

---

## Research Article

### Evaluation of indicators for improving the irrigation water use efficiency: Case of Guelma-Boucheggouf irrigated perimeter, Algeria

Abdelhak Kebieche\*, Brahim Mouhouche

National Higher School of Agronomy (ENSA former INA), El Harrach, Algiers, Algeria,

---

#### Article history:

Received 10 August 2024

Revised 01 September 2024

Accepted 04 September 2024

Published 21 December 2024

#### Keywords:

Algeria

Irrigation

Water efficiency

Water management

#### \*Corresponding author:

E-mail:

[kebiechemadr@gmail.com](mailto:kebiechemadr@gmail.com)

#### Abstract

This study contributes to the evaluation of irrigation performance in the irrigated perimeter of Guelma-Boucheggouf, located in the Wilaya of Guelma in northeastern Algeria. The aim was to evaluate the irrigation water-use efficiency (WUEi) as a performance indicator of the irrigated system at the perimeter with regard to the existing distribution scheme. It is calculated according to the equation adopted within the framework of the Mediterranean Strategy for Sustainable Development "Plan Bleu" (MSSD) in 2008. It is the product of the overall efficiency of the supply-distribution network (E1) and the plot irrigation efficiency (E2), and is subject to the irrigation methods used. The calculations yielded irrigation water-use efficiency (WUEi) of 46.1%. Examining the results for the 2019 to 2022 irrigation campaigns revealed significant losses between the pumped volumes and the ones released, which indicates a low adduction efficiency (Ea) of 54.22% and explains the inadequacy of the release system compared with the water saving strategies adopted by the national water plan in Algeria. The results also reveal the importance of the existing distribution system reflected by a distribution efficiency (Ed) of 82.08%, which reduced the overall efficiency of the network (E1) calculated from the two efficiencies to 56.58%, indicating an average loss of 9.8 Hm<sup>3</sup> between the released volumes and those distributed. The plot efficiency (E2), calculated at 82%, was acceptable due to its dependence on the irrigation methods used; however further improvement is needed

---

---

#### How to cite:

Kebieche, A. & Mouhouche, B. (2025). Evaluation of indicators for improving the irrigation water use efficiency: Case of Guelma-Boucheggouf irrigated perimeter, Algeria. *Journal of Agriculture and Applied Biology*, 6(1): 38 - 51. doi: 10.11594/jaab.06.01.03

## 1. Introduction

Algeria is ranked 30<sup>th</sup> among countries with high water stress (Kuzma et al., 2023). Considering the limit values of 1000 and 1700 m<sup>3</sup> per inhabitant per year according to the World Health Organization (WHO), which allow us to distinguish the different levels of water availability per inhabitant (World Health Organization [WHO], 2016), Algeria with less than 300 m<sup>3</sup> per inhabitant per year 500 to 600 m<sup>3</sup> per inhabitant per year (Bessaoud et al., 2019) and 400 m<sup>3</sup> per inhabitant per year in 2024 is facing a water scarcity of renewable resources estimated at 18 billion m<sup>3</sup> (Food and Agriculture Organization [FAO], 2019; National Agency for Integrated Water Resources Management [AGIRE], 2024). This standard went from 1500 m<sup>3</sup> per inhabitant per year in 1962 to 361 m<sup>3</sup> per inhabitant per year in 2004 and less than 500 m<sup>3</sup> per inhabitant per year in 2021 (National Economic, Social and Environmental Council [CNESE], 2021).

Agriculture represents approximately 70% of the world's freshwater consumption and the prime user of mobilized water globally, exceeding 70-80% in arid and semi-arid zones (Omar et al., 2019). However, impacted by climate change, this water is essentially allocated to human food, thus causing a considerable decrease in irrigated agricultural production. This decrease in production will mainly affect field crops of considerable importance in food security, such as rice (*Oryza sativa* L.), which is one of the most important cereal crops worldwide (Abd El-Reheem et al., 2022; Khater et al., 2023); according to the Food and Agriculture Organization (FAO), nearly 80% more rice will be needed by 2025. In the same context, Algeria has been strongly hit by a drop in wheat production, and is facing a constant increase in its needs for this essential food, nearly 60% of which is imported. As a result, the Algerian population, estimated at 50 million inhabitants by 2030, will need 15 to 20 billion m<sup>3</sup> mobilized per year (Mouhouche, 2012) or 15 to 18 billion m<sup>3</sup> per year (Akli, 2023) against nearly 11 billion m<sup>3</sup> per year currently according to the Ministry of Hydraulics. Irrigation water needs are estimated to reach 12 billion m<sup>3</sup> per year by 2030, according to a target of 2 million irrigated hectares compared to the mobilizable potential estimated at 18 billion m<sup>3</sup> (Guergueb & Ferhat, 2021).

In response, Algeria mobilized additional unconventional resources in addition to taking action to combat water loss in all its forms. This is how the irrigation sector has benefited from large programs to rehabilitate irrigation infrastructure and other measures to encourage the use water-saving systems on plots. The goal is to increase the irrigation water supply from just over 7 billion m<sup>3</sup>, estimated by the Ministry of Water Resources (Ministry of Water Resources, 2023), to 12 billion m<sup>3</sup> in 2030.

On the other hand, the irrigated surface area remains low, particularly at the level of the 42 Large Irrigated Perimeters (GPIs) which have been in operation, with less than 80 000 ha irrigated over the last nine years according to the operating reports of the management organization, i.e. the National Office of Irrigation and Drainage (ONID), which has a rate of 43% of the irrigable potential (National Office for Irrigation and Drainage [ONID], 2023). Low annual allocations and losses upstream of the distribution networks are the main causes. The average volume distributed for the same period is 365 million m<sup>3</sup> while the need is approximately 717 Hm<sup>3</sup>, indicating a satisfaction rate of less than 40%, accentuated by climatic hazards and the low yields of the irrigated system.

However, improving irrigation water-use efficiency (WUEi) remains a major challenge for effective and efficient demand management. As an indication, it is calculated at 61.5% for all the irrigated areas of Northeast Algeria (Nini & Mebarki, 2020) and 40.08% for Guelma-Boucheggouf perimeter (Nini, 2021). The evaluation of this relevant indicator allows better management of water for agricultural use. From that perspective, our work was carried out in the perimeter of Guelma-Boucheggouf, which has a total irrigable area of 9250 ha that has been in service since 1996. This choice is motivated by the place it occupies in the development of the region, recognized for its strong agricultural vocation.

The purpose of this study was to evaluate the performance of irrigated systems corresponding to the three components of the perimeter distribution scheme: transport, distribution and water application to the plot, it indicates the efficiency of the entire irrigation system in making water available to the plants, measured as the ratio of water available for plants to water supplied from the source (Kilemo, 2022). The efficiency index WUE<sub>i</sub> expresses the ratio between the volumes released from the dam and that received and used on the plot.

Experts estimate that in this type of irrigation system the overall efficiency is at least 30%, while well-managed systems achieve 50 to 90% in pumped networks. It is a purely hydraulic indicator that allows us to assess the operations in an irrigated perimeter. The study is based on the analysis of measurable data obtained in the field. The expected results allow the evaluation of possible margins for improvement in the performance of existing networks and consequently the level of water use efficiency, taking into account all controllable losses throughout the perimeter and thus the performance of irrigation and the efficiency of its management throughout four irrigation campaigns from 2018-2019 to 2021-2022.

## **2. Materials and methods**

This study is based on the analysis of measurable field data, and intends to study the current performance of irrigated systems and the impact of efficiency indicators on improving the yields of irrigation networks. The indicators selected are those related to the use of water at different scales.

The efficiency analysis covered four irrigation campaigns from 2019-2020 to 2021-2022, and was built on data linked to the water and soil resources of the study area, namely the irrigation volumes of the perimeter, distributed and those actually placed ahead of plots as well as the actually irrigated surfaces per irrigation method.

The study begins with the collection, processing and analysis of the data and their impact on the irrigated system in relation to the overall efficiency of the distribution network and the efficiency of the irrigation plot, and its use according to irrigation methods and irrigated areas. This analysis covers the three main segments of the distribution scheme, namely transport, distribution and application to the plot.

### **2.1 Study zone**

#### **2.1.1 Location**

The study area is located in the Wilaya of Guelma, located 60 km from the far northeast region of Algeria (36°46'N, 7°28'E, altitude 279 m). It consists of two alluvial plains, Guelma and Bouche-ggouf. The first, Guelma, contains the plains of Oued Seybouse and the ancient confluences valley of Oued Cherf and Bouhamdane to the West toward the commune of Boumahra to the East, and the second plain of Bouche-ggouf extends from Boumahra in the West to Bouche-ggouf in the East (Figure 1).

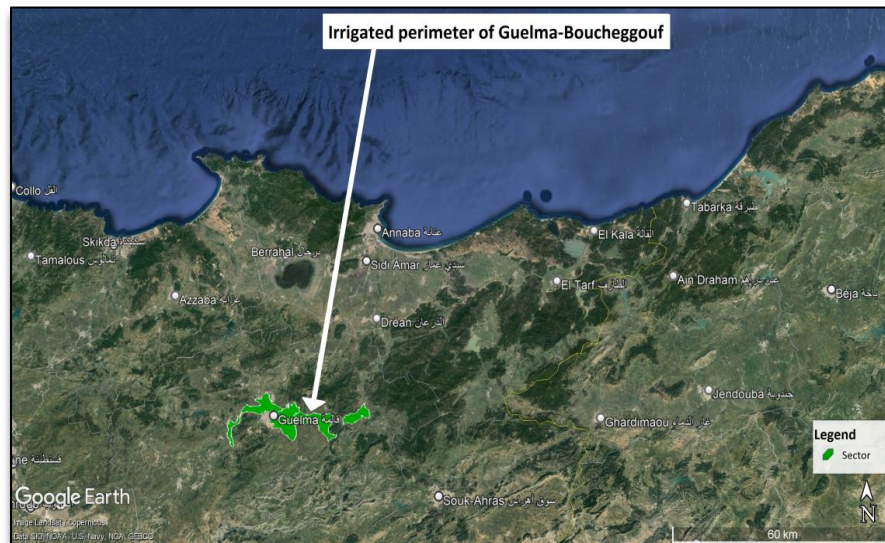


Figure 1: Geographic location of the study area

### 2.1.2 Irrigation water resources

These resources consist of water withdrawn from the Hammam Debagh dam, which is located 20 km west of the perimeter and has a capacity of 180 million m<sup>3</sup>. The theoretical average volume reserved for irrigation is 54.7 million m<sup>3</sup> per year for a potentially irrigable area of 9250 ha, which is the theoretical average need for 5913 m<sup>3</sup> ha<sup>-1</sup> (Tetraktys Association, 1981).

### 2.1.3 Climatic characteristics

The northern region of the Wilaya is dominated by a subhumid climate while the southern region is dominated by a semiarid climate. According to data from the Guelma meteorological station between 1990 and 2020, the annual average temperature in 1994 was the hottest with an average of 19.17 °C, while that in 1992 was the coldest with an average of 16.52 °C. Precipitation varied from 982.5 mm on average in 1992 to 381.8 mm in 2008, which was considered the driest year (Figure 2).

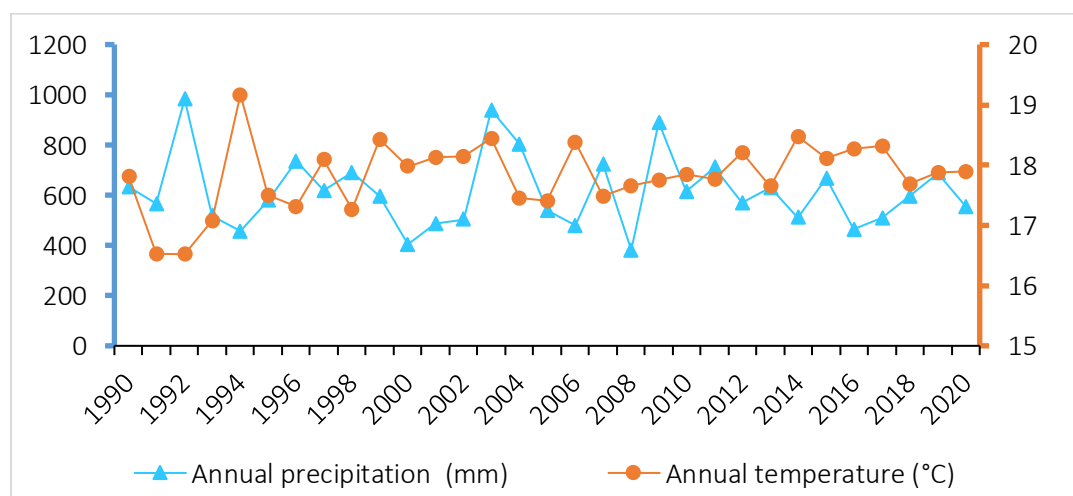


Figure 2: Average annual precipitation and temperature

### 2.1.4 Ombrothermal diagram

According to the graphic tool of Henri Gaussen (1952), the results of analyzing monthly averages of precipitation and temperature of the study zone (Guelma Station: 1990-2020) classify its climate as mild and cool from November to April and hot from May to October (Figure 3).

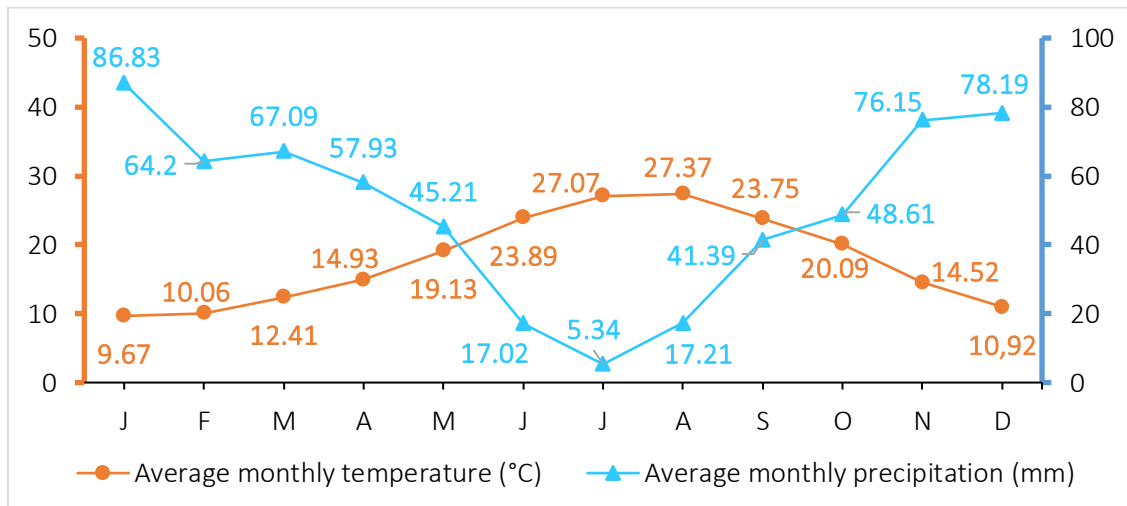


Figure 3: Gaussen ombrothermal diagram of Guelma region (1990 - 2020)

In hygrometric terms, it is a temperate semiarid zone with an annual average relative humidity of 68.3% (Ababsa, 2018) or 68.92% (Belmami & Harfi, 2023).

## 2.2 Presentation of the Guelma-Boucheeggouf irrigated perimeter

### 2.2.1 Spatial frame

Spread on both banks of Oued Seybouse, the perimeter of Guelma-Boucheeggouf stretches approximately 80 km west to east from the confluence of Oued Bouhamdane and Oued Cherf (Wilaya of Guelma). The system is divided into six autonomous distribution sectors characterized by an independent management plan and water supply for each (Figure 4, Table 1).

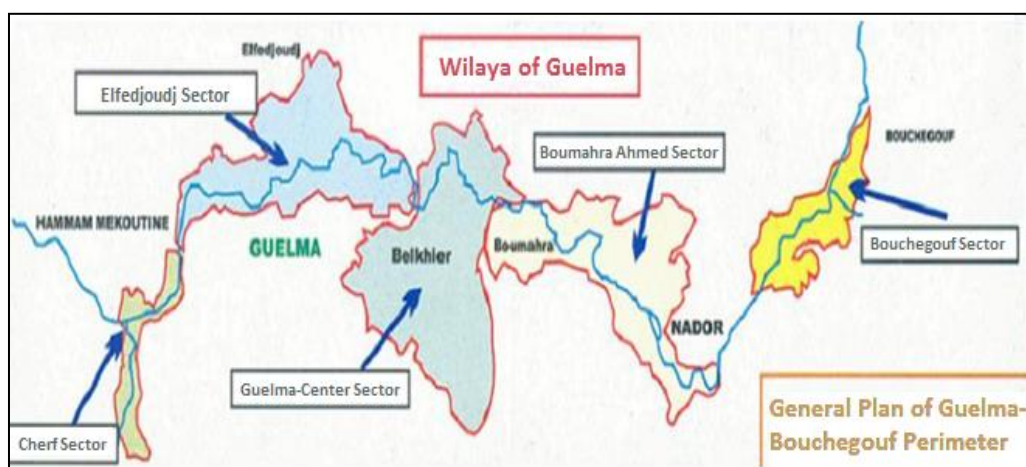


Figure 4 : General plan of Guelma-Boucheeggouf perimeter



Table 1: Spatial framework of Guelma-Boucheggouf perimeter (*Tetraktys Association, 1981*)

| No. | Irrigation sectors | Surface (ha) |           | Water requirements (m <sup>3</sup> ) |
|-----|--------------------|--------------|-----------|--------------------------------------|
|     |                    | Equipped     | Irrigable |                                      |
| 1   | Guelma             | 3500         | 3255      | 19400000                             |
| 2   | Cherf              | 605          | 565       | 3300000                              |
| 3   | Boumahra           | 2600         | 2420      | 14300000                             |
| 4   | El-Fedjoudj        | 2355         | 2190      | 12900000                             |
| 5   | Boucheggouf        | 880          | 820       | 4800000                              |
|     | Total              | 9,940        | 9,250     | 54,700,000                           |

### 2.2.2 Distribution plan of irrigation water

It consisted from water released from the Bouhamdane Dam in Oued Seybouse. Water is recovered at the water intake weirs downstream of each sector and then raised by pumping stations to discharge stations located near the weirs. The water is then brought by mixed underground delivery-distribution pipes to the irrigated plots through semi buried control and compensation reservoirs, with a capacity varying from 6700 to 33900 m<sup>3</sup> upstream of each sector. Water is made available to irrigators through irrigation terminals of varying diameters from 100 to 150 mm, that are equipped with flow and pressure regulators as well as water meters. The average pressure at each outlet was 4 bars delivering 15 to 45 m<sup>3</sup> h<sup>-1</sup> depending on the case. The irrigation campaign generally extends from April to November or even December for late-season crops.

## 3. Results and discussion

The evaluation and interpretation of the results revolve particularly around the percentage of irrigation water use efficiency (WUE<sub>i</sub>). In terms of hydraulic performance, it is recognized as an essential indicator for evaluating water loss measured through a supply and distribution network, from the storage and/or mobilization structure to the irrigated plots, while also considering the irrigation methods used.

It is the product of the transport and distribution network efficiency (E1), taking into account the volumes released, distributed and placed at the head of plots, by the efficiency at the plot level (E2) (*Blinda & Giraud, 2012*), calculated using the volumes distributed and those placed ahead of the plots according to the areas irrigated by a specific irrigation method.

The equation 1 used to evaluate the irrigation water use efficiency within the perimeter was adopted within the framework of the Mediterranean Strategy Sustainable Development (MSSD) in 2008 as follows:

$$WUE_i = E1 \times E2 \quad (1)$$

Of which :

- E1: product of the efficiency of supply (Ea) and distribution (Ed);
- E2: efficiency in the irrigation plot.

### 3.1 Calculation of the overall efficiency of network E1

#### 3.2

The overall efficiency of the networks (E1) was calculated according to equation 2, adopted from the works of the National Water Plan (PNE) in 1997, and expressed as a percentage (%):

$$E1 = Ea \times Ed \quad (2)$$

Of which:

- Ea: adduction efficiency (%);
- Ed: distribution efficiency at the head of the plots (%).

### 3.2.1 Adduction efficiency ( $E_a$ )

Expressed as a percentage (%), this parameter reflects the first segment of the perimeter distribution diagram between the dam (withdrawal point) and the pumping stations (head of the distribution networks). It is calculated using equation 3 as follows:

$$\text{Adduction efficiency } (E_a) = \frac{\text{Volume at the head of the network } (V_{mtr})}{\text{Released volume } (V_l)} \times 100 \quad (3)$$

The result obtained is the ratio of the volume pumped or placed at the head of the network to the volume released from the dam in  $\text{m}^3$ . This approach provides information on route losses caused by the method of release carried out in the Oued. It is evaluated at an average rate of 54.22% (Figure 5), or the equivalent of  $6.5 \text{ Hm}^3$ , which is excessive and do not accord with the objectives of improving irrigation water use efficiency. This low performance shows the disadvantage of the release method used to bring water to the perimeter. It is lower than that calculated for the same area in 2007 with a rate of 71% (Kebieche, 2007).

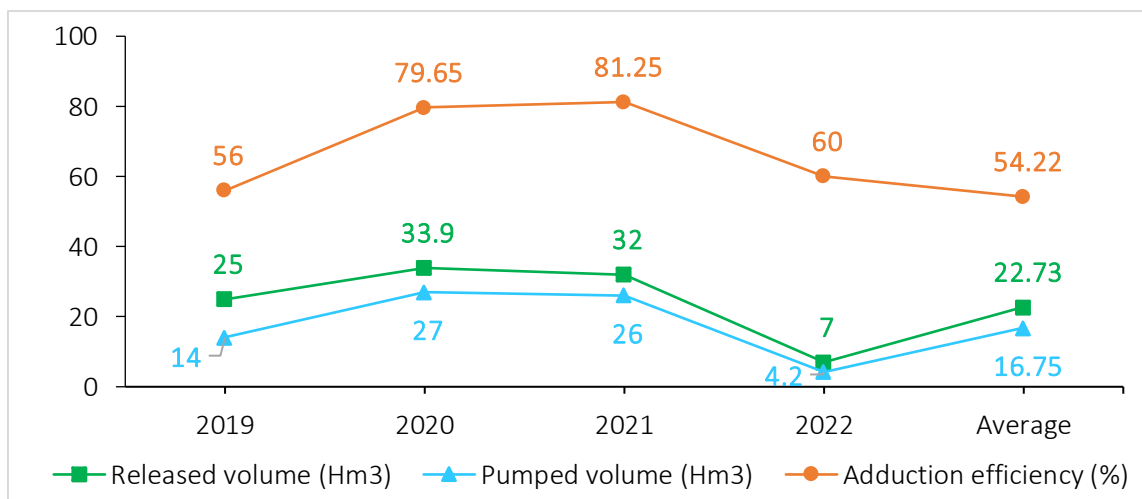


Figure 5: Evolution of adduction efficiency ( $E_a$ ) as a percentage of Guelma-Boucheggouf perimeter (irrigation campaigns 2019 – 2022)

Note that the release method adopted within the initial study of the water supply project to the perimeter over more than 20 km discords with the principles of water conservation. Huge losses of more than 45% of the released volume are recorded. This situation requires well thought-out solutions and the implementation of a pipe supply system.

### 3.2.2 Distribution efficiency ( $E_d$ )

The distribution efficiency is expressed as a percentage (%) and was calculated by relating the volumes actually distributed ( $V_d$ ) to the plot (made available to irrigated crops) and those placed at the head of the perimeter networks (pumped). It is calculated according to the following equation 4:

$$\text{Distribution efficiency } (E_d) = \frac{\text{Distributed volume } (V_d)}{\text{Volume at the head of the network } (V_{mtr})} \times 100 \quad (4)$$

It covers the second segment of the network (pumping stations – plots) and provides information on the losses caused in the distribution network such as pipes, storage structures and various types of online distribution equipment. The average value obtained is 82.08% (Figure 6), and

seems pertinent because the losses estimated at this level are less than 18%, depending in particular on the type of existing pipes and networks, which shows the importance of the distribution method for watertight and well-maintained pipes.

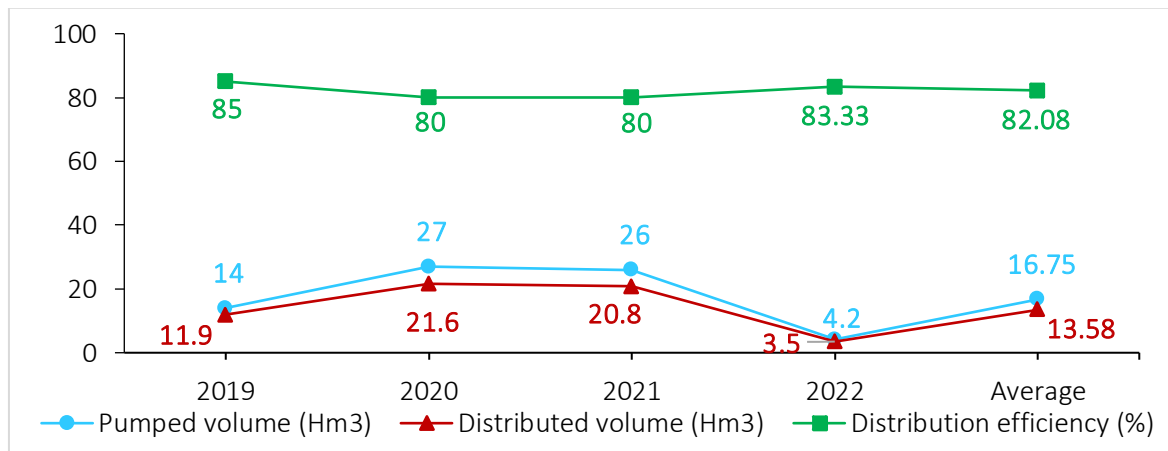


Figure 6: Evolution of distribution efficiency ( $E_d$ ) as a percentage of Guelma-Boucheggouf perimeter (irrigation campaigns 2019 - 2022)

High-quality products are fundamental to any efficient water distribution system. The investment costs of choosing poor quality pipes far exceed those of investing in high-quality products. Therefore, we suggest the replacement of existing pipes and control equipment with others of superior quality in the future rehabilitation programs of this perimeter, by installing the necessary tools and technological equipment that allow better management, such as remote monitoring.

### 3.2.3 Calculation result

Referring to equation 2, the average overall network efficiency ( $E_1$ ) was calculated to be 56.58%. Its evolution is graphically represented below and varies from 47.6 to 65% depending on the campaign (Figure 7).

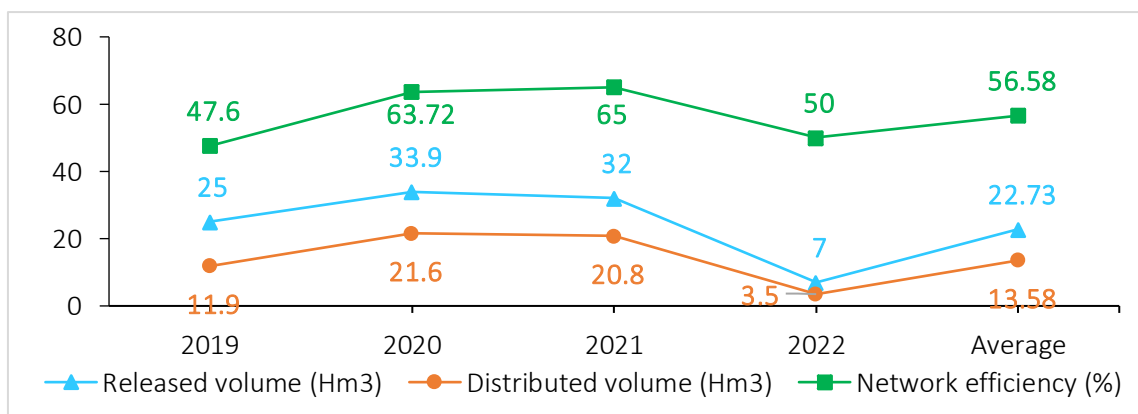


Figure 7: Evolution of network efficiency ( $E_1$ ) as a percentage of Guelma-Boucheggouf perimeter (irrigation campaigns 2019 - 2022)

As a result, it has been noted that the release of water from dams in rivers causes significant loss of range; particular attention must be paid to improving route and distribution efficiency, which was around a national average of 65% in 2016 (Boulahia, 2016).



### 3.3 Calculation of irrigation efficiency per plot E2

E2 is the sum of efficiencies per plot of each irrigation mode, weighted by the proportion of the different modes. It is used to estimate water losses due to using it to irrigate a given crop. It represents the estimated application efficiency, by relating the quantity of water brought to the head of the plots and the volume actually consumed for a given area over a known period and a well-determined growth cycle, knowing that the difference between the water consumed by these crops and that brought to the head of the plots represents the losses at the plot. It is based on water volume ratios, so it is expressed in %. The concept of efficiency per plot is used in irrigation engineering, to evaluate the technological performance of irrigation systems (Wittling & Molle, 2017). The efficiency per plot in the field is the ratio between water volumes used for the crops the volumes at the entrance to the irrigated plots. It is determined using equation 5 as follows:

$$E2 = \sum_1^n \frac{S_m \times E_m}{S_t} \quad (5)$$

Of which:

- n : number of irrigation methods (gravity, sprinkler, micro-irrigation);
- $S_m$  : irrigated surface in hectares per irrigation method;
- $E_m$  : water efficiency under the different irrigation methods (estimated);
- $S_t$  : the total irrigated surface in hectares.

For calculation purposes, the average theoretical values of the efficiencies of the irrigation methods used are 75% for sprinkling, 50% for gravity and 85% for localized irrigation (Blinda, 2009); these values vary depending on the pedoclimatic conditions characterizing the study areas: for example, 80-85% for sprinkling (Zella, 2015) and 40%-50% for gravity (Echikr, 2018) were evaluated. For drip irrigation, it increases to approximately 75-90% (Wittling & Molle, 2017).

#### 3.3.1 Calculation results

The average efficiency per plot (E2) was calculated for the 2018-2019 to 2021-2022 irrigation campaigns for an average irrigated area of 2112 ha during the study period. The analysis of irrigation campaigns showed that the gravity irrigation mode was insignificant or in fact nonexistent during the study period. This factor was not taken into consideration in the calculations.

Considering the utilization rates per irrigation method taken from the ONID operation reports, the average irrigated areas per method and per campaign are as follows (Table 2).

*Table 2: Evaluation of the rates of irrigation methods utilization (%) and irrigated areas (ha) per campaign in Guelma-Boucheggouf irrigated perimeter (2019-2022)*

| Irrigation campaigns | Irrigated area per irrigation method (ha) |                                            |           |                                            |           | Distributed volume (m³) |
|----------------------|-------------------------------------------|--------------------------------------------|-----------|--------------------------------------------|-----------|-------------------------|
|                      | Total (ha)                                | Areas irrigated per irrigation method (ha) |           | Utilization rate per irrigation method (%) |           |                         |
|                      |                                           | Aspersion                                  | Localized | Aspersion                                  | Localized |                         |
| 2019                 | 1 233                                     | 580                                        | 653       | 47,04                                      | 52,96     | 11 900 000              |
| 2020                 | 3 689                                     | 1926,6                                     | 1762,09   | 52,23                                      | 47,77     | 21 600 000              |
| 2021                 | 2 924                                     | 1024,8                                     | 1899,12   | 35,05                                      | 64,95     | 20 800 000              |
| 2022                 | 601                                       | 2,50                                       | 598,90    | 0,42                                       | 99,58     | 3 500 000               |
| Average              | 2 112                                     | 883                                        | 1228      | 34                                         | 66        | 14 450 000              |

The results obtained allowed the calculation of the average efficiency at plot E2 according to equation 5 taking into account the following parameters:

- $n$  = The irrigation methods used, sprinkling (a) and localized (l) ;
- $S_{ma}$  = Irrigated surface in sprinkler mode (ha) ;
- $E_a$  = Water efficiency in sprinkler mode (75%) ;
- $S_{ml}$  = Irrigated surface in localized irrigation mode (ha) ;
- $E_l$  = Water efficiency in localized irrigation mode (85%).

The average E2 efficiency obtained was 82%, and it varied from 80 to 85% (Table 3). It is acceptable and depends on irrigation methods and their utilization rates. It is also noted that localized irrigation in the perimeter occupies a considerable place with an average utilization rate of 66%, compared to 34% for sprinkling; this denotes the important performance of irrigation at the plot in the perimeter.

*Table 3 : Evaluation of the average efficiency per plot (E2) in the irrigated perimeter of Guelma-Boucheggouf (2019 – 2022)*

| Irrigation campaign | Sprinkler     |           | Localized     |           | Total (ha) | E2 (%) |
|---------------------|---------------|-----------|---------------|-----------|------------|--------|
|                     | $S_{ma}$ (ha) | $E_a$ (%) | $S_{ml}$ (ha) | $E_l$ (%) |            |        |
| 2019                | 580           | 75        | 653           | 85        | 1 233      | 80     |
| 2020                | 1926,6        | 75        | 1762,09       | 85        | 3 688,6    | 80     |
| 2021                | 1024,80       | 75        | 1899,12       | 85        | 2 923,9    | 81     |
| 2022                | 2,50          | 75        | 598,90        | 85        | 601,4      | 85     |
| Average             | 883           | 75        | 1079          | 85        | 2 112      | 82     |

The plot efficiency, varying from 80 to 85%, remains acceptable and reveals the progress in spreading water-saving irrigation methods. Nevertheless, using water-saving systems requires specific facilities such as collective basins in order to allow access to the resource more frequently (Tazekrit et al., 2017). It is also suggested to equip the perimeter with technological tools for innovative irrigation. This allows an additional water gain of more than 25% compared to current numbers.

### 3.4 Assessment of water use efficiency (WUEi) in Guelma-Boucheggouf perimeter

#### 3.4.1 Calculation results

The application of equation 1 allowed to obtain an irrigation water use efficiency (WUEi) of 46,1% as shown in Table 4 and Figure 8 below.

*Table 4: Evaluation of irrigation water use efficiency (WUEi) in the Guelma-Boucheggouf irrigated perimeter (2019 – 2020)*

| Irrigation campaign | Released volume (Hm <sup>3</sup> ) | Pumped Volume (Hm <sup>3</sup> ) | Adduction efficiency (%) | Distributed volume (Hm <sup>3</sup> ) | Distribution Efficiency (%) | network efficiency E1 (%) | Plot efficiency E2 (%) | WUEi (%) |
|---------------------|------------------------------------|----------------------------------|--------------------------|---------------------------------------|-----------------------------|---------------------------|------------------------|----------|
| 2019                | 25.00                              | 14.00                            | 56.00                    | 11.90                                 | 85.00                       | 47.60                     | 80                     | 38,1     |
| 2020                | 33.90                              | 27.00                            | 79.65                    | 21.60                                 | 80.00                       | 63.72                     | 80                     | 51       |
| 2021                | 32.00                              | 26.00                            | 81.25                    | 20.80                                 | 80.00                       | 65.00                     | 81                     | 52,7     |
| 2022                | 7.00                               | 4.20                             | 60.00                    | 3.50                                  | 83.33                       | 50.00                     | 85                     | 42,5     |
| Average             | 22.73                              | 16.75                            | 54.22                    | 13.58                                 | 82.08                       | 56.58                     | 82                     | 46,1     |

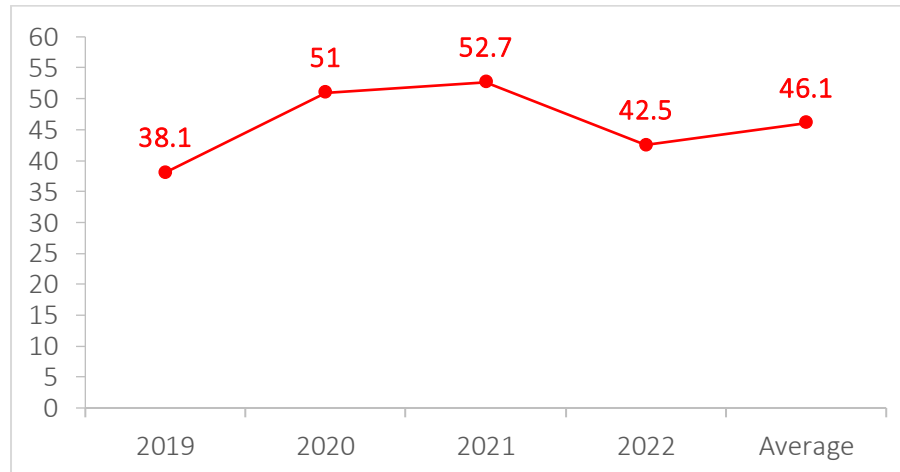


Figure 8: Evaluation of irrigation water use efficiency (WUEi) in the Guelma-Boucheggouf irrigated perimeter (2019 – 2020)

The calculation results reveal that the distribution efficiency indicator at a rate of 82.08% is high. It evaluates the average water loss caused by the pumping stations to the head of plots, and was estimated at an acceptable rate of less than 18%. This was in relation to adduction modes using watertight and well-maintained pipes, unlike the course efficiency estimated at 54.22%, which was low and inconsistent with the aim of improving the overall efficiency of water use, due to its dependence on the water release mode into the Oued, thus causing enormous course losses. These results reduced the overall efficiency (E1) of the supply-distribution network to a fair average level of 56.5%, indicating an average water loss of 9 million m<sup>3</sup> each year compared to an average released volume of 22.73 Hm<sup>3</sup>.

The efficiency E2, which indicates the degree of irrigation water recovery at the plot, was at 82%, which is considerable compared to the average of 74% calculated for all the large irrigated perimeters of Algeria (BRL Ingénierie & National Office of Rural Development Studies [BNEDER], 2005). This indicator of plot efficiency informs us about the importance of water-saving equipment and its usefulness in improving irrigation performance. A total of 66% and 34% of the water saving equipment was utilized for drip irrigation and sprinklers, respectively, for an average total irrigated area of 2112 ha, strongly contributing to the improvement of plot efficiency. This shows that the perimeter is adequately equipped; hence the potential to maintain the rate of losses at the plot at an acceptable level is strong.

As a result, and given that irrigation water use efficiency is the product of water supply and distribution efficiency upstream of the perimeter and irrigation plot efficiency, we observed the best practices that could be adopted to reduce water loss, by modernizing the distribution networks and encouraging the use of water saving techniques at the plot. According to Plan Bleu, the average irrigation water efficiency in certain Mediterranean countries in 2005 was, for example, 20% in Albania, 36% in Algeria, 38% in Egypt, 45% in Turkey and 62% in Spain (Thivet & Blinda, 2007). Additionally, the irrigated land and water use efficiency in Central Asia remains critically low; 40% of water is lost due to filtration from irrigation canals (Vinokurov et al., 2023).

#### 4. Conclusions

The route efficiency (Ea) evaluated at 54.22% remains insufficient and does not accord with the objectives of improving irrigation water use efficiency. It shows the disadvantage of the release method used for supplying water to the irrigated perimeter, unlike the distribution efficiency (Ed) evaluated at 82.08% which seems more relevant. It shows the importance of the

distribution method in watertight and well-maintained pipes. The result of these two indicators reduced the overall network efficiency (E1) to 56.5%, indicating an average water loss of 9.8 million m<sup>3</sup> each year compared to an average released volume of 22.73 Hm<sup>3</sup> during the analysis period. The plot efficiency (E2), calculated at 82%, is considered acceptable compared to the national average of 74% in the large irrigated areas of Algeria. It depends on the irrigation methods and the type of installations on the plot, and shows the importance of existing water-saving equipment and its impact on improving irrigation performance. Furthermore, the efficiency at the plot (E2), calculated at 82% is considered acceptable compared to the national average evaluated at 74% in the large irrigated areas of Algeria. It depends on the irrigation methods and the type of installations on the plot and provides information on the importance of existing water-saving equipment and its impact on improving irrigation performance. Despite the absence of periodic studies to evaluate the average efficiency of irrigation methods used in the study area, we were able to highlight the importance of water-saving irrigation systems such as sprinkler and localized irrigation and their impact on water use efficiency. This led us to call on similar studies carried out in several regions of the country, obviously taking into account soil and climatic conditions similar to those in our study area. This calls on researchers to develop specific studies capable of responding more precisely to our needs and making the results even more effective. In conclusion, the water use efficiency (WUEi) of Guelma-Boucheggouf perimeter, calculated at 46.1%, is insufficient and does not meet the objective of improving the performance of irrigated systems in Algeria. The modernization of transmission and distribution networks and the implementation of rational and intelligent irrigation systems are actions to adopt in order to cope with the accelerating effects of climate change and the constant increase in demand for water. Finally, deepening this study by identifying the best model for a better valorization of water for agricultural use is recommended.

## Acknowledgement

The authors wish to express their gratitude and cordiality to all those who have contributed directly or indirectly to the accomplishment of this work.

## Author's declarations and contribution

The authors declare the absence of any conflict of interest. All authors contributed actively to the realization of this work, read and approved the final version of the manuscript.

## References

- Ababsa, B. (2018). *Etude de l'évolution des précipitations dans la région de Guelma* [Study of the evolution of rainfall in the region of Guelma] [Master thesis, University of Mohamed Khider of Biskra]. University of Biskra Repository [Direct Link](#).
- Abd El-Reheem, S., Awad, M., Abd el Gawad, F., Cottb, M., & Okasha, M. (2022). Influence of operating parameters on the milling quality of long-grain white rice. *INMATEH Agricultural Engineering Journal*, 68(3), 669-680. [CrossRef](#)
- Akli, R. (2023). Situation hydrique, le diagnostic de Attar : «Il faudrait disposer de 15 à 18 milliards m<sup>3</sup>/an d'ici à 2030» [Water situation, Attar's diagnosis: "We should have 15 to 18 billion m<sup>3</sup>/year by 2030"]. *L'Algérie Aujourd'hui*. [Direct Link](#).
- Belmami, I., & Harfi, D. (2023). *Les macroinvertébrés benthiques bioindicateurs de la qualité écologique des milieux lotiques: Cas de la Seyebose Nord est d'Algerie* [Benthic macroinvertebrates, bioindicators of the ecological quality of lotic ecosystems: The case of Seyebose in the northeastern Algeria] [Master thesis, University of 8 Mai 1945 of Guelma]. University of Guelma repository. [Direct Link](#).

- Bessaoud, O., Pellissier, J.-P., Rolland, J.-P., & Khechimi, W. (2019). *Rapport de synthèse sur l'agriculture en Algérie* [Synthesis report on agriculture in Algeria]. Working paper. Centre de Documentation Méditerranéen [CIHEAM] Montpellier. [Direct Link](#)
- Blinda, M. (2009). *Stratégie méditerranéenne pour le développement durable : Efficience d'utilisation de l'eau* [The Mediterranean Strategy for Sustainable Development: Water Use Efficiency]. Plan Bleu-The Mediterranean Action Plan of the United Nations Environment Program [UNEP/MAP]
- Blinda, M., & Giraud, J.P. (2012). *More efficient water use in the Mediterranean* (14). Plan Bleu-The Mediterranean Action Plan of the United Nations Environment Program [UNEP/MAP]. [Direct Link](#).
- Boulahia, A. (2016). *L'eau d'irrigation en Algérie* [Irrigation water in Algeria], [Master thesis, University of Mentouri of Constantine]. University of Constantine repository. [Direct Link](#).
- BRL Ingénierie & National Office of Rural Development Studies [BNEDER]. (2005). *Etude de la tarification de l'eau à usage agricole* [Study of the pricing of water for agricultural use]. Ministry of Water Resources
- Echikr, K. E. (2018). *Dimensionnement du Réseau d'Irrigation par Aspersions de Pomme de Terre, Tipaza* [Sizing of the potato sprinkler irrigation network, Tipaza] [Master thesis, University of Saad Dahlab of Blida]. University of Blida Repository. [Direct Link](#).
- Food and Agriculture Organization [FAO]. (2019). *Water efficiency, productivity and sustainability in the NENA regions (WEPS-NENA), Algeria - Background and sites*. [Direct Link](#).
- Guergueb, M., & Ferhat, F. (2021). La gestion des eaux en Algérie : Vers un nouveau paradigme [Water management in Algeria : Towards a new paradigm]. *Journal of Advanced Economic Research*, 6(01), 303-315
- Kebieche, A. (2007). *Gestion rationnelle de l'eau d'irrigation au niveau d'un périmètre irrigué, Enjeux et perspectives : Cas du périmètre de Guelma-Bouchehouf* [Rational management of irrigation water in an irrigated perimeter, challenges and prospects : The case of Guelma-Bouchehouf perimeter] [Magister thesis, National Higher School of Agronomy of Algiers]. National Higher School of Agronomy repository. [Direct Link](#).
- Khater, A., Fouda, O., El-Termezy, G., Abdel hamid, S., El-Tantawy, M., El-Beba, A., Sabry, H., & Okasha, M. (2023). Modification of the rice combine harvester for cutting and binding wheat crop. *Journal of Agriculture and Food Research*, 14, 100738. [CrossRef](#)
- Kilemo, D.B. (2022). The review of water use efficiency and water productivity metrics and their role in sustainable water resources management. *Open Access Library Journal*, 9(1). [Cross-Ref](#)
- Kuzma, S., Saccoccia, L., & Chertock, M. (2023). *25 Countries, Housing One-Quarter of the Population, Face Extremely High Water Stress*. World Resources Institute. [Direct Link](#)
- Ministry of Water Resources. (2023). *Situation des ressources en eau en Algérie. Les assises nationales de l'agriculture sur les perspectives du développement de l'agriculture algérienne* [Situation of water resources in Algeria. National agricultural meetings on the for the development of Algerian agriculture]. April 2023, Algiers, Algeria
- Mouhouche, B. (2012). Les problèmes du manque d'eau en Algérie: Une réalité qui fait peur [The problems of water scarcity in Algeria: A frightening reality]. *Djadid El-iktissad Review*, 07, 40-57
- National Agency for Integrated Water Resources Management [AGIRE]. (2024). Désalement, réutilisation, économie de l'eau : Trois piliers de la politique de l'eau en Algérie [Desalination, reuse, water economy: three pillars of water policy in Algeria]. *Eau le mag (4th edition)*. 6-9
- National Economic, Social and Environmental Council [CNESE]. (2021). *Journée d'étude sur le stress hydrique en Algérie* [Study Day on water stress in Algeria]. [Paper presentation]. 8 June 2021, Algiers, Algeria



- National Office for Irrigation and Drainage [ONID]. (2023). *Bilan annuel d'exploitation, campagne d'irrigation*. [Annual operating report]. January 2023, Algiers, Algeria.
- Nini, F. (2021). *Du barrage à la parcelle irriguée : Etude sur l'eau et valorisation des grands périmètres irrigués dans le Nord-Est Algérien* [From the dam to the irrigated plot: A study on water and the development of large irrigated perimeters in northeastern Algeria] [Doctoral dissertation, University of Mentouri of Constantine]
- Nini, F., & Mebarki, A. (2020). L'efficience de l'utilisation de l'eau d'irrigation : cas du périmètre de Guelma-Boucheggouf, Algérie [Irrigation water use efficiency : the case of guelma-boucheggouf perimeter, Algeria]. *La Houille Blanche*, 106(2), 5-13. [CrossRef](#)
- Omar, A. A., Omuto, C., & Ondieki, S. (2019). Determination of irrigation supply efficiency in challenging environment: Case Study of Bal'ad District, Middle Shabelle Region in Somalia. *Computational Water, Energy, and Environmental Engineering*, 8(1). [CrossRef](#)
- Tazekrit, I., Benslimane, M., Hamimed, A., Hartani, T., & Khaldi, A. (2017). Gestion concertée de l'eau des grands périmètres irrigués ; Cas de la plaine de Habra (nord-ouest algérien) [Concerted water management of large irrigated perimeters ; Case of the Habra plain (north-west Algeria)]. *Larhyss Journal*, 30, 121-136
- Tetraktys Association. (1981). *Etude d'aménagement hydro-agricole de la plaine de Guelma-Boucheggouf* [Hydro-agricultural planning study of Guelma-Boucheggouf plain]. Ministry of Hydraulics
- Thivet, G., & Blinda, M. (2007). *Améliorer l'efficience d'utilisation de l'eau pour faire face aux crises et pénuries d'eau en Méditerranée* [Improving water use efficiency to address water crises and shortages in the Mediterranean]. Plan Bleu-The Mediterranean Action Plan of the United Nations Environment Program [UNEP/MAP]. [Direct Link](#).
- Vinokurov, E., Ahunbaev, A., Chuyev, S., Adakhayev, A., Sarsembekov, T. (2023). *Efficient Irrigation and Water Conservation in Central Asia*. Reports and Working Papers 23/4. Almaty: Eurasian Development Bank. [Direct Link](#).
- Wittling, C., & Molle, B. (2017). *Evaluation des économies d'eau à la parcelle réalisables par la modernisation des systèmes d'irrigation* [Evaluation of water savings at the plot that can be achieved by the modernization of irrigation systems]. National Research Institute of Science and Technology for Environment and Agriculture [IRSTEA]
- World Health Organization [WHO]. (2016). *Stratégie de coopération de l'OMS avec l'Algérie : 2016-2020* [WHO Cooperation Strategy for Algeria: 2016–2020]. World Health Organization, Regional Office for Africa. [Direct Link](#).
- Zella, L. (2015). *Irrigation, eau, sol et plante* [Irrigation, water, soil and plant] (1st ed.). Office of University Publications