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RESEARCH PAPER

Modernizing irrigation at Acequia Real Del Jucar, Valencia: assessing the transition from surface irrigation to drip irrigation and the end-user perspective

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Abstract

This study examines the transition from surface to drip irrigation in Sector 23 of the Acequia Real del Júcar (ARJ) irrigation district in Spain, through a performance evaluation based on field experiments, on-site observations, and stakeholder perspectives. Spatial observations in 428 plots, representing 51% of the area, revealed that 73% used drip irrigation, 8% used surface irrigation, and 12% was fallow or abandoned. Surface irrigation showed high application efficiency but only met 65.6% of crop water needs, while drip irrigation, with good distribution uniformity, satisfied only 57% and 33.9% of crop needs due to issues such as emitter clogging. Drip systems required higher maintenance (93%) compared to surface systems (14%), which had higher abandonment rates. Main crops cultivated included oranges and persimmons. Herbicide use was common in drip-irrigated fields, while mowing and plowing were more common in surface-irrigated fields. Findings based on farmer and manager perspectives emphasize that, beyond technical efficiency, user behavior and perceptions play a significant role in irrigation system success. These findings provide practical, spatially grounded insights for improving irrigation strategies and irrigation modernization should be evaluated not only in terms of technical efficiency, but also in relation to maintenance requirements, agricultural management practices, and land use decisions. The results can guide policy and investment decisions aimed at enhancing sustainability in agricultural water management.

Introduction

The Acequia Real Del Júcar (ARJ) (2022), an Irrigation Scheme in the Valencia region of Spain serves as the foundation for this project.

Between 1950 and 1986, Spain's agricultural policy prioritized the expansion of irrigation zones, a strategy that, despite yielding economic benefits, has placed significant pressure on the country's water resources, leading to shortages (DGA, 2010; Sanchis-Ibor et al., 2017). To mitigate water losses and improve water service quality and agricultural productivity, pressure pipe systems are progressively replacing surface irrigation, which is perceived as inefficient (Playán and Mateos, 2006). In response to the Júcar River Basin Authority's decision to reduce water rights and allocations from the Tous Dam, the Acequia Real del Júcar (ARJ) must reconsider its water distribution strategy (V. Llopis Córdoba, personal communication, 12 May 2022).

The ARJ has set an objective to fully transition to drip irrigation by 2025. However, since the project's initiation in 2005, only 17 out of 40 sectors have been converted, highlighting a substantial disparity between projected and actual progress (V. Llopis Córdoba, personal communication, 12 May 2022). The reasons for this delay remain uncertain, though it is suggested that farmers feel coerced into abandoning traditional irrigation practices and perceive the benefits of drip irrigation as limited. The transition necessitates financial contributions not only from governmental institutions but also from farmers themselves, posing an additional challenge (Ortega-Reig et al., 2017). While the modernisation of ARJ is expected to enhance water conservation, irrigation efficiency, agricultural productivity, and reduce labor and fertilizer costs, a comprehensive quantification of these benefits, as well as a comparative analysis between drip and surface irrigation, remains absent.

The slow pace of the transition to drip irrigation is impeding the region's overall irrigation modernisation efforts. The diverse perspectives of stakeholders regarding irrigation performance and water conservation further complicate the assessment of this shift. Additionally, limited research exists on the perceptions of water conservation and irrigation efficiency among irrigation managers and users. Initial interviews indicate notable differences between sectors using surface and drip irrigation. Economic challenges, including declining crop prices—comparable to those of three decades ago—along with the financial burden of labor and fertilizers, hinder farmers' ability to sustain irrigation. Furthermore, the relatively small landholding size, averaging 1.5 hanegadas (approximately 1,246.5 square meters), exacerbates the difficulty of achieving viable agricultural productivity, thereby threatening farmers' economic sustainability (Smart Water Magazine, 2022).

Concerns have also been raised regarding the increasing proportion of abandoned farmland and the younger generation's declining interest in agricultural activities. While these challenges are primarily associated with surface irrigation, the modernisation process through drip irrigation has progressed across 40% of the area, potentially enabling farmers to reallocate their resources to enhance yields (Darouich et al., 2014; Pereira et al., 2012).

To evaluate the transition from surface to drip irrigation, this study aimed to collect relevant data, selecting Sector 23, located centrally within the ARJ irrigation district, as the focus area. Currently, the Acequia Real del Júcar lacks an up-to-date assessment of irrigation performance and agricultural practices that differentiate between drip and surface irrigation. This project seeks to address this gap by analyzing existing irrigation performance levels and compiling data from management, irrigation users, and field observations. The study outputs include a performance evaluation and comparison of drip and surface irrigation systems, a spatial overview of irrigation and agricultural practices in Sector 23, and an analysis of irrigation managers' and users' perspectives on different irrigation methods. These findings will contribute to a more comprehensive understanding of the ongoing transition and its implications for the region.

Materials and Methods

Study Area

The Acequia Real del Júcar (ARJ) region is situated in southeastern Spain, between Alicante to the north and Valencia to the south, within the lower Júcar region of the Júcar River Basin (Figure 1).

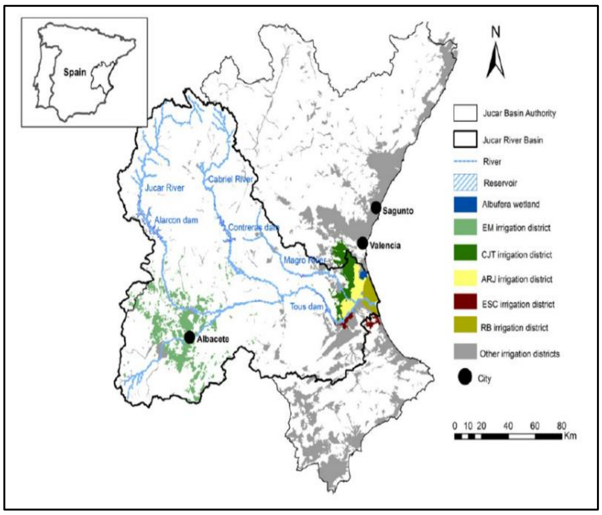

Figure 1. Overview of the Júcar river basin District with the location of the Acequia Real del Júcar in yellow (Kahil et al., 2016)

This basin encompasses three primary irrigation zones: the upper Júcar, lower Júcar, and the Turia Basin (Kahil et al., 2016). The region experiences a semi-arid Mediterranean climate, with an annual precipitation range of 300–600 mm. Summers are characterized by hot and dry conditions, while winters are mild, with an average annual temperature of approximately 18°C (Kahil et al., 2014; Kahil et al., 2016). A significant reduction in environmental flows has severely impacted downstream water users, with water availability in the ARJ region declining by approximately 70% over the past four decades, resulting in substantial environmental degradation of water-dependent ecosystems (García-Mollá et al., 2013).

Although the ARJ region has traditionally been known for citrus production, declining orange prices have led farmers to diversify their crops. They now cultivate apricots, dates, watermelons, and winter vegetables such as onions, potatoes, garlic, and lettuce

(Kahil et al., 2016; Poblador et al., 2021). Additionally, water-intensive crops such as avocados have recently been introduced (Sommaruga and Eldridge, 2021).

As of 2005, surface irrigation was the predominant irrigation method, covering 19,985 hectares. However, by 2025, it is expected that all surface irrigation systems will be replaced by drip irrigation (V. Llopis Córdoba, personal communication, 12 May 2022). Water for drip irrigation is supplied through the Júcar-Turia Transfer pipeline, which conveys water from the Tous Dam across the Júcar River to the Turia River near Valencia. This pipeline, running parallel to the main canal, delivers water to both the traditional acequia surface irrigation network and the pressurized drip irrigation system. Consequently, surface irrigation channels receive water from both the pipeline and the main canal.

Sector 23, located at the core of the ARJ irrigation network, is primarily dedicated to citrus cultivation, where both surface and drip irrigation techniques are employed. Figure 2 provides an overview of the ARJ irrigation scheme, illustrating the case study area, key sectors, and the progress of irrigation modernization.

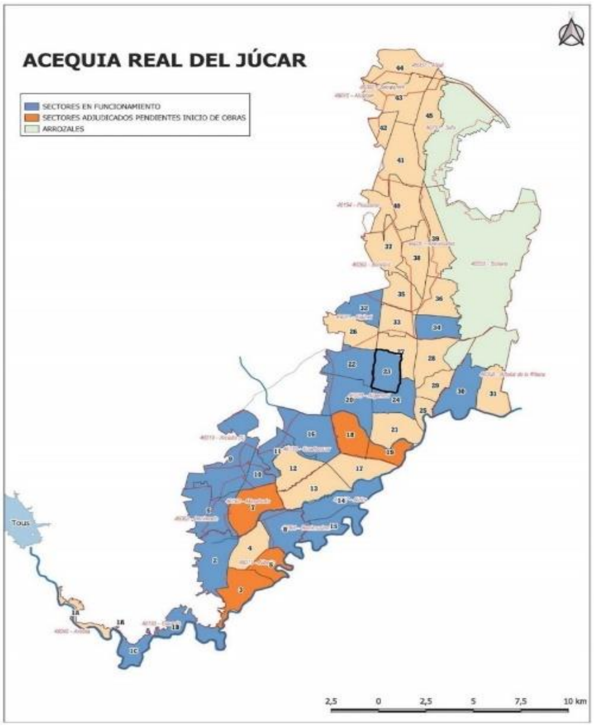

Figure 2. The Acequia Real del Jucar sectors. With traditional surface irrigation sectors (beige), modernized drip irrigation sectors (blue), partly modernized drip irrigation sectors (orange), rice surface irrigation sectors (green) and the selected sector of our project (black). (Acequia Real Del Júcar, n.d.)

Data Collection

Figure 3 represents the research methodologies used in data collection, their aims and, accordingly, the output.

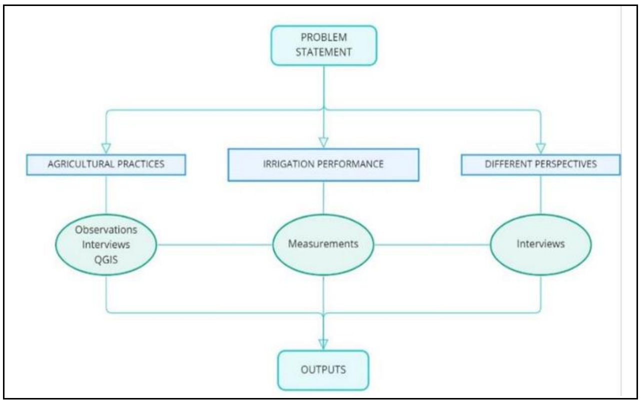

Figure 3. Graphical representation of the methodology and outputs

Two areas irrigated by drip irrigation in Sector 23 and two areas irrigated by surface irrigation were selected in the nearby of Sector 23, for comparing and evaluating their irrigation capabilities (Figures 4 and 5). These decisions were influenced by the permits and availability of farmers. Research components included water height in surface irrigation areas, irrigation time, emitter discharge, and canal flow. In summary, the manner in which irrigation is supplied affects its performance. Whether the crop's water needs were satisfied and whether the irrigation was uniform were determined in this study.

Figure 4. Water delivery canals and location of surface irrigation fields

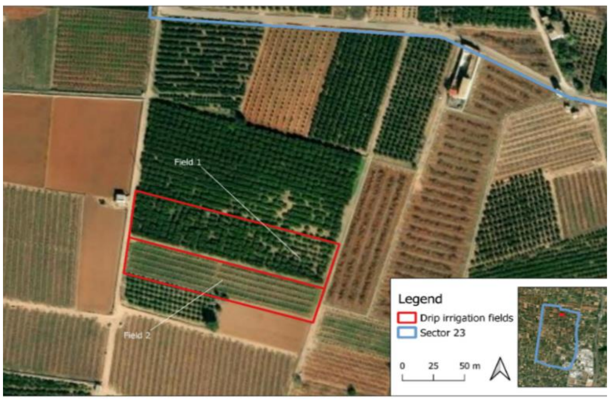

Figure 5. Location of drip irrigation fields

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The effectiveness of drip irrigation is mostly determined by the agronomic and hydraulic design, the calibre of the materials utilised, the irrigation process, and the upkeep of the infrastructure (Schilardi and Morábıto, 2011). The application efficiency (AE) and distribution uniformity of the applied water (DU) are the primary criteria used to evaluate drip irrigation (Pereira, 1999). Low uniformity increases the risk of agricultural water deficit in the less irrigated fields and results in water losses from percolation in the most irrigated areas (Bohórquez and Ruiz, 2011).

Distribution uniformity (DU)

Merrian and Keller (1978) devised a method that involves monitoring the applied discharge for n repetitions and comparing the average discharge with respect to the lowest quarter section of the applied discharge in order to calculate distribution uniformity in drip irrigation. As the following expression:

$$DU = \frac{q_{25\%}}{q_{avg}} * 100 \quad \text{.......................} \ (1)$$

Where:

DU → Distribution uniformity (%)
$q_{25\%}$ → Average of the lowest discharge quarter (L/h)
q_{avg} → Average discharge (L/h)

Using graduated cylinders and a chronometer, more than ten emitter discharge measurements were made per field in order to assess the drip irrigation system's distribution homogeneity. Within sector 23, data collection is intended to take place in at least two distinct fields. The range values used to classify the distribution uniformity in drip irrigation are shown in Table 1.

Table 1. Performance indicators for drip irrigation (Merrian and Keller, 1978).

Classification	Distribution uniformity (%)
Excellent	>90
Good	80-90
Regular	70-80
Poor	60-70
Inadequate	<60

Application efficiency (AE)

The crop water requirement in relation to the daily applied water was taken into account while calculating the drip irrigation application efficiency. Could be stated in terms of volume or depth of water (Howell, 2003; Pereira, 1999). Application efficiency was calculated by using Equation 2;

$$A_e = \frac{CWR}{W_a} \ x \ 100 \text{............................} \ (2)$$

Where:

AE → Application efficiency (%)
CWR → Crop water requirement per irrigation event (mm or m^3)
W_a → Water applied per irrigation event (mm or m^3)

Conveyance Efficiency

Equation below illustrates how the conveyance efficiency of drip and surface irrigation took into account the inlet water discharge to the field as well as the inlet water discharge from a specified checkpoint (García-Petillo, 2008):

$$C_e = \frac{Q_f}{Q_{cp}} * 100 \text{.............................} \ (3)$$

Where:

C_e → Conveyance efficiency (%)
Q_f → Inlet discharge to the field (m^3 /s)
Q_{cp} → Inlet discharge from the checkpoint (m^3 /s)

The application and conveyance efficiencies determine the irrigation efficiency in both drip and surface irrigation. This equation was used to generate this parameter (Brouwer et al., 1989):

$$IE = \frac{A_e * C_e}{100} \quad \text{..............................} \ (4)$$

Where:

IE → Scheme irrigation efficiency in drip and surface irrigation (%)
A_e → Application efficiency (%)
C_e → Conveyance efficiency (%)

In the case where application efficiency was above 100%, an adequacy was defined (RWS), using the following equation:

$$RWS\ (\%) = \frac{Water\ depth\ applied}{Crop\ water\ requeriment\ in\ depth\ water} * 100 \text{ ..} \ (5)$$

Observations conducted in Sector 23 were systematically assessed using structured observation forms. The evaluation focused on various factors, including crop types, land conditions, irrigation techniques, and weed management strategies. Prior to data collection, a standardized methodology was established through a structured observation sheet developed on Google Forms. These structured observations facilitated the creation of a spatial overview of the distribution and application of surface and drip irrigation within the sector. Strict criteria were defined for agricultural and irrigation practices to ensure objectivity in deriving qualitative results. Irrigation practices were categorized into three types: drip, surface, and non-irrigation. Additionally, field and crop maintenance were classified into three levels: low, medium, and high. Weed removal methods were recorded based on specific indicators—herbicide use was noted when weeds were absent, with no visible signs of mowing or plowing. Fields where soil had been loosened and displaced through plowing were identified separately, while mowed fields were characterized by visibly cut weeds. Furthermore, the state of the fields was classified into four primary categories: in use, abandoned, fallow, and unknown.

In addition to field observations, semi-structured interviews were conducted to gather insights from participants regarding their backgrounds and interests in agriculture. The primary objective of these interviews was to understand participants' perspectives on surface and drip irrigation. Moreover, the interviews served as a tool to review and refine the assessment metrics, ensuring a comprehensive evaluation of irrigation practices in Sector 23.

Results and Discussion

Field Observations during Data Collection

Surface and drip irrigation trials were conducted to assess irrigation performance in the designated measurement area and adjacent irrigated farms. During surface irrigation, it was observed that numerous gate entries along the canal were obstructed with concrete blocks intended to regulate water flow. However, leakage occurred through these blocks, leading to soil collapse near field entrances due to continuous water inflow. This issue was managed by filling the affected areas with concrete debris. Additionally, field heterogeneity was identified as variations in the dimensions of basin gutters (height, length, and width) that influenced irrigation performance. The irrigation strategy, which involved sequentially opening field gates during irrigation, was another factor affecting efficiency. Furthermore, the presence of weeds and leaf debris interfered with water distribution.

In the drip irrigation trials, multiple operational issues were identified, primarily related to the condition and maintenance of the system. Drip lines were frequently found folded and twisted, reducing system efficiency, while air blockages were observed, particularly toward the end of the irrigation cycle. It was reported that the system had not been maintained since its installation three years prior, despite routine maintenance being crucial for optimal performance. Maintenance should prioritize primary system components, including mains, subgrids, laterals, and emitters, alongside regular cleaning of filters to prevent clogging. A notable observation was the application of irrigation water containing salts along with fertilizers in sector 23, which poses a risk of clogging in emitters and pipes, thereby reducing system efficiency and longevity. Despite these risks, no acid treatment was applied, as the salts were not perceived as a significant issue. However, literature suggests that chemical treatment and enhanced filtration can mitigate clogging problems (Bounoua et al., 2016; Jarwar et al., 2019).

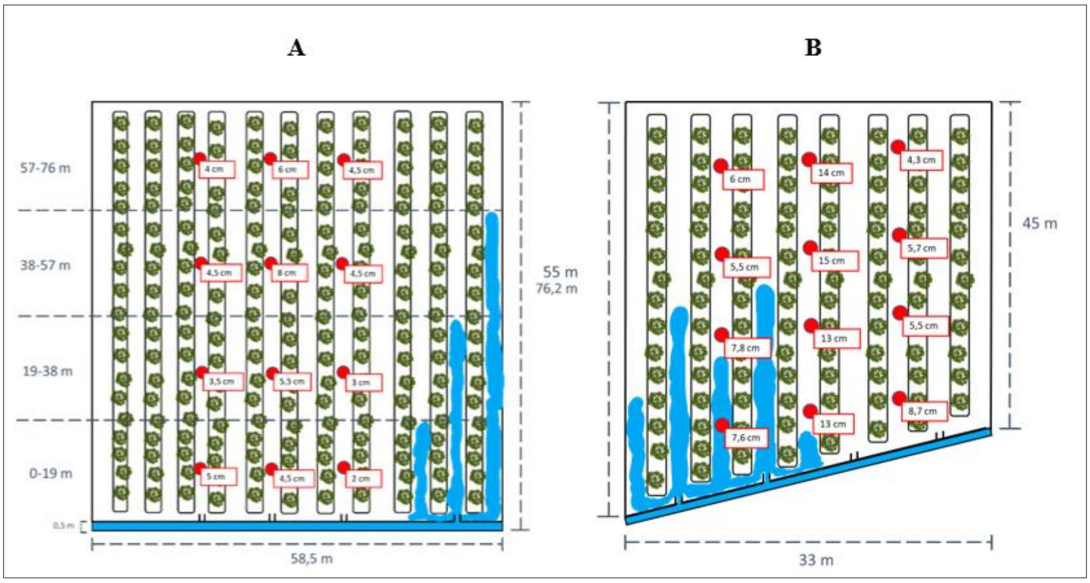

Figure 4. Graphical representation of surface irrigation in the first field (A) and second field (B) (red points represent water depths after irrigation cut-off)

Irrigation Performance Measurements

A graphical representation of the areas irrigated by surface irrigation is shown in Figure 4. The assessment of irrigation performance included the evaluation of application and conveyance efficiency across surface irrigation systems. In the first surface irrigation field, 226.7 m^3 of water was applied, resulting in an average application depth of 50.9 mm. However, the crop's water requirement was calculated as 345.61 m^3, corresponding to an average depth of 77.53 mm. Accordingly, the application efficiency was calculated as 65.6%, indicating that only 65.6% of the required water was applied, and the crop's irrigation requirement was not fully met, pointing to a water deficit. In the second field, 136 m^3 of water was applied with an average depth of 82.4 mm, while the crop's requirement was 127.9 m^3 (77.53 mm). The application efficiency in this case was 94.1%, also suggesting a slight water deficit, although closer to the crop's needs compared to the first field. In both cases, the irrigation process spanned 21 days (Table 2).

Table 2. Application efficiency in surface irrigation

Parameter		Field 1	Field 2
Water applied to field	Volume (m^3)	226.7	136
	Depth average (mm)	50.9	82.4
Water required for crop	Volume (m^3)	345.61	127.9
	Depth average (mm)	77.53	77.53
Application Efficiency (%)		152.45 (Only 65.6% of the required water was applied)	94.1

Conveyance efficiency was measured with reference to a checkpoint located 328.2 meters from the first field and 98.3 meters from the second. The conveyance efficiency was calculated as 89.57% for the first field and 97.9% for the second (Table 3).

Table 3. Conveyance efficiency in surface irrigation

Parameter	Field 1	Field 2
Length canal in field one related to checkpoint (m)	328.2	98.3
Discharge delivers in the beginning of the field (m^3/s)	0.089	0.111
Discharge delivers in the checkpoint (m^3/s)	0.099	0.113
Conveyance efficiency (%)	89.57	97.9

According to the ARJ Irrigation Control Centre (ICC), the high-pressure pipeline supplying water to the drip irrigation system operates at a reported 100% conveyance efficiency, implying that all supplied water reaches its designated fields without losses. However, given the inherent losses in water delivery systems, this claim remains subject to scrutiny. Since upstream flow dynamics influence conveyance efficiency, measurements were taken at a downstream checkpoint where no fields were being irrigated to ensure stable conditions and obtain reliable data. Potential sources of water loss include leakage through canal linings and malfunctioning gates. Regular manual maintenance and timely repairs of minor canal structures are critical in mitigating these losses (Jadhav et al., 2014). Considering both application and conveyance efficiency, overall irrigation efficiency was estimated at 89.6% in the first field and 92.1% in the second (Table 4). The assumption of 100% application efficiency in the first field reflects the fact that the crop's irrigation requirement was not fully met within the system, rather than indicating an absence of water losses.

Table 4. Water delivery canals in surface irrigation zone

Parameter	Field 1	Field 2
Irrigation efficiency per system (%)	89.6	92.1

In the context of drip irrigation, the discharge per emitter was measured in the field and defined using data from the Irrigation Control Centre (ICC) of the ARJ. In Field 1, the measured discharge was found to be lower than the reported discharge by the ICC, with a discrepancy of approximately 0.6 L/hr (average of 24 emitters). In Field 2, the measured discharge was found to be approximately equivalent to the reported discharge by the ICC, with a discrepancy of approximately 0.1 L/hr (average of 15 emitters) (Table 5). Table 5 presents general irrigation information from ICC. The first field is irrigated twice per day from Monday to Saturday, while the second field is irrigated once each Monday, Wednesday, Friday, and Saturday.

Table 5. Irrigation data

Number of irrigations	Parameter	Field 1	Field 2
1st	Discharge applied (m^3/han/hr)	0.99	0.8
	Volume applied (m^3)	10.1	4.9
	Irrigation time (min)	74	75
2nd	Discharge applied (m^3/han/hr)	1.11	-
	Volume applied (m^3)	10.8	-
	Irrigation time (min)	70	-

In the first field, discharge per emitter is 1.69 L/hr according to the ICC-ARJ; 1.085 L/hr according to measurements (average). In the second field, discharge per emitter is 1.3 L/hr according to ICC-ARJ; 1.28 L/hr according to measurements (average)

It is plausible that the discrepancy in discharge is attributable to the accumulation of salt and organic matter within the emitters, in addition to entrapped air issues. The configuration and condition of the drip lines in the second field were superior to those in the first field. Additionally, the second field has younger trees, which suggests that the irrigation system may be more recent than that of field one.

The application efficiency in both drip fields was above 100%, in accordance with the established definition of application efficiency, which is constrained to a maximum value of 100%. Consequently, the relative water supply parameters were calculated, indicating that the applied water only fulfilled 57% and 33.9% of the crop water requirements in the first and second field, respectively (Table 6).

Table 6. Application efficiency in drip irrigation

Parameter		Field 1	Field 2
Water applied to field	Volume (m^3)	0.031	0.0128
	Depth average (mm)	1.89	1.21
Water required for crops	Volume (m^3)	0.055	0.038
	Depth average (mm)	3.32	3.58
Application Efficiency (%)		175.46 (Only 57% of the required water was applied)	295.2 (Only 33.9% of the required water was applied)

The distribution uniformity (DU) in the first field was found to be 81%, while in the second it was 90.1%. According to the classification system proposed by Merrian and Keller (1978), these results could be classified as "good" and "excellent," respectively (Table 7). It is important to note that, in light of the discrepancies between the discharge measurements and the reported data by the ICC, the distribution uniformity (DU) in the first field is relatively close to the classification of "regular" (70-80%), while the second is close to "good" (80-90%).

Table 7. Distribution uniformity in drip irrigation

Parameter	Field 1	Field 2
Average discharge (mm/min)	31.58	37.40
Average discharge of the lower quarter ($q_{25\%}$) (mm/min)	25.58	34
Distribution Uniformity (DU) (%)	81	90.1

The irrigation efficiency in both drip irrigation fields is computed as 100% because application efficiency exceeds 100%, and conveyance efficiency is assumed to be 100%. It is important to note that this does not reflect reality.

The noticeable entrapped air problem in the drip lines (evidenced by the continued release of air from the pipe even when the irrigation was nearing completion) prompted the development of an entrapped air revision. This revision aimed to identify the specific pipe lengths where the problem was most prevalent. In a previous study, Quintana-Molina et al. (2021) proposed an equation that defines the water velocity in small pipeline diameters with the objective of removing entrapped air. The equation has been validated for diameters between 12.7 and 19.05 mm and downward angles between 0° and 60°.

It was determined that air valves were not installed in the areas measured in sector 23. The rate of water discharge is observed to decrease along the drip line, which is accompanied by a corresponding reduction in the average water velocity. In the event that the water velocity is unable to displace portions of entrapped air through hydraulic means (i.e., by the water flow), it is necessary to install air expulsion-intake valves (Jarwar, 2019; Sanders, 1992). During the field experiments, it was observed that the drip lines exhibited a maximum downward angle of 5 degrees. The minimum water velocity required for the removal of air in this pipe angle is 0.183 m/s. As illustrated in Table 8, between three-quarters and the conclusion of the drip line, instances of entrapped air may arise in both drip irrigation fields. This is due to the fact that the velocity of the water within the pipeline is less than the velocity required for the removal of entrapped air through hydraulic means.

Table 8. Water velocity in different pipeline points

Point of reference from pipeline beginning	Drip irrigation field 1		Drip irrigation field 2	
	Discharge per irrigation drip line (m^3/s)	Water velocity (m/s)	Discharge per irrigation drip line (m^3/s)	Water velocity (m/s)
Beginning	1.42E-04	0.7071	1.09E-04	0.5416
Middle	7.11E-05	0.3536	5.44E-05	0.2708
Three quarters	3.55E-05	0.1768	2.72E-05	0.1354
Seven eighths	1.78E-05	0.0884	1.36E-05	0.0677

The findings from the field experiments are subject to several limitations, primarily due to the small sample size, which reduces the reliability of performance evaluations. To enhance representativeness, data collection should be expanded, and studies should be conducted in areas beyond Sector 23. During the four-week testing period, several constraints were identified. Initially, only two fields—each employing a different irrigation method—were considered in this study. However, comparing the performance of surface and drip irrigation is inherently challenging, as farm-specific conditions vary and system performance fluctuates over time, necessitating continuous evaluation (Roth et al., 1995). In general, comparisons between surface and drip irrigation should be framed within the broader context of irrigation planning (Darouich et al., 2014).

Furthermore, agricultural practices and irrigation methods differ between surface and drip systems. Field-level actions and procedures undertaken by farmers are integral to these applications. Soil tillage practices, including the use of machinery, influence soil conditions, particularly in the presence of soil degradation and erosion. Fertilizer application affects both crop quality and nutrient distribution. Additionally, weed and pest control techniques involve the spraying of crops and soil, often requiring the application of herbicides and pesticides, which are linked to land use management (Pereira et al., 2002).

Overall, irrigation technology and agricultural practices significantly impact the type and amount of labor required in farming operations (Kaini et al., 2020). Therefore, any assessment of irrigation efficiency should also consider the broader agricultural and socioeconomic factors that influence irrigation system performance and sustainability.

Spatial Overview of Irrigation and Agricultural Practices

The transect observations encompassed 428 fields, representing approximately 51% of all parcels in the sector. These data were mapped using GIS to highlight the spatial distribution of agricultural and irrigation features. The analysis excluded residential areas, which are not typical for irrigation systems. The irrigation methods revealed that surface channel irrigation was used on only 8% of fields, while drip irrigation covered the majority (73%). Fields under drip irrigation exhibited dry, solid topsoil, and surrounding waterways appeared deserted. Approximately 12% of the area was non-irrigable due to fallow and abandoned fields. In terms of field maintenance, 42% of fields were categorized as high maintenance, 36% as medium, and 14% as low maintenance. Drip irrigation fields mainly showed medium (42%) and high (51%) maintenance levels, whereas surface irrigation fields

Figure 5. Observational classifications of sector 23 with 5A Irrigation type, 5B Maintenance level, 5C Weed removal strategy, and 5D Crop types

exhibited more frequent low (14%) maintenance, with a smaller proportion requiring high maintenance (31%). Fallow and abandoned fields were classified as high and low maintenance, respectively, due to the absence of irrigation.

The weed-removal strategy in the area primarily involves the application of herbicides, covering over 50% of the land. Farmers were also observed using herbicide-based pesticides, such as glyphosate, for weed control. Mowing and plowing accounted for 10-13% of the weeding methods. Due to the dense crop configurations and irregular tree lines in most orchards, automated weed removal is challenging. Among fields with drip irrigation, 60% were treated with herbicides more frequently than mowed (15%) or plowed (8%). For surface irrigation, spraying was the most common method (38%), with mowing and plowing being less frequent. Additionally, 32% of respondents indicated farming could occur without irrigation, while 3% deemed mowing as insignificant. The status of 39% of the practices remains unknown, and 25% involve herbicide usage.

Table 9. Weed removal strategy per irrigation type

Weed removal strategy	Drip amount	%	Surface amount	%	No Irrigation amount	%
Herbicides	186	59,8	12	37,5	8	25,8
Ploughed	24	7,7	7	21,9	10	32,3
Mowed	47	15,1	6	18,8	1	3,2
Unknown	54	17,4	7	21,9	12	38,7
Total	311		32		31	

Figure 5D displays the crop diversity in the region, with kiwifruit (17%) and oranges (59%) being the most common crops. Other crops, such as peaches, nectarines, peppers, tomatoes, and potatoes, accounted for 1% of the fields. Additionally, some fields were in early germination stages, cultivated in greenhouses, or covered with plastic. Approximately 6% of the areas were classified as unidentified. Table 10 indicates no statistically significant difference between drip and surface irrigation concerning crop types. Drip irrigation fields showed a slightly higher prevalence of kaki and oranges, while surface irrigation fields favored vegetables, which accounted for 9%. The yield rate was 36% higher in areas with abandoned and fallow fields.

The field condition is illustrated in Figure 6. A significant proportion of fields (77%) have been observed to be actively cultivated and classified as ready for use. Abandoned land comprised 8.5% of the total area, while 4% was left fallow. The remaining locations are either residential areas or of unknown designation. A comparison of the field condition with the type of irrigation (4A) (Table 11) reveals that drip irrigation is employed in the vast majority of fields

Table 10. Crop type per irrigation type

Crops	Drip amount	%	Surface amount	%	No irrigation amount	%
Orange	214	69,0	19	59,4	7	21,2
Kaki	64	20,6	5	15,6	1	3,0
Citrus	13	4,2	1	3,1	0	0,0
Peach & Nectarine	2	0,6	0	0,0	1	3,0
Vegetables	3	1,0	3	9,4	0	0,0
Others	2	0,6	1	3,1	1	3,0
Multiple crops	2	0,6	0	0,0	0	0,0
No crop	0	0,0	0	0,0	12	36,4
Unidentifiable	10	3,2	3	9,4	11	33,3
Total	310		32		33	

Table 11. Field status per irrigation type

Field Status	Drip Amount	%	Surface Amount	%	No Irrigation	%
In Use	297	95,5	25	78,1	2	4,5
Abandoned	7	2,3	3	9,4	26	59,1
Fallow	0	0,0	2	6,3	14	31,8
Unknown	7	2,3	2	6,3	2	4,5
Total	304		32		44	

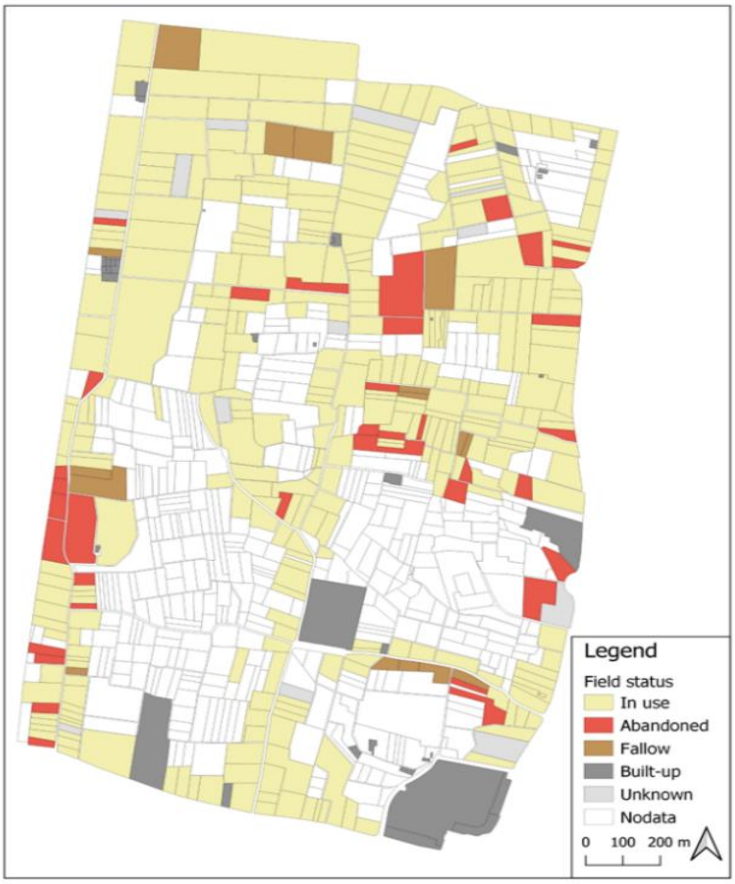

Figure 6. Observational classification of sector 23 with field status.

(96%). Surface irrigation is employed in 78% of cases, with 9% of fields having been abandoned and 6% remaining fallow. Of the non-irrigated fields, 59% were most often abandoned, while 32% were left fallow.

Perspectives

An analysis of stakeholders' views on surface and drip irrigation was conducted through structured interviews with farmers and irrigation managers. The goal was to gather insights from individuals directly involved in field operations within the ARJ. Interviews, lasting between 30 to 60 minutes, included general questions on the respondents' roles and experiences, followed by inquiries on water conservation, irrigation practices, and system performance. People's perspectives are obtained throughout the observation process even though it is preceded by a discussion. There were issues with the observation form's closed questions, which revealed that the fields varied from one another and that a plot occasionally included more than one crop or growth stage. Asking more targeted questions will enable a more focused and thorough study (Knott et al., 2022). Men over 45 and one woman made up the majority of the interviewees' diversity. This may restrict how comprehensive the viewpoints are.

Farmers' responses on water savings from modern irrigation systems were mixed, with some uncertainty about the ultimate use of conserved water, while others suggested it was redirected to regions like Andalucia or Albufera. A few farmers highlighted financial savings from drip irrigation, though concerns about the system's cost were noted, as drip irrigation is three times more expensive than surface irrigation. Additionally, some farmers were unaware of the exact composition of fertilizers applied through the irrigation systems, and while a drip farmer mentioned a reduction in weeds, others expressed doubts about yield improvements. Furthermore, during the time when water requirements were measured, the heatwave changed the typical weather and increased the crop water requirements. Farmers have discovered that drip irrigation increases yields and makes management easier. Farmers' first understanding runs counter to these opinions and needs more investigation. In the future, it will be important to find out why, in the event that the crop water requirement is not fulfilled, farmers' discontent with the trickle is still ongoing. Dripping is more convenient to farmers since it requires less effort (Jarwar, 2019). This could be the primary driver behind farmers choosing to invest in drip rather than crop water requirement. It was evident from the discussions that farmers are eager to modernize. But it was evident from the way the difficulties were phrased that investments needed to be made, which might account for the modernization's delay.

Interviews with surface irrigation regulators revealed that irrigation practices varied based on field characteristics such as weed density, slope, and tree age, with customized irrigation plans developed for each field. In contrast, drip irrigation doses are determined based on soil and tree leaf analysis, with adjustments made every three months. Maintenance practices differed for the two systems: drip irrigation requires regular checks and fixes by the irrigation engineer, while surface irrigation maintenance is more hands-on, with farmers paying for services related to canal cleaning. Overall, while both irrigation types have their advantages, the implementation and maintenance processes reflect different levels of responsibility and operational dynamics.

Conclusion

In order to contribute to the Acequia Real del Jucar region's goal of irrigation modernization, irrigation system sites, referred to as sector 23, were subjected to a performance review informed by field experiments, field observations, and user perspectives. The evaluation of irrigation performance during the transition from surface to drip irrigation in Sector 23 of the ARJ irrigation district revealed notable differences in efficiency across systems and fields. In surface irrigation, application efficiency was calculated as 65.6% in the first field and 94.1% in the second, both indicating water deficits, with the first field showing a greater shortfall. Conveyance efficiency was 89.57% and 97.9% for the first and second fields, respectively. Despite the Irrigation Control Centre's (ICC) claim of 100% conveyance efficiency in drip systems, field-based observations suggest potential losses due to canal leakage and structural deficiencies. Overall irrigation efficiency was estimated at 89.6% in Field 1 and 92.1% in Field 2. In the drip irrigation context, discrepancies between reported and measured emitter discharges were observed, 0.6 L/hr in Field 1 and 0.1 L/hr in Field 2, highlighting the importance of field validation. Additionally, irrigation schedules differed between the fields, with Field 1 receiving water twice daily on weekdays and Field 2 irrigated four times weekly. These findings underscore the critical role of field-based performance monitoring, maintenance, and scheduling in optimizing irrigation efficiency during system transitions.

A spatial assessment of irrigation and agricultural practices in Sector 23 was conducted through structured observations of 428 fields, representing 51% of the total area. Drip irrigation was the predominant method, applied in 73% of fields, while surface irrigation was limited to 8%. The majority (77%) of fields were actively cultivated, whereas 12% remained abandoned or fallow. Drip-irrigated fields required moderate (42%) to high (51%) maintenance, while surface irrigation fields had a lower maintenance classification (14%). Citrus orchards, particularly orange (59%) and persimmon (17%), were the most commonly cultivated crops, with slightly higher kaki and orange prevalence in drip-irrigated fields. Observations revealed significant differences in agricultural practices between irrigation methods. Drip irrigation fields were well-maintained, with frequent herbicide application, whereas surface irrigation fields exhibited higher abandonment rates and lower maintenance. Non-irrigated fields, including rainfed and degraded areas with unused canals, also had elevated abandonment rates. Weed management practices varied, with herbicide application more common in drip-irrigated fields, while mowing and plowing were preferred in surface irrigation. Notably, vegetable cultivation was more prevalent in surface-irrigated fields than in drip-irrigated ones.

This study examined the performance differences between surface and drip irrigation systems in Sector 23, incorporating both field experiments and stakeholder perspectives. Results indicated that while drip irrigation was perceived as more efficient in water conservation and field management, it required higher upfront costs and more centralized maintenance compared to surface irrigation, which relies more on direct, field-level management. Farmers favored drip irrigation for its ability to reduce labor intensity, improve crop yield, and mitigate water scarcity. However, challenges such as emitter clogging and air entrapment in drip lines highlighted the need for regular maintenance and water quality management. The study also emphasized the importance of installing water flow measurement stations in surface irrigation systems and recalculating transport efficiency in high-pressure pipelines. Furthermore, it is crucial to address the declining interest in agriculture among youth and promote sustainable practices to enhance irrigation system efficiency. Finally, this study demonstrates that the success of irrigation modernization depends not only on technical efficiency but also on user behavior, maintenance strategies, agricultural practices, and land use decisions, offering insights for developing sustainable irrigation strategies, particularly in water-scarce regions.

Author Contribution

G.C.A: collecting data, conceptualization writing draft report and writing article, analysed the results; **E.Q.M:** collecting data, conducting fieldwork, project administration, writing draft report; **E.V:** carrying out fieldwork, performing and evaluating spatial overview, writing draft report; **H.C.M:** methodology, conducting structured interviews, writing draft report; **E.T:** carrying out observations, data collection and writing draft report, resources.

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Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that might appear to influence the work reported in this paper.

References

Acequia Real del Júcar (2022). Acequia Real del Júcar. Una de las instituciones de regadío más antiguas de España. Recovered from https://www.acequiarj.es/

Bohórquez, J. M., & Ruiz, N. (2011). Evaluaciones de riego localizado para conseguir un manejo uniforme y eficiente del agua. *Junta de Andalucía. España*.

Bounoua, S., Tomas, S., Labille, J., Molle, B., Granier, J., Haldenwang, P., & Izzati, S. N. (2016). Understanding physical clogging in drip irrigation: in situ, in-lab and numerical approaches. *Irrigation Science*, *34*, 327-342.

Brouwer, C., Prins K. & Heibloem M. (1989). Irrigation Water Management: Irrigation Scheduling. *Training manual* No. 4: FAO.

Darouich, H. M., Pedras, C. M., Gonçalves, J. M., & Pereira, L. S. (2014). Drip vs. surface irrigation: A comparison focussing on water saving and economic returns using multicriteria analysis applied to cotton. *Biosystems engineering*, *122*, 74-90.https://doi.org/10.1016/j.biosystemseng.2014.03.010

Dirección General del Agua (DGA). (2010). Estrategia nacional para la modernización sostenible de los regadíos. Ministerio de Medio Ambiente y Medio Rural, y Marino: Madrid, España.

García-Mollá, M., Sanchis-Ibor, C., Ortega-Reig, M. V., & Avellá-Reus, L. (2013). Irrigation associations coping with drought: the case of four irrigation districts in Eastern Spain. *Drought in arid and semi-arid regions: A multi-disciplinary and cross-country perspective*, 101-122.https://doi.org/10.1007/978-94-007-6636-5_6

García-Petillo, M. (2008). Manejo del riego: uso de instrumentos de medición de agua del suelo y del estado hídrico de los cultivos, presentación de casos de estudio incluso en riego deficitario. *Jornadas sobre "Ambiente y Riegos: Modernización y Ambientalidad*.

Howell, T. A. (2003). Irrigation efficiency. *Encyclopedia of water science*, *467*, 500.

Jadhav, P. B., Thokal, R. T., Mane, M. S., Bhange, H. N., & Kale, S. R. (2014). Improving conveyance efficiency through canal lining in command area: A Case Study. *International Journal of Engineering Innovation & Research*, *3*(6), 820-826.

Jarwar, A. H., Wang, X., Wang, L., Zhaoyang, Q., Mangi, N., Pengjia, B., & Shuli, F. (2019). Performance and evaluation of drip irrigation system, and its future advantages. *Journal of Biology, Agriculture and Healthcare*, *9*(9). https://doi.org/10.1038/s43586-022-00150-6

Kaini, S., Gardner, T., & Sharma, A. K. (2020). Assessment of socio-economic factors impacting on the cropping intensity of an irrigation scheme in developing countries. *Irrigation and Drainage*, *69*(3), 363-375.https://doi.org/10.1002/ird.2427

Kahil, M. T., Albiac, J., & Dinar, A. (2014). The debate on water policies: Evidence from drought in Spain. https://doi.org/10.22004/ag.econ.206460

Kahil, M., Albiac, J., Dinar, A., Calvo, E., Esteban, E., Avella, L., & Garcia-Molla, M. (2016). Improving the Performance of Water Policies: Evidence from Drought in Spain. *Water, 8*(2), 34. https://doi.org/10.3390/w8020034

Knott, E., Rao, A. H., Summers, K., & Teeger, C. (2022). Interviews in the social sciences. *Nature Reviews Methods Primers*, *2*(1), 73.https://doi.org/10.1038/s43586-022-00150-6

Merrian, J. L. & Keller, J. (1978). Farm irrigation System Evaluation: A guide for Management. (271 p). Agricultural and Irrigation Engineering Department, Utah State University, Logan, UT.

Ortega-Reig, M., Sanchis-Ibor, C., Palau-Salvador, G., García-Mollá, M., & Avellá-Reus, L. (2017). Institutional and management implications of drip irrigation introduction in collective irrigation systems in Spain. *Agricultural water management*, *187*, 164-172.https://doi.org/10.1016/j.agwat.2017.03.009

Pereira, L. S. (1999). Higher performance through combined improvements in irrigation methods and scheduling: a discussion. *Agricultural Water Management*, *40*(2-3), 153-169.https://doi.org/10.1016/S0378-3774(98)00118-8

Pereira, L. S., Oweis, T., & Zairi, A. (2002). Irrigation management under water scarcity. *Agricultural water management*, *57*(3), 175-206.https://doi.org/10.1016/S0378-3774(02)00075-6

Pereira, L. S., Cordery, I., & Iacovides, I. (2012). Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agricultural water management*, *108*, 39-51.https://doi.org/10.1016/j.agwat.2011.08.022

Playán, E., & Mateos, L. (2006). Modernization and optimization of irrigation systems to increase water productivity. *Agricultural water management*, *80*(1-3), 100-116.https://doi.org/10.1016/j.agwat.2005.07.007

Poblador, N., Sanchis Ibor, C., & Kuper, M. (2021). The landing of parachuted technology: Appropriation of centralised drip irrigation systems by irrigation communities in the region of Valencia (Spain). *Water Alternatives*, *14*(1), 228-247.

Quintana-Molina, E., Prado-Hernández, J.V., Monserrat-Viscarri J. (2021). Pérdida de energía y remoción de aire atrapado por medios hidráulicos en conducciones por gravedad con pendientes descendentes. VI Congreso Nacional de Riego, Drenaje y Biosistemas COMEII 2021. México. Recovered from https://www.riego.mx/congresos/comeii2021/files/ponencias/extenso/COMEII-21013.pdf

Roth, R. L., Sanchez, C. A., & Gardner, B. R. (1995). Growth and yield of mature 'Valencia'oranges converted to pressurized irrigation systems. *Applied Engineering in Agriculture*, *11*(1), 101-105.https://doi.org/10.13031/2013.25722

Sanchis-Ibor, C., Boelens, R., & García-Mollá, M. (2017). Collective irrigation reloaded. Re-collection and re-moralization of water management after privatization in Spain. *Geoforum*, *87*, 38-47.https://doi.org/10.1016/j.geoforum.2017.10.002

Sanders, D. C. (1992). Maintenance considerations for drip irrigation systems. *HortTechnology*, *2*(1), 38-38.https://doi.org/10.21273/HORTTECH.2.1.38

Schilardi, C., & Morábıto, I. (2011). Desempeño del riego por superficie en el área de regadío de la Cuenca del Río Tunuyán Superior, Mendoza, Argentina. *Fundación Taeda*.

Smart Water Magazine. (2022). Agriculture in Spain: Water as a key player. Smart Water Magazine Editorial Team. https://www.smartwatermagazine.com/news

Sommaruga, R., & Eldridge, H. M. (2021). Avocado production: Water footprint and socio-economic implications. *EuroChoices*, *20*(2), 48-53.https://doi.org/10.1111/1746-692X.1228