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Research Article

Analysis and Diagnosis of the Management of Irrigation Systems in the Mitidja West Irrigated Perimeter

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Abstract

Evaluating the performance of irrigation systems makes it possible to improve agricultural water management and consequently increase water productivity. In this perspective, the present study consists in highlighting the degree of technical performance of irrigation systems at the farm and plot scale, in relation to the level of control of irrigation by farmers and to try to improve irrigation management. The experimental trial of irrigation monitoring and evaluation was conducted in the irrigated perimeter of the West Mitidja (slice I) on two farms (EAC 1 and 4) equipped with the three irrigation systems (gravity, sprinkler and drip). The approach adopted consists of measuring the flow rate at the water point outlet and at the head of the plot; evaluating the water stocks in the soil before and after each irrigation and calculating the uniformity coefficient and water distribution. The results obtained show poor water distribution for the three irrigation systems due to lack of irrigation equipment (pressure gauge, flow meter, valves) and faulty installation and maintenance of the equipment. Uniformity coefficients for both systems (sprinkler and drip) are below standards 70% < CU < 90%. These results demonstrate the need to train farmers in the mastery of pressure irrigation in order to make the best use of water resources.

Keywords: Mitidja West; Irrigated Perimeter; Irrigation; Performance Indicator; Water Productivity

Abbreviations

APIR: After Irrigation; AVIR: Before Irrigation; da: Apparent Density; EAC: Collective Farming; ENSA: Agricultural National High School; Hcc: Field Capacity; Hpf: Permanent Wilting Point; N: Number of Skates in the Plot; Ng: Number of Drippers; P: Hourly Rainfall; Q: Flow Rate at the Head of the Plot; Q_{moy}: Average flow Rate of the Drippers; T: Irrigation Duration (h); Tmoy: Average Time to Fill a Line; Zr: Root Depth.

Introduction

The scarcity of water resources and the increasing global demand for water, particularly in the agricultural sector, which accounts for 70 per cent of global water consumption [1], is fuelling the debate on how to improve water use efficiency and productivity [2]. Irrigation stakeholders, including policy makers and irrigators, need indicators on irrigation efficiency and water productivity in order to develop appropriate strategies for sustainable water resources management. In Algeria, water consumption in the agricultural sector is about 7 billion m^3 on average per year, i.e. 70%, bearing in mind that overall national consumption (drinking water consumption of the population, needs of the industrial and agricultural sectors) is 10.6 billion m^3/year [3]. Indeed, the adoption of a rational approach to the management of irrigation water in the irrigated perimeter proves to be indispensable. As several authors have shown in their work on irrigated perimeters. In this context, Chabaca [4] carried out a study on a few farms in the Mitidja plain west tranche I in order to assess the performance of irrigation systems at farm and plot scales. It showed that losses ranging from 15 to 30% between water source points and the plot. Also, the empirical use of irrigation techniques such as sprinkling and spot irrigation results in sub-standard efficiency. Ouradi [5] assessed the irrigation water needs of Hamiz irrigated perimeter (East Mitidja), and showed a volume of 9.5 Hm^3 to cover the water needs of this perimeter. In Tunisia and Morocco which benefit from a similar climate, El Amri., *et al.* [6] followed a test on the uniformity of distribution of irrigation water by the drip network in the irrigated perimeter of Zaafrana II. Yacoubi., *et al.* [7] studied the impact of distribution uniformity in sprinkler irrigation on the water response of potato. They reported that water was better distributed in the soil than at the surface with a CUsol groundwater distribution uniformity coefficient greater than 90%. M'sadak., *et al.* [8] carried out a diagnosis of the performance of a non-mechanized sprinkler irrigation system known as conventional sprinkler irrigation at plot scale. In this perspective, this study aims to highlight the degree of technical performance of irrigation systems at farm and plot level, in relation to the level of control of irrigation by farmers, and to try to improve irrigation management.

Materials and Methods

Study site

The study site is the irrigated perimeter of the Mitidja West Tranche I (figure 1), it is positioned between 36°36' North of Latitude and 2°54' East of Longitude and at an altitude of 256 m. The study site belongs to the subhumid bioclimatic stage. The average annual rainfall over a 47-year period (1970-2017) is 627 mm, fluctuating between a minimum of 277 mm (dry period) and a maximum of 940 mm (wet period). Average potential evapotranspiration during the same period is close to 432.33 mm, varying between 523 mm and 363 mm.

The soil of the experimental plot is clay-silt textured. The characteristic volumetric humidity's measured in the ENSA pedology laboratory are 37.51% at field capacity and 22.45% at the permanent wilting point.

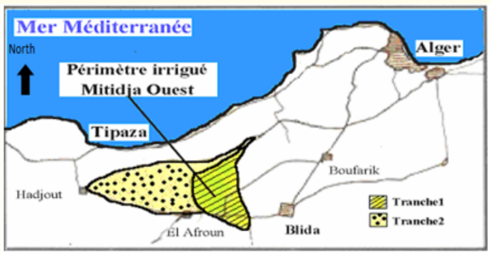

Figure 1: Location of the West Mitidja Plain.

Farms examined

We carried out monitoring of irrigation practices on two collective farms presented in table 1. These farms were chosen for the following reasons: they are close to the road and therefore easily accessible; the existence of three irrigation systems; the availability of a water source; and they have several types of crops. In EAC 1, we chose three plots of 1 hectare, which are cultivated respectively by Onion, Chard and Eggplant. The irrigation systems practiced for each plot are sprinkler, gravity-fed and drip, respectively. On the other hand, in EAC 4, we chose two plots of 1 hectare; they are cultivated by orange trees. The irrigation systems used for each plot are gravity-fed and drip irrigation, respectively.

Analysis of irrigation practices

Gravity

- **Determination of the flow rate at the entrance to the plot of land:** We measured the flow rate at the entrance to the plot using a 20-litre bucket by calculating the time it took to fill it with a stopwatch.
- **Filling time and dose in the seguia:** Using a stopwatch, we measured the irrigation time, which is usually equal to the time it takes to fill the seguia.

N° d'EAC	Town	domain	Area (ha)	Attributes	Speculations	Origin of Irrigation water
EAC 1	Bouguara (Blida)	Allouache	7	7	Market garden	Upstream of the El-Harrach river
EAC 4	Mouzaia (Blida)	Taib zeghaimi	5	4	Citrus	drilling

Table 1: Situation of the farms studied.

- **Monitoring of soil moisture content:** Moisture levels were assessed after and before each rainfall and/or irrigation event, using the gravimetric method. All the measurements were carried out in grid form (four samples per line, giving 16 samples for four levels (20, 40, 60 and 80 cm) before and after irrigation (Avir and Apir).

Drip irrigation

Dripper flow measurements

The uniformity test consists of measuring the flow rate in the unit plot at the level of 16 well-distributed drippers [9]. Four points of the ramp gate were selected; the first ramp, one third of the ramp gate, two thirds of the ramp gate and the last ramp (figure 2). Then, on each of these ramps, four drippers were selected; the first at the beginning of the ramp, the second at one third of the ramp, the third at two thirds of the ramp and the fourth at the end of the ramp. Then the flow rate of each drip tray was measured. A total of 16 drippers were selected in each plot unit and 160 flow rate measurements were taken across the entire study plot.

The study of the homogeneity of water distribution at the watering station was based on the uniformity coefficient [10].

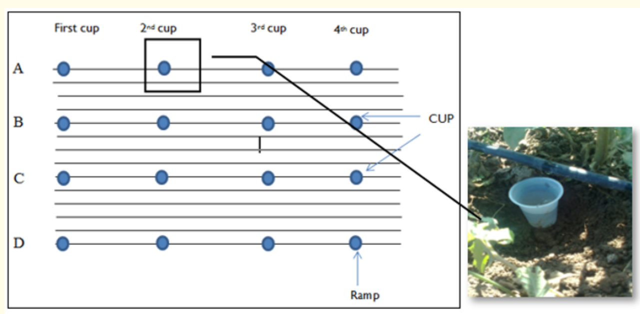

Figure 2: Location of flow measurement points.

Sprinkling

Characteristics of the irrigation network

The total number of sprinklers used is 12, all identical, dual jet sprinklers mounted on 60 cm vertical rods (Figure 3). The spacing between sprinklers is 8m. The measured range is 6 to 7m.

Ramp characteristics

The ramp used is 63mm in diameter and 100 meters long. During For irrigation, the farmer applies a line device (irrigation by a single line consisting of 12 sprinklers) with a station parking time of 90 minutes. The irrigated area per station Sp (ha) is equal to 0.1728 ha.

Sp (ha) = [L x e]/10000

With:

Sp (ha): Irrigated Area Per Shift;

L: Length of the Irrigated Strip = 108m;

e = Spacing x ^{2} = 16m.

Evaluation of the irrigation system

We measured four sprinklers and associated 24 containers per sprinkler, the containers are arranged in the form of a letter L and the distance between two containers in succession is 0.5m (Figure 3).

The performance indicators used for each irrigation system (gravity, drip and sprinkler) is shown in table 2.

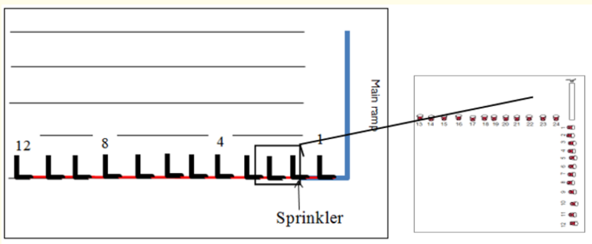

Figure 3: Schematic presentation of the plot and the sprinklers.

	Indicators	Formulas
Gravity	Conduction efficiency (%)	Ec (%) = Net volume (m^3)/ Gross volume (m^3)
	Dose reduced per hectare D (m^3/ha)	D = (Tmoy. * Q * N)/S (ha)
	Total Amount of Water TAW (mm)	TAW = (Hcc-Hpf)*dz*da
	Application efficiency (Ea %)	Ea (%) = Net dose/Gross dose
	Water losses WL (%)	WL (%) = 100 - Ea
Drip irrigation	Uniformity Coefficient (CU) (%)	100
	Irrigation dose D (m^3/ ha)	D = T * Qmoy. * Ng
	Coefficient of technological variation	$C = \frac{\bar{A}_{(q)}}{q_{moy}}$
Sprinkler	Uniformity Coefficient (CU) (%)	$CU = 100\left[1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\lvert q_i - \bar{q}\rvert}{\bar{q}}\right]$
	Irrigation dose (D) (m^3/ ha)	D = T * P
	Application efficiency (Ea %)	Ea = Net dose/Gross dose
	Water losses (%)	WL = 100-Ea

Table 2: Performance indicators and their calculation formulas.

Results and Discussion

Gravity

Determination of head-end flow rate

Table 3 shows the results of the flow measurement at the outlet of the supply points and at the headland at the outlet of the supply line.

According to this table, it is found that there is a water loss of 1 l/s for EAC No. 1 between the head of the water supply line and the plot entrance, i.e. 10% of the volume brought in at the head of the supply line, which gives a transport efficiency of 90%, this ratio is good compared to that of EAC No. 4. On the other hand, the transport efficiency of EAC No. 4 is 60%, i.e., the rate of losses in the feeder pipe is 40%, which is significant compared to the losses in operation No. 1. They are mainly due to leaks in the water supply line. This observation is consistent with that reported by Kessira [11], which showed that in the perimeters of the networks wastage and losses are estimated at 40%.

Farms	EAC 1	EAC 4
Water outlet (drilling, water retention)	10 l/s	10 l/s
Entrance to the plot	9 l/s	6 l/s
Losses (l/s)	1	4
Conduction efficiency (%)	90	60

Table 3: Headland and Plot Head Flow Measurement Results.

The time it takes to fill the seguias

We carried out measurements on the filling time of some seguias in the farms studied. The results obtained are shown in table 4.

According to Table 4 and Figure 4, it can be seen that there is heterogeneity in the volumes brought in between the seguias; this heterogeneity is mainly due to deep and lateral infiltration; presence of cracks in the plot; poor maintenance of the seguias (levelling) and the presence of weeds after the 1st irrigation. We can say that the filling time of the seguias depends on the flow brought upstream of the seguias, the length of the seguias, the shape and uniformity of the seguias.

	EAC 1				EAC 4			
N° seguia	1	2	3	4	1	2	3	4
Filling time (min)	86	77	83	97	17	14	9	13

Table 4: Filling time of seguias.

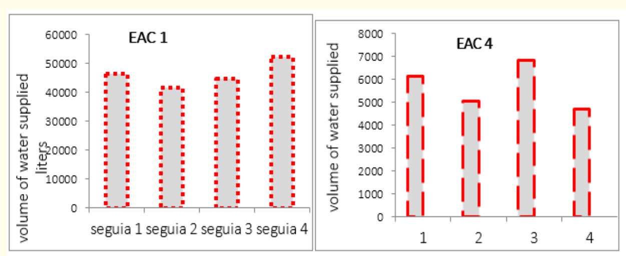

Figure 4: Variation in volumes contributed for each seguia (EAC 1 and EAC 4).

Application efficiency

Table 5 summarizes the results of the calculation of gross and net reduced rate per hectare, available reserve, application efficiency and water losses.

For the first exploitation (EAC 1) the flow measured and delivered at the head of the plot is 9 l/s, it provides a global volume of 4993,676 m^3/ha, the water losses are 87.82%. On the other hand, for the second farm (EAC 4) the flow measured and delivered at the head of the plot is 6 l/s, it provides a total volume of 550.58 m^3/ha, water losses are 45.99%.

Indicator	EAC 1	EAC 4
Net reduced dose per hectare (m^3/ha)	608.28	297.4
Gross reduced rate per hectare (m^3/ha)	4993.676	550.588
Useful reserve (mm)	55.26	44.88
Application Efficiency (Ea %)	12.18	54.01
Water losses (%)	87.82	45.99

Table 5: Results of performance indicators.

The net dose determined from the stock values before and after irrigation, reduced to the hectare for the two farms (EAC 1, EAC 4) are respectively 608.28 m^3/ha; 297.4 m^3/ha, which gives an application efficiency of 12.18% for farm EAC 1, which is very poor, and 54.01% for farm EAC 4.

In conclusion, we can say that the volumes of water distributed to the plots monitored are variable. This discrepancy is due to several factors, in particular the watering time which depends directly on the appreciation of the irrigators and the heterogeneity of the flows at the head of the plots. The application efficiencies obtained are indicators that encourage the improvement of the irrigation system practiced in order to save water. As an example, for EAC No. 1, water gains of 15 to 20% are possible if improvements are made at the intake pipe and plot level. Otherwise, the results obtained on flows and inputs in EAC No. 1, even in EAC No. 4, show that this situation has negative consequences on water saving, resulting in inequitable, uncontrollable distributions and huge water losses within the perimeter.

Drip irrigation

Table 6 shows the results of the calculation of performance indicators for localized irrigation.

Indicator	EAC 1	EAC 4
Uniformity Coefficient (UC) (%)	74.57	83.66
Irrigation dose (m^3/ha)	81.20	68.29
Coefficient of technological variation	0.26	0.12

Table 6: Calculation results of the performance indicator.

From the results obtained, it is found that there is heterogeneity in the distribution of the flow rates of the drippers due to the absence of maintenance work (cleaning of drippers and changing of drippers). The uniformity coefficient for the two farms is between 70% < CU < 90%, so according to Tiercelin's assessment the network needs to be cleaned. Chabaca [4] followed a trial on 25 greenhouses, conducted by drip irrigation, and found a CU equal to 77%. El Amri., *et al.* [6] found a CU of well over 90%, demonstrating the good condition of the irrigation network.

The value of coefficient of technological variation for the EAC 1 and EAC 4 operation are respectively 0. 26; 0.12, according to the classification of CEMAGREF, these values are in the very good box, that is to say the drippers of these networks have a good manufacturing homogeneity.

Sprinkling

The volumes of water collected in the rain gauges allow the hourly rainfall of the sprinkler to be calculated. The measurement of the rainfall, the flow delivered by the pump and the duration of irrigation allow knowing the gross dose brought back to the scale of the plot.

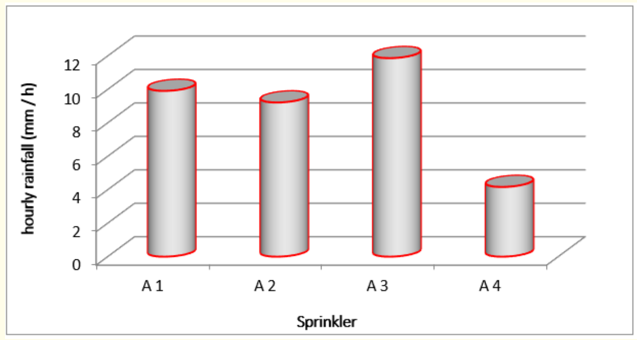

Figure 5: Variation in hourly rainfall.

From this figure, it can be seen that the measured hourly rainfall varies from sprinkler to sprinkler. This heterogeneity of watering can be explained by the operation of the sprinklers, their condition; leaks at the level of the boom; the speed of rotation of each sprinkler; cracks at the nozzles; misalignment of the boom and the inclination of the feet of the sprinklers.

Performance indicator

The result of calculating the performance indicators for this type of irrigation system is shown in table 7.

Indicator	EAC 1
Uniformity Coefficient (U.C.) %	73.69
Irrigation dose (m^3/ha)	307.65
Net dose (m^3/ha)	230.88
Application efficiency %	75.04
Water Loss %	24.95

Table 7: Calculation results of the performance indicators.

According to the results obtained, it is noted that the average blade of water collected between the sprinklers varies from 4 to 10 mm, with a total average of 8.79 mm/h, with 3.5 hours of irrigation, the farmer contributes 30,765 mm/h, i.e. 307.65 m^3/ha, and the easily usable reserve is 207.8 m3/ha, which indicates that the majority of farmers do not master the notions of doses, soil water reserve and irrigation time.

The uniformity coefficient is 73.69%, it is less than 80%, which indicates that there is a bad uniformity in the water distribution, we have noticed at the time of irrigation that there are waterlogged places and others which are characterized by the absence of water (dry areas), these results are mainly due to the pressure variations during irrigation which influences the jet range and the rotation speed of each sprinkler. Chabaca [4] followed up on a lettuce crop under sprinkler irrigation and found a CU of 78%. Yacoubi., *et al.* [7] found a CU of 76.8%.

The net dose determined from the stock values before and after irrigation, brought back to the hectare is 230.88 m^3/ha, which gives an efficiency of 75.04% which is good, i.e. 24.95% of the losses, they are mainly due to water losses by deep percolation, as well as water losses by evaporation and wind effect.

Conclusion and Recommendations

On the basis of the findings and results obtained we have recorded the following conclusions.

Gravity

- Irrigation doses brought by agriculture are largely lost and not valued by the crops;
- This irrigation practice induces additional water consumption in a context of low water resource availability.

Sprinkling and drip

- The irrigation network installed by the farmer includes the minimum equipment;
- The empirical use of these irrigation techniques results in sub-standard efficiency;
- The uniformity coefficient (70 to 85%) indicates a significant clogging knowing full well that the CU should be above 90%.

As prospects

- Efficiency gains are possible by making the water tightness of the return water channels or by using more suitable techniques (valve ramps, flexible ducts, etc.).
- The management of these modern techniques supposes on the part of the farmer the knowledge of his soil (RU, granulometry, RFU) to determine the dose to be brought and the duration of the contribution, as well as the interval between two irrigations.

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