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ASSESSMENT OF THE WATER NEEDS OF APRICOT AND OLIVE CROPS UNDER ARID CLIMATIC CONDITIONS: CASE STUDY OF TINIBAOUINE REGION (NORTHEAST OF ALGERIA)

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ABSTRACT: The Tinibaouine region, located in north-eastern Algeria on the borders of the Batna-Belezma Mountains, is characterized by a semi-arid to arid climate with an average annual rainfall not exceeding 465 mm and an average annual temperature of around 22 ° C. This region is characterized by the cultivation of apricots as essential crop followed by that of olives, whose plots are all irrigated with the Tinibaouine spring water. These are 450 Ha of trees for apricot and 108 Hectare for olives which constitute the principal revenue of the citizens of this small village. This paper estimated the crop reference and actual evapotranspiration (ETO) respectively and the irrigation water requirement of apricot trees and olive trees. The long recorded climatic data, crop and soil data, effective water allocation and planning, the information about crop water requirements, irrigation withdrawals were computed with the Cropwat model which is based on the United Nations' Food and Agriculture Organization (FAO), the Penman-Monteith method was used to estimate ETo. Crop coefficients (Kc) from the phenomenological stages of apricot and olive were applied to adjust and estimate the actual evapotranspiration ETc through a water balance of the irrigation water requirements (IR). The results showed that the annual reference evapotranspiration (ETO) was estimated at 3.71mm / day. The irrigation requirements were estimated at 35800 m^3/ hectare for apricot, 6980 m^3/ hectare for olive, also Irrigation needs estimated on land at 14185, 05 m^3/ hectare for olive and apricot.

Keywords: Algeria, Agricultural, Economic, Irrigation.

1. INTRODUCTION

This note concerns the determination of the water needs of the apricot crop in Tinibaouine region, located in arid climatic zone, in the North East of Algeria. The cultivation of apricots is the main natural resource exploited in this region, the olive tree being accessory, making the Tinibaouine spring, from which the irrigation is done with a rate of around 100 l/s, becomes a high center of interest for a depending population of around 10.000 inhabitants.

The annual rainfall measured varies between 140 mm to 464 mm, with an average of 245 mm and the annual average of temperature is around 22 °C.

The comparison between the crops water needs estimated by Cropwat and the flows delivered by the spring shows a large imbalance.

Erratic rainfall and reduced flows of the Tinibaouine spring observed in recent year's raises with acuity the problem of the water management in this region.

The diminution of water loss through notably the reduction of evaporation is discussed in this note.

2. MATERIALS AND METHODS

2.1 Geology:

The studied area is located in the eastern extension of the Hodna plain; it corresponds to a depression wedged between the reliefs of Hodna Mountains in the north, El Guetiane Djazzar in the East and Djebel Ech Cheffa in the West. Geological and geophysical studies have identified the existence of the following aquifers:

The Mio-Pliocene and Quaternary formed by calcareous, sandstone, conglomerate and sands. The upper Cretaceous limestone composed by dolomitic permeable formations. The bedrock is formed by the Cenomanian marls while the semi-permeable roof (partial coverage) is represented by calcareous and marl formations containing both permeable and impermeable levels (Fig 1 and 2).

The spring is located in the Tinibaouine village center. It emerges by a flow in Quaternary alluvial formations, in favor of a NW-SE fault that runs along the south Kef Rached [1]. The current flow rate is about 100 l/s.

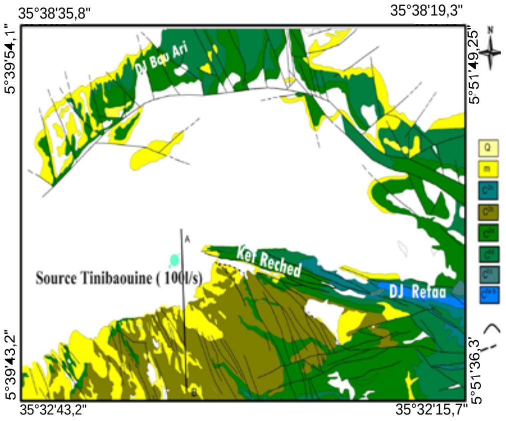

Fig.1 Geological context of Tinibaouine region

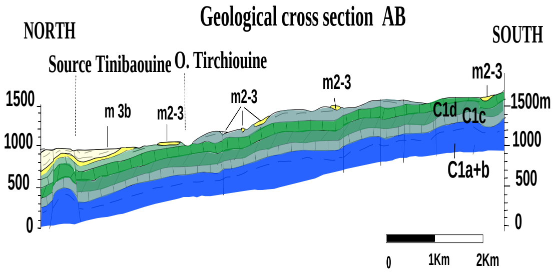

Fig.1 Geological cross section of Tinibaouine area [2]

Note: m^{2-3}: Miocene, c^{5-6a}: upper Stantonian to Maastrichtian, c^{3-4}: Coniacian, lower Stantonian, c^{2b}: upper Turonian, c^{2a}: lower Turonian, c^{1d}: upper Cenomanian -Turonian, c^{1c}: middle – upper Cenomanian, c^{1a-b}: lower Cenomanian.

2.2 Hydro-climatic Context

The climate is semi-arid influenced by the humid stream of the Mediterranean Sea in winter and warm and influenced by the Sahara in summer. For the period 1998-2010, annual rainfall measured varies between 140 mm to 464 mm and the annual average of temperature (T°) is around 22°C.The evaporation is intense and leads to a loss-water balance (Fig.3).

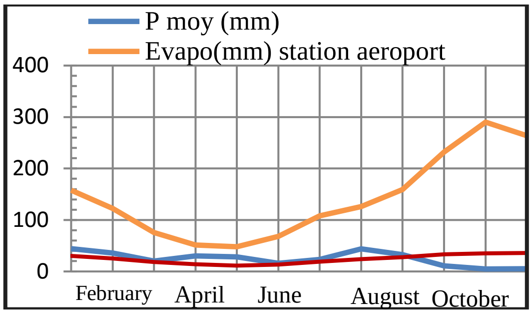

Fig.3 Rainfall, T° and evaporation: 1998-2010

The annual average of rainfall is 245 mm, on all sub basins of Achou and Boureghda (135.3 km^2) representing a contribution to the rate of water of 100 l/s of the Tinibaouine spring. The rainfall decreased gradually since 1970 causing a decrease in the flow rate from 200 l/s in 2005, to 100 l/s actually (Fig.4).

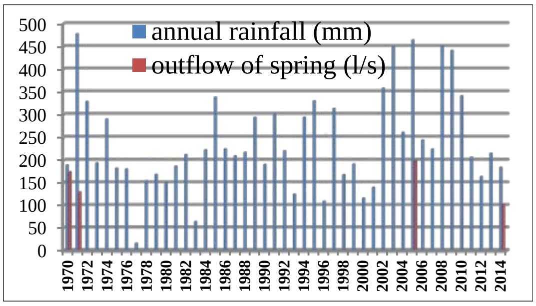

Fig. 4 Annual rainfall and the spring flow rate

2.3 Agricultural Context

The Tinibaouine region is characterized by tree crops (450 Hectare for apricot trees and 105 Hectare for olive). The apricot crop and incidentally that of olives are practically the only self-sustaining economy of the region. The other crops represent only 4% of the total area (652 Hectare). All plots are irrigated by the spring of Tinibaouine with a well-developed network (called seguias) (Fig.5).

Water needs increase gradually from autumn with a decrease during the winter season.

In some cases, farmers whose plots are subject to water stress during periods of irrigation, use in boreholes, often illegal, to meet their needs, thus threatening the sustainability of the spring, even if the aquifer is located several km to the south.

2.4 Water Management of Tinibaouine Spring

The water management system distributed by seguias has required the establishment of an elaborate legal and technical framework [3]. This former supply and distribution system was known by the Romans who surrounded it by constructs in the aim to use its pure and clear water. Water Units of irrigation (called Nouba) are calculated for all the owners according to the areas to be irrigated. This distribution is registered and regulated by an official act. The share of each is planned on a definite period and increases each time we move away from the spring (6, 21 and 30 days).The spring flow is shared with a diverter in 05 major seguias whose distribution is reported in fig. 5.

Table 1 Category of system seguias

Principals Seguias		Code		rate flow (l/s)
Rate flow of the spring				104
Tamtelt		1		23,36
Tabourit		2		11,7
Rhaouat	Bala	3	3-1	29,9
	Maadjidj		3-2	
Sidhoum		5		25,9
Hemada		4		13,69

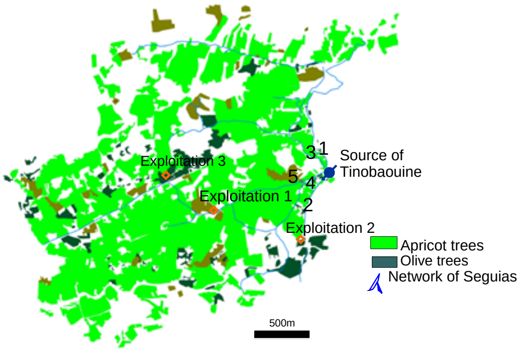

Fig. 5 Distribution of the seguias network

3. DETERMINATION OF THE WATER NEEDS

The water needs of the apricot and olive crops will be determined by the use of Cropwat (in its free version) that is irrigation management support software developed by FAO in 1992. It is based on the evaporation formula of Penman-Monteith modified. It offers the opportunity to develop an irrigation schedule based on various agricultural practices and it permits to assess the effects of lack of water on crops and efficiency of different irrigation practices.

3.1 The Climate Data Used in the Calculation of Water Needs

The temperature data, relative humidity and wind velocity are those of Barika climate station remote from Tinibaouine of 35 km with a series of 14 years.

Given the total lack of data on sunshine duration, we used those of Biskra due to similar climate and the distance (80 km in the South-East). The monthly precipitation data are those of the rainfall station of the same study area (N'gaous) for the same period (1977-1990) (Fig.6).

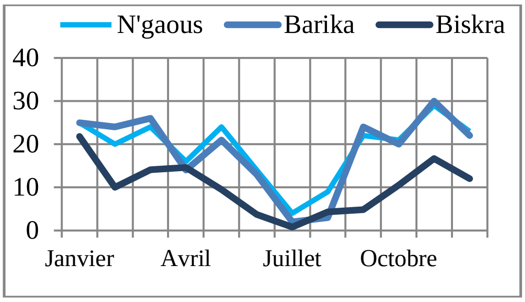

Fig. 6 Monthly rainfall variations: 1977-1990

3.2 Soil and Agricultural Related Data

The soil features required in the management of irrigation and the determination of the useful reserve, are related to two factors: the soil texture (most of the perimeter is composed by sand and clay) and the deep of rooting (Table 2) [4].

Table 2 Soil-related data

	Texture	
	Sand	Clay
Usable water	140 (mm/m)	180 (mm/m)
Maximum rate of rainfall infiltration	40 (mm/day)	40 (mm/day)
Maximum rooting depth	0,6 or 1,2(m)	0,6 or 1,2 (m)
Initial dry soil moisture (%) Of usable water)	0%	0%
Initial soil moisture available	140 (mm/m)	180 (mm/m)

The crop coefficient values (KC) of each culture (apricot and olive) introduced in Cropwat are defined depending on the growth stage of the plant, the force of the wind and the average value of the minimum humidity prevailing in our study area [8]. Cropwat requires the entry of 3 values KC (initial, mid-season, harvest). We adapted planting dates by considering agricultural practices in northern Algeria [9]-[10]-[11].

4. RESULTS AND DISCUSSION

4.1 Estimation of Evapotranspiration by Cropwat

The evapotranspiration values calculated by the formula of FAO (Penman-Monteith) are presented in Table 3 and reported in Figure 7. The expression of this eq. (1) is:

$$ET_0 = C*(w*Rn(1-w)*F(u)*(ea-ed)) \qquad (1)$$

ETO : represents the reference evapotranspiration in mm/ day.

w: weighting factor reflecting the effect of radiation on different temperature and altitude.
Rn: net radiation
F (u): wind-related function.
ea: saturation vapor pressure at the average temperature of the air, in milliards.
ed: average of actual vapor pressure of the air, expressed in milliards.
(ea - ed) and C: correction factors to compensate day and night weather.

Table 3 Evapotranspiration (mm/d) of N'gaous [5]-[6]-[7]

	Temp	Temp					
	Min	Max	H	W	INS	Ray	ETo
Jan	-5.0	7.1	67	164	7.0	11.0	1.17
Feb	-5.8	10.0	69	181	7.6	14.0	1.63
Mar	-3.6	13.0	48	207	8.8	18.5	2.81
Apr	-2.4	16.7	46	233	9.2	21.8	3.77
May	5.6	21.3	54	216	9.9	24.3	4.49
Jun	8.8	26.9	31	224	10.9	26.2	6.25
Jul	16.0	30.9	26	207	12.2	27.7	7.15
Aug	15.0	29.8	34	198	10.4	23.9	6.30
Sep	6.0	25.3	45	216	9.4	20.1	4.84
Oct	0.4	19.1	54	181	8.1	15.3	2.97
Nov	-2.6	13.3	58	172	6.8	11.3	1.87
Dec	-6.2	8.6	62	155	7.1	10.4	1.25
Ave	2.2	18.5	50	196	8.9	18.7	3.71

Note: T: temp, H: humidity (%), Wind (km/day), INS: insulation (hours), R: ray m j /m²/day, ET0 (mm/day).

It is found that the peak month for global demand (ET0) is in August, with an average of 6.30 mm/day.

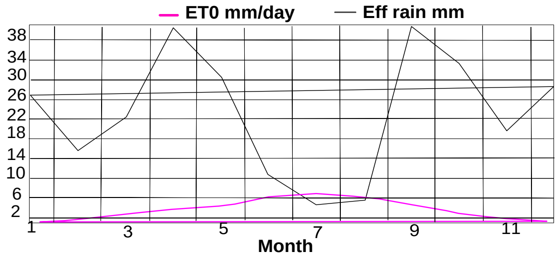

Fig. 7 Evapotranspiration and effective rainfall

4.2 Determination of the Effective Rainfall

We opted to work on Cropwat with the USDA method to account losses due to surface runoff and deep percolation, Table 4 gives the values of effective rainfall calculated by the eq. (2) of the USDA.

$$P_{eff} = (P_{mean} * (125 - 0.2 * P_{mean})) / 125 \qquad (2\text{-}1)$$

Pour $P_{mean} <= 250$mm/month.

$$P_{mean} = 125 + 0.1 * P_{mean} \qquad (2\text{-}2)$$

Pour $P_{mean} > 250$mm/month.

Table 4 Effective rainfall of N'gaous region

Months	Rainfall	Effective rainfall
Jan	28.1	26.8
Feb	16.0	15.6
Mar	23.3	22.4
Apr	43.9	40.8
May	32.6	30.9
Jun	11.1	10.9
July	4.8	4.8
Aug	5.5	5.5
Sep	44.3	41.2
Oct	35.7	33.7
Nov	20.5	19.8
Dec	30.5	29.0
Total	296.3	281.4

4.3 Computation of the Water Requirements per Decade

The water needs calculated by Cropwat for apricot and olive crops are presented in figures 8.

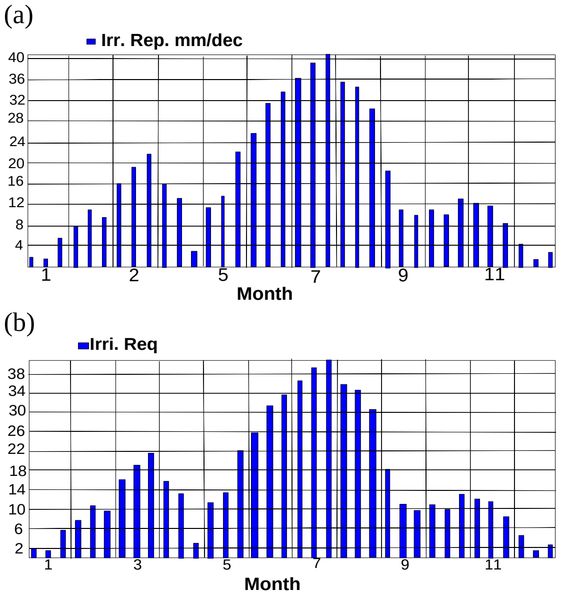

Fig. 8 Crops water needs (mm/dec) a; apricot, b: olive

It appears that water needs of olive trees grew in the period June to August, this is mainly due to the increase of the crop coefficient during the foliage stage [12], which is the summer season which also corresponds to the Eto highest period [13]-[14]-[15] [16]-[17] Fig. 9

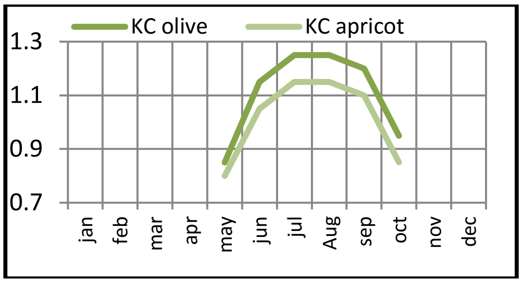

Fig. 9 Crop coefficient (KC) variation

4.4 Determination of the Irrigation Dose on Field

Field work focused on the quantification of the irrigated area, crop type, method of access to water and the allocated water flow [18].

To check out some of the answers, we conducted flow measurements in three farms, exploitation 1(Taabache), exploitation 2 (Mechaala) and 3 (Ghenfoud) (Table 5).
Exp 1: Q Hemada = 13, 6(l/s), QF = 15(l/s), 750 000 (m²) Apricot and 50 000 (m²) olive.
Exp 2: Q Sidhoum = 25, 9 (l/s), Q Tabourit = 11,7l/s Q Hemada = 13, 6(l/s) Q total =51, 2(l/s), 360 000(m²) apricot and 40 000 (m²) olive
Exp 3: Q Maadjidj = 9, 93(l/s), 30 000 (m²) apricot and 10 000(m²) olive.

Table5 Irrigation needs estimated on land (m^3/ hectare)

			EXP 1	EXP 2	EXP 3
Gross volume		Apr	258	14	48
		Oliv	2	2	12
Gross dose		Apr	35,4 mm or 354 m^3/ha	7,168 mm or 71,68 m^3/ha	171,07 mm or 1710,7 m^3/ha
		Oliv	4,11 mm or 41,1 m^3/ha	9,21 m or 92,1 m^3/ha	14,29 mm or 142,9 m^3/ha
Irr. req per cycle	Start irr	apr	June 20	June 20	July 20
		oliv	July 10	July 10	July 10
	End	apr	October 15	October 15	October 15
		oliv	July	July	July
	N° of irr	apr	7	9	5
		oliv	2	2	1
Water needs		apr	2478 m^3/ha	645,12 m3/ha	8553,5 m^3/ha
		oliv	82,22 m^3/ha	184,32 m3/ha	142,9 m^3/ha

Note: Irr. Req: irrigation requirements, Apr: apricot, Oli: Olive.

The comparison between theoretical demand and the rate water flow delivered by Tinibaouine spring shows a large deficit (Table 6) that forces farmers to reduce irrigated plots or to adopt other alternatives like: buying water elsewhere, digging deep boreholes or the storage of rainfall in small hill dams.

Table 6 Comparison between water requirements estimated by Cropwat and Irrigation needs

Crops	water requirements by CROPWAT	Irrigation needs estimated on field (m3 / hectare)
Apricot trees	35800	12957,1
Olive tress	6980	695,58

4.5 Technical Measures for Water Economy

Using low pressure underground pipes can significantly reduce water losses caused by transportation, irrigation time, evaporation and infiltration.

These last two settings are naturally higher in seguias (ground gutter). In addition, evaporation losses are also important especially in distribution seguias at low flow with a large base and a small height. The diameter of the main pipe and the distribution network is calculated by the formula of Bonnin [19] and the pressure drop calculation in the distribution network is performed according to the eq. (3) of Darcy Weisbach [20].

$$D = Q^{1/2} \qquad (3)$$

Calculating of the velocity, eq. 4:

$$V = 4Q / \Pi D^2 \qquad (4)$$

Where Q = rate flow in l/s and D= diameter in m.
Calculation of pressure drop, eq. 5:

$$J = \frac{\gamma V^2}{D2g} = \frac{8yq}{\Pi^2 g D^2} \qquad (5)$$

J: loss (in m of fluid charge per m of pipe)
γ: coefficient of loss
V: velocity in m/s
D: internal diameter of the pipe in m
q: rate flow in m^3/s
g: gravity acceleration in (m/s^2).

$$g = J_1 * l \qquad (5\text{-}1)$$

$$Q_2 = \sqrt{Q_1^2} * (J_2 / J_1) \qquad (5\text{-}2)$$

L=length of the pipe in m.

The results of pressure drop calculation and the comparison between the rate of water provided by seguia and pipes (high density pipes) are presented in table 7 and 8 below:

Table 7 Calculation of loss and rate of water in the pipe

	L	D	Q1	V	Unit loss	Q2	Unit loss
3	2170	116	13,6	1,29	0,031	20,01	0,067
5	3230	172	29,9	1,29	0,016	46,55	0,053
2	1070	108	11,7	1,27	0,036	12,10	0,038
3-2	2452	99,6	9,93	1,27	0,042	15,55	0,103

Note: L: Length (km), D: diameter (mm), V: velocity (m/s), Q1 and Q2: rate of water (l/s).

Table 8 Comparison of the rate of water provided by seguias and by high density polyethylene pipes

	Distance from the spring (m)	Q (l/s) by seguia	Q (l /s) Water proof HDPE pipe	Economy m^3/day
3	2170	13,6	20,01	353,82
5	3230	25,9	46,55	1784,16
2	1070	11,7	12,10	34,56
3-2	2452	9,93	15,55	485,56

Water losses during the path between the spring and the plots are caused by infiltration in driving land and evaporation.

It is clear that investment in a sealed pipe will result in a great saving of water [21].The irrigation Passage seguias irrigation to polyethylene pipes provides a water saving of 14185, 05 m3 /day.

5. CONCLUSION

In this paper, we have tried to estimate olives' and apricots' needs of water in the region of Tinibaouine, which is located in an arid area, with a yearly rainfall of around 250 mm.

The comparison of the water needs for irrigation calculated by CROPWAT showed a huge water deficiency that significantly slows the development of the agriculture in this region.

Nevertheless, the use of dripping irrigation system by replacing seguias by solid HDPE pipe allows a relative water field saving.

The measurements allowed us to have a magnitude order on the amount of the water needs of crops of apricot and olive in an arid region of eastern Algeria;

A big imbalance is noted between water availability and theoretical needs of these crops and threatens seriously the sustainability of this agricultural activity.

Finally, we must be aware that the rational management of water has concrete implication, particularly the social-economic viability. It will be achievable if all parties work together.

6. ACKNOWLEDGEMENTS

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