[Playan, E.; Salvador, R.; Bonet, L.; Camacho, E.; Intrigliolo, D. S.; Moreno, M. A.; Rodriguez-Diaz, J. A.; Tarjuelo, J. M.; Madurga, C.; Zazo, T.; Sánchez-de-Ribera, A.; Cervantes, A.; Zapata, N. (2018). Assessing telemetry and remote control systems for water users associations in spain. Agricultural Water Management, 202, 89-98.]

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Institut Valencià
d'Investigacions Agràries

The final publication is available at

[http://dx.doi.org/10.1016/j.agwat.2018.02.015]

Assessing Telemetry and Remote Control Systems for Water Users Associations in Spain

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Abstract

A decades-long policy for irrigation Telemetry and Remote Control (TM/RC) systems in Spain has led to installations for approximately 260 Water Users Associations (WUAs), with a total estimated area of 1.0 M ha of agricultural land. This is believed to be the largest deployment of such technologies in the world. These systems have been installed in financial cooperation between public administrations and WUAs. This paper set out to characterize these systems, assess the causes for their individual success or failure, consider their future evolution and support policy updates. A survey with 110 questions was addressed to 84 WUAs distributed throughout the country. Further, an interview with four questions was addressed to 24 selected stakeholders intervening in irrigation TM/RC projects: from policy makers to farmers. The results provide a detailed overview of these systems in Spain, characterizing the WUAs in which they are installed, their technological traits, their maintenance, the problems they face in their daily operation, their current use, the factors limiting wider use, and the willingness of the WUAs to continue bearing the costs to use TM/RC features in the future. A large majority of TM/RC systems are regularly used to improve WUA water and energy management, and receive proper maintenance. However, in 15% of WUAs, farmers are not satisfied with the TM/RC system, and in 19% of the WUAs the TM/RC system

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cannot operate half of the hydraulic valves connected to them. We found that early technology applications failed more than recent applications, evidencing a process of technological maturity. The standardization of TM/RC systems, adaptation of the system to WUA specificities, training of WUA personnel, and a sufficiently long guarantee period stood as critical variables for success in the implementation of these technologies.

Keywords

irrigation, energy, modernization, electronics, software, water use efficiency

1. Introduction

The first scientific references to Telemetry and Remote Control Systems (TM/RC) date back to the 1950s: medical, industrial and environmental applications were soon identified as promising economic sectors for this incipient technology (West, 1952; Hanes, 1959; Barr and Boas, 1960). Later on, agricultural water management became a target for TM/RC developments due to the geographical dispersion and low density of control and information points (Playán et al., 2013). The first step was mechanical automation, which started in pressurized irrigation in the 1960s with the development of hydraulic control valves. Mechanical devices were soon combined with electronic controllers for on-farm irrigation using solenoids and mini-hydraulic control circuits. By the end of the 20th century, TM/RC systems were installed in large farms and - particularly - in the infrastructure of Water Users Associations (WUA). The technical goals were to control large irrigation networks and to acquire data for water management purposes. A typical TM/RC system for an irrigation network is composed by a control station (usually a PC) and a number of nodes distributed throughout the irrigated area and communicated with the control station. Depending on system topology, some nodes can concentrate the information of other nodes and then report this information to the control station (and vice versa). Nodes are connected to a series of actuators (typically hydraulic control valves) and sensors (i.e., pressure, volume).

As a demonstrator of these incipient technologies, in the 1980s, the Ministry of Agriculture of the Government of Spain (MAPAMA) installed a TM/RC prototype in the 100-ha experimental farm of the National Irrigation Technology Centre (CENTER). Despite the complexity of the technology available in those days, the system permitted to remotely open/close valves, operate continuous-move irrigation machines, sprinkler solid sets and drip irrigated fields, read water meters and supervise farm-wide irrigation operation. Maintenance of the TM/RC prototype was not an easy task, requiring intense dedication by engineers and technicians. The TM/RC system at CENTER was operated as a demonstration unit and as a laboratory for irrigation development and irrigation modernization policies.

At the end of the 20th century, irrigation development plans were slowing down owing to growing limitations in irrigation water supply. At the same time, National Irrigation Modernization Plans were implemented by MAPAMA (2002, 2010). In addition, most Regional Governments designed and applied their own irrigation modernization plans.

These plans targeted irrigation modernization at the (WUA level, typically replacing canals and ditches by pipelines, and building pumping stations and reservoirs within the irrigated area. These new WUA infrastructures are often called “collective networks” (Zapata et al., 2007). They extend from the WUA water intake(s) to the hydrants located at the farms. Consequently, these networks do not belong to individual farmers, but to the WUA.

MAPAMA (2015) estimated that irrigation modernization had affected 1.5 M ha since 2000. The total investment in collective infrastructure was 3,815 M€, supported by the National Government (46%), Regional Governments (23%) and WUAs (31%) (MAPAMA, 2015). In addition, farmers invested in new on-farm irrigation equipment (mostly sprinkler and drip), occasionally counting on subsidies by Regional Governments.

The application of these irrigation modernization policies in the 21st century had a profound effect on irrigation systems in Spain. The annual survey of crop area and yield performed by MAPAMA (2016) since 2002 permits assessing the changes in irrigated area and irrigation method (Figure 1). According to these official data, in 2016 drip irrigation was used in 50% of the irrigated area, with surface and sprinkler irrigation amounting to 26% and 24% of the area, respectively. It can be presumed that in the period 2002-2016 a large part of the surface irrigated area was transformed to sprinkler and drip irrigation, while some sprinkler irrigated area was transformed to drip irrigation. The survey reports on a strong association between irrigation methods and crops, which was also observed in similar analyses performed in California (Tindula et al., 2013).

The modernization of collective irrigation infrastructure involved the participation of national or regional public companies created to manage this process in cooperation with the WUAs. Till 2010, irrigation modernization projects commonly included a TM/RC system for use by a WUA. From 2010 onwards public funds were not abundant, and TM/RC systems were only installed in selected WUAs. Some TM/RC systems were installed in Spain before the National Irrigation Modernization Plans that were implemented in the 21st century. These systems used adaptations of industrial or urban technology supplied by just a few multinational companies. During the first years of systematic installation of TM/RC systems, a national industry flourished, with about twenty companies developing products for collective irrigation networks. In many cases, products were not completely developed and tested at the time of the contract, and the last phases of product development were actually financed through contracts with public irrigation companies. This case can be regarded as an early, involuntary implementation of the “Public Procurement of Innovative Solutions” processes currently implemented in Europe (European Commission, 2017).

In general, the installation of TM/RC systems in Spain responded to the drive of Public Administrations, which saw this as a key technology to modernize irrigation operation and management. Many WUAs showed interest in these systems, which could improve water management and intensify the use of modern technologies. The research community also saw potential in the installed TM/RC systems to address bottlenecks that limited improvements in water use efficiency and in farmers’ revenue. These include optimizing water and energy efficiency (Rodríguez-Diaz et al., 2012; Tarjuelo et al., 2015; Zapata et al., 2017), automating irrigation scheduling at the WUA scale (Playán et al, 2013), or implementing regulated deficit irrigation (Ballester et al., 2014) in collective networks. In addition, TM/RC systems have also proven useful to analyze water use at the WUA and farmer levels with unprecedented detail (Lorite et al., 2013; Stambouli et al., 2014), as well as to forecast irrigation water demand in collective pressurized networks (Pulido-Calvo et al., 2007; González Perea et al., 2015).

During the first years of TM/RC system deployment in WUA-managed irrigation systems, it was clear that the technology needed to improve in terms of reliability. At the same time, applications were unavailable at that time to exploit the databases created by the TM/RC systems. Finally, most WUA employees lacked the required ability to maintain and exploit TM/RC systems, particularly when simultaneously dealing with a new collective network and the new irrigation methods.

Widespread installation of TM/RC systems in Spain constitutes a case study of technology deployment for irrigation. This technology brought new perspectives to agricultural water managers. At the same time, the risks of such technological deployment were relevant, and could have led to rejection or to reduced application. Fifteen years since the onset of the irrigation modernization plans that supported the generalization of TM/RC systems, this paper sets out to evaluate the TM/RC systems installed in Spanish WUA-managed irrigation systems, pursuing the following objectives:

1. Assess the nature, use and maintenance of the TM/RC systems;

2. Establish causes for success and failure of individual TM/RC systems;
3. Identify changes required to make TM/RC systems more useful for water and energy conservation;
4. Consider the evolution of these TM/RC systems in the near future; and
5. Support policy development for TM/RC system implementation.

2. Materials and methods

The information analyzed in this paper was obtained through a survey of WUAs having TM/RC systems and through interviews with selected stakeholders. While the survey provided in-depth information from just one type of stakeholder - the WUAs - the interviews provided targeted information from all agents involved in the installation and exploitation of Spanish TM/RC systems.

2.1. Surveying WUAs

The identification of WUAs to be surveyed required an initial phase of desk research, in which WUAs equipped with TM/RC systems were identified in different areas of Spain. A number of these WUAs were asked to respond to the survey, and a large fraction of them agreed and were ultimately surveyed.

A survey was prepared containing 110 questions. The vast majority were closed questions (leading to qualitative variables, in which values are called “categories”), with open questions used for the irrigated area and the area of the TM/RC system (leading to quantitative variables, in which values are numbers). The survey was prepared in a spreadsheet application, and was designed to be performed face-to-face or over the telephone. Surveys were performed between March and September 2017. Each survey required 20-40 minutes, depending on the use and maintenance of the TM/RC system and on any additional information provided by the WUA. The survey was divided into these sections:

- Characteristics of the WUA and the person answering the survey (21 questions)
- Characteristics of the installed TM/RC system (26 questions)
- Maintenance performed on the TM/RC system (13 questions)
- Problems of the TM/RC system in the WUA (11 questions)
- Current use and status of the TM/RC system (19 questions)
- Factors limiting a more intense use of the TM/RC system (10 questions)
- Willingness to bear TM/RC costs in the future (10 questions)

Each survey produced a vector of responses, and the set of 83 surveys resulted in a matrix which was analyzed with the statistical package SPSS (IBM, version 24). In addition to basic descriptive statistics, contingency tables were built for the analysis of pairs of qualitative variables. The Pearson χ^2 test was performed to assess statistical independence between pairs of qualitative variables. In this test, the null hypothesis is that pairs of qualitative variables are independent. If the null hypothesis can be rejected, then the pair of qualitative variables shows some statistical association.

A significant Pearson χ^2 test permitted assessment of the degree of association using two coefficients, depending on the type of qualitative variable (nominal, dichotomous or ordinal). The Pearson Contingency Coefficient (*CC*) was used for all types qualitative variables, and it ranges from 0 to 1. Values close to 1 indicate strong association between the variables. The Kendall Tau-b (τ_B) was only used for pairs of ordinal variables. This coefficient ranges from -1 to 1. The interpretation of τ_B is similar to that of the correlation coefficient used for quantitative variables.

A probability level of 5% was used for the Pearson χ^2 test and to assess the statistical significance of CC and τ_B.

2.2. Estimating the number of WUAs with TM/RC systems, and the total national area

The combination of the number of WUAs equipped with TM/RC systems and their average area (obtained from the survey) permitted to estimate the number of WUAs in Spain with TM/RC systems and the total area covered by this type of technology.

2.3. Interviewing key stakeholders

A set of 24 interviews was performed to complement the survey with regard to specific topics. Following the analysis of the survey data, four questions were designed to provide increased depth and/or wider perspectives on key issues raised by the survey:

- What have TM/RC systems already achieved in WUAs?
- How can WUAs improve the exploitation of the installed TM/RC systems?
- What are the main technical limitations of the installed TM/RC systems?
- What will be the key contributions of TM/RC systems to water and energy management in the next decade?

Questions were addressed (face-to-face or over the telephone) to specific target groups: policy makers (national or regional), public irrigation modernization companies (national or regional), TM/RC manufacturers, engineering firms, WUAs and farmers. Interviews were conducted between September and October 2017, whereby textual information was collected. A summary and key opinions were arranged in tables to facilitate the analysis of stakeholders' opinions.

3. Results

3.1. The WUAs and the persons answering the survey

The 84 surveyed WUAs were distributed throughout the main irrigated regions and river basins of Spain. The persons answering the survey were, for the most part, WUA managers or other WUA personnel. Only in 9% of the cases was the survey answered by the WUA President or Members of the Board.

The total irrigated area corresponding to the surveyed WUAs was 0.407 M ha. The average size of the irrigated area was 4,850 ha, ranging from 180 to 42,000 ha. The main irrigation methods were sprinkler and drip (48% each). Only four surface-irrigated WUAs were surveyed (5%). Of the surveyed WUAs, 38% applied only one particular irrigation method. Wide differences were observed in WUA access to water. Most WUAs (63%) suffered water shortages during some years, while 21% reported no restrictions and 16% suffered very frequent or permanent restrictions.

Most of the surveyed WUAs irrigated field crops (51%), followed by orchards (30%). A few WUAs specialized in vineyards (8%), vegetables (6%) or olive trees (5%), and 80% of the surveyed WUAs produced multiple crop types. The most frequent farm size was less than 10 ha (51%), including land in property and under lease. Only 2% of the farms were larger than 60 ha.

Only 20% of the surveyed irrigation projects with TM/RC systems were constructed before 2000. The most frequent period for the finalization of these WUA-managed irrigation networks was between 2005 and 2010 (45%), followed by the 2010-2015 period (18%). Eighty percent of the surveyed WUAs corresponded to irrigation modernization projects. Most irrigation projects were co-funded by MAPAMA (57%) or by Regional Governments (39%), often acting through public irrigation companies. Only 4% of the projects did not rely on public subsidies. The most frequent cost of the irrigation network (on-farm equipment not included) was less than 6,000 €/ha (42%), followed by the category 6,000-8,000 €/ha (29%). Most WUAs (87%) had at least one pumping station. The most frequent annual energy cost for pumping was 100-200 €/ha (35%), with 21% of WUAs paying more than 200 €/ha. The typical static lift was less than 80 m (62%), but 13% of WUAs pumped water higher than 160 m. Half of the WUAs declared farmers to be quite satisfied with the collective irrigation infrastructure (not including the TM/RC system), while 42% were very satisfied, and none were dissatisfied.

3.2. The estimated extension of irrigation TM/RC systems in Spain

The total area covered by TM/RC systems in the surveyed WUAs was 0.332 M ha, compared to the total irrigated area of 0.407 M ha, as presented above. The average WUA irrigated area under TM/RC was 3,949 ha per system, ranging from 45 to 42,000 ha. According to the estimates performed by the authors, the number of Spanish WUAs with TM/RC systems could be as high as 260, and the total extension of TM/RC irrigated land in the country could amount to 1.0 M ha. A literature review showed no evidence of similar national efforts in other countries for the deployment of collective TM/RC systems for agricultural irrigation purposes.

3.3. The installed TM/RC systems

The coverage of TM/RC systems ranged from the main water distribution network (8%), to the main network and the hydrants (68%) and to the network, the hydrants and the irrigation sectors within the farms (24%). Regarding communications, radio was the most frequent medium (46%), followed by GPRS (24%), buried cable (20%), and combinations thereof (10%). The survey permitted to identify 16 manufacturers of TM/RC systems. It is important to note that 24% of the surveyed WUAs had TM/RC systems from more than one manufacturer. This is an issue of concern, since there is currently no recognized international standard for communications within TM/RC-enabled systems.

A typical TM/RC system was composed of 50-200 nodes, controlling 200-1,000 irrigation valves. The most frequent type of node power supply was a battery with solar panel (58%), followed by buried cable (20%) and battery without a solar panel (19%). Almost all the systems permitted remote valve operations and acquisition of data from analogic sensors (e.g. pressure transducers). In 74% of the surveyed WUAs, reservoirs or pumping stations were also equipped with TM/RC hardware. In 36% of the systems, the WUA could modify the number of nodes without the technical support of the equipment manufacturer. In 27% of the WUAs farmers could interact with the TM/RC system via the internet. The vast majority of systems could be programmed to send alarms based on pressure, discharge or volume of water use.

A large part of the surveyed WUAs could not provide the cost of the TM/RC system (37%), given that this cost was often included in the total cost of the project. The most common cost range was less than 150 €/ha (21%), although some WUAs reported costs of more than 400 €/ha (12%). Taking into account the estimated area of TM/RC systems in Spain, the total cost of these installations is estimated to be 240 M €.

When the TM/RC projects were completed, only 60% operated correctly; 35% of the TM/RC systems initially failed to deliver all the design functionalities. Twenty-six percent of the surveyed WUAs declared farmers to be very satisfied with the TM/RC system, while 44% were quite satisfied. Eleven percent of WUAs were partially satisfied, and 15% were dissatisfied. Satisfaction with the TM/RC system was clearly lower than the satisfaction with the whole collective network.

Ninety-two percent of the surveyed WUAs declared that the TM/RC system had a guarantee period. This period was reported to be of one (19%), two (58%) or more years (14%). Eighty percent of the WUAs declared that the guarantee included the replacement of defective equipment. However, fewer WUAs reported guarantee coverage for software updates (46%), periodic revisions (40%) or integral system maintenance (43%).

3.4. Maintenance performed on the TM/RC systems

Seventy percent of the WUAs reported having received training courses for the maintenance of the TM/RC system. The level of the courses was basic (38%), intermediate (26%) and advanced (6%). Sixty-nine percent of the WUAs received an operations manual. Forty percent of the WUAs hired a company for the maintenance of the TM/RC system. In 18% of the WUAs the manufacturer provided this service. Among the WUAs hiring a company, 54% were quite satisfied, while 41% were very satisfied. The rest of the WUAs counted on their own personnel for TM/RC maintenance. Fifty-three percent of them were university graduates. System maintenance can be judged satisfactory since 45% of WUAs reported that they only needed a few hours to repair the TM/RC system. Only 5% of WUAs reported average repair times in excess of one week.

Regarding the nature of the maintenance incidents, WUAs provided the most frequent causes of problems in each part of the system. Communication and electric supply problems were often found in the system nodes. Regarding the sensors and actuators, problems were reported in the opening/closing of valves. The most commonly replaced system parts were batteries and the electronic components of the nodes.

3.5. Problems of the TM/RC systems in the WUAs

WUAs were presented with eleven possible causes for problems in the TM/RC system. They had to categorize these issues according to their importance, from “not important” to “very important” (Table 1). The “not important” category was the most frequent for all issues. However, variability was important in the fraction of WUAs reporting that the issues were important or very important. Summarizing these findings, five causes of problems were identified as critical. These are listed in order of decreasing relevance:

- Unstable communications;
- Insufficient maintenance;
- Problems during the installation of the system;
- Poor adequacy of the TM/RC system to the requirements of the WUA, and
- Adverse climate (damaging the RM/RC system).

3.6. Current use and status of the TM/RC systems

Seventy-one percent of the WUAs reported using the TM/RC system daily during the irrigation season. The rest of WUAs reported frequent (10%), infrequent (11%) or no use (8%). WUAs declared frequency of use of the system for specific applications:

- Supervising discharge in the network (74%)
- Reading the water meters (68%). 55% of the WUAs use TM/RC water meter data for billing purposes. 30% of the WUAs need to manually type the information into the billing application.
- Detecting failures in the network (63%)
- Supervising pressure in the network (63%)
- Opening and closing hydrant valves (61%)

- Reducing the cost of electricity which for Spanish WUAs varies with the day of the year and with the hour of the day (58%)
- Irrigating the fields of the farmers (19%)

The key expectation of the WUAs regarding the TM/RC system was to improve the control and management capacities (75%). Only 15% set out to improve the quality of life of the farmers. These expectations were generally fulfilled by the TM/RC system, since most WUAs used the system as planned (42%) or for more than planned (30%). However, some WUAs used the system less than planned (19%), and 8% of the WUAs did not use it at all. Forty-two percent of the WUAs believed that there were other types of TM/RC system that are more suited to their needs than the one they have.

WUAs were requested to describe the current status of the TM/RC system. In 88% of the WUAs the control station was functioning. In a next step, WUAs were requested to declare the percentage of nodes operating properly for different node capacities (Table 2). Results were not very different among node capacities. Some 40% of the WUAs kept the whole system in operation, and about 30% more had more than 80% of the nodes operating properly. However, 25-40% of the WUAs reported relevant limitations in node capacities. The capacity to operate sector valves was the one for which lowest performance was reported.

3.7. Factors limiting a more intense use of the TM/RC systems

Table 3 presents the percentage of surveyed WUAs reporting different degrees of importance of different possible limitations in the use of the TM/RC system. In all cases, “not important” was the most frequent answer. Among the ten possible limitations, the following seven were identified as critical (presented in order of decreasing relevance):

- Problems with communications between the central station and the nodes;
- Problems in the electronics at the nodes;
- Low reliability in water meter reading;
- The TM/RC system does not solve the WUA’s problems;
- The TM/RC software is not user-friendly;
- Low reliability in valve opening/closing; and
- The TM/RC system produces plenty of information, but it is not clear how to use it for managing the network and evaluating operations.

3.8. Willingness to bear TM/RC costs in the future

Eighty-two percent of the WUAs declared being ready to continue investing in the maintenance of the TM/RC system. Among them, 49% would give this cost a high priority. Only 11% would give this cost a low priority. However, when considering other possible investments by the WUA, the TM/RC system did not rank first. Priority destinations for investments were:

- Improving the irrigation network infrastructure (55%);
- Improving the TM/RC system (25%);
- Improving the technical capacity of WUA personnel (6%); and
- Improving the administrative capacities of WUA personnel (5%).

The majority of WUAs declared being ready to bear costs in the future to sustain and improve the capacities of their TM/RC system. The types of capacities are presented in the following list in order of decreasing acceptation:

- Receiving reliable alarms for network failure; reducing the cost of energy for pumping (77%);
- Controlling pressure in the network, and controlling discharge and water allocation in the network (74%);
- Remotely operating hydrant valves (65%);
- Automatically irrigating all plots and their sectors, using a software that applies crop water requirements (40%); and
- Manually irrigating all field plots and sectors, and scheduling irrigation from the TM/RC software for each valve (38%).

In general, the ranking of capacities responds more to WUA managerial interests than to farmers' interests. If farmers would have been directly surveyed, preferences would probably have been different, with on-farm irrigation capacities ranking high on the list.

3.9. Variables associated to WUA satisfaction with their TM/RC system

The association between variable "satisfaction of WUA farmers with the TM/RC system" and a number of other variables was assessed. A number of candidate WUA variables showed no association with TM/RC satisfaction:

- WUA location and extension: region (Autonomous Community) of Spain, river basin, total WUA area and total TM/RC area.

- WUA irrigated farming: main irrigation method, water availability, crop types, farm size.
- WUA infrastructure: cost of the irrigation network, cost of the TM/RC system, existence of pumping stations, pumping static lift, average cost of energy (€/ha/yr)
- TM/RC technical characteristics: type of communications, manufacturer, node energy supply.
- TM/RC installation and maintenance: training courses, and educational level of the person responsible for system maintenance.
- Problems of the TM/RC systems in the WUAs: Poor training of personnel, insufficient maintenance, low personnel dedication, adverse climate, poor quality of materials and incorrect use.

A reduced number of candidate variables showed a significant statistical association with TM/RC satisfaction:

- WUA Infrastructure: the date of finalization of the irrigation project (*CC* = 0.521; τ_B positive, non-significant) and the general satisfaction with the irrigation network (*CC* = 0.399; τ_B = +0.337).
- TM/RC installation and maintenance: the duration of the guarantee period (*CC* = 0.443; τ_B = +0.204), the hiring of external companies for system maintenance (*CC* = 0.402), the time required to repair the system (*CC* = 0.571; τ_B = -0.266) and the level of expectations fulfillment (CC = 0.667; τ_B = 0.596)
- Problems of the TM/RC systems in the WUAs: Unstable system (*CC* = 0.600; τ_B = -0.400), incorrect installation (*CC* = 0.534; τ_B = -0.429), defective components (*CC* = 0.438; τ_B=¿-0.251), vandalism (CC = 0.439; τ_B non-significant) and system does not fit the WUA needs (*CC* = 0.575; τ_B = -0.383).

3.10. Results of the stakeholders' interviews

Tables 4 to 7 summarize the results of the interviews. In each question a number of general comments were provided by the different stakeholders. These are presented in the first line of each table. The presentation of the rest of comments permits differentiation among the distinct points of view of the six types of stakeholders.

Interviewees agreed that TM/RC systems have already resulted in water and energy conservation, leading to an increase in farmers' income. Specific stakeholders focused on progress towards transparent and responsible management, the adoption of performance indicators, increased WUA capacity to respond to changes, and the implementation of volumetric water delivery restrictions to farmers.

In order to improve the exploitation of the installed TM/RC systems, stakeholders agreed on the importance of maintenance, training and robustness in communications. These issues had already been identified in the survey. Some comments focused on the low flexibility of the installed systems, and pointed at specific measures such as increasing the number and type of sensors connected to the systems, exploiting the information in the TM/RC database, and delivering information directly to farmers.

Stakeholders agreed on a number of technical limitations in the installed systems: rapid obsolescence, lack of interoperability and standardization, unstable communications and dependence on a given manufacturer. Specific comments on this issue included: poor capacity to integrate water and energy management, difficulties to expand the network, or high node energy consumption.

The general view on the contributions of TM/RC systems in the coming decade included water, energy and labor management, integration with precision farming through "big data" and water and energy simulation tools. Specific views included: the adaptation of technology deployment to specific WUA requirements, the elaboration of individualized information for farmers, a generalized reduction in the cost of information generation and communication, and the elaboration and application of irrigation schedules. One WUA posed a key question for the coming decade: can WUA-managed networks be effectively operated in the future without TM/RC systems?

4. Discussion

4.1. TM/RC systems and agricultural water management

The results above indicate that TM/RC systems are currently installed in a large total irrigated area in Spain, and that farmers are – for the most part – satisfied with this infrastructure. WUAs expected that TM/RC systems would increase their managerial capacities, and this seems to have been achieved in most of them. Reducing energy costs for pumping, reading water meters and managing the network seem to be important current applications of the system, according to the survey responses. Most benefits of TM/RC systems are managerial in nature, lead to improvements in WUA operation and have the potential to decrease farmers' irrigation costs. However, these applications alone are not expected to significantly increase irrigation efficiency or water productivity. For instance, irrigation water application depth has shown large spatial variability in WUA-managed systems with and without TM/RC systems (Salvador et al., 2011; Lorite et al., 2013).

Nineteen percent of the surveyed WUAs are currently using the TM/RC system to replace all or part of the farmers' involvement in irrigation operations. In some cases, farmers schedule irrigations and the WUA executes the schedule; in others, the WUA schedules irrigation and farmers can modify it. This application requires TM/RC systems extending to the irrigation sectors of each farm (such systems are only installed in 24% of the WUA-managed irrigation systems) and relevant management capacities at the WUA office. Centralized irrigation management generalizes a systematic approach to irrigation scheduling and to water and energy efficiency, frees farmers from updating their irrigation controllers (farmers no longer need on-farm controllers), and can succeed in implementing complex schedules, such as regulated deficit irrigation or avoiding periods of high wind speed in sprinkler irrigation. Even when the WUA directly performs irrigation, the spatial variability in irrigation water application has been reported to remain high (Stambouli et al., 2014). Specific on-farm practices, such as fertigation, would be quite difficult to manage in a centralized way by the WUA.

Specialized WUA management databases and agrometeorological networks can have a synergic effect with TM/RC systems when it comes to centralizing irrigation at the WUA (Playán et al., 2014). Additionally, sensors are being developed to guide irrigation decision making based on plant (Miras-Avalos et al., 2017) or soil (Bonet et al. 2010) status. Sensors can be connected to WUA TM/RC systems to produce spatially-distributed, real-time information on water status. An expert system can interact with all these elements to develop and execute adaptive irrigation schedules responding to a wide set of environmental, agronomic and economic variables. Despite the relevant scientific progress on these issues, this technology is not currently available in the market. However, 40% of the surveyed WUAs showed interest to pay for such systems in the future, underlining the importance of continuing irrigation scheduling research and innovation efforts in this direction.

4.2. Causes for success and failure of TM/RC systems

The analysis of variables related to farmers’ satisfaction with the WUA TM/RC system permits the assessment of some traits associated with the success or the failure of this technology for a given WUA. Results indicate that successful TM/RC application can be found in WUAs of any size, on-farm irrigation method, productive orientation, access to water and cost. Moreover, according to the survey results, the technical aspects of the system did not prove relevant to success. Apparently, any type of TM/RC systems can succeed for any WUA. These findings contrast with the experiences reported by some WUAs, which associate their success/failure to specific TM/RC technologies or manufacturers. The adequacy of a specific technology to the specific traits of a WUAs seems to be more important than the technology itself. For instance, WUA mobile phone coverage, mountain relief, electric storms and the presence of high-voltage electric lines seem to be key variables when opting for radio, GPRS or cable communication systems.

Among the factors statistically associated with farmers’ satisfaction, it is important to single out those where a clear cause-effect link can be established:

- The significance of the date of finalization of the irrigation project confirms that the technology matured over time. Recent installations produced more satisfied users than earlier installations.
- The duration of the guarantee has been found to be an important key to success, as it ensures commitment of the manufacturer / installer. In a technology that produces some unsatisfied users even in recent applications, this factor continues to be important.

- Incorrect installation, defective components, adequacy of the system to the WUA and vandalism have been pointed out as causes of TM/RC system failure. These factors can be successfully addressed at the design, installation and guarantee periods.

In other factors, a statistical association is clear, but cause and effect are not:

- Satisfaction with the TM/RC system was associated with satisfaction with the whole irrigation project, and with the fulfillment of expectations, indicating that this complex technology is best appreciated in a general context of suitable project development.
- Variables related to maintenance (hiring an external company or the time required to repair the system) can be both cause and effect of users' satisfaction. For instance, WUAs that are unsatisfied with the TM/RC system often abandon maintenance and will not hire a company for this purpose.

4.3. Standardization of TM/RC systems for collective irrigation

There is currently no specific international standard for TM/RC systems. Regarding national standards, we are only aware of the Spanish standard "UNE-EN 15099-1:2007 "Remote monitoring and control for irrigation systems. Part 1: General considerations".

The survey revealed that 24% of the surveyed WUAs had network installations from more than one manufacturer. In addition, most WUAs have a TM/RC system for the collective network plus a specific TM/RC system for the pumping stations. These systems are produced by different manufacturers and cannot communicate with each other. Consequently, water and energy management in the WUA is fragmented. It is currently common to find several computers in a WUA acting as control stations for different systems and having very limited software interaction, if any. In addition, all WUAs use a management database. Lack of communication between TM/RC systems and the management database explains why 30% of the WUAs can read the water meters from the office, but then need to type this information into the WUA management database.

MAPAMA is aware of these problems and currently leads a Working Group in ISO Committee ISO/TC23/SC18 "Irrigation and Drainage Equipment" focusing on the development of a standard for TM/RC in irrigation. Responding to public interest, such standard needs to protect the rights of TM/RC users and manufacturers. Standardization will favor concurrence in the TM/RC sector, increasing the quality of the systems in the market. Additionally, compliance with the standard will ensure communication flow between all Information Technology elements of a WUA, and will ease progress in management modes, such as advanced irrigation scheduling techniques (e.g. regulated deficit irrigation, precision irrigation) or centralized management of water and energy.

4.4. Policy support regarding the installation of TM/RC systems

The findings of this research permit to establish lines of policy action regarding new TM/RC projects:

- User satisfaction is associated to the fulfillment of user expectations. Therefore, it is very important to identify the expectations of the WUA and to consider them during the design phase of a TM/RC project. Nurturing fruitful dialogue between the design engineers and the WUA seems to be a key for success.
- The coverage (main network / hydrants / sectors) and the capacities of the TM/RC system need to respond to the management modes to be implemented by the WUA after the project. For instance, if water meters will only be read once a year and alarms on hydrant discharge are not required, it may not be cost-effective to use the TM/RC system to read the water meters. Very simple TM/RC systems (covering the main network) can be very useful and cost-effective for WUAs with low involvement in water management. According to the survey, such TM/RC systems invariably produced very satisfied and satisfied users.
- WUAs having high energy requirements will benefit from the capacity of TM/RC systems to reduce the energy bill. Additionally, these WUAs often read water meters frequently (about every month) to issue water bills and therefore to recover energy costs. These WUAs seem to be adequate candidates for high-performance TM/RC systems.
- The TM/RC project should include quality control tests for the components and their installation, along with a sufficiently long guarantee period. Sixty-nine percent of the unsatisfied users of TM/RC systems declared that the system was not operating properly when the WUA received it.
- Many WUAs verbally reported difficulties in controlling TM/RC installation and in effectively using the guarantee period because they were overloaded with the reception of the new collective network. This may have been a major cause

of TM/RC problems. As a consequence, it seems convenient to delay the installation of the TM/RC system until the new network is fully operative. This may imply a delay of two-three years in some cases, which could effectively reduce the risk of failure. Managing this delay constitutes a financial and administrative challenge.

- In 19% of the WUAs, less than 50% of the nodes can currently operate hydraulic valves. These WUAs approximately correspond to the 15% of dissatisfied users and the 11% of partially satisfied users. The situation of these WUAs should be assessed to find a solution: about half of them continue to be interested on the technology, and are ready to bear additional costs in the future.

5. Conclusions

A decades-long policy for irrigation TM/RC systems in Spain has led to installations in approximately 260 Water Users Associations (WUAs), with a total estimated extension of 1.0 M ha. The overall estimated construction cost is 240 M €, which was supported by public administrations and WUAs. A large majority of TM/RC systems are daily used to improve WUA water and energy management and receive proper maintenance. As a consequence, TM/RC systems can be judged as very satisfactory, in general, and are contributing to improve the managerial capacities of the WUAs.

Early TM/RC applications failed more than recent applications, evidencing a process of technology maturity during the time frame in which the TM/RC systems were installed in Spanish irrigation systems (since the last decade of the 20^{th} century). Additional traits of successful projects are: 1) the integration of WUA needs in TM/RC project design; 2) a sufficiently long guarantee period and quality control during the installation phase (detecting unstable or defective components); 3) adequate training or WUA personnel or hiring of external services; and 4) a maintenance plan for the TM/RC system.

Despite the generalized success, in 15% of WUAs farmers are not currently satisfied with the TM/RC system, and 11% show partial satisfaction with the system. Further, in 19% of the WUAs the TM/RC system cannot operate 50% of the hydraulic valves connected to them. Despite the reported problems, half of these WUAs continue to be interested in TM/RC systems.

A number of technical and policy action lines have been presented in this paper to increase the success of present and future TM/RC applications. Most WUAs believe that this technology will soon generalize in collective agricultural water networks. Issues like standardization, training, maintenance and farmer-oriented management stand as critical to achieve this vision of the future.

6. Acknowledgement

Thanks are due to the Water Users Associations responding to the survey, and to the stakeholders responding to the interviews. Their cooperation made this research possible.

Funding: This work was supported by the Spanish State Research Agency (*Agencia Estatal de Investigación*) of the Ministry of Economy and Competitiveness (MINECO) of the Government of Spain, grant numbers: AGL2013-48728-C2-1-R, AGL2014-59747-C2-1-R, AGL2014-59747-C2-2-R, RTC-2015-3453-2 and RTC-2016-4972-2.

7. References

Ballester, C., Castel, J., Abd El-Mageed, T.A., Castel, J.R., Intrigliolo, D.S. 2014. Long-term response of 'Clementina de Nules' citrus trees to summer regulated deficit irrigation. Agric. Wat. Manage. 138:78-84.

Barr, N.L., Voas, R.B., 1960. Telemetering physiologic responses during experimental flights. American Journal of Cardiology. 6(1): 54-61.

Bonet, L., Ferrer, P.J., Castel, J.R., Intrigliolo, DS. 2010. Soil capacitance sensors and stem dendrometers. Useful tools for irrigation scheduling of commercial orchards? Spa. J. Agr. Res. S2:S52-S65.

European Commission. 2017. Public Procurement of Innovative Solutions. https://ec.europa.eu/digital-single-market/en/public-procurement-innovative-solutions (accessed: 16/8/2017).

González Perea, R., Camacho, E., Montesinos, P. and Rodriguez-Diaz, J.A. 2015. Irrigation demand forecasting using artificial neuro-genetic networks. Water Resources Management, 29(15), 5551-5567.

Hanes, F.P. 1959. Design of telemetering networks for flood-control reservoir operation. Proceedings of the Institute of Radio Engineers. 47(5): 978-983.

Lorite, I.J., Santos, C., García-Vila, M., Carmona, M.A. and Fereres, E. 2013. Assessing irrigation scheme water use and farmers' performance using wireless telemetry systems. Computers and Electronics in Agriculture. 98:193-204.

MAPAMA. 2002. Plan de Regadíos. http://www.mapama.gob.es/es/desarrollo-rural/temas/gestion-sostenible-regadios/plan-nacional-regadios/ (accessed: 16/8/2017).

MAPAMA. 2010. Estrategia para la Modernización Sostenible de los Regadíos. http://www.mapama.gob.es/es/calidad-y-evaluacion-ambiental/participacion-publica/pp_2009_p_019.aspx (accessed: 16/8/2017).

MAPAMA. 2015. Aumenta la superficie regada en España pero se mantiene una tendencia a la baja en el volumen de agua de riego utilizado en el sector agrario. http://www.mapama.gob.es/es/prensa/noticias/aumenta-la-superficie-regada-en-espa%C3%B1a-pero-se-mantiene-una-tendencia-a-la-baja-en-el-volumen-de-agua-de-riego-utilizado-en-el-sector-agrario-/tcm7-367091-16# (accessed 16/8/2017).

MAPAMA. 2016. Encuesta sobre Superficies y Rendimientos Cultivos (ESYRCE). http://www.mapama.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/esyrce/ (accessed 16/8/2017).

Miras-Avalos, J.M., Perez-Sarmiento, F., Alcobendas, R., Alarcón, J.J., Mounzer, O. Nicolás, E. 2017. Maximum daily trunk shrinkage for estimating water needs and scheduling regulated deficit irrigation in peach trees. Irrig. Sci. 35(1):69-82.

Playán, E., Salvador, R., López, C., Lecina, S., Dechmi, F. and Zapata. N. 2014. Solid-set sprinkler irrigation controllers driven by simulation models: opportunities and bottlenecks. ASCE Journal of Irrigation and Drainage Engineering, 140(1):1-10.

Pulido-Calvo, I., Montesinos, P., Roldán, J., Ruiz-Navarro. F. 2007. Linear regressions and neural approaches to water demand forecasting in irrigation districts with telemetry systems. Biosystems Engineering 97:283-293.

Rodríguez Díaz, J.A., Pérez Urrestarazu, L., Camacho Poyato, E., Montesinos, P. 2012. Modernizing water distribution networks. Lessons from the Bembézar MD irrigation district, Spain. Outlook on Agriculture. 41(4): 229-236.

Salvador, R., Martínez-Cob, A., Cavero, J. and Playán, E. 2011. Seasonal on-farm irrigation performance in the Ebro basin (Spain): crops and irrigation systems. Agric. Wat. Manage. 98(2011):577-587.

Stambouli, T., Faci, J.M., Zapata, N. 2014. Water and energy management in an automated irrigation district. Agricultural Water Management 142:66-76.

Tarjuelo, J.M., Rodriguez-Diaz, J.A., Abadía, R. Camacho, E., Rocamora, C., Moreno, M.A. 2015. Efficient water and energy use in irrigation modernization: Lessons from Spanish case studies. Agric. Wat. Manage. 162: 67-77.

Tindula, G.N., Orang, M.N., Snyder, R.L. 2013. Survey of Irrigation Methods in California in 2010. Journal of Irrigation and Drainage Engineering, Vol. 139, No. 3, 233-238.

West, J.C., 1952. A system utilizing coarse and fine position-measuring elements simultaneously in remote-position-control servo mechanisms. Proceedings of the Institution of Electrical Engineers – London. 99(68): 135-143.

Zapata, N., Playán, E., Martínez-Cob, A., Sánchez, I., Faci, J.M. and Lecina, S. 2007. From on-farm solid-set sprinkler irrigation design to collective irrigation network design in windy areas. Agric. Wat. Manage. 87(2): 187-199.

Zapata, N., El Malki, E.H., Latorre, B., Gallinat, J., Citoler, F.J., Castillo, R., Playán, E. 2017. A simulation tool for advanced design and management of collective sprinkler-irrigated areas: a study case. Irrig. Sci. 35(4):327-345.

8. List of Tables

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Table 1. *Surveyed WUAs (%) reporting different degrees of importance of different possible causes for problems in their TM/RC systems.*

	Not important	Low importance	Important	Very important
Poor training of personnel	48	23	16	12
Unstable communications	40	21	22	17
Insufficient maintenance	43	22	27	9
Low personnel dedication	58	16	16	10
Incorrect installation	47	17	14	22
Defective components	55	26	5	14
Vandalism	44	27	21	7
Adverse climate	38	23	30	9
Poor quality of materials	47	25	16	13
Incorrect use	69	19	6	5
System does not fit the needs	49	16	18	18

Table 2. *Surveyed WUAs (%) reporting different percentages of nodes operating properly for different node capacities.*

	Nodes operating properly:				
Node capacities:	0%	0-50%	50-80%	80%-100%	100%
Open / close hydrant valve	16	4	3	36	41
Open / close sector valve	31	8	2	21	38
Read water meter	12	5	7	29	47
Read pressure sensor	15	7	14	27	37

Table 3. *Surveyed WUAs (%) reporting different degrees of importance of different possible limitations in the use of the TM/RC system.*

	Not important	Low importance	Important	Very important
Problems in the nodes	42	31	10	18
Low reliability in valve operation	48	27	9	16
Low reliability in water meter reading	41	31	17	11
Low reliability in pressure sensor reading	58	25	13	4
Problems with communications	40	24	11	25
Non user-friendly software	45	31	13	11
Poor communication between TM/RC and billing software	52	32	14	2
The system does not solve the problems of the WUA	60	15	10	16
WUA personnel cannot valorize the system	77	13	6	3
Plenty of information; not clear how to use it	58	19	12	12

Table 4. *Summary of the results of interview question: What have TM/RC systems already achieved in WUAs?*

Stakeholder group	**Summary and key answers**
General comments	• Conserve water, Organize water delivery, reduce the energy bill, detect failures, increase farmers' income.
Policy Makers	• Discard traditional bad practices in water management. • Transparent, responsible management: all operations are recorded by the system. • Swift detection of management incidences.
Public irrigation modernization companies	• Facilitate implementation of preventive management, moderating operational cost and extending the life of the network. • Control of on-farm equipment: discharge, pressure and timeliness of irrigation. Report to farmers. • Assess irrigation network performance using indicators.
TM/RC manufacturers and installers	• In success stories, robust, user-friendly operation. • In failure stories, useless investments and extreme complications in water management. • Since water service is granted by the TM/RC systems, WUAs can focus on hydraulics, energy and water. • Increase WUA capacity to react to changes in the system.
Irrigation engineering firms	• Achievements depend on the WUA and on TM/RC technology. • Where properly used, TM/RC systems are cost-efficient and have radically changed the way WUAs operate. • TM/RC has strongly modified irrigation projects.
WUAs	• Increased awareness of the WUA responsibility. • Optimization of pumping as a consequence of pressure control • Effectively implement volumetric water restrictions to farmers. • Reduced labor requirement from WUA personnel and farmers.
Farmers	• Control irrigation application. • Water management is now more responsible and fairer.

Table 5. *Summary of the results of interview question: How can WUAs improve the exploitation of the installed TM/RC systems?*

Stakeholder group	**Summary and key answers**
General comments	• Develop TM/RC maintenance plans. • Improve WUA personnel training or hire an external company. • Address communication failure, the critical aspect limiting TM/RC system use.
Policy Makers	• Take into account that many aspects of the installed systems are difficult to modify.
Public irrigation modernization companies	• Analyze the obtained results and develop a specific plan for each WUA. • Increase the number sensors (water quantity and quality, valves, pumping stations…) and alarms. • Assess software requirements to exploit the data collected by the TM/RC system. • Consider that TM/RC are tools for advanced WUA management: these WUAs must plan maintenance and pay back for a period of about ten years. • Focus on the critical services of TM/RC systems: low personnel requirements and basic information.
TM/RC manufacturers and installers	• Extending TM and RC capacities to farmers' mobile phones. • Adapt the TM/RC system to WUA specificities as much as it is technically possible. • WUAs cannot receive at the same time the new network and the TM/RC system. They need time to absorb the technology.
Irrigation engineering firms	• Provide more useful information to farmers. • The cost of consumables and replacements needs to be moderate for WUAs to engage. • Subsidies and low implication in decision making make it difficult for farmers to appreciate the value of the TM/RC technology.
WUAs	• Software tools are required for the exploitation of the TM/RC database. • Give more management capacities to farmers through mobile applications. • Agronomic advise on crop water status to optimize irrigation.
Farmers	• Overcome the difficulties in TM/RC robustness to make this system central un WUA water management.

Table 6: *Summary of the results of interview question: What are the main technical limitations of the installed TM/RC systems?*

Stakeholder group	Summary and key answers
General comments	• Several isolated TM/RC systems are used in WUAs for different purposes: reservoirs, pumping stations, collective network… • Unstable communication between the central unit and the nodes. • WUAs depend on the manufacturer of their TM/RC system: there is currently no interoperability. Standardization is required to optimize WUA investments.
Policy Makers	• Limited telemetry capacities, since manufacturers often focused on remote control. • Poor capacity to integrate energy management. • Low sensor robustness for the local climatic conditions. • Proprietary systems produced by an industry where many companies have now disappeared. This limits continuity in operation.
Public irrigation modernization companies	• Obsolescence limits the exploitation of the systems. It is difficult and expensive to update system components. • Dialogue between engineers and WUAs during project conception would have eased technical limitations. • Solar panel powered nodes often have limited connection time. • In rolling terrains radio TM/RC systems will require many communication nodes, increasing investment and maintenance costs.
TM/RC manufacturers and installers	• Difficulties to expand the network since technology is proprietary and may be obsolete. • The electronic components are subjected to very fast obsolescence. Sometimes it is impossible to find replacements. WUAs often acquire large stocks of components, anticipating future needs. • Limitations derived from the contracting process and budget cuts, which affect the TM/RC system more than other parts of the project.
Irrigation engineering firms	• Software does not support dynamic, responsive WUA management. • Installed systems have low flexibility to accommodate new realities, such as pumping with solar energy.
WUAs	• Nodes have high energy consumption. • Consumables are expensive and difficult to find. • Software does not support fast, simple exploitation of the TM/RC information
Farmers	• The TM/RC system is complex to operate. • Components become obsolete very quickly. • Energy consumption, vandalism of solar panels, high cost of battery replacement.

Table 7. *Summary of the results of interview question: What will be the key contributions of TM/RC systems to water and energy management in the next decade?*

Stakeholder group	**Summary and key answers**
General comments	• Adjust water and energy use to the requirements. Reduce the energy bill. • Further improvements in labor conditions of farmers and WUA personnel. • Integrate TM/RC systems with irrigated farming, use a variety of data sources (meteorological, agronomical, organizational, land tenure) in decision making. • Lead WUA and farmers towards precision farming. • Integration with water and energy use efficiency simulation tools.
Policy Makers	• Exploit big data analysis (TM/RC databases in conjunction with meteorology and other sensors). • Adapting technology deployment to every situation, WUAs will find cost-efficiency in their TM/RC systems.
Public irrigation modernization companies	• Generalize preventive management. • Provide farmers with individualized, real-time information for success in their farming operations. • Implement network performance indicators pursuing quality control in water and energy management. Indicators can be associated to incentives to WUA personnel.
TM/RC manufacturers and installers	• Early detection of failures. • Increase the number and type of environmental sensors to guide irrigation management. • Gather additional information through distributed low-cost devices. • Adopt robust industrial standards for irrigation applications.
Irrigation engineering firms	• Reduction in the cost of the technology will lead to widespread application. This will permit to exploit big data in irrigated agriculture. • Irrigation will be fully automated. Farmers' interaction will not be required. This implies a societal change, for which technology and farmers need to get ready.
WUAs	• Providing more and better information to farmers. • Complete automation of WUA irrigation: from meteorological and farming information to water application. • Can WUA networks be effectively operated in the future without TM/RC systems?
Farmers	• Irrigation scheduling, water use forecast. • Combine with meteorological databases for optimum water application.