Research article

Impact of a Drip Irrigation System on Planning and Management of Water Delivery in a Large-Scale Irrigation Scheme in Morocco

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Received 19 January 2023 Accepted 10 May 2023 (*Corresponding Author)

Abstract Increasing water scarcity is lowering the agricultural production of the Tadla region in Morocco. This necessitates the Moroccan government to actively stimulate farmers about converting their irrigation systems from surface irrigation (furrow) to drip irrigation and subsidize the investment costs by 80%–100%. Therefore, this study aimed to clarify the impact of the drip irrigation system on the planning and management of water delivery after the conversion program from surface (furrow) irrigation to drip irrigation in the Beni Amir irrigation district on the right side of the Tadla region. The water management practices before and after conversion were gathered through discussions and interviews with officials and representatives of the management team responsible for the study irrigation scheme. An open questionnaire survey was also conducted, focusing on farmers' irrigation management practices such as on-farm water distribution methods, application rate, water adequacy, and equity water satisfaction level before and after conversion, and the results were analyzed by paying attention to their farms' upstream, midstream, and downstream locations. The analysis reveals that most of the interviewed farmers indicated satisfaction with equitable water distribution. Some variations in the water management system may occur due to the conversion project, such as an increase in irrigation time and increased cost and labor in water management. These will have an impact on the CDA's (Agriculture Development Center) overall water management monitoring and planning at the tertiary canal, as well as farmers' water management labor.

Keywords water scarcity, surface irrigation, drip irrigation, water management

INTRODUCTION

Morocco is among the most water-stressed countries in the world. Since the late 1970s, Morocco has seen its water inflows (from surface water) decline, from an annual average of 22 billion m^3 between 1945 and 1978 to an annual average of 15 billion m^3 between 1979 and 2018 (World Bank, 2022). The main strategy for adaptation to climate change in this region is the conversion from surface irrigation to drip irrigation. Consequently, the region needs rational and sustainable management of irrigation water. One of the solutions to save water in this area is to optimize irrigation inputs based on water availability and agricultural water demand according to the real needs of crops and in agreement with their phenological development. This necessitates the Moroccan government to actively stimulate farmers about converting their irrigation systems from surface irrigation (furrow) to drip irrigation and subsidize the investment costs by 80%–100%. Farmers owning more than 5 ha can apply for a subsidy of 80%, while those with 5 ha or less can apply for subsidies of 100%. These subsidies are part of the National Irrigation Water Saving Plan of 2007, which was summarized in the Green Morocco Plan in 2008. The National Irrigation Water Saving Plan aims to counterbalance the water deficits that the country faces. According to the plan, stimulating the conversion of 550,000 ha (of these, 217,940 ha will be through collective conversion and 332,060 ha through individual conversion (Belghiti, 2009)).

The Irrigation Management Transfer (IMT) of the 1970s attempted to establish the water user's association (WUA) after government-built irrigation facilities and transferred management to the WUA. Also, in participatory irrigation management (PIM) proposed by the World Bank since the 1990s, beneficiary farmers' participation in all irrigation development processes (construction, operation, management, and maintenance) has been required (Samad and Vermillion, 1999). Many researchers have proposed ways to manage and regulate the allocation and distribution of commonly held resources by human communities. Elinor Ostrom's framework has inspired a robust commons literature that investigates how human communities manage and regulate the allocation and distribution of commonly held resources. The earliest, and perhaps most well-known, strand in this common's literature deals with the distribution of natural resources, with an emphasis on the use or consumption of these resources (Azergun, 2020). Eight frameworks were designated by Ostrom for equitable and effective management of the commons (the commons are those things or resources that people own together), which requires both effective institutional arrangements and shared social capital among system participants (Ostrom, 2009; Ostrom et al., 2003).

OBJECTIVE

A brief survey was conducted to clarify the impact of drip irrigation on the planning and management of water delivery after the conversion program from surface to drip irrigation at the Beni Amir irrigation scheme in the Tadla region. The data collected and the results analyzed can be used as preliminary findings to guide future research.

METHODOLOGY

Study Area

The Beni Amir irrigation district is located on the right side of the irrigated perimeter of the Tadla region in the southwest of Morocco and has a total irrigated area of 34,000 ha. The outline of the Beni Amir irrigation district is shown in Fig. 1. The study area is in the arid and semi-arid regions, receiving about 300 mm of rainfall per year, most of which is received during the rainy season from November to March. The main crops are alfalfa, olives, maize, fruits (citrus), sugar beets, wheat, and vegetables. The irrigation water source is the Ahmed El Hansali Dam reservoir. Water released from the dam is distributed to the fields via the main, lateral (14 canals), and tertiary canals. Surface irrigation has been commonly practiced, and drip irrigation has been recently introduced under the Green Morocco Plan.

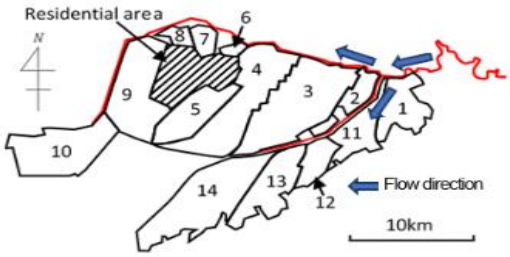

Fig. 1 The outline of the study area

The red line is the main canal, and the numbers represent farm blocks served by 14 lateral canals.

Data Collection and Analysis Methods

Data were gathered through discussions and interviews with officials and members of the irrigation scheme's management team. The layout of the irrigation system of the Beni Amir irrigation district was collected from the Regional Office on Agriculture Enhancement, Tadla (ORMVAT). Regarding the management and operation of the irrigation organization, a guided discussion was held with the responsible management team, which is Watershed Management Agency (ABHOER). An open questionnaire survey with 13 farmers (4 farmers at upstream, 5 farmers at midstream, and 4 at downstream locations) was conducted. The information gathered consists of farmers' socioeconomic conditions, farming methods, satisfaction levels for water sufficiency and equity, and some of their challenges regarding the newly introduced drip irrigation methods. The questions were asked individually through a face-to-face interview with farmers in the study of irrigation scheme. The field survey was conducted in September 2022, and it was an extreme drought year when compared with the last 20 years' record of rainfall data. Also, Farmers were unable to obtain water from the dam due to the drought, so they dug deeper wells up to 500 meters to get water. This eventually led to an overuse of groundwater, which has resulted in decreased quality and quantity for many farmers. The water management structure and distribution systems of the Beni Amir irrigation scheme were investigated before the conversion.

The irrigation scheme has established water management organizations in which government agencies control, plan, and decide on water distribution methods for beneficial farmers. This is a rare case in the management of public irrigation schemes. Although there is WUA, it does not function regarding PIM. In an ideal situation, WUA, which is composed of beneficiary farmers, takes on the responsibilities of operation, management, and maintenance of the irrigation systems after their development through the PIM concept. Hence, it may be required to investigate how equitable water distribution was accomplished without the PIM concept of water management. Elinor Ostrom suggests 8 frameworks to initiate sound collective action for equitable and sustainable commons management, which it seeks to employ in various scales and configurations. Therefore, Ostrom's frameworks were used to diagnose the current water management system of the Beni Amir irrigation scheme.

Water Management System and Planning

In each irrigation season, the water delivery plan from the dam to the Beni Amir irrigation district is decided in consultation with ABHOER, which is responsible for water resources management in the Tadla region, and ORMVAT, which is responsible for water distribution planning and management in the irrigation districts of the Tadla region. The amount of water to be distributed is communicated to the Agriculture Development Center (CDA), which is responsible for managing the distribution of water to the tertiary canals. The CDA coordinates the farmers' requests for water distribution, determines the date, time, and volume of water to be distributed to each field, and distributes water to the tertiary canals. The responsibility of water distribution in the field canals is left to each farmer during his scheduled irrigation period, which is decided by the ORMVAT and ABHOER (Katsuyuki

et al., 2022). The schematic diagram of water supply and management responsibilities is shown in Fig. 2.

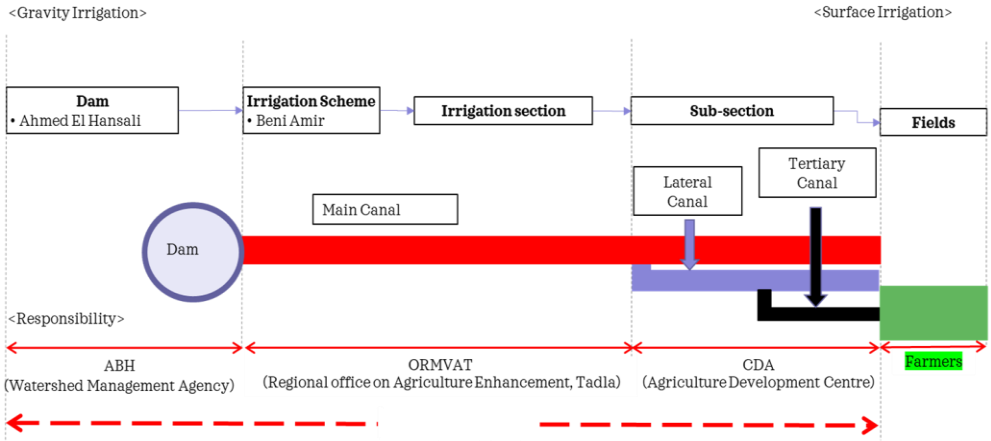

Fig. 2 The schematic diagram of water supply and responsibilities for management

RESULTS AND DISCUSSIONS

General Evaluation of Water Management Concerning Ostrom's 8 Frameworks for Managing the Commons

The survey result in Fig. 3 revealed that even though the study irrigation scheme is run by government organizations, the majority of farmers who were surveyed expressed satisfaction with how fairly water is distributed and managed. As a result, it is necessary to examine how equitable water distribution was accomplished without the PIM concept of the water management system.

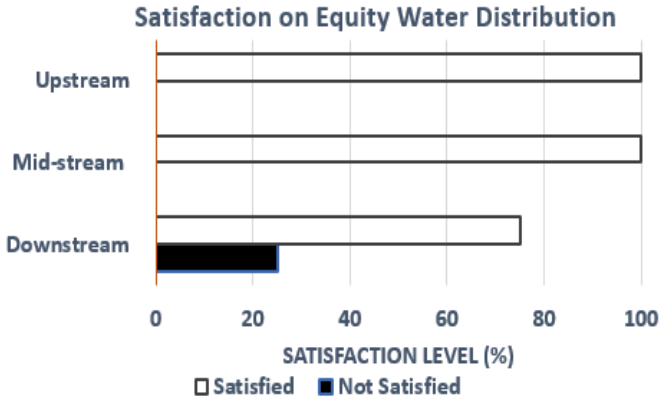

Fig. 3 Survey result of farmer's satisfaction with equity water distribution

The Beni Amir irrigation scheme's adherence to the eight frameworks for managing the commons with the rules employed in water management and planning will help explain how it was able to sustain itself without using the PIM concept while still providing fair water distribution to farmers.

Table 1 demonstrated that the 8 management frameworks proposed by Elinor Ostrom had been adhered to. This supported the irrigation system's successful management and equitable water distribution to farmers.

Table 1 Eight frameworks of managing the common by Elinor Ostrom

Nos.	8 Frameworks of managing the common by Elinor Ostrom	Result
1	Commons need to have clearly defined boundaries	Yes
2	Rules should fit local circumstances	Yes
3	Participatory decision-making is vital	Yes (by Govt)
4	Commons must be monitored	Yes
5	Sanctions for those who abuse the commons should be graduated	Yes (by Govt)
6	Conflict resolution should be easily accessible	Yes
7	Commons need the right to organize	Yes (by Govt)
8	Commons work best when nested within larger networks	Yes (by Govt)

Effect of Change to Drip Irrigation on Water Management

The conversion is done in such a way that farmers utilize the tertiary canals to get and store water in the newly constructed small pond for drip irrigation purposes. The storage capacity of the pond for farmers with less than 5 ha is 3,200 m^3 (20 m x 20 m x 8 m) and is connected to the tertiary canal as the main water source. Water is temporarily stored before being pumped to the overhead tank and used for drip irrigation. Therefore, farmers can store water during their scheduled rotation time and use it for drip irrigation as needed.

The findings of this study indicated that the conversion project may cause certain changes to the water management system, which could have an impact on the CDA's and farmers' long-term monitoring and planning of water use. The changes are highlighted below.

Storing More Water in the Newly Constructed Small Ponds for Drip Irrigation

Farmers have a chance to store enough water more than is required during their existing scheduled rotation time. If before the conversion, 3 hours were scheduled for each farmer, now that farmers can store water, they may need at most 24 hours (30 l/s X 3600 X 24 = 2,592 m^3) to be able to have enough water to pump to their overhead tank. Therefore, the average water rotation time will increase, making it difficult to adjust with non-converted farmers to achieve equity in water distribution during times of scarcity.

The ability of farmers to divert and store adequate water during their unscheduled rotation phase may lead to an increase in water theft. Therefore, CDA will increase the level of supervision and monitoring. Consequently, the CDA's labor and water management costs will rise as well. However, when there is enough water in their ponds, farmers can schedule their irrigation period as desired. Farmers will then spend less time managing their water resources.

Change in the Cropping Pattern

According to the survey, most of the farmers' cropping patterns changed after the conversion to drip irrigation. Before the conversion, farmers usually plant cereal and forage crops such as maize, alfalfa, etc. to provide food for their livestock. After the conversion, farmers are now planting fruit trees, particularly citrus and olive trees, as they are high-value crops and to compensate for the running expenses of drip irrigation. The non-converted farmers may require more water to irrigate their cereal and forage crops through surface irrigation. Since the CDA allocates an equivalent amount of water to farmers before the conversion, the water allocation plan will change with the conversion. This will also affect the water scheduling plans of both the CDA and the farmers to suit each farmer's irrigation method.

Farmers' Low Capacity for Using Drip Irrigation

The survey showed that many farmers have limited knowledge about the operation and maintenance of drip irrigation. This makes them reluctant to introduce the conversion project. The partial conversion of some farms may require regular monitoring and supervision to ensure proper scheduling is followed. This will increase the CDA's water management labor and costs.

Increase in Groundwater Use

Farmers are now able to pump water from wells and store it in their small ponds. This will increase groundwater withdrawal and may lead to groundwater overexploitation. The impact of the overexploitation of groundwater resources on their quantity and quality can be witnessed by many farmers, as discussed during the survey. Also, farmers increased the frequency and duration of their irrigation after the conversion project. Due to the extreme drought of the year 2022, farmers cannot get water from the canals. Therefore, most farmers try to deepen their wells to about 500 m to get adequate water to store in their small ponds.

CONCLUSION

The impact of the drip irrigation system on water delivery planning and management following the conversion of surface (furrow) irrigation to drip irrigation was studied. Based on the findings, the following were concluded.
(1) Farmers had equitable water distribution, as most farmers interviewed expressed satisfaction with equitable water distribution. Compliance with Ostrom's eight frameworks may aid in the successful management of the irrigation system and equitable water distribution to farmers.
(2) Some changes occur as a result of the conversion project, which may have an impact on the CDA's and farmers' overall water management monitoring and planning. These include as follows;
(i) Storing more water in the newly constructed small ponds for drip irrigation
(ii) Change in the cropping pattern
(iii) Farmers' low capacity for using drip irrigation
(iv) Increase in groundwater use

ACKNOWLEDGMENTS

This work was supported by IPDRE, Tottori University.

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