Enabling variable rate sprinkler irrigation of open field crops

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Introduction

Climate change and the need to prevent yield losses due to drought periods are driving an increasing use of irrigation in agriculture. Meanwhile, agriculture is required to become more efficient in its water footprint, given the competing and equally relevant civil and industrial uses. In water demanding open field crops (e.g., tomato, corn, etc.) Precision Irrigation (PI) [1] has shown the potential to significantly decrease the amount of water required by the crop across the growth season, if driven by a suitable Decision Support System (DSS) incorporating adequate soil, crop, weather, and agronomic knowledge. The potential for water saving ranges from a few % to 50%, in a number of case studies investigated worldwide [1] as well as in Northern Italy [2], and is typically assumed to be above 20%.

When within-field soil spatial variability is significant, or spatially varied management operations are adopted, Variable Rate Irrigation (VRI) can provide further benefit [3] in terms of yield and water use efficiency. The added value of VRI vs. PI in terms of input water reduction is less well quantified, but it is typically estimated in the range 5-10% [4]. Clearly, even small benefits in individual farms would accrue into large and significant water saving or reduced irrigation infrastructure investment by water reclamation consortia and local admnistrations. Unfortunately, the higher cost and operational complexity of equipment suitable for VRI are deterring farmers from their broad adoption. Indeed, sprinkler irrigation covers a significant fraction of irrigated land worldwide (above 60% in Europe and above 40% in Northern America) [5]. Techniques enabling automatic monitoring, planning and control of machines equipped with VRI capabilities, including sprinkler-based machines, can have therefore a significant impact toward water use efficiency and sustainability.

Objectives

Site-specific VRI sprinkler irrigation systems are classified into speed control systems and zone or nozzle control systems [4,6]. In speed control systems, water application depth is changed by varying the speed of the self-propelled sprinkler. Hence, these systems enable differential irrigation in rectangular segments or triangular pie-shaped areas, with linear move or center pivot sprinkler systems, respectively. In zone control systems, the irrigator is equipped with controlled valves or nozzles enabling also different amount of water applied along the length of the irrigation bar. Even though zone control systems offer a higher potential for water and energy optimization, their adoption has been very limited [4,6].

The purpose of this contribution is to highlight the obstacles hindering deployment of VRI in many farms and some current trends toward VRI in Northern Italy, with a special focus on Emilia-Romagna, where in the last few years we have contributed to the design of system solutions enabling PI and VRI across the whole irrigated area of the region. Being Emilia-Romagna one of the Italian regions at the forefront of agricultural production and innovation in irrigation, as well as a leading district of sprinkler irrigation equipment manufacturers, we assume that this contribution can be relevant to other areas and countries.

Materials and methods

Several interviews, focus groups, meetings and polls with stakeholders (including farmers, agronomists and consultant experts, public administrators, water reclamation consortia, equipment manufacturers) have been conducted in the course of project POSITIVE (www.progettopositive.it) in order to understand the priorities and the obstacles toward a full exploitation of PI and VRI in Emilia-Romagna agriculture. To our knowledge (including private communications with equipment manufacturers), virtually all sprinkler irrigation equipment deployed at farms in Northern Italy do not include controllable nozzles, and thus are not suitable for zone-based operation. However, since 2020 many new or revamped sprinkler systems (mostly hose reels equipped with spray booms or sprinklers and a few pivot systems) installed in the same area are equipped with control units enabling VRI via speed control.

A key strategy to reap the potential benefits of VRI is (1) to provide farmers for all plots with a tailored, optimized DSS advice integrated in a dynamic VRI prescription taking into account all the peculiarities of the crop and plot, and (2) to automatically program (if feasible) the VRI equipment available on site so as to apply the prescription according to the offered variability features, thereby minimizing the effort required to the farmer to directly program the machine for each irrigation.

Developing an appropriate VRI prescription requires assessment of the actual variability in the field. In order to enable VRI across the whole Emilia-Romagna region, a protocol has been developed to include vegetation information in the IRRIFRAME DSS based on remote sensing data [8]. The protocol relies on the products (multispectral images) provided by Sentinel-2 satellites at 10m x 10m resolution. Moreover, a procedure has been designed to directly feed with the VRI prescription both linear move and center pivot machines equipped which offer suitable web APIs. Further ongoing work deals with rain gun sprinklers mounted on a towed trolley, a type of equipment largely used thanks to its relatively low cost and easy deployment in multiple sites.

Results

At each satellite transit (every 5-3 days based on locations of registered fields) products are retrieved for large areas via the Copernicus Hub API, and the area of interest for each plot segmented. Data are verified for correctness and update. Cleaning operations are applied for outlier removal and to cope with presence of artifacts nearby or within the plot and edge effects. Moreover, a coordinate system transformation is applied to align satellite data with the reference frame adopted by the DSS. Plot-specific NDVI and EVI maps at 10m x 10m resolution are then computed from the cleaned images, formatted, and uploaded in the IRRIFRAME DSS.

To enable machine-to-machine operation, the VRI prescription map must be transformed into an irrigation plan suitable for the available equipment, which - as discussed above - implements VRI using speed control. In the designed VRI advisory service [8], the DSS knows the type of irrigation machine associated by the farmer to each plot, and the abstract *VRI prescription map* (defined in terms of water depth to be delivered in each 10 m x 10 m cell) is automatically transformed into a *VRI application map* articulated in rectangular stripes [9] or triangular pie slices whose size is determined by minimum and step values dictated by the machine. The VRI application map is eventually sent to the irrigation equipment for each registered plot according to a time schedule determined by the irrigation advisory service. The ensuing application map therefore incorporates all the agronomic knowledge required for a valid PI prescription as well as the remote or local sensing information needed for VRI, to the extent allowed by the available equipment.

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References

1. Sadler EJ, Evans EG, Stone KC, et al. (2005) Opportunities for conservation with precision irrigation. Journal of Soil and Water Conservation 60: 371–379.
2. Mannini P, Genovesi R, Letterio T, (2013) IRRINET: large scale DSS application for on-farm irrigation scheduling. Procedia Environmental Sciences 19: 823–829.
3. Hedley CB, Yule IJ, (2009) Soil water status mapping and two variable-rate irrigation scenarios. Precision Agriculture 10: 342–355.
4. Evans RG, LaRue J, Stone KC, et al. (2013) Adoption of site-specific variable rate sprinkler irrigation systems. Irrigation Science 31: 871–887.
5. Pereira LS, Goncalves LM (2018) Surface irrigation. Oxford Research Encyclopedias, Environmental Science, Oxford University Press, 1–38.
6. O'Shaughnessy SA, Evett SR, Colaizzi PD, et al. (2019) Identifying advantages and disadvantages of variable rate irrigation: An updated review. Applied Engineering in Agriculture 35: 837–852.
7. Lo T, Heeren DM, Martin DL, et al. (2016) Pumpage reduction by using variable-rate irrigation to mine undepleted soil water. Transactions of the ASABE 59: 1285–1298.
8. Amoretti M, Lodi Rizzini D, Penzotti G, et al. (2020) A Scalable Distributed System for Precision Irrigation. IEEE Int. Conf. on Smart Computing, SMARTCOMP 2020, 338–343.
9. Aleotti J, Amoretti M, Nicoli A, et al. (2018) A Smart Precision-Agriculture Platform for Linear Irrigation Systems. 26th Int. Conf. on Software, Telecomm. and Computer Networks, SoftCOM 2018, 1–6.