Testing automatic irrigation in paddy rice fields: lesson learned in a northern Italy rice farm

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ABSTRACT

Rice is one of the major staple food crops in the world. In Europe, Italy is the main rice producer, with almost all of the production concentrated in the north-east of the country. Traditionally rice is grown in fields flooded from before seeding to close to harvest. This water management technique requires a huge labor for farmers who have to manually adjust inlet and outlet gates in order to maintain a constant ponding water level in the fields. A new water soft-path strategy based on the introduction of automatic water flow rate regulation systems is under investigation in a rice farm of about 40 ha located south of Milan, in northern Italy. The general purpose of the experimental activity is: (i) to test their reliability in a traditional rice context, and (ii) to assess their environmental and economic sustainability. The installed instrumentation is constituted by four PikoGate® automatic gates positioned in strategic points of the farm irrigation canal network and Ferit® water level sensors installed in five groups of fields. To date, automatic gates and water level sensors have been installed and tested, and a new irrigation algorithm has been implemented to allow the automatic management of a predetermined ponding water level in the fields, which may change in time based on site-specific conditions. Results achieved so far will be presented describing the adopted automatic solutions and their responsiveness to the site-specific conditions.

Keywords: irrigation management, automatic system for irrigation, remote-controlled gate, water level sensor, real-time monitoring.

1. INTRODUCTION

Italy is the leading rice producer in Europe, accounting for more than half of the total production of this high-quality crop (Masseroni et al., 2018; Facchi et al., 2018). Typically, rice is grown in fields that have been flooded from planting to pre-harvest, and this traditional irrigation technique (i.e. continuous submersion) is considered an important water resource sink. This technique dominates in most areas and is characterized by low irrigation efficiencies (Cesari de Maria et al. 2016). Additionally, the irrigation management requires a lot of human labor because, to date, it is still based on maintaining a predetermined water level in the paddies through the manual regulation of the irrigation inflow rate (Masseroni et al., 2017).

In this context, the application of flexible, automated regulation devices for managing irrigation in paddy fields appears as a viable solution that can be exploited to (i) increase water use efficiency of rice cultivation and (ii) decrease efforts dedicated to the irrigation flow rate regulation at field and farm scale, without changing the traditional irrigation flooding practices. More in detail, hydraulic infrastructures based on a

system of coordinated automatic gates located in strategic points of the farm irrigation network can allow to maintain optimal water levels within the farm channels, providing more consistent and reliable irrigation fluxes through at the farm service points.
In light of the developments on the application of automation systems in irrigation, Lombardy region (which is the most important region in Italy both from the industrial and agricultural point of view, with over 7000 km^2 of irrigated surfaces) is promoting bottom–up initiatives in the form of 'information and pilot project actions' with the main purpose to demonstrate the potential of innovative irrigation management systems at the farm and district scales, fostering the collective sharing of the modernization objectives. Therefore, in this work we examine and discuss the results obtained in one of these demonstration projects, consisting in the first example in Europe of a transition to a flexible and remote-controlled management of irrigation in a paddy rice farm. In particular, the new technological solutions adopted for a coordinated flow rate regulation will be described and the algorithm implemented for maintaining a predetermined ponding water level in the fields according to on site-specific conditions will be presented.

2. THE CASE STUDY

The flexible and remote-controlled system of gates has been installed and tested in the 'Cascina Ca' Granda Milano' which is a paddy rice farm (40 ha in size) located in south Milan and consisting of 10 fields of about 4 ha each, on average (Fig. 1).

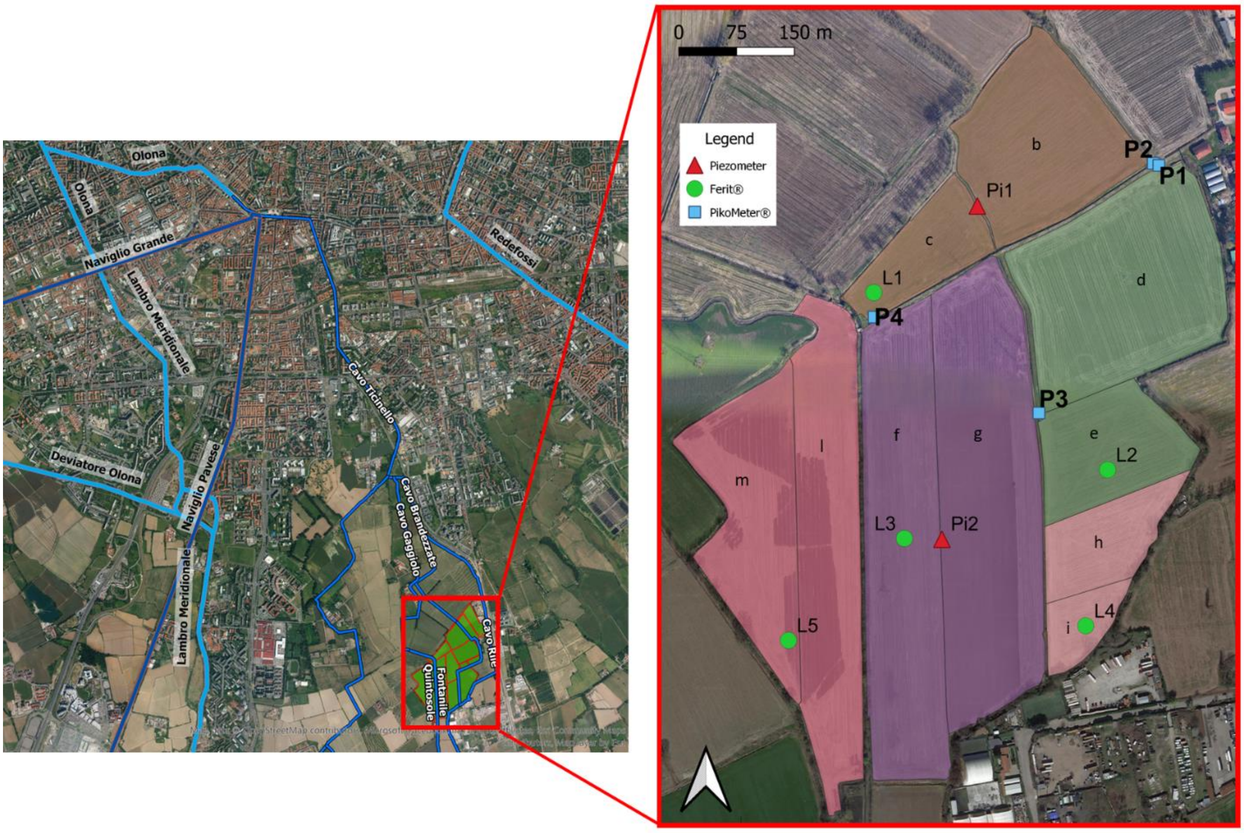

Fig.1. Cascina Ca' Granda Milano rice farm. In the picture, the field subdivision in blocks and the position of the instrumentation is shown.

The fields are characterized by a toposequence (from north to south) that facilitates the watering procedures. More in detail, the fields are subdivided in five different blocks (i.e. *bc, de, hi, fg, lm*) which are characterized by a single water flow entry point. For instance, in the block *bc* the only inlet point is located in *b*. From *b* the water flows in *c* since it is topographically more depressed than *b*. According to the toposequence, the fields are irrigated as follow: block *bc* is submerged first, then follows the block *de,* as third the block *hi* and then the block *fg,* finally the block *lm.*

All fields have been seeded with rice and the adopted irrigation practice is the continuous flooding. In particular, rice is seeded in dry soil at the end of April and the fields are flooded when rice is approximately around the three-leaf stage (i.e. about one month after the seeding). The harvesting is typically planned in mid-September, whereas the water into the fields is drained at the end of August. The nominal flow rate delivered to the farm from the irrigation consortium is about 250 l/s in continuous during the irrigation season (i.e. from April to September). The water is delivered to the farm from north, i.e. upstream of the gates P1 and P2. No drainage points are present in the fields, whereas only one farm drainage point is activated in case of overflows.

3. INSTRUMENTATION INSTALLED

In strategic points of the farm canals (P1-4 in Fig. 1) four automatic and remote-controlled PikoMeter® gates (Rubicon Water, AU) were installed (Fig. 2a) for managing watering into the fields. The PikoMeter® are constituted by three main components i.e. an ultrasonic level sensor inside the frame of the gate, a flow meter and a steel gate. The flow meter measures flow rate across the gate; hence the volume integrating the flow rates during irrigation. This meter consists of a cylindrical box with 20 ultrasonic transducers across 5 planes of measurement. The flow meter can measure with an accuracy of +/- 2.5% for velocities greater than 25 mm/s. The water level obtained by the ultrasonic level sensor is measured with an accuracy of 0.5 mm and a resolution of 0.1 mm. The gates are equipped with a adaptative control software that allows managing their operation through three different setpoint levels of configuration i.e. maintaining a fixed (i) gate opening, (ii) upstream water level (U/S) or (iii) downstream flowrate (D/S).

In addition to the PikoMeter® five ultrasonic water level sensors (Ferit®) were installed in each fields block (Fig. 2b). The Ferit® position in the field was decided according to the farmer's experience i.e. where its measurement would be representative of the water level in the block (L1-L5 in Fig. 1).

a b

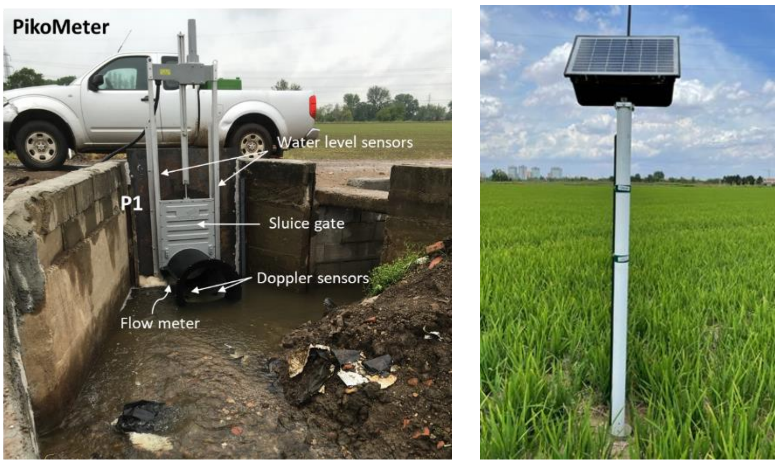

Fig.2 – Instruments installed in the experimental field of Cascina Ca' Granda Milano. (a) PikoMeter® gate, (b) Ferit® water level sensor.

Each Ferit® continuously monitors the water level in paddy field and sends the information to a master control system (FarmConnect® Gateway – Rubicon Water AU) that provides instructions, through a tailored algorithm developed in the context of this experimentation, to maneuver the gates as required to maintain a predetermined water level in the field. Finally, the FarmConnect® Gateway provides an interface between cellular networks and PikoMeter® and Ferit®. This interface uses the Telstra NextG protocol to routinely upload the data [through a global system for mobile (GSM) connection] to a Host Server for remote monitoring and control.

4. GATE CONTROL ALGORITHM

A tailored gate control algorithm written in Python 3 and running on PythonAnywhere® environment was implemented to provide instructions to maneuvering the PikoMeter® gates from information monitored by Ferit® sensors. The algorithm was able to send HTTP requests to the "Rubicon Site Operations" Application Programming Interface (API), this latter based on RESTful architectural style. The algorithm architecture is presented in Fig. 3 and briefly described in the following.

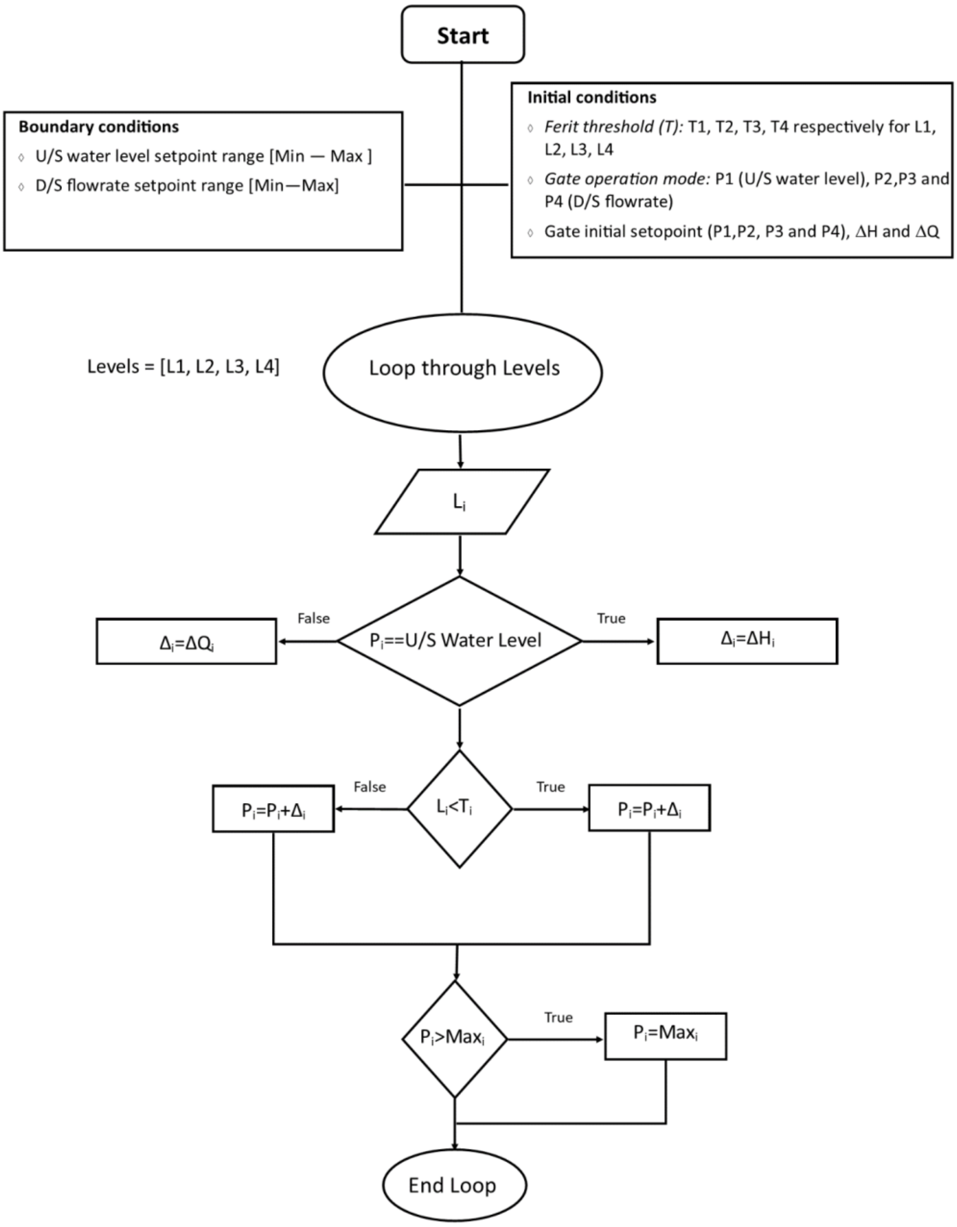

Fig. 3-Algorithm architecture.

At the beginning, P1, P2 and P4 are close, whereas P3 is open. P1 works for maintaining a fixed upstream water level, while P2, P3 and P4 a fixed flowrate. An optimal water level that would be maintained into the fields is chosen before irrigation (hereafter threshold - T) and compared with the measurements performed by the Ferit® sensors.

The farm canal upstream of P1 and P2 fills up when the water is delivered by the irrigation consortium, and once a suitable level is reached, it enters into the block *bc*. Until the water level in the first block is less than the threshold, the P1 U/S water level setpoint increases of 5 cm at a time (ΔH) up to the maximum allowed value. If the water into the field exceeds the threshold (with a tolerance of about 10 mm), the P1 U/S water level setpoint decreases of ΔH up to the minimum allowed value. This control is done with a time scheduling of 3 min. During the maintenance phase of the U/S water level, water excess from P1 is released downstream in the block *de.* Once the water level registered by L2 reaches the threshold, the P2 is opened. In particular, if the water level registered by L2 exceeds the threshold, the D/S flowrate setpoint of P2 is increased of 1 l/s at a time (ΔQ) up to the maximum allowed value, while if the water level measured by L2 is less than the threshold, the D/S flowrate setpoint of P2 is decreased up to the minimum allowed value. Downstream P2, the water flows toward block *hi.* In this case the gate (P3) is already opened and the water enters into the field *h* and then *i*. Once the water level registered by L4 reaches the threshold, the P3 is closed. More in detail, if the water level registered by L4 exceeds the threshold, the D/S flowrate setpoint of P3 is decreased of ΔQ up to the minimum allowed value, while if the water level measured by L4 is less than the threshold, the D/S flowrate setpoint of P3 is increased up to the maximum allowed value. After the submersion of *hi*, it is the turn of *fg* block. In this case, when the water level registered by L3 reaches the threshold, the P4 is opened and the water flows in the last block *lm*. The submersion phase of *fg* follows the same philosophy of that applied to submerge the block *de*. Ferit® L5, located in the last block, notifies (through an alarm) potential irrigation problems as, or even before, they occur.

5. RESULTS AND DISCUSSION

The effect of the gate control algorithm on the water level inside the fields is shown in Fig. 4, where the evolution of water level in the block *bc* (L1) is reported for a brief period of time (about 12 hours).

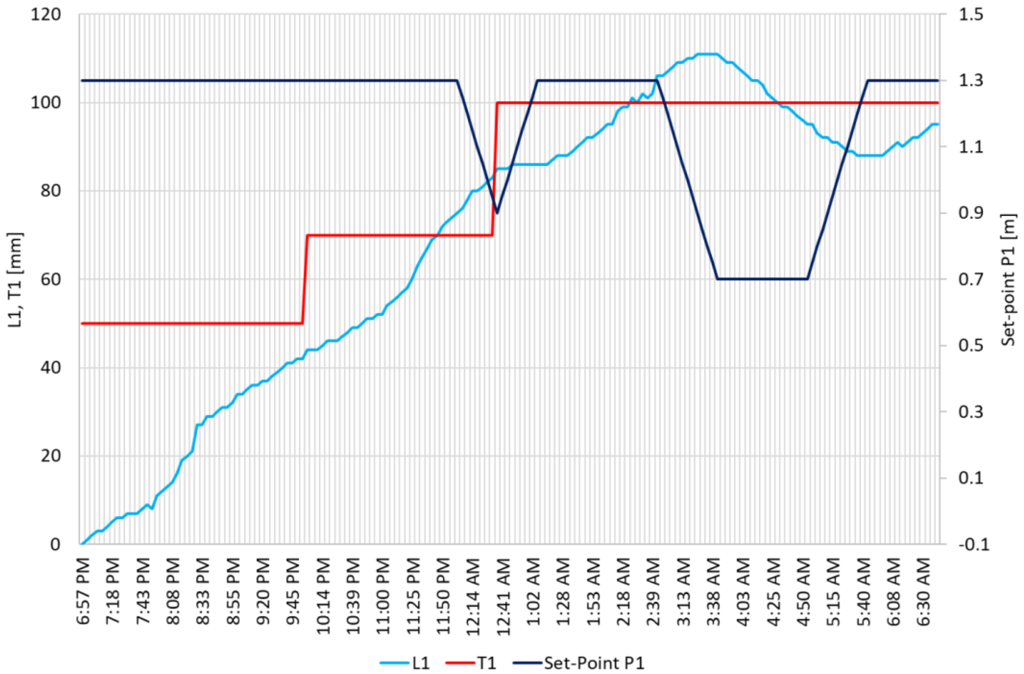

Fig. 4 – Time evolution of (i) water level into the block (bc) (L1), (i) gate setpoint (P1) and (iii) water level threshold (T1).

In this example of flow regulation, the water level threshold (T1) was set at about 50 mm for the first 3 hours (from 7:00 PM to 10:00 PM), 70 mm for the next 2 hours (from 10:00 PM to 12:00 AM) and finally at 100 mm. After the algorithm run, the gate setpoint (P1) rapidly increased up to the maximum value set up in the algorithm (1.3 m) until the water level in the field resulted in less than T1. At about 11:25 PM, the water level L1 reached the threshold T1 (50 mm) and the gate P1 automatically decreased its setpoint up to about 0.9 m. Water level into the field stopped to increase for some instant of time, then the T1 was increased at 100 mm and the gate responded increasing its setpoint up to the maximum allowed value (1.3 m). The water level into the field increased up to the new threshold (at about 2.39 AM) and then decreased.

As a result of this algorithm configuration, a lag-time has to be taken into consideration before that the water level into the field changes its pattern as a consequence of the modification of setpoint value. In fact, if we pay attention on the trend of L1 just after the modification of the gate setpoint (P1) occurred at about 2.39 PM, we can observe that the water level still increases for about half an hour and then decreases. This behavior is due to the fact that water needs of a time to flow from the inlet point of the field to the end of the field (where the Ferit® sensor is installed), and a too large range of allowed gate setpoints can cause wide fluctuations of water levels into the field. For instance, in the right part of Fig. 4 is evidenced as the water level oscillates of about +/- 10 mm around the threshold.

6. CONCLUSIVE REMARKS

In this work an innovative automatic system designed to support the traditional rice irrigation was presented. The system is composed by four PikoMeter® gates for automatic and remote-controlled flow regulation in the farm canals and five Ferit® sensors for the real-time monitoring of water levels into the fields. A new algorithm was implemented (run through an API interface) to create a connection (currently non-existent) between water level measurements into the fields and gate maneuvering. In general, the automatic irrigation system was robust and did not reveal any mechanical malfunctioning during the examined irrigation seasons. The algorithm resulted stable and guaranteed a robust and continuous connection between Ferit® sensors and PikoMeter® gates. One of the lessons learned during the experimentation is that the way to change the gate setpoints should be improved. The change should be proportional to the water level registered by the Ferit®, without waiting to reach a certain threshold. This might limit the oscillation of the water level in the field around the threshold, decreasing the number of gate maneuvering.

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