POSITIVE: UN PROGETTO DI IRRIGAZIONE INTELLIGENTE PER L'AGRICOLTURA 4.0

POSITIVE: A SMART IRRIGATION PROJECT FOR AGRICULTURE 4.0

Francesca Ventura[1], Marco Vignudelli[1], Giovanni Maria Poggi[2]*, Tommaso Letterio[3], Stefano Anconelli[3]

[1] DISTAL Dipartimento di Scienze e Tecnologie Agro-Alimentari, viale Fanin 44, 40127, Bologna (Italy)
[2] BiGeA Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Piazza di Porta S.Donato 1, 40127, Bologna (Italy)
[3]CER Consorzio per il Canale Emiliano-Romagnolo, via Masi 8, 40137, Bologna (Italy)
* giovannimaria.poggi2@unibo.it

Abstract
POSITIVE (Scalable Operational Protocols for precision agriculture) is a precision agriculture project for variable rate irrigation designed to improve the functionality of the IRRIFRAME system, the irrigation advice service of the Emilia-Romagna region. POSITIVE is based on satellite remote sensing, the use of vegetation indices for crops, IoT (Internet of Things) technologies, Big Data and 4.0 irrigation machinery. A central server manages the information flows and provides variable rate irrigation maps for farmers as final users. The system is public and free. In the first year of "IRRIFRAME plus" system experimentation (improved version of IRRIFRAME through POSITIVE machinery), at the experimental farm located in Mezzolara di Budrio (BO - Italy), promising results have been obtained for maize, with a WUE (Water Use Efficiency) going from 4.2 g l^{-1} (with standard IRRIFRAME service) to 5.2 g l^{-1}. For sparse crops, such as tomato and onion, results were not so satisfactory. The future years of experimentation will allow to improve the calibration of VI-crop coefficient (Kc) correlation in order to improve the response in condition of partial soil cover and wetting condition.

Parole chiave
Agricoltura di precisione, irrigazione rateo variabile, indici da satellite.
Keywords
Precision agriculture, variable rate irrigation, satellite indices

Introduction
Promoting Climate Change adaptation is one of the most important objectives of the 2014-2020 Rural Development Programs of European Union (European Commission, 2013). The POSITIVE Project (Scalable Operational Protocols for precision agriculture - http://www.progettopositive.it/nqcontent.cfm?a_id=19491) was financed by a POR-FESR 2018 call of the Emilia-Romagna Region, with the idea of creating a public support system for precision irrigation/fertirrigation at variable rate as an evolution of IRRIFRAME (www.irriframe.it) regional irrigation service developed by CER (Consorzio di bonifica per il Canale Emiliano Romagnolo). IRRIFRAME service performs soil water balance calculation taking into account plant development, atmospheric thermal regime, rainfall and evaporative demand, providing free irrigation advice to farmers who register their plots on the platform. POSITIVE strategic objective is to make actually available the great potential offered by current technologies (satellite remote sensing, IoT - Internet of Things, Big Data), often underutilized by final users due to their complexity, for precision agriculture. POSITIVE means having Protocols, that is, executive procedures and standard interfacing methods well defined. Protocols must be Operational, therefore concretely applicable, not reserved for contexts that require specialized skills, and Scalable, not limited to the single company or to the single individual experiment, but capable of being replicated in a broad context without technological limitations. The project involves public regional authority, land reclamation consortia, universities, and private stakeholders, such as farmers, agro-industrial companies, producers of irrigation equipment and technological solutions, policy makers of agricultural and environmental policies, all united by the urgent challenge of Climate Change. Aim of this work is to present the first year of results obtained using prescription maps for VRI (variable rate irrigation).

Materials and Methods
The first year of POSITIVE project experimentation (2019 agronomic season) was dedicated to the validation of the correlations between vegetation indices (VIs) and the main biophysical parameters that can be used in precision agriculture practices. In relation to the planned applications, it was decided to focus on the following parameters: Leaf Area Index (LAI), Canopy Chlorophyll Content (CCC), Leaf Chlorophyll Content (LCC), leaf water content (EWT) and crop coefficient (Kc). At CER "Acqua Campus" experimental farm, located in Mezzolara di Budrio (BO), three crops were studied: tomato, onion and corn. For each crop, two plots were evaluated: one not irrigated and one irrigated according to the calculation performed by IRRIFRAME. For each plot, based on the Sentinel-2 grid, an Elementary Surface Unit (ESU) was identified corresponding to a pixel of 20x20m. Within each ESU, at four Sentinel-2 flight during the season, the following biophysical parameters were assessed: phenological measurements (aimed at calibrating the Kc of IRRIFRAME

model), average crop height, LAI using a ceptometer, SPAD (Soil and Plant Analyzer Development) measurements for LCC estimation. For each survey date, satellite images were downloaded and pre-processed. Through the algebraic combination of Sentinel-2 multispectral bands, more than 100 vegetation indices have been calculated, and among these, were selected those able to better estimate the chosen parameters. DISTAL (Dipartimento di Scienze e Tecnologie Agro-Alimentari - Università di Bologna) performed the measurement of the biophysical parameters under study, while CRAST (Centro di Ricerca Analisi geoSpaziale e Telerilevamento, Università Cattolica del Sacro Cuore) performed the calculation and validation of the VIs (Amaducci et al., 2020). The best indices for correcting irrigation recommendations provided by IRRIFRAME, regardless of the crop, were, following the validations carried out by CRAST, the Enhanced Vegetation Index (EVI) and the Normalized Difference Vegetation Index (NDVI). The POSITIVE system operates by means of the POSITIVE SERVER (developed and hosted by CIDEA - Centro Interdipartimentale Energia Ambiente, Università degli Studi di Parma) which manages all the incoming and outgoing data flows of the various subsystems (fig.1). The ARPAE (Agenzia regionale per la prevenzione, l'ambiente e l'energia dell' Emilia-Romagna) server Sat Service downloads and processes the data of Sentinel-2 satellite, generating the digital maps of NDVI and EVI vegetation indices. POSITIVE SERVER receives the indices maps, processes them and sends them to the IRRIFRAME/IRRINET subsystem which integrates the value of the indices and, based on them, generates a new enhanced Kc. This new value of crop coefficient is assimilated within the calculation of the water balance, to produce variable rate irrigation prescription maps. Specifically, the average EVI value calculated for the plot is used to adjust the Kc generated by IRRIFRAME for that plot, while the NDVI map is used for spatialization, i.e. to generate the variable rate irrigation within the same plot. The maps are time-dynamic because updated at every satellite overflight. The POSITIVE SERVER also integrates a further series of soil moisture data from a ground sensors network (Terra & Acquatech-Università di Ferrara, IMEM-CNR) to improve the definition of the actual Kc. The irrigation advice is returned to the POSITIVE SERVER which sends to the 4.0 irrigation machinery, equipped with a receiving control unit and actuators able to perform irrigation at variable rates (OCMIS Irrigazione S.p.A.). A webGIS (Centro Ricerche Produzioni Animali- CRPA) to manage irrigation called SAMS (Smart Agronomic Management System) completes the POSITIVE pack available to the farmers.

In 2020, the second year of the project, the functionality tests of the system were carried out with variable rate irrigation applied on three main open field crops: corn, onion, and tomato, at "Aqua Campus" CER experimental farm. For each crop two plots were set, one managed with the conventional IRRIFRAME method, already available for the farmers in Emilia-Romagna, the other using the "IRRIFRAME plus" irrigation advice, improved by POSITIVE SERVER.

Results and Discussion

Tests were carried out by comparing field trials irrigated by the conventional IRRIFRAME (*CIf*) method vs the POSITIVE one (from now called "IRRIFRAME plus", *If*+). Table 1 summarizes water consumption, yield and Water Use Efficiency (WUE) achieved for year 2020 in CER experimental farm. As regards maize, a good result can be observed in terms of water savings obtained through the integration of IRRIFRAME service with satellite indices. WUE, thanks to POSITIVE system, in fact goes from 4.2 g l^{-1} to 5.2 g l^{-1}, with an irrigation volume of 190 and 150 mm, respectively. As regards to onion and tomato, on the other hand, going from IRRIFRAME system to POSITIVE system, in the first case has no appreciable difference in terms of irrigation volumes and WUE, while in the second case the IRRIFRAME system seems to work better than POSITIVE, assessing a smaller irrigation volume that lead to a greater WUE.

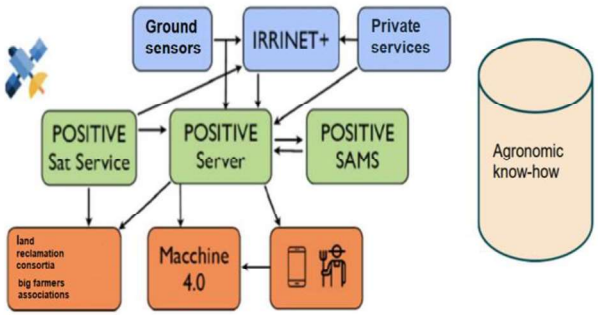

Fig. 1. Positive system architecture (fonte www.progettopositive.it)
Fig. 1. Architettura del Sistema POSITIVE (source www.progettopositive.it)

Tab. 1. Apporti idrici, rese ed efficienza d'uso dell'acqua per le colture della sperimentazione 2020.
Tab. 1. Water intake, yield and Water Use Efficiency for 2020 experimental crops.

Crop	Irrigation mm	Rainfall mm	Yield t ha^{-1}	WUE g l^{-1}
Mais *CIf.*	190	219.4	17.2	4.2
Mais *If*+	150	219.4	19.4	5.2
Onion *CIf.*	289	206.6	62.4	1.3
Onion *If*+	282	206.6	63.6	1.3
Tomato *CIf.*	240	180	71.3	17
Tomato *If*+	263	180	44.8	10.3

Conclusions

The first year of experimentation with IRRIFRAME plus protocol (2020 agronomic season) provide still partial results with irrigations at a prototypical level, however the system designed by the POSITIVE project allows a more advanced and efficient use of irrigation even at this level. The application at regional scale of the system means that even a very small percentage reduction in irrigation applied to crops becomes a large amount of water saved, and has important effects especially in case of water scarcity, as often happens in recent years. Furthermore, POSITIVE system offers a free service available to all farmers in the region. Those who do not have the machines and technology necessary for the implementation of a VRI, can still take advantage of a more accurate Kc, resulting from the adjustment through EVI. On the other hand, those who have the instruments can realize a VRI by spatializing the Kc using the NDVI map. The results achieved so far are clearly preliminary, obtained from a single year of agronomic experimentation in a single experimental farm. Nevertheless, these first results allow us to draw some interesting conclusions. For maize, the POSITIVE system appears to be very promising. This could be an excellent opportunity to improve the efficiency of water use in the regional agricultural sector, since corn is a crop of central importance in Emilia-Romagna, and it has a high irrigation demand. The system, on the other hand, shows some critical issues regarding crops such as onion and tomato. This type of crops exhibits a very different behavior than maize, in terms of land cover rates. Furthermore, in the specific case of the tomato, at the moment of veraison, the relative prevalence of the vegetation on the red berry can represent a further source of disturbance. For these reasons, the calibration of Kc with the integration of satellite indices on these crops will certainly require further efforts. The ambitious goal of the POSITIVE project is to implement a homogeneous system, capable of providing reliable data on a wide variety of crops, so as to offer a regional service for the largest possible number of farmers in Emilia-Romagna, in order to translate the water savings of individual farmers, in an important rationalization of the use of water resources at the regional level. In literature, NDVI and EVI are considered to be reliable indices to calibrate crop coefficients. For example, Togliatti et al. (2019) report their use to perform various types of observations on crops, such as phytosanitary status, vigor and phase of the life cycle. NDVI is in fact widely considered an indicator of photosynthetic capacity, and its use in conjunction with EVI has the purpose of reducing the tendency of NDVI to saturate for high values of LAI (Cai et al., 2018). The fact that the most satisfactory results have been obtained on maize is not surprising. In 2016, Wagle et al. found that EVI can track seasonal variations for Light Use Efficiency and Water Use Efficiency in corn, so that EVI can be used to parameterize these two quantities, in order to make predictions on crop evapotranspiration. Moreover, Shao et al. (2021) obtained a high resolution spatial distribution for corn Kc, based on EVI. This result starts from the consideration that Kc map can be obtained starting from the spatial distribution of LAI. LAI map is in turn obtained from EVI values, which showed a high correlation with LAI ($R = 0.81$).

As regards onion and tomato, evidence has already emerged in the literature regarding a more difficult estimation of biophysical parameters related to Kc (for example LAI) from Sentinel-2 imagery, due to a scarce and dispersed soil cover, which results in a strong influence of bare soil (Pasqualotto et al., 2019). Nevertheless, promising remote sensing applications linked to the estimation of biophysical parameters, Kc and WUE for this type of crops are starting to emerge (Marino et al., 2014), also specifically through the use of Sentinel-2 satellite images (Kaplan et al., 2021), demonstrating the possibility of improving the POSITIVE system in the coming years of experimentation.

Given these considerations, POSITIVE has produced interesting and promising results, especially considering that they are the result of a single and preliminary year of agronomic experimentation of IRRIFRAME plus system, in a single experimentation site.

Partnership

- Partner Lab: CIDEA Università di Parma, CRAST Università di Piacenza, CER Canale Emiliano Romagnolo, Terra&Acqua Tech Università di Ferrara, CRPA (Centro Ricerche Produzioni Animali)
- Associated Partners: IMEM-CNR, Dip. Scienze e Tecnologie Agro-Alimentari DISTAL UniBO, ARPAE, Az. Agr. Stuard
- Private companies: APOFruit, Mutti, Casella, OCMIS irrigazione S.p.A., SIME, WINET, Horta, DINAMICA, OI Pomodoro, ANBI-ER, AMIS, Consorzio Agrario Parma
- Collaborators: Lepida

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