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Are Water User Associations Prepared for a Second-Generation Modernization? The Case of the Valencian Community (Spain)

César González-Pavón ¹, Jaime Arviza-Valverde ¹, Ibán Balbastre-Peralta ¹,
José Miguel Carot Sierra ² and Guillermo Palau-Salvador ^{3,*}

¹ Centro Valenciano de Estudios del Riego, CVER, Universitat Politècnica de València, Camí de Vera s/n, 46022 València, Spain; csagonpa@doctor.upv.es (C.G.-P.); jarviza@agf.upv.es (J.A.-V.); ibbalpe@agf.upv.es (I.B.-P.)

² Departamento de Estadística e Investigación Operativa Aplicadas y Calidad, Universitat Politècnica de València, Camí de Vera s/n, 46022 València, Spain; jcarot@eio.upv.es

³ INGENIO (CSIC-UPV), Universitat Politècnica de València, Camí de Vera s/n, 46022 València, Spain

* Correspondence: guipasal@agf.upv.es

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Abstract: This work focuses on the situation of the technological transition to new technologies in drip irrigation in the Valencian Community (Spain). The study covers the last decade with data from interviews to managers of Irrigation Communities in 2010 and 2018. We analyze the main technological problems in seven topics: (i) Catchment & Pumping; (ii) Storage & Regulation; (iii) Treatment & Filtering; (iv) Transport & Distribution; (v) Maneuver, Regulation & Protection; (vi) Automation; (vii) Theft and Vandalism. We also have researched the influence of the performance of the Automation system, the presence of a technician in the Irrigation Community and the use of sensors or climatic data. Results show that problems related to technological maintenance of filtering systems or automation are very common and important and they are more important in large Irrigation Communities. We have also observed that mostly large ICs are using sensors or climatic data for their irrigation schedule. We can conclude that their current situation is focused in the daily maintenance of technological problems, inherited from the first modernization processes at the beginning of 21st century. Hence, they are far away from a second stage of modernization or the smart irrigation pushed by the new advances on technology.

Keywords: new irrigation technologies; WUAs; modernization; professionalization; technical management; drip irrigation; collective management

1. Introduction

In the past decades, water management has been a central issue for local, national and international public and private policies. In this context, studies focused on the implementation of new technologies on irrigation management are relevant for sustainable water policy of irrigation infrastructure and expansion [1].

Initially, water policy in Spain was focused on the development of public hydraulic infrastructure (reservoirs, water transfers, irrigation channels) in order to increase water availability and develop new irrigated areas [2]. The Spanish Irrigation National Plan began in 1995 [3,4] and initiate an enormous shift in the implementation of pressurized irrigation technology, as explained in detail [5]. Moreover, the 2005–2008 drought compelled the government to review and reorient the irrigation plan in order to implement ways of reducing water use in agriculture and gain efficiency [6]. In 2006, triggered by

an ongoing drought period, a shock plan for irrigation modernization included new actions and financing with an aim of saving more water [7].

Moreover, the drip irrigation transformation in Valencian Community was implemented before other Spanish regions. The technological transformation to drip irrigation in Valencian irrigation can be divided in two phases: a first one beginning around 1985 where the implementation of drip irrigation corresponds to farmer's initiative, both corresponding to new irrigated areas and to areas characterized by important scarcity [8] and a second phase beginning in 2000 with a prominent role of public investment programs for modernization of approximately 130,000 ha [9].

The effort of these policies has focused on improving technical efficiency in order to save water. According to Allan [10], Lecina et al. [11] and Playán and Mateos [12] improving technical efficiency is an option that benefits farmers, and manufacturers with very little political interference. However, some weaknesses of the national Irrigation Plan implementation have also been mentioned: a lack of monitoring plan to track effectiveness during implementation or the apparent lack of a previous established criteria to decide how to allocate funds in relation to the established objectives [7,9,13].

In this sense, there are relatively few studies focused on the adoption of these new technologies or practices. Some of these studies are focused on the introduction of drip irrigation on developing countries. This is the case of the study of [14] where they compare the adaptation of drip irrigation between Israel, a technically advanced country, with Sub-Saharan countries, where the introduction of drip irrigation is more recent. Garb and Friedlander [14] use the concept of "technology translation", defined as the streams of socio-analytic thinking of how technologies evolve and travel. In a previous work, Friedlander and Lazarovitch [15] had analyzed the main technical problems in 61 drip irrigation projects in Sub-Saharan countries, which included blockages, wear and tear and issues with drip lines and filters. Moreover, other studies, such as Ahmad and Khan [16] also analyze the implementation of drip irrigation in developing countries, along with the water and energy savings after the application of new technologies. In general, there is a great concern on the need to deal with the poor performance of large-scale irrigation systems, as it is explained in detail first by Plusquellec [17], and it was later applied in other situations by Masseroni [18], de Bont et al. [19] and Koech and Langat [20]. In this sense, adopting drip irrigation technologies in the southeastern Spain is a central issue with an implication in financial benefits for farmers [21]. Furthermore, Alcón et al. [22] analyzed the main reasons for the farmers in southeastern Spain to adopt drip irrigation technologies and they highlighted the influence in this decision of educational factors, technological testing, loan availability and institutional factors.

In many cases, drip irrigation transformation is associated with high-profit precision agriculture [4]. This subject is relevant in the Spanish context, where there are more than 7.000 registered Water User Associations. Most of the studies are focused on yield production [23], water-saving [12,24] or organizational and institutional changes [5,25,26]. Among these studies, we would like to highlight the concept of second-generation modernization mentioned first by Soto-Garcia et al. [27], which is defined as applying new technologies focused on the automation of hydraulic infrastructure and irrigation services. This concept was also used by Alcón et al. [28] to explain the performance of Water User Association in Eastern Spain when analyzing the automation of the system. In this sense, new trends are focused on investigating smart irrigation systems as new technologies that optimize irrigation schedules, reducing water consumption or potential contamination [29,30].

However, institutions need time to define the strategy, get organized and adapt to the needs of users. In this sense, drip irrigation is a relatively recent change and the process of transformation is at an initial stage in many cases. For this reason, the objective of this research is to analyze the actual situation of drip irrigation technology in the Valencian Community, at the East part of Spain. The research was performed by interviewing managers of 25 Water Users Association (WUA) analyzing the degree of modernization and automation of the WUAs and the main technological problems encountered in their daily activity.

2. Materials and Methods

2.1. Case Study

In Spain, the irrigated area amounts to more than 3.7 million hectares of which 7.7% belong to the Valencian Community. The water, with which this surface is supplied, to a large extent, is managed by WUAs. These WUAs collectively managed the irrigation systems and they are recognized all over the world [5,31,32]. They are non-profit organizations, and have their own rules to manage water distribution and resolve conflicts [5]. Land-tenure structure is characterized significantly by small plots; hence it can be referred as a small-holding system, as most farmers own less than 1 ha [33]. In the Valencian Community, there are more than 700 WUAs.

Valencian Community is characterized by a semi-arid climate consisting of irregular rainfall and seasonal summer scarcity that occurs when irrigation requirements are at their height [34]. The predominant agricultural crops are citrus (30%), vineyards (12%) and cereals (7%) and the remainder consists of different woody (46%) and horticultural crops (5%) [35]. The Mediterranean climate, in combination with the existing cropping pattern, creates a situation where water is vital for farmers.

The study area of this work focuses on the Valencian Community. The sample consists of 30 Water User Association, 7 of which are located in the province of Valencia, 8 in Castellon and 15 in Alicante. In Figure 1, the WUAs selected are located geographically and categorized by size. The WUAs were divided in two groups by their size, “Small WUAs” with a supplied surface less than 700 ha (in blue at Figure 1) and “Large WUAs” with an irrigated surface bigger than 700 ha (in red at Figure 1).

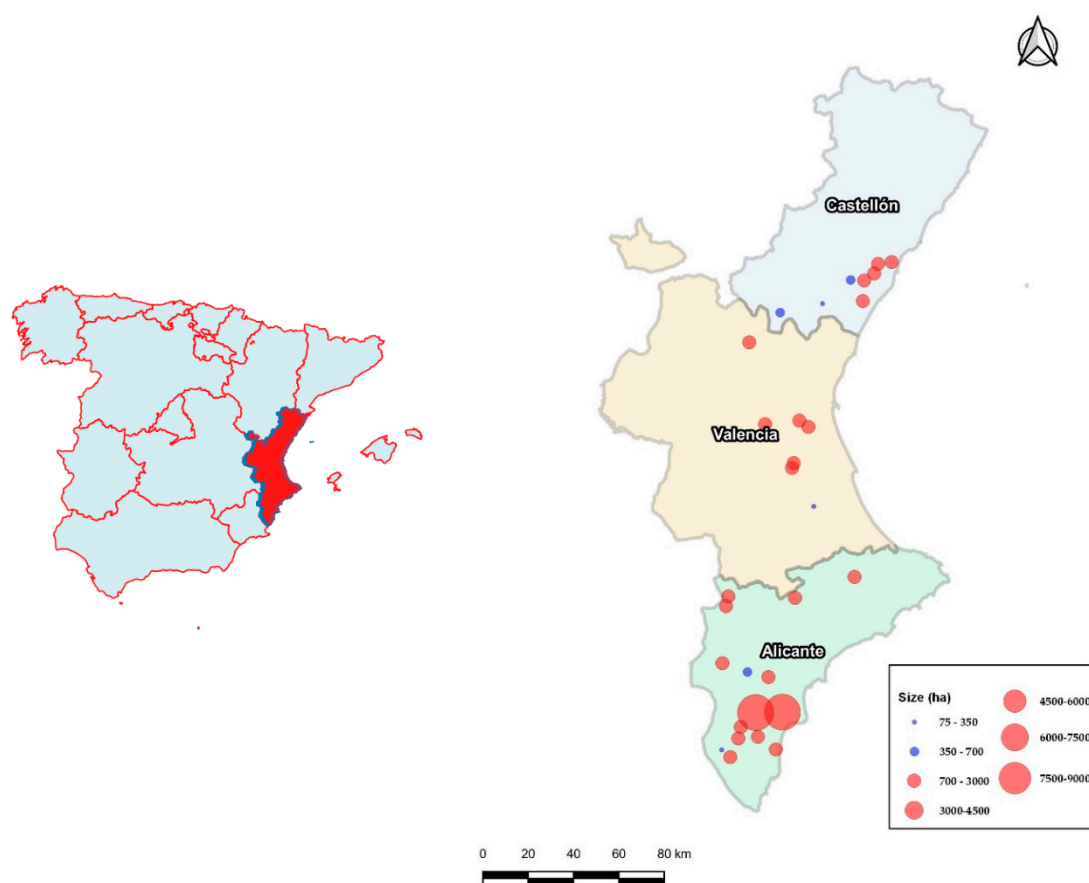


Figure 1. Location of the selected WUAs categorized by size. In blue, the “Small WUAs” and in red the “Large WUAs”.

Data collection was carried out by conducting interviews to the WUAs' managers. The interview with 25 questions was conducted to each manager of the WUAs. The manager is generally a farmer with many years of agricultural experience and who has been elected by the members of the WUA. The profile of the interviewees were males between 50 and 70 years of age. The data was collected in 2010 and 2018 to analyze the evolution of the implementation of drip irrigation. The research methodology of this investigation is based on an interpretative research paradigm [36] where qualitative research methods have been used to gather data, but also to systematize the interpretations of the different interviewees.

In 2010, the interviews focused on questions about irrigation management, automation and problems in the management and the infrastructure of the WUAs. The problems found in the interviews were grouped into 7 categories according to the part of the network affected (Table 1). The categories in which the detected problems have been grouped are:

Table 1. Dimensions and variables of the survey.

Dimension	Year	Variables	Detailed Problems	Questions
Problems at operation and design	2010 & 2018	Catchment and pumping	Pumping groups Pressure in networks Water quality Material quality	Yes/No Reasons
	2010 & 2018	Storage and operation	Pools design and maintenance Water quality	Yes/No Reasons
	2010 & 2018	Treatment and filtering	Filter clogging Water quality	Yes/No Reasons
	2010 & 2018	Transport and distribution	Pipe breaks Material quality Inadequate materials Inadequate pipe design Inadequate hydrants location	Yes/No Reasons
	2010 & 2018	Maneuver, regulation and protection	Low pressure in plots Flow meter blocking Gate malfunctioning Manometer malfunctioning Air valve malfunctioning	Yes/No Reasons
	2010 & 2018	Automation	Breaks in automatic gates Communication failures Rodents	Yes/No Reasons
	2010 & 2018	Theft and vandalism	Manholes Photo-voltaic modules Cooper Special devices	Yes/No Reasons
Automation performance	2010 & 2018	Automation satisfaction	-	Likert scale
	2018	Soil moisture sensors	-	Yes/No Type Location
Applying new technologies	2018	Technical workers	-	Yes/No Qualification
	2018	Agro climate Data	-	Yes/no Type

i. Catchment and pumping: collection of water from natural or artificial sources in order to be used for irrigation. Within this dimension, problems were observed in groundwater and surface catchments, pumping systems or the resource coming from wastewater treatment plants.

ii. Storage and operation: storing the captured water for later use in irrigation. They are usually reservoirs of loose materials or storage tanks, and allow irrigation operation, admitting turn-based and on-demand irrigation.

iii. Treatment and filtering: system to obtain water to be physically and chemically treated in order to avoid clogging of the irrigation emitters and in many cases to provide basic fertilized water for irrigating crops.

iv. Transport and distribution: Problems were considered related to the network of pressure pipes (pipes) and ditches that connect the collection and storage points with the irrigation plots.

v. Elements of maneuver, regulation and protection of the network: elements that allow regulating the pressure and flow of the network. All the hydrants, with their gates, flow meters and air valves, are included. They also take into account the multi-user elements.

vi. Automation systems: Issues related to the communication and action systems to control and organize irrigation more efficiently. Remote control by radio or cable connections is normally used.

vii. Theft and vandalism: Although these problems affect the rest of the previous categories, they have been separated due to the magnitude of problems encountered, all those aspects related to the theft of material are included, especially manholes, photo-voltaic modules, cooper cables and special devices.

Moreover, in 2018, after the initial analysis, questions related to the professionalization of the WUAs by means of the presence of a qualified technician and the use of agro climate data were added. Table 1 summarizes the dimensions of the interview, as well as their main variables.

Finally, once the results were obtained, categorized and analyzed, 7 interviews were carried out with senior agricultural engineers with an extensive experience in designing, executing and maintaining irrigation projects. The profiles of the senior engineers are detailed in Table 2. These interviews were conducted by presenting the obtained data of the research and discussing with the engineers the reasons and implications of the main results.

Table 2. Profiles of the experts interviewed for discussing the main results obtained from the WUAs.

Gender	Age	Position	Degree
Male	48	Technical Engineer	BSc. Agriculture Engineer
Male	52	Manager of irrigation consulting	BSc. Agriculture Engineer
Male	58	Manager of irrigation consulting	PhD. Agriculture Engineer
Male	27	Technical Engineer	MSc. Agriculture Engineer
Male	47	Technical Engineer	PhD. Agriculture Engineer
Female	48	Commercial Engineer	BSc. Agriculture Engineer
Male	47	Manager of irrigation consulting	MSc. Agriculture Engineer

2.2. Statistical Analysis

In order to study the relationships between the detected problems and the variables, which characterized the WUAs (size, presence of technician, use of agro climate data and use of sensors) contingency tables were created. The Fisher's Exact Test has been used to evaluate the significance of these relationships, due to the variables being categorical and because the sample is small (cells of the contingency table less than 5). When using this test the p -value is exact and not an approximation [37]. The analysis was carried out with SPSS software [38] and only relations with a p -value lower than 0.1 was considered. We choose this value to find a balance between the significance level and power.

3. Results

3.1. The Main Problems in Water User Associations

The main problems detected in WUAs have been grouped into 7 large dimensions (Table 1). The percentages of WUAs, which have experienced each of these problems, are shown in Figure 2, both for 2010 and 2018.

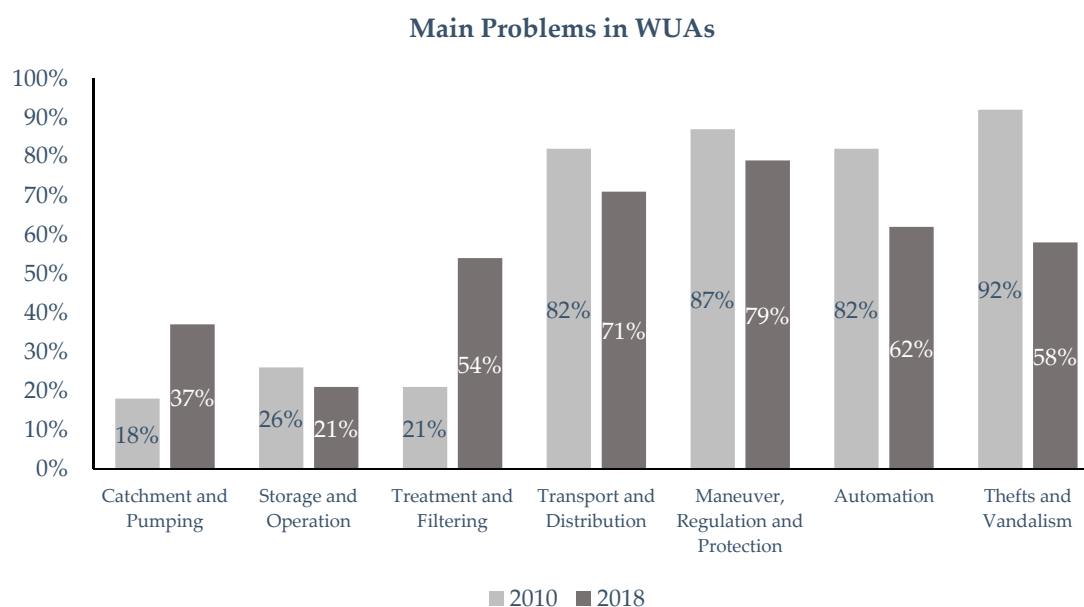


Figure 2. Percentage of WUAs with problems in the seven main dimensions for 2010 and 2018.

In 2010, the main problem was theft and vandalism with 92% of the WUAs affected, almost at the same level as the problems related to automation, transport and distribution, and maneuver, regulation and protection, with 82%, 82% and 87% respectively. There is a clear relationship between thefts and vandalism and the other three types of problems, although thefts affect different elements of the network, their incidence is greater in the elements that form the automation, distribution and control elements of the facilities.

Other causes that would explain the importance of the problems detected in the automation systems are the interference or failure in communicating for extreme weather conditions by radio systems (22%), poor connectivity for reading water meters (26%), and failures with the operation of solenoid valves in hydrants (25%). The latter was considered an essential issue, as an expert stated in one of the interviews.

“The most important problem was the operation of solenoid valves in hydrants. We also had to make decisions to reduce their usage instead of improving irrigation efficiency by increasing their lifetime warranty.”

Most of these problems were a consequence of the rush to execute projects around 2008 coinciding with the real estate bubble crisis. In those projects, there was a huge investment in technologies that were not really tested or standardized for remote control. This situation created a dependency for maintenance or new improvements or connections, which up until now have not been solved in many cases. In some cases, the persistence of these problems has led to a reduction in the usage of automatic water meters readings. The alternative measurement system consisted in calculating the water consumption proportionally to the irrigated surface, without any control on the real amount of water used at the expense of decreasing irrigation efficiency.

For transport and distribution, the main problem observed by WUA’s managers is due to pipe breaks (30% of WUAs), as a result of deficiencies and poor quality in the manufacture of PVC-U and

GRP pipes like one of the experts highlighted. In addition, a bad installation was also observed in many cases. A large number of distribution networks were carried out during those years and due to the real estate crisis, big construction companies shift their interests to build irrigation projects. Moreover, these big companies could offer low budgets, which did not guarantee the acquisition of high-quality materials or monitor the correct execution of the work. For this reason, some of the large pipe networks were not designed correctly, because of the rush to build and budgets cuts. There was a lack of preventive maintenance systems, which have led to an increased number of emergency repairs as a result of excessive pressures and breaks of the installed materials. As one of the experts stated, the correct design and maintenance could reduce the cost of these reparations.

“When talking about maintenance there is a golden number, 80% for preventive maintenance and 20% for emergency repairs. For a technician, it is very hard to convince a Water User Association to invest in preventive maintenance. But when this number is established, it works beautifully.”

Finally, in relation to elements of maneuver, regulation and protection, the interviews carried out reflected a malfunction in gate and air valves (22%) due to lack of maintenance and especially in the blocking of the flow meters (30%) due to an inadequate installation. These effects were analyzed in detail by Balbastre Peralta [39], concluding that a better design of hydrants was needed in order to achieve an acceptable performance of the WUAs.

However, in 2018, a change in the importance of the detected problems was observed. A significant decrease of thefts and vandalism occurred, as it will be explained in more detail in Section 3.2. Moreover, the main problems detected were related to elements of maneuver, regulation and protection with 79% of the WUAs affected, nevertheless, there was also a decrease in percentage with respect to 2010.

If we analyze in detail the problems detected in 2018 for each category, we observe that in the case of maneuver, regulation and protection, the most important problems continue to be those related to the blocking of flow meters (29%) and malfunction in gate valve (29%), maintaining values similar to those of 2010.

The problems in catchment and pumping facilities increased their importance from 18 to 37% from 2010 to 2018. This expansion is due to a lack of maintenance in the facilities and renewal of equipment that is causing a reduction in the performance and efficiency of the pumping groups. Among these problems, the ones related to the lack of pressure available to the end user grew from 18% to 38%. This decrease could be related to the increase in problems in treatment and filtering which varied from 21% to a worrying 54%, not only in community facilities but also because of filter clogging problems which have increased in multi-user hydrants (33%). These problems can lead to a progressive increase in pressure losses with its consequent decrease in the available pressure for irrigation subunits [40] and consequently a reduction in irrigation efficiency.

In 2018, there is also a growing concern about the poor quality in the installation of materials (35%), this growth is due to the fact that the WUAs were perceiving a decrease in the durability of all the facilities managed, which can also be related to the high concentration of irrigation constructions around 2010 and the market's inability to provide high-quality materials for all the WUAs modernization to drip irrigation [41]. It is important to establish an accurate lifetime warranty for the different materials insure a viable financial plan. While lifetime of pumps and pipelines could be between 20–25 years, other devices in the hydrants must be estimated to last a maximum of 10 years.

If the automation dimension is analyzed in detail, even though there was a general decline from 2010 to 2018 (82 to 62%), there is an increase in problems because of the bite and breakage of the connection cables by rodents, and communication failure for those cases in which its operation is carried out by radio systems. The problems in automation systems with cable communication also increased from 8% to 21%. This increase could be due to old installations where ongoing maintenance was not carried or where the wiring installation was not performed correctly and safely.

After this one-dimensional analysis, the possible relations between the detected problems and the variables which characterized the WUAs: size, presence of technician, use of agro climate data or use

of sensors, were researched by means of contingency tables using the Fisher's Exact Test to evaluate their significance.

An interesting correlation was found in the interaction between the WUAs' size and the problems with Treatment and Filtering. Although in 2010 no correlation was observed ($p = 1.00$), in 2018 the p -value obtained was of 0.09. Figure 3 shows that for 2010, both large and small WUAs do not present differences with these kinds of problems, with 0% in small ones and 28% for the large ones. However, in 2018, an important increase for small WUAs is observed with 20% of small systems presenting problems with filtering, while in large ones 63% showing this kind of problems. This situation cannot be explained by an error of the devices because filtering and treatment facilities are designed for a lifetime warranty of at least 20 years. However, the lack of maintenance or the absence of qualified technicians at the small WUAs can explain the malfunction of the filtering and treatment systems. This maintenance requires a very accurate knowledge of the filtering process, not only in the design, but also in the exploitation of the WUA [40].

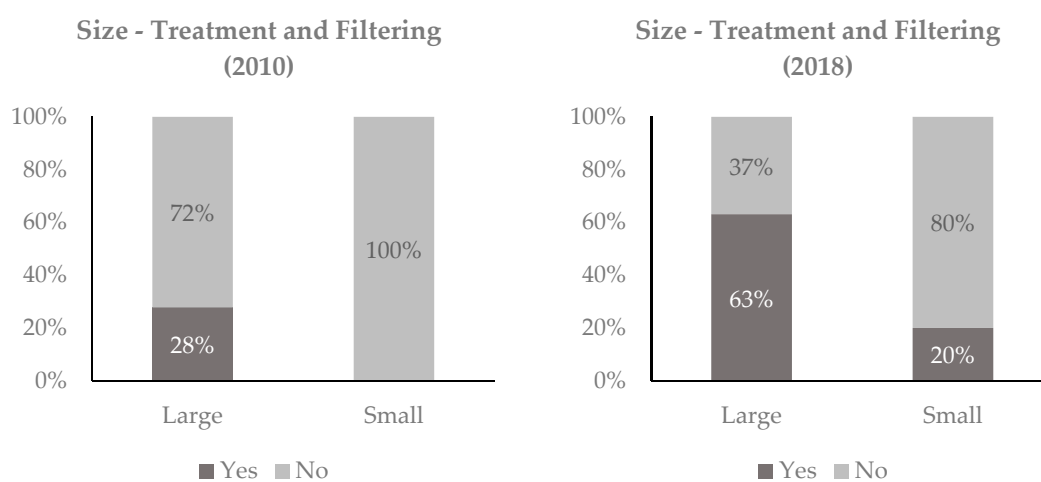


Figure 3. Relation Size—Treatment and Filtering in 2010 and 2018.

Finally, another interesting correlation was found between the presence of a technician and problems with Catchment and Treatment and Filtering, the interaction between the WUAs' size and the problems with Treatment and Filtering. In 2018 the p -values obtained were of 0.05 and 0.09, respectively. Figure 4a shows that for 2018, the 36% of the WUAs with a technician had problems in catchment, while the WUAs without a technician did not report any problem. Moreover, this situation also happened when we analyzed problems with Filtering and Treatment. While 71% of WUAs with a technician had problems, only 30% without a technician identified these problems. This situation might be explained by two factors (Figure 4). On the one hand, the presence of a technician helps to identify these kinds of problems, which are related to maintenance of filters and equipment. On the other hand, the presence of a technician allowed the WUAs to modernize their devices and introduce new equipment, which can present more problems due to automation. This was explained by one of the experts, who described the situation in small WUAs as follows:

“I think that in the small WUAs which there are no technicians hired, the same or even more problems appear, but not detected, such as pumps out of their range, or they are parched. In the case of filtering, the farmers clean the filters and everything seems to work correctly again, although the problem is not completely solved.”

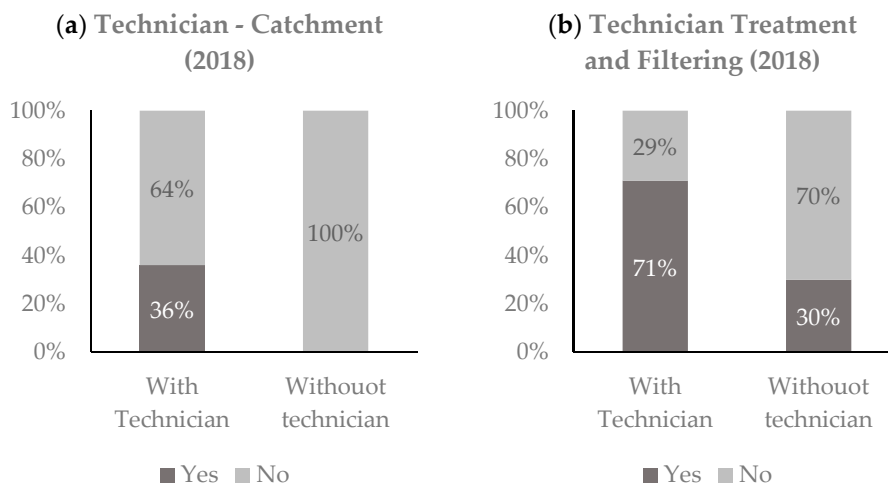


Figure 4. Relation Technician and Catchment (a) and Treatment and Filtering (b) in 2018.

Nonetheless, as it is shown in Section 3.3, there is a strong relation between the WUAs’ size and the presence of a technician. This fact could lead to the misinterpretation of which of the two variables are involved in the correlation with both problems.

3.2. Theft and Vandalism

Taking into account that theft and vandalism were one of the most pressing problems at WUAs, a more detailed study was carried out regarding the elements affected. A trend can be observed of the reduction on thefts of heavy iron material from elements, such as manholes, doors and gates (60% in 2010 to 5% in 2018) and a considerable increase in theft of copper from electric wiring (0% in 2010 28% in 2018). The other two groups have remained more or less constant with a slight decrease from 2010 to 2018 (21% to 13% and 44% to 38% in photovoltaic modules and valves, respectively). These comparisons can be observed in Figure 5.

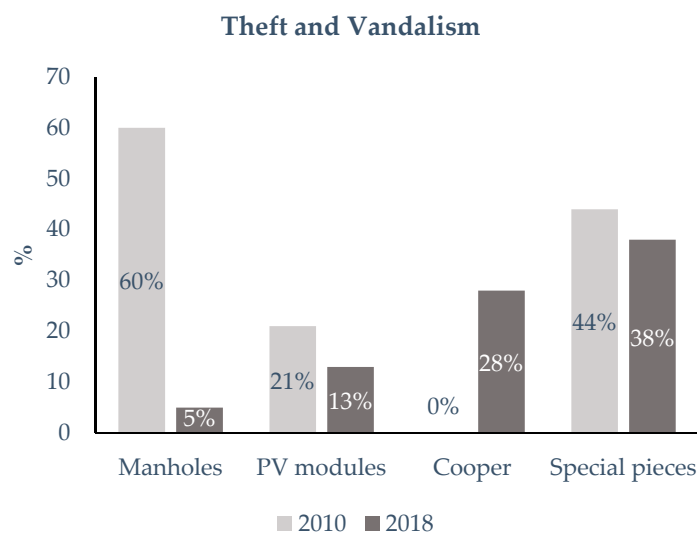


Figure 5. Main problems derived from theft and vandalism.

If we analyzed closely the results presented in this paper, we can observe that the main problems detected are related with thefts with the purpose of selling the material on the black market. This differs in other cases reported by other authors, where vandalism and thefts take place as a reactive action of farmers who oppose to the change of technology [42] or the increase in irrigation surface which jeopardizes their water supply [43]. However, in the Valencian Community’s case, thefts and

vandalism are not related to a social acceptability of irrigation technology, but with common felonies or misdemeanor, which was also observed by Ortega-Reig et al. [25]. In fact, the highest robbery rate in 2010 could be related to the economic crisis of 2008 which severely affected the Spanish society and had an impact on the amount of felonies committed in isolated houses and rural areas [44]. The difficulty with these common delinquents are that are very difficult to chase and catch in rural areas [45]. The consequences are that farmers tend to replace the stolen pieces with lower quality ones or not replace them at all, because the farmers' insurance policies do not cover the repeated theft of the components. As a result, WUAs are hesitant to introduce or replace expensive components such as solar panels or automation systems. An example observed in our research is some WUAs have begun to manually or directly measure water consumption instead of using the automatic flow meters measurements due to the continued theft of these devices. Furthermore, the other option used by one of the WUAs is to install security alarm systems. However, these systems are very expensive and only large WUAs with high budgets can afford the investment. The case of the copper theft is also significant. The increase of this kind of theft is directly related to the increase of its price over the last years as it happens all over the world [46].

3.3. Automation Performance

Another aspect to consider in more detail is related to automation performance. As we have seen previously, problems of automation have decreased from 82% in 2010 to 62% in 2018. However, regarding satisfaction with the automation system using a Likert scale, there have been no great differences from 2010 to 2018, as shown in Figure 6.

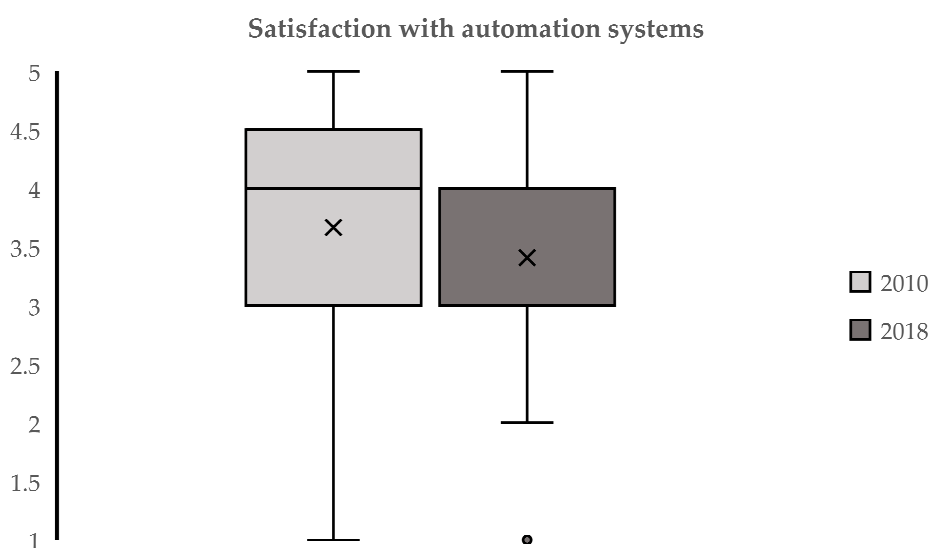


Figure 6. WUAs satisfaction with automation systems using a Likert scale, being: 1 (strongly disagree); 2 (disagree); 3 (neutral); 4 (agree); and 5 (strongly agree). The cross mark represents the medium value.

As we can observe in the results, the average and standard deviation for each year are 3.7 ± 1.5 and 3.4 ± 1.1 for 2010 and 2018, respectively. The main difference is that there has been less dispersion of the values in 2018 than in 2010. An interesting element in the interviews is that most of the farmers do not manage the automation since the WUA's manager or technician controls it. Generally, this activity is outsourced and as a result, the managers have a low margin to introduce improvement or changes. Moreover, the managers of WUAs have a clear goal of maximizing production using the same amount of water, thereby reducing as much as possible their hydraulic problems. In general, automation works well except in extreme weather conditions, sharp landscapes or wild animals, elements beyond their control. This is opposite to the findings of Bernouniche et al. [47] where they state that automation implies a real problem to farmers in Morocco because of their lack of knowledge in understanding the

technology. Nonetheless, as stated by different experts, in the Valencian Community, a technician hired by the WUA or a specialized external company should manage the automation system, but this does not always happen. Automation is a key-element in what Soto-Garcia et al. [27] and Alcón et al. [28] called the second-generation of modernization which should be taken into account in the transition to a more modern and digital agriculture. However, in many cases the setup of the automation was self-made by the WUA without a previous study, using a process of trial and error to make improvements, which has led to systems not being standardized and difficult to update to new technologies and applications.

3.4. Professionalizing Irrigation Systems

As we explained in the methodology, from 2010 to 2018 we introduced several questions related to making the WUAs more professional. These variables were the presence of a technician hired in the WUA for water management, the use of sensors both on the plot and in the general system and the use of meteorological data for irrigation management. In Figure 7, the percentages of WUAs that answered positively to these questions are observed, resulting in values of 58, 38 and 34% respectively.

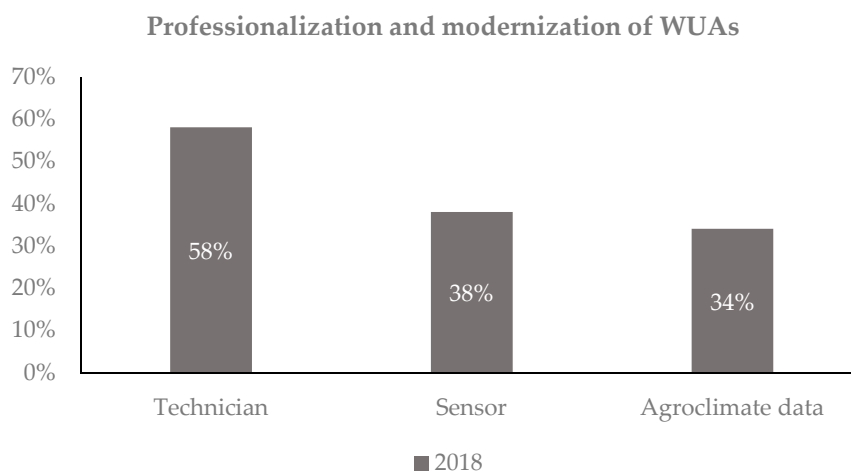


Figure 7. Percentage of WUAs that are hiring a technician, using sensors or agro climate data. These variables were added in the 2018 survey.

In a more detailed analysis, the size of the WUAs is directly related to the presence of technicians in their management. We performed a contingency table analysis and the results using the Fisher's Exact Test showed a p -value of 0.03. The direct explanation is related to economic factors. Since the hiring of technicians implies an important fixed cost, many of the Small WUAs argued that they couldn't afford to pay the monthly costs that this activity generates. This happens because they do not have a long-term view where maintenance cost could exceed the fixed one.

As shown in Figure 8a, in large WUAs, 79% have hired a technician, but in small WUAs only 30% have one on their staff. These small WUAs usually subcontract the task that they cannot deal with on their own, which means sporadic expenses and a much lower annual amount than that of a hired person. On the other hand, in the large ones, this cost represents a very low percentage of the total expenses since they are distributed among a greater number of farmers, because of this reason, most of them have at least one hired technician.

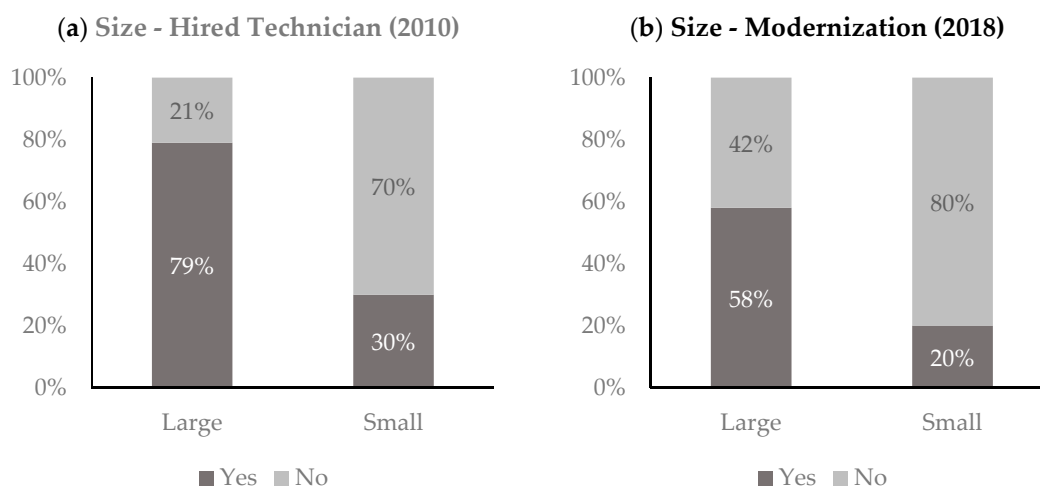


Figure 8. (a) Relation between WUAs size and hiring of technicians; (b) Relation between WUAs size and modernization, considering the hiring of a technician and the use of sensors or agro climate data for irrigation calculation.

Moreover, we consider that the professionalization of a WUA is accomplished when there is a technician, they use sensors for irrigation management and they manage agro climatic parameters for irrigation programming. This fact implies an upgrade in the modernization degree of WUAs. However, as it is observed in the results of this paper these changes are not generalized in the entire region. We can observe in Figure 8b, that there is a relation with the size of the WUA, 43% of the large WUAs interviewed have adopted the three elements in their daily operation while none of the small ones have introduced them (p -value of 0.047 in Fisher's exact test).

Furthermore, if these data are analyzed in more detail, the WUAs, which have adopted the three elements, are the ones between 700 to 3000 ha, as we can see in Figure 9. This can be explained by the fact that small WUAs cannot afford the investment of this modernization. Besides, the two larger ones (more than 3000 ha) did not adopt them either. This can be explained because these two WUAs were created for administrative purposes by many small WUAs. In these cases, the technical management was still carried out by the original small WUAs, so there is no need for the consortium to hire a technician. Nonetheless, large WUAs supply large areas and are interested in using new technologies for irrigation scheduling. In fact, as we have observed in Figure 8a, most of them have hired a technician (79%). Moreover, WUAs have received subsidies for the modernization of their facilities in relation to the rational use of water. Sometimes, only large WUAs have the economic capacity to apply and, then, they are obliged to introduce elements to measure and improve irrigation efficiency, hence its use is becoming more widespread.

In this sense, a tension arises between the managers of the WUAs, normally a farmer, and the hired technician. Generally, the managers have the goal to increase productivity and reduce costs. They normally want to simplify the hydraulics and are reluctant to introduce new technologies, which they think that will make their professional activity more complex. However, although the hired technicians have the same objectives as the managers, they have normally not been involved in the system's design, so they have to control a system with deficiencies or with non-standardized protocols. Besides, they do not have the power to make decisions and must follow the WUAs indications. Furthermore, they have to learn how to navigate, improving the system slowly by convincing the WUAs' managers without challenging the major cultural constraints, doing their best in the current status quo.

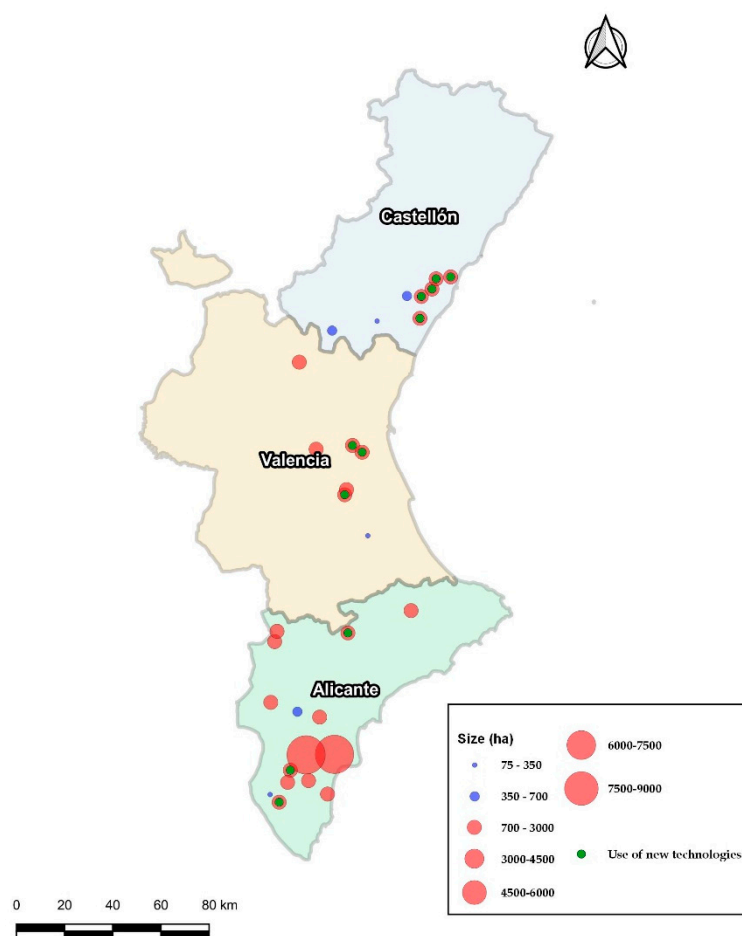


Figure 9. WUAs that both hire a technician and use new data for irrigation calculation.

Nevertheless, policies from the regional government are trying to foster this change by introducing new conditions in a governmental order in 2018 for the tender of subsidies in new modernization projects [48]. In this order, they give preference to proposals that incorporate facilities, equipment, devices and any other information and communication technologies that allow for better irrigation management and a reduction in water consumption. This situation has changed the previous trend and it is generalized the installation of soil moisture sensors and smart control systems in this new modernization projects, however as one of the experts expressed; what is important now is that they learn how to use them.

“We are now installing humidity sensors in all our projects, even in the small WUAs. Now the challenge is for the WUAs to use them, and to use them correctly”.

In summary, the situation in Valencian Community is far from the current movement of smart irrigation or digital irrigation. While big companies with single-crop farming are investing in high-technology production and management, from drones to robotics [49], the WUAs located in Valencian Community are still managed by many farmers who own small plots and are not prepared socially or culturally for this kind of transition. The question that arises from this analysis is whether these WUAs are prepared for the second-generation modernization [27] or the smart irrigation which is driven by the new advances on technology. Currently, our results show that these WUAs are struggling with more common problems, such as pumping, filtering or thefts, and are not focused on the transition to new technologies. And, moreover, they are not willing to make this kind of investment in a complex agroindustry system with very low economic benefits and securities [50]. As one of the experts summarized:

“I would say that WUAs cannot run the risk of delaying the second modernization. However, a social and cultural change is needed to introduce new technologies. Maybe they cannot afford a RPAS (Remotely Piloted Aircraft System) drone usage three times a year, but they can use humidity sensors, hire a part time technician, have preventive maintenance, improve their system by a proper efficiency study and so on. Then, they will be one step closer in order to apply newer technologies.”

Furthermore, the WUAs are facing one of their most crucial moments. It is obvious that WUAs cannot afford not to modernize their irrigation systems, because it is essential for their long-time survival. For that, they have to undergo a profound social and cultural change to introduce new technologies along with hiring technicians, introducing preventing maintenance or promoting a generational leap.

4. Conclusions

The study has shown the evolution of the WUAs' main problems that have been detected in the Valencian Community over the last decade. After grouping the problems and studying them, it has been observed how their trend has changed over the last years. In 2010, the main problem faced by the WUAs was vandalism and thefts, surely due to the economic crisis that the country was going through at that time. However, in 2018 the situation was different, the main problems they encountered were of technical nature, the majority being those related to maneuver, regulation and protection. As a general rule, all the problems detected have decreased in 2018 but the percentage of affected communities is still important. All these problems fall directly on the users who, in the case of being very frequent and important, such as power cuts in the summer season, can translate into higher repair costs or economic losses in their plantations due to the malfunctioning of the facilities.

In order to analyze the presence of these problems and understand them, their correlation with the variables that characterize a WUA such as the size or the presence of qualified technical personnel was studied. The relationship between size and problems in treatment and filtering was significant for 2018. The explanation was related to the maintenance of the filtering systems, both in the design and the exploitation. This situation entailed that filtering systems are not being replaced and, in many times, they are not adequate for the filtration requirements. Furthermore, it was observed that the problems in recruitment, treatment and filtering were related to the presence of a contracted technician. Obviously, the presence of the technician does not increase these problems, but it does detect them and can be solved more quickly before they cause more serious problems.

Since theft and vandalism was one of the most predominant problems, a more in-depth analysis was carried out. In 2010, the most stolen items were those of metallic materials that were sold on the black market. This situation coincided with the economic crisis in Spain and the high unemployment rates. In 2018, the increase in copper theft occurred and its price increased by more than 50% compared to previous years. These robberies imply a high cost to the WUAs, so many have made the decision to use pieces of plastic materials for special elements such as flowmeters.

Another important aspect analyzed has been the professionalization and modernization of WUAs. It is concluded that the larger WUAs, which have greater financial resources, are those that can afford to have a contracted technician. Similarly, the use and application of new technologies in the field of water is more widespread in those of larger size. Both humidity sensors and use of climatic data allow them to optimize both the volumes consumed and the irrigation intervals. This aspect is of vital importance for many communities, particularly in the south of Valencian Community where water resources are more limited. Despite this, not all of them use it, since the need for personnel who know how to interpret the data is essential.

Finally, it can be affirmed that the Water User Associations continue to suffer problems in basic elements of their facilities. Despite the improvement in the last decade, these problems are still notable. On the other hand, the use of new technologies is becoming more widespread among the larger WUAs, which means that the degree of modernization of these technologies are increasing over time. Whilst this trend is very important in intensive and single-crop exploitations which are investing in smart irrigation, it is still out of reach of many WUAs with small plots and a large number of

different farmers. The WUAs in the Valencian Community are still struggling with more common problems, such as filtering, regulation and distribution of water. This situation is not unique in this region, if not common with many of the Mediterranean countries and other parts of the world with WUAs with many farmers and smallholdings. More structural changes, such as taking a chance on professionalization and hiring of technicians, are needed in order to introduce new technologies and a real transition to smart irrigation.

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