, M.; Drago, A.; Guidi, V. From Gas Sensors to Artificial Neural Networks: A New Precision Farming Approach for Crop Coefficient Determination. *Proceedings* **2024**, *97*, 91. https://doi.org/10.3390/proceedings2024097091

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 25 March 2024

1. Introduction

The agricultural sector is constantly looking for new sustainable ways to optimize crop yields and to efficiently manage water resources. The crop coefficient (evapotranspiration Kc) is an effective parameter to monitor the plant conditions. To date, predictive methods to estimate the Kc have relied on historical time series or on technical instruments, such as lysimeters, which have low accuracy, are time-consuming, require manual operations, and are not portable [1]. In recent years, the use of sensors in precision agriculture has emerged as a promising technology. In particular, an array of chemiresistive gas sensors based on semiconducting metal oxides (SMOX) would represent an effective low-cost and fully portable alternative, which can be controlled remotely in real time, and in principle, many prototypes can be spread all over the field to monitor different areas locally [2]. In this study, a new and efficient way of processing data from crops by coupling an artificial neural network (ANN) with data from gaseous emissions is presented. The aim is to predict the variation over time of the Kc of tomato, which is one of the main cultivated crops in Italy.

2. Materials and Methods

The apparatus was composed of 2 parts: the sensing system and the algorithm for the data analysis. The former was equipped with an array of 4 SMOX sensors in order to monitor emissions of plants during the various development stages, together with a relative humidity and a temperature sensor, and a camera with visible and near infrared filters, to obtain quantitative measures of the NDVI vegetation index. In addition, we had at our disposal other agronomic data, which form a compendium between the theoretical model and daily measurements of the main water parameters of the soil, the weather, the growth phase, and the actions taken by human operators in the field. The data of a 3-year measurement campaign were used and processed through an ANN, which was envisioned as a regression model, with a fully connected structure. As for the crop coefficient from tabulated data, we applied a Gaussian filter, paying attention that no local maxima were generated (which is not in line with a biological trend), and we used this as the reference value for network testing. The developed network consisted of an input layer of 9 neurons (one for each input feature), three hidden layers of 25, 25, and 10 neurons with ELU activation, and an output layer of only 1 neuron with RELU activation, with the crop coefficient being greater than zero. The algorithm was the Adam optimization of the well-known stochastic gradient descent, and the cost function was the root-mean-square error. The inputs were the daily averages of the 6 sensor signals, the day, the thermic sum, and the amount of water received by the crop (rainfall and watering). Training and test sets were divided at a ratio 8:2.

3. Discussion

The performance of the neural network against the crop coefficient is shown in Figure 1. The constructed algorithm showed promising results, indicating its potential for use in predicting crop yields and water usage more accurately. The development of an ANN capable of forecasting the crop coefficient using detections of plants' gaseous emissions represents a significant step forward in agricultural technology. However, there is still room for improvement, thus providing a more comprehensive view of the plants' physiological status, which could further enhance the model's accuracy. Further research in this area could lead to significant advances in sustainable agriculture practices, benefiting both farmers and the environment.

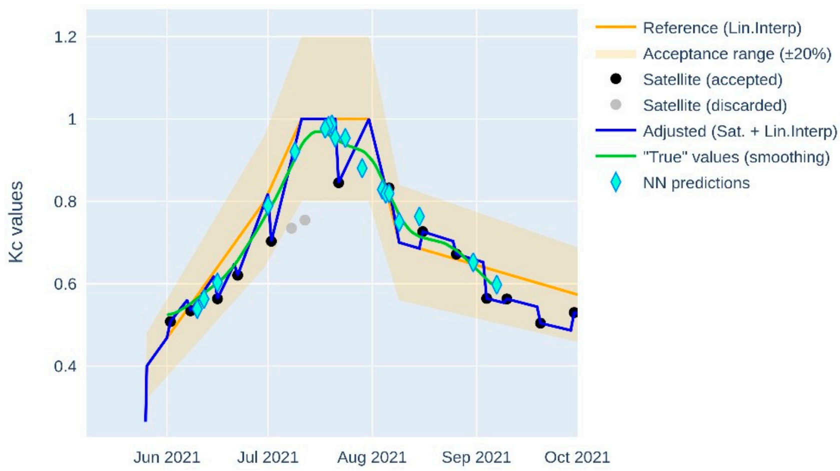

Figure 1. Test phase of the neural network (last two entries of the legend).

Author Contributions: Conceptualization, F.T. and B.F.; methodology, F.T.; software, A.D.; formal analysis, F.T.; investigation, M.V.; writing—original draft preparation, F.T.; writing—review and editing, B.F.; funding acquisition, V.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Programma Operativo Nazionale 2014–2020—Dottorati di ricerca su tematiche dell'innovazione e green—D.M. 10 agosto 2021, n. 1061.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: This work has been supported by the Canale Emiliano Romagnolo through the access to the POR-FESR 2014-2020 POSITIVE project's data taken from the Irriframe platform.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Han, X.; Wei, Z. Crop evapotranspiration prediction by considering dynamic change of crop coefficient and the precipitation effect in back-propagation neural network model. *J. Hydrol.* **2021**, *596*, 126104. [CrossRef]
2. Fabbri, B.; Valt, M. Correlation of gaseous emissions to water stress in tomato and maize crops: From field to laboratory and back. *Sens. Actuators B Chem.* **2020**, *303*, 127227. [CrossRef]