Evaluating economic sustainability of the first automatic system for paddy irrigation in Europe

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Summary
Italy is the leading rice producer in Europe, accounting for more than half of the total high-quality production of this crop. Rice is traditionally grown in fields that remain flooded starting with crop establishment until close to harvest, and this traditional irrigation technique (i.e., continuous submergence) is recognised as an important water resource sink (almost 40% of the irrigation water available worldwide is used for paddy areas). Meanwhile, the water management in rice areas requires a high level of labour because it is based on maintaining a predetermined water height in paddy fields and because the regulation of input and output flow is typically operated manually by the farmer. This study aims to evaluate the economical sustainability of adopting automatic and remote-controlled systems for irrigation of paddy fields. The results show that the investment is affordable for Italian farmers, it amount on average at about 650 € hectare^{-1} and it is repaid in about 15 year.

1. Introduction
Rice is a staple crop for more than half the world's population. Approximately 90% of world rice production is grown in Asia, while the quantities produced in Europe are relatively limited (approximately 2 million tons). Italy, with more than half of the total European rice production, is the first producer of the old continent, while Spain, Greece, Portugal and France appear in the top five producers providing about 30%, 10%, 5% and 3% of the total European rice production, respectively (EUROSTAT 2013, ISTAT 2009). The most important rice-growing area in Italy is a portion of the Padana plain located to the east of Ticino river, straddling the regions of Lombardy and Piedmont in northern Italy (more than 200.000 hectares, 92% of the Italian rice surface). Although the main objective of the rice farms is productive, areas in which the prevailing crop is rice create a peculiar agro-ecosystem characterized by the presence of water in the fields for several months each year (Masseroni et al. 2017b). The prolonged presence and circulation of water, due to continuous flooding of fields from wet-sowing until close to harvest, represents a distinguishing feature of these rice areas, some of which have also been included in the European ecological network NATURA 2000 and on the official list of the European Special Protected Areas (Habitat Directive, 92/43/EEC). However, the traditional irrigation technique, based on continuous flooding during the growing season, still dominates in most areas (for example, in 85% of the northern Italy rice area) and is characterized by very low irrigation efficiencies and a high level labor requirement performed by workers (named in Italian "acquaioli"), which combine rich hands-on experience and local traditional knowledge. Although there are no accurate

literature measurements related to the time that farmers spend for irrigation management of their fields, it may be estimated that a significant fraction of the working day during the agricultural season is dedicated to the manual control and adjustment of the gates to maintain the correct levels of water inside the paddy fields. This fraction of the day can vary considerably depending on the extension of the cultivated area, the growing period and the fragmentation of the rice-growing property. Consequently, these features affect the fixed costs of individual companies, primarily for the assumption of seasonal workers' time that is dedicated full-time or part-time to irrigation management. The implementation of reliable automatic irrigation systems which support the manual operations of these workers is strictly encouraged especially by farmers in order to ensure a more rational allocation of water in the fields according crop conditions.
The purpose of this study concerns the evaluation economic sustainability of the first automatic and remote controlled gate prototype (already described in its hardware and software components in Masseroni et al. (2017a)) originally designed for furrow, basin or border irrigations and rearranged for a traditional rice irrigation in Europe and tested with a pilot project in Italy.

2. Materials and Methods

The pilot project was carried out in the agricultural season 2016 (from April to September) in a paddy field of the Cerino farm (45° 08' 00.00'' N; 8° 44' 42.15'' E) located in Semiana (PV). The system was composed by one BayDrive® gate of 70cm width for automatic and remote-controlled flow regulation, one FlumeMeter® box for inlet flow measurements, one FloodTech® sensor for the real-time monitoring of water level in the field, and lastly one FarmConnect Gateway® as a connection device to the cellular network. All devices were designed by Rubicon Water industry involved in the project together with Civil Engineering department of University of Melbourne.
The assessment of the economical performance is performed analyzing the improvements achieved by the automated irrigation system with respect to traditional rice irrigation management features. In particular, traditional rice irrigation management practices were extrapolated from questionnaires distributed by the National Rice Center technicians to 45 farmers homogenously spread over a rice area of about 1500 km^2 located between the Ticino and Sesia rivers. The 13 questions listed in the interview are the following and the answer referring to the agricultural season 2016: (i) Municipality where the farm is located. (ii) Utilized Agricultural Area (UAA) for rice cultivation within the farm. (iii) Type of seeding method, surface devoted to each method, and irrigation management. In particular: (iiia) Dry seeding and delayed FLooding (DFL); (iiib) Water seeding and continuous FLooding (WFL); (iiic) Dry seeding and intermittent IRrigation (DIR). (iv) Number of diversion canals used for the farm irrigation supply. (v) Methodology of water delivering to the farm (i.e. continuous or rotational). (vi) Level of farm fragmentation (i.e. time the farmer spends to reach the farthest rice field). (vii) Type of irrigation: (viia) Gravity irrigation; (viib) Tractor with water pomp (pumped irrigation). (viii) Irrigation management (i.e. manually or based on automatic systems). (ix) Number of times per day that the inlet gate to a generic rice field needs to be maneuvered/adjusted. (x) Man-hours a day required for farm irrigation. (xi) Number of workers involved in the irrigation procedures. (xii) Number of times the irrigation system requires maintenance in an year. (xiii) Annual average cost for the irrigation network maintenance (e.g. gate replacement, canal relining etc.).

Starting from questionnaire responses, a cost-benefit analysis of the economic impact of automation on farmer's income is performed through Net Present Value (NPV) methodology (Khan 1993).

3. Results and Discussion

The average cost for a complete automated irrigation system inferred by Rubicon quotations and composed by one BayDrive® gate, one FloodTech® sensor, transmission antenna, communication and actuation protocols, power supply, and FarmConnect® software is about 7,704 € (subdivided in 1,540 € for the gate, 700 € for the rubber insert, 1,806 € for the water level sensor, 3,224 € for the antenna, communication protocols, 245 € for installation and finally 189 € for FarmConnect® software and commissioning). The gate cost can vary considerably in function of the BayDrive® width, however, in this study we chose the price of a generic gate of about 70cm width according the dimension used in the pilot project. In addition to this cost, an annual maintenance fee for automation of about 21 € gate^{-1} year^{-1} and FloodTech^{-1} year^{-1} is required, which include software upgrade services, gates maintenance and data storages. An annual SIM card recharge service of about 315 € year^{-1} has to be included.
The cost of the initial investment for the surveyed farms is on average 43,474€. This cost was obtained by multiplying the fixed costs for the automation system (i.e. 1,540 € for gate, 700 € for rubber insert 1,806 € for the water level sensor, 378 € for software and commissioning) for the mean number of fields per farm (supposing one field - one gate). The mean number of fields per farm is about 9, the latter calculated as the ratio between the mean UAA for the surveyed farms (about 63 hectares) and the mean size of a rice field (about 7 hectares). Furthermore, to the previous costs, 3,224 € plus 245 € respectively for central gateway transmission device and for installation (both costs are independent by the number of fields) are summed.
The life-time of the whole automatic system is supposed to be 20 years, after which all the devices should be replaced with new equipment.
Regarding the management costs of a traditional rice irrigation system, the overall hours invested in a day for the farm irrigation were multiplied for (i) the hourly cost of a non-specialized agricultural worker (13.73 € hour^{-1} by ISTAT information), (ii) the days of an irrigation season (about 90 days) and, lastly, (iii) the number of workers involved in irrigation procedures. The irrigation management cost amounts to 3,400 € year^{-1} as well as 2,300 € year^{-1} for the irrigation network maintenance.
The NPV methodology was applied to quantify the profitability of the automation adoption and separately the manual option, by subtracting the actual value of cash outflows (including initial cost) from the actual value of cash inflows over the life time of devices (20 year). A discount rate of 5% is supposed.
The cash outflows for the automation solution are: (i) the initial investment (43,474€) at the first year; (ii) the annual fee for automation and SIM card recharge service (688 € year^{-1}); (iii) the cost for farm canals maintenance (about 460 € year^{-1}) supposed to be 20% of the total cost of the irrigation network maintenance;(iv) the cost for the gates tele-control (supposed about 15 min day^{-1}) of about 309 € year^{-1} (i.e. 13.73 € hour^{-1} x 15 min day^{-1} x 90 days year^{-1} x 60^{-1} hour min^{-1}). While the cash outflow for the manual solution are: (i) the labor cost for traditional rice irrigation (3,400 € year^{-1}); (ii) the cost of irrigation network maintenance (2,300 € year^{-1}).
The results show that the NPV at the end of the 20th year is positive (about 9,400 €) for the automation solution and therefore the investment can be accepted and can be selected over the manual option (Fig. 1). The investment is fully repaid at the end of the

14th year, with a total capital cost of ranging from 638 to 689 € hectare^{-1} the former in the case where Gateway® and installation costs are amortized across 12 properties as usually performed in the Australian installations.

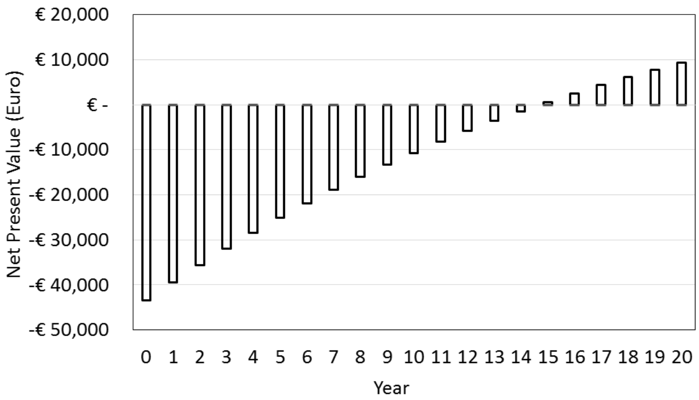

Fig. 1. Cost-benefit analysis over 20 years of the automatic irrigation system life time.

4. Conclusion

The current costs for the automation appear affordable for the Italian rice farmers since the NPV of the automatic solution is positive. Moreover, many externalities connected with an automatic and remote controlled management of irrigation should be taken into account if the performances of these systems are evaluated on a wider spatial scale (i.e. irrigation district or basin scales). In these cases, the maintaining of the ecological, landscape and environmental functions of the gravity-fed irrigation systems and the continuous monitoring of the binominal crop water requirements - water availability, give to the irrigation water managers the possibility to plan the water allocation and to regulate water distribution in function of farmer requirements. This overall improvement of the management performance could provide a profitable growth in revenue of irrigation consortia, in particular reducing the time spending for gates maneuvering especially in the context of Padana plain where the length of the irrigation network exceeds the 40,000 km. Lastly, the combination of flow regulation and measurements provided by the automatic irrigation system, can be a valuable support for the regional water authorities in order to evaluate the actual water consumptions according to the national law and European Union recommendations. This might provide an overview on irrigation efficiencies over the territories allow a more rational planning of irrigation resources.

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