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Calculation of water needs of the main crops and water resources available in a semi-arid climate, case of Zana-Gadaïne plain, Northeastern Algeria

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ABSTRACT/RESUME

Abstract: *The relative scarcity of water resources in Algeria and their unequal distribution induce a rational use of available resources. The Zana-Gadaïne plain appears as an exemplary case study, where the difficulties posed by the problem of crop water needs versus the availability of water resources appear. This article, based on field surveys and in-situ measurements, aims to identify the pressure of irrigation on water resources and the optimization of their use in an agricultural area, where irrigated agriculture represents 85% of the water consumption of the Zana-Gadaïne plain. The piezometric study in correlation with hydrogeological data reveals that groundwater resources are limited, aggravated by wastage resulting in a consequent drawdown of 24 meters over 11 years. The analysis of interannual climate variability has enabled us to draw rainfall maps characteristic of the evolution of rainfall over the past decades where we observe a net deficit in precipitation. We calculated the evapotranspiration and the requirements in irrigation water for each crop in order to compare them with the available hydric resources and the establishment of irrigation schedules for the principal irrigated crops. The analysis of interannual climate variability has enabled us to draw rainfall maps characteristic of the evolution of rainfall over the past decades where we observe a net deficit in precipitation. We calculated the evapotranspiration and the requirements in irrigation water for each crop in order to compare them with the available hydric resources and the establishment of irrigation schedules for the principal irrigated crops.*

I. Introduction

The agriculture is a productive sector characterized by the greatest demand for water, mainly due to farming needs higher than the pluviometric contributions. In addition, the generalization of irrigation is being spread over large agricultural perimeters, where the productive potential of the soil is closely linked to the availability of water during the summer period (stretching). The needs of plants are not constant over time; there is a particular sensitivity to water deficit at certain periods of their vegetative cycle [11]. Irrigated crops are more economically efficient, so it becomes important to ensure efficient and rational management of water resources [8]. The objective of this research is to understand the dynamic interactions between precipitation, groundwater resources and crop water requirements in a semi-arid environment. The plain of Zana-Gadaïne, is part of the northern plains of the wilaya of Batna belonging to the catchment area of the highlands of Constantine and extends over an area of 1400 km^2, (Figure 1) , and Inhabited by a population of about 45000 souls (General Census of Population and Habitat 2008). Drought and the increasing anthropogenic constraints linked to agriculture, agricultural and urban pumping are affecting the availability of water resources. The main focus of this paper is the study of climate variations and their impact on the level of the water table.

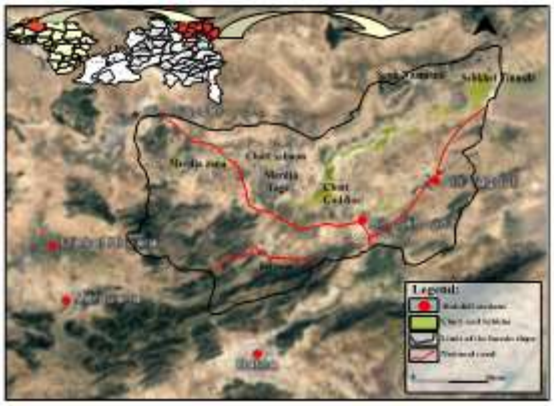

Figure 1.*Carte Geographical location of Zana-Gadaïne plain (Google Earth 2016)*

II. Materials and methods

II.1. Geological Context

The Zana-Gadaïne basin is part of the Jurassic Cretaceous set constituting the over thrust layers of northeast Algeria (South Setifian Allochtonous set). It appears like a platform that moved on the Triassic cover [17-32]. There are two structural sets, the mountain and the plain sectors. The mountain sector is composed of the Cretaceous and Jurassic scales in anticlinal position. In the North, it is the South Setifian Allochtonous set composed of the scales of Djebel Guedmane, Tizourit, Merzeguene, Roknia, Messaouda and Azraouat of Cretaceous age, very pleated. To the South, East and West, the landforms belong to the parautochthonous and autochtonous north Auresien formed by the scales of the mountains of Ain Yagout, Dj. Tafraout, Koudiat Tfouda, Dj. Sarif, Dj. Mestaoua and Dj. Zana of Jurassic-Cretaceous age (Figure 2). The plain sector, which is formed by a Mio-Pliocene-Quaternary filling, probably caused by the erosion of these scales [6].

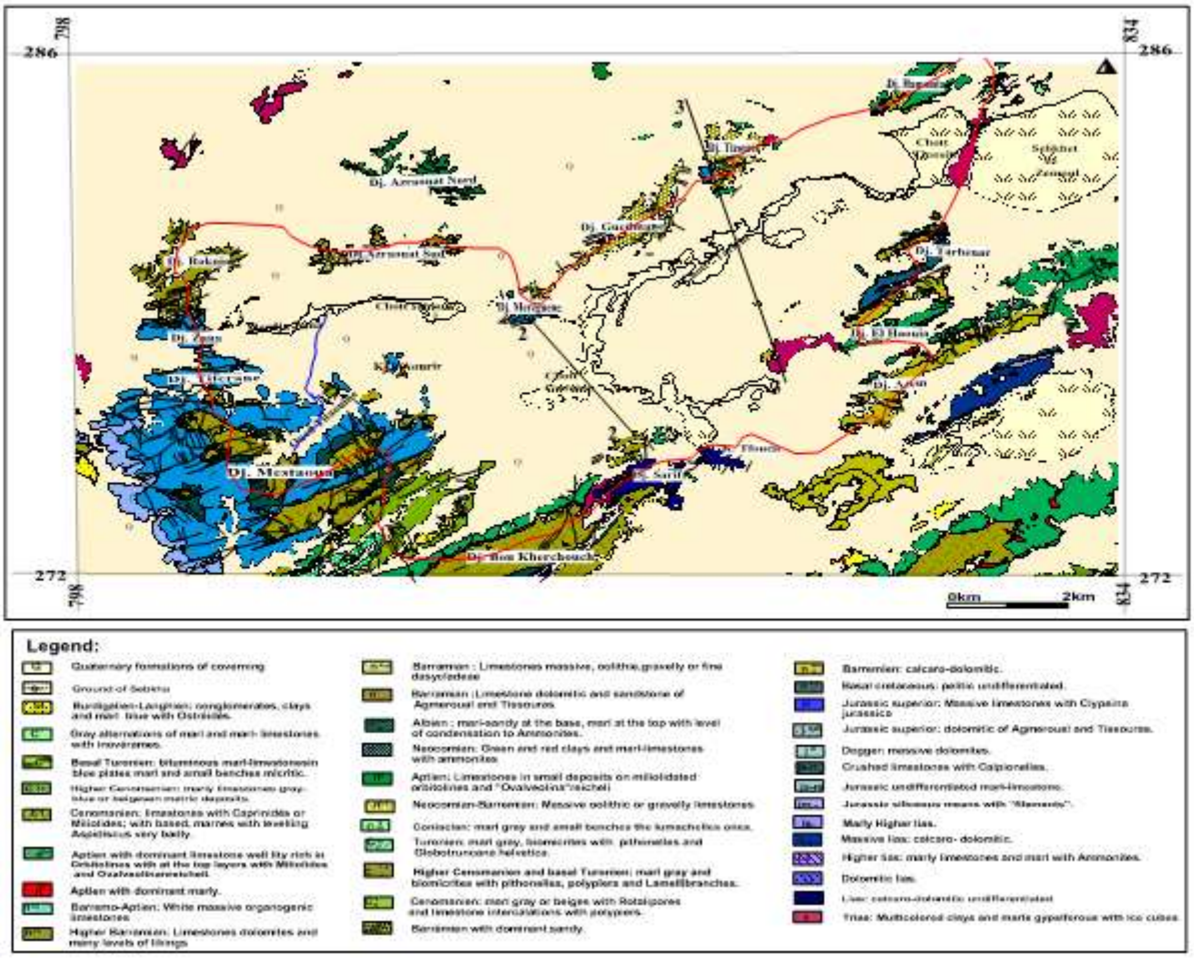

Figure 2. *Geological map of the Zana-Gadaïne plain. Scale1/50 000 (After J.M. Villa 1977, redrawn by author)*

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II.2. Hydrogeological approach

The piezometric study of a water table provides important information on the characteristics of the aquifer. In particular, it makes it possible to assess in a global way the flow conditions of the groundwater, as well as their feeding, drainage and variation of their reserves [23]. We have identified more than 500 wells and boreholes that capture the surface and deep aquifer distributed over the whole of the plain according to the dispersion of agglomerations and arable land.

These catchment structures are intended to meet domestic and agricultural needs.

The inventory of water points shows that most of the structures are completely tubed boreholes. The combination of geology, geophysics [12] and the stratigraphic logs of the boreholes allowed us to know the geometry and the nature of the aquifer complex of the Zana-Gadaïne plain. There are two systems: a surface aquifer in the upper levels and deep karst aquifer. The shallow aquifer has as a base permeable or less permeable formations of Mio-Pliocene-Quaternary cover (Figure 3).

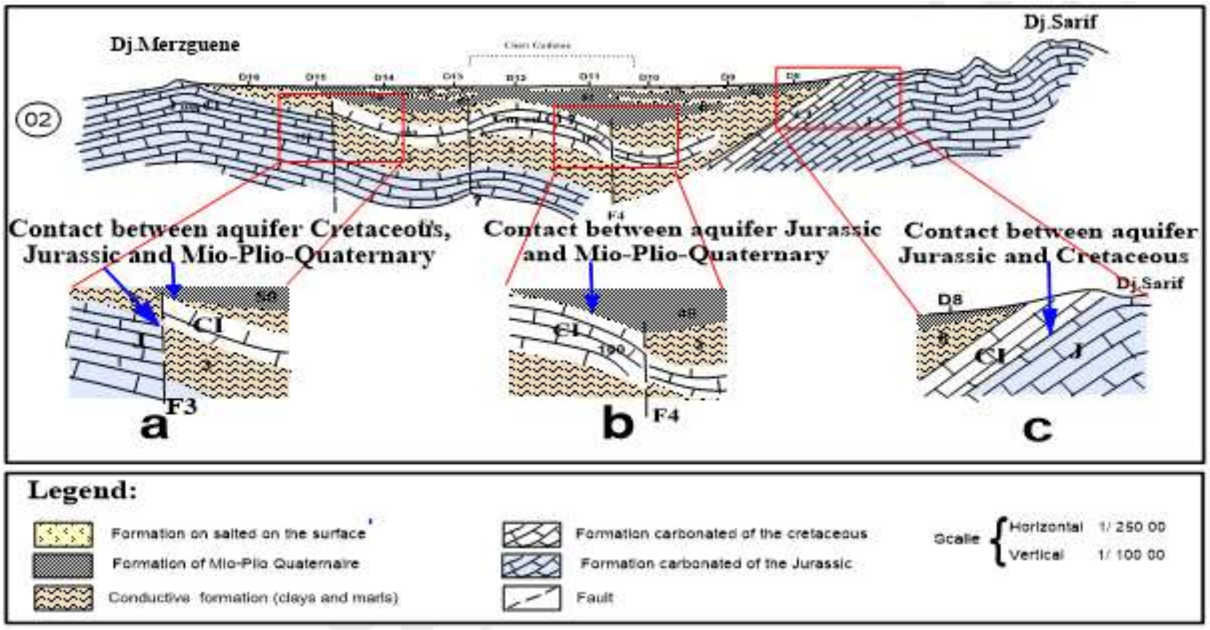

Figure 3. *Contact between the different aquifers*
(J : Jurassic , CI : Lower Cretaceous, Cm : Middle Cretaceous)

The system is composed of a deep aquifer of cretaceous and Jurassic ages composed of a thick carbonate mass of dolomitic limestone shoals of about 350 m and surface aquifer of Mio - Plio-Quaternary age with a thickness of 200 m in the west in the center of the plain Zana and up to 500 m East in the center of the plain of Gadaïne (clay-marl collapsing ditch), (Figure 4). The two aquifers of the Jurassic and Cretaceous are excellent reservoirs is confirmed by the presence of sources such, Ain Zana, Ain Taga and Ain Merzeguene and drillings such as Zana N° J6 (56 l/s), Zana N°J7 (42 l/s), Zana N° J8 (55 l/s), Zana N° J8' (39 l/s) and Zana N° J9 (14 l/s)[7]. Annual ground water withdrawals for agricultural needs established on the basis of all the boreholes identified and according to the withdrawn flows are estimated at 62 million m3 / year.

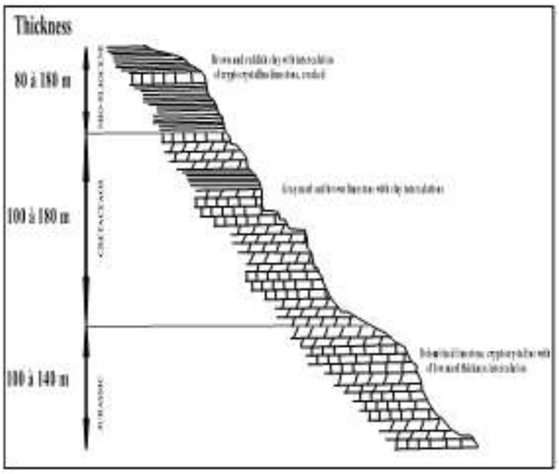

Figure 4. *Typical cross-section of the Zana Gadaïne plain*

II.3. Hydrodynamic conditions

The depth of the measured piezometric level varies between 08 and 61m. The lowest loads are located in the natural depressions of Chott Gadaïne, Saboun and Tinnsilt. The maximum loads are established at the edges of the plain in contact with the reliefs. The Zana-Gadaïne plain is characterized by iso-pizes curves parallel to the borders of the massifs, which means that the reliefs feed the covering with a direction of flow converging towards the drainage zones (Chott Tinnsilt, Gadaïne and Saboun), following a direction from North-West to South-East, South-East to North-West, South-North, North-South and from West to East (Figure 05). The piezometric map reveals two water dividing lines, one separating Chott Gadaïne from Chott Saboun and the other Chott Gadaïne from Chott Tinnsilt following the north-west south-east direction, parallel to the -east direction, parallel to the underground flow direction. These watershed lines are perfectly aligned with topography and geology, which highlights collapsing ditches.

The calculated transmissivity for the surface aquifer ranges from $3.6*10^{-3}$ to $8*10^{-4}$ m²/s, it increases towards the depressions, while the permeability is between $2*10^{-5}$ and 10^{-4} m/s with a decrease towards the depressions. The storage coefficient is in the order of $1.082*10^{-3}$, so we can deduce that we are in front of a semi-captive aquifer and this is due to the presence of clayey intercalations between the permeable layers. This is supported by the geology of the basin [7].

The calculated transmissivity for the deep aquifer ranges from 10^{-3} to 10^{-4} m²/s, it increases towards the depressions as to the permeability, it is between $1.8*10^{-5}$ m/s at Djebel Roknia and Mestaoua and $4.0*10^{-6}$ m/s towards Merjda de Zana [6].

The calculated hydraulic gradient is variable from one area to another. It is important of the order 0.007 in the northern part of the plain of Zana and of the order 0.005 in the central part.

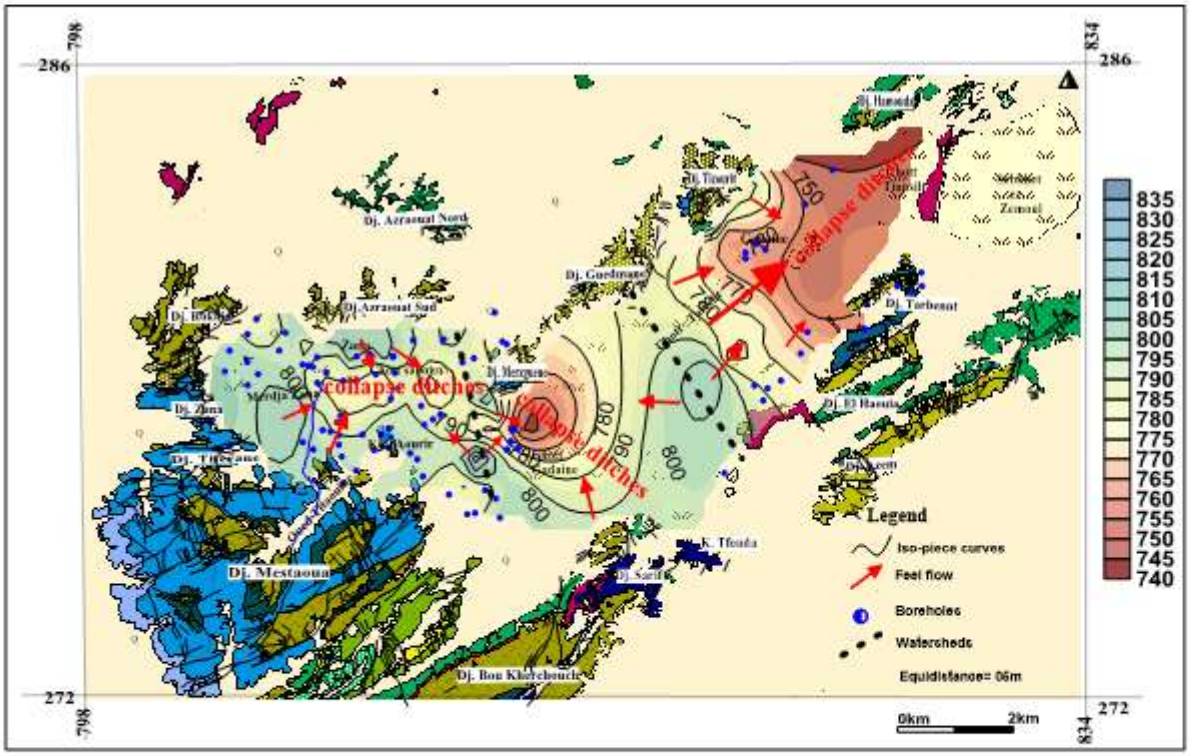

Figure 5.Piezometric map of the surface water table of the Zana-Gadaïne plain (2016)

II.4. Cultivation practices

The Zana-Gadaïne plain has been characterized these last years by the intensification of agriculture in the plain. This development is characterized by an anarchic spatial distribution, (Figure 6). The factor responsible for this spatial distribution is the combination of the nature of the soil and the rainfall [3]. Depending on access to groundwater resources, the main crops in the region are dominated by cereal crops, which occupy 47% of the usable agricultural area, i.e. 10415 ha. The strong presence of cereal crops is justified by the simplicity of the techniques, the most practiced (durum wheat, soft wheat, oats and barley). In second position comes the fodder crops distributed on 38% of the usable agricultural area, i.e. 8397 ha, the most widely grown crops are sorghum, alfalfa and Maize. Vegetable crops occupy only 13% of the usable agricultural area, i.e.2878 ha, the most widely grown crops (lettuce, onion, Tomato and potato).

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As for arboriculture, it occupies only 3% of the useful agricultural area i.e. 618 ha.

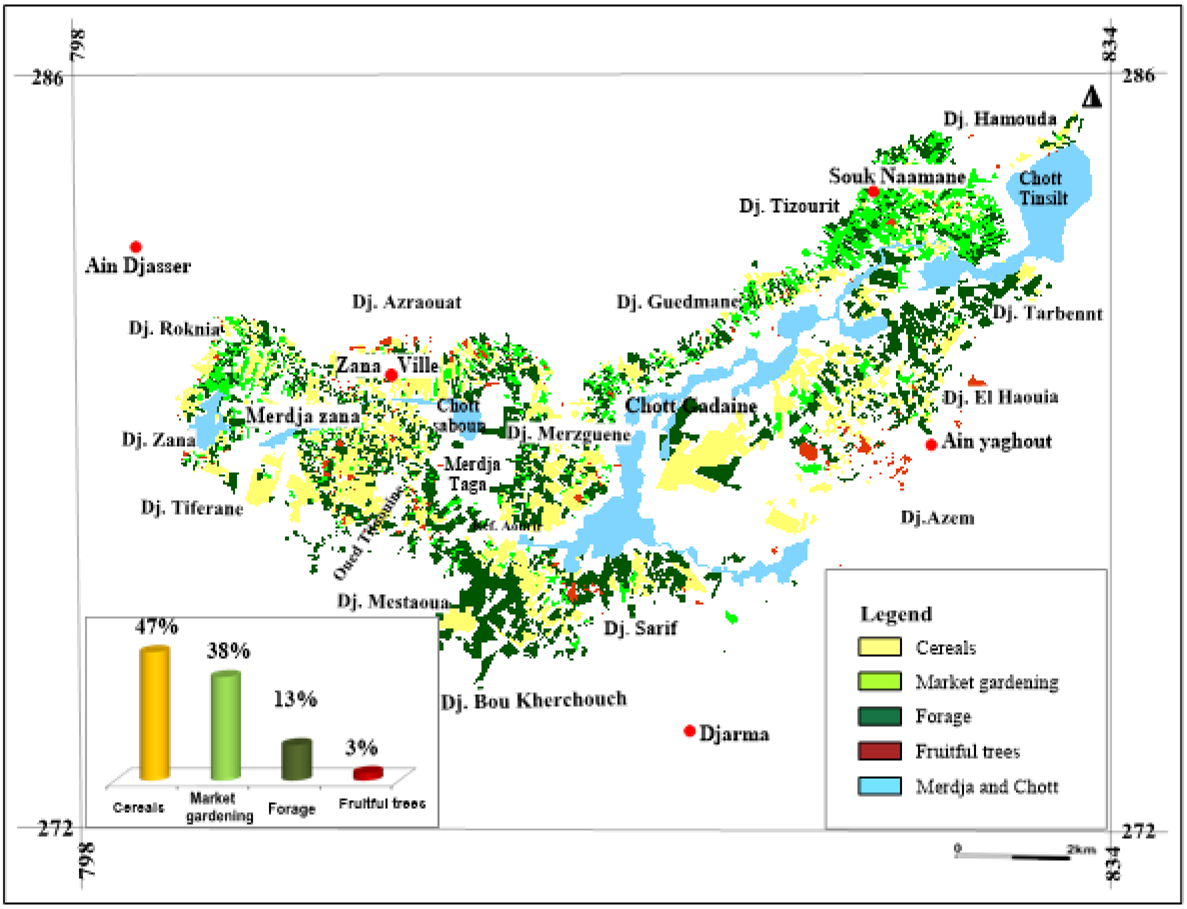

Figure 6. *Crop distribution in the Zana-Gadaïne lime pit (2016)*

III. Results and discussion

III.1.Spatiotemporelle study of the variation of the levels piezometric

The water table recharge is mainly carried out by precipitation, and any change in precipitation regime is expected to have an impact on the groundwater resource [14]. Variations of piezometric levels were followed in time and space during the period 2006-2016. All piezometers show a decrease in water level the water varies from one piezometer to another (Figure 7). From the annual piezometric maps drawn up, we noticed a reduction then an increase in 2015.The reduction of the piezometric levels is the result of the low recharge of the water table (low annual rainfall) and over-pumping. However, in 2015, an increased water level is visible in the north and south of the plain around the massifs.

This rise coincides with the significant pluviometry recorded during 2014 (strong increase in precipitations) and probably the result of local agricultural practices (fallow year) . 2014 is the rainiest year with an annual precipitation recorded at the Ain Skhouna station of 339 mm and 336 mm at the Ain Djasser station. The piezometric levels have strongly fallen during the ten last years (2006-2016) with a drawdown of approximately 24 m . This allows us to conclude that each year we have a drawdown of 2.4 m.This significant drawdown reflects imbalance in the balances of aquifer, which is mainly due to low recharge (aquifer refill remains closely linked to the permeability of the formations crossed and the distribution of rainfall during has hydrological year, but to delays in receiving the first effective rains) and to increased exploitation to satisfy the requirements out of water.

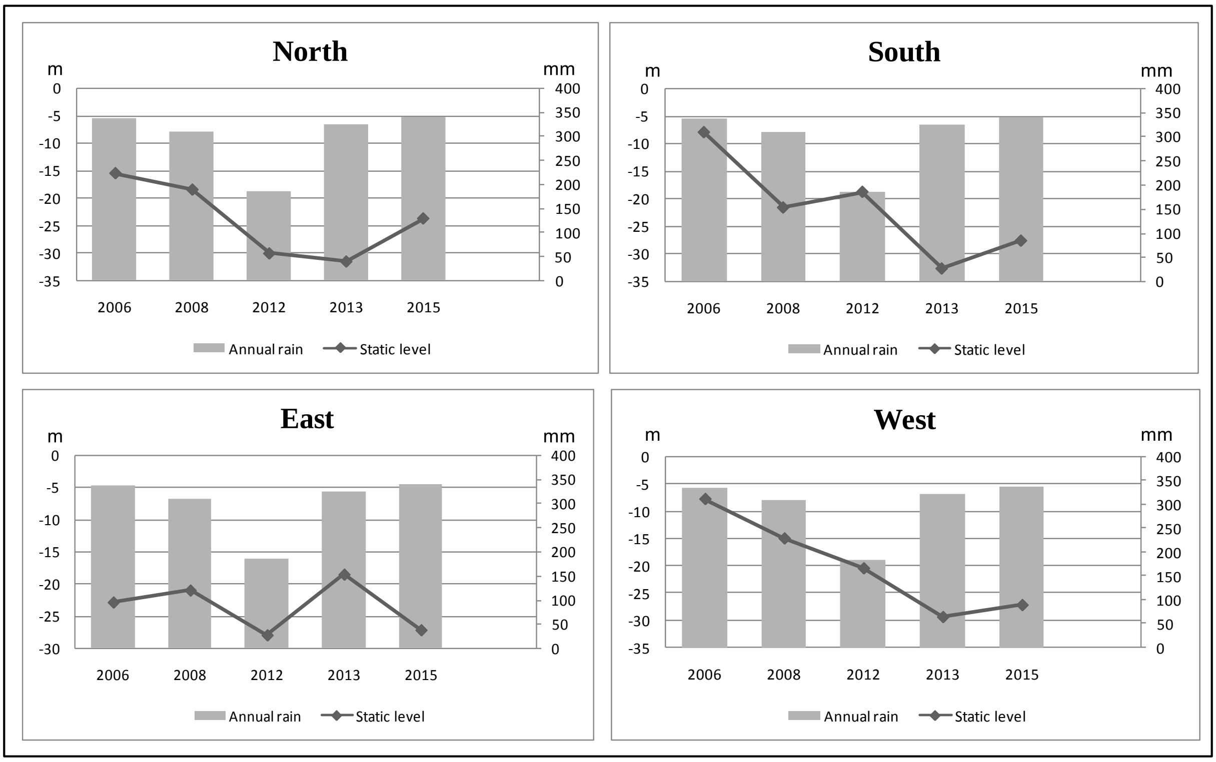

Figure 7. *Static level variations (2006-2016)*

III.2. Climatic condition

The hydrological balance established according to the method of C.W. Thornthwaite which has the advantage of estimating for each month: the actual evapotranspiration, the reserve easily usable, the agricultural deficit and the surplus[31]. This method is based on the concept of water reserve easily usable (RFU). The estimation of this parameter was made by applying the formula of Hallaire 1960 (quoted by J. Ricard) given below:

$$\mathrm{RFU} = \frac{1}{3}\mathrm{Da} * \mathrm{He} * \mathrm{Pr} \qquad (1)$$

Where: RFU (m) the reserve easily usable,
Da apparent density of the soil taken equal to 1.4, He retention capacity taken equal to 0.3, Pr (m) depth of roots taken equal to 0.4.
The ETR covers only 38.5% of the PET, the PET consumes almost all of the precipitations. This induces a weak surplus and therefore the recharge of the aquifer is very limited. The observation of the graph of the hydrological balance leads us to say that PET is important from April to November, with values reaching 174 mm in July, which are necessary for the irrigation. From November, there is a reconstitution of the stock which is accompanied by an increase in the RFU, which reaches its maximum between January and March.
Beyond this period, there is a decrease in the RFU, reflecting an exhaustion of the stock, (Figure 8).

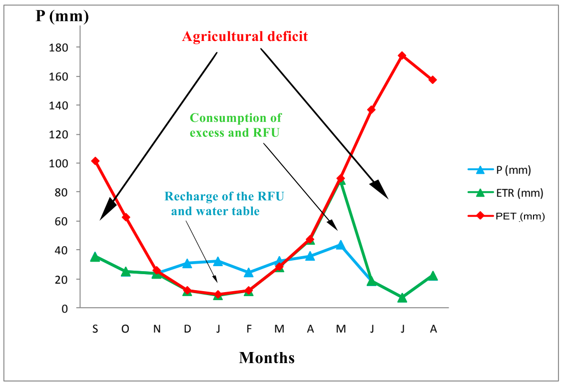

Figure 8. *Monthly variation of the elements of the hydrous assessment, Station Ain Skhouna*

III.3. Distribution of rainfall

Climate-sensitive agriculture is one of the sectors most vulnerable to the impacts of climate change [16]. Before carrying out any statistical study, on a series of annual rainfall data, it is necessary to check whether this series is part of the same statistical population, or whether there are several populations [19-20]. The rainfall maps drawn from the rainfall records for the period 1970-2015 [26] show a disturbance of the climate regime. Rainfall is low with an annual average of 356.6 mm. The rainfall recorded is irregular in its monthly, seasonal and annual distribution. A water deficit is clearly visible. Geographically the spatial distribution of precipitation on the plain of Zana-Gadaïne decreases from the North to the South, the large deficits are significant in the North-East and North-West of the plain.

The period 1970-1989 was the most marked by a net rainfall deficit, particularly in the northwestern part. The watering period is 1990-2015, when there is an increase in rainfall on the whole plain, and especially during the period 2000-2015 when there is a significant rainfall in the south of the plain (mountainous area) (Figure 9).

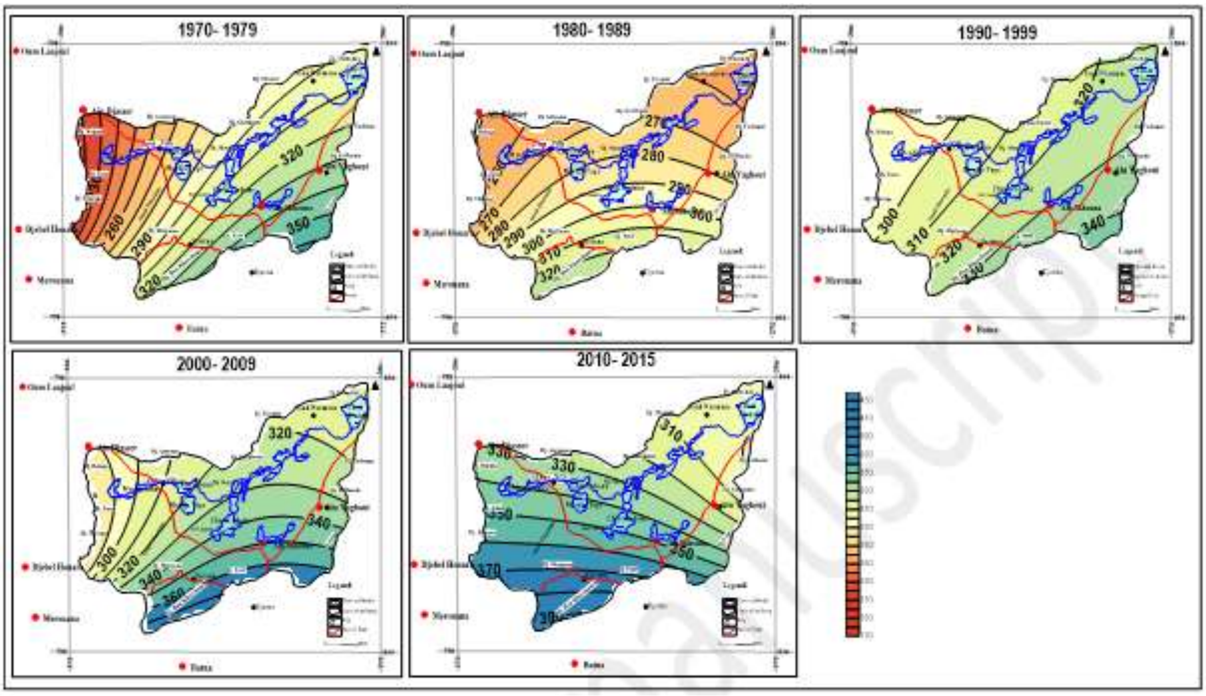

Figure 9.*Evolution of rainfall (1970-2015)*

III.4. Estimate of Evapotranspiration by Cropwat

Determining the water requirements of these crops requires the calculation of the potential evapotranspiration (PET) required for agricultural and hydrological projects [21]. in the absence of precise numbers concerning withdrawals of water intended for the agricultural use, we carried out a theoretical calculation based on the formula of Penman-Monteith [24,30] by the use of software Cropwat (free version), which is a software of assistance to the management of the irrigation developed by the Food and Agriculture Organization (FAO) in 1992 [15], based on the modified Penman - Monteith formula [27]. It allows the calculation of the water needs of crops and the quantities of irrigation water. It also offers the possibility to develop an irrigation schedule according to various cultivation practices and to assess the effects of water scarcity on crops and the efficiency of different irrigation practices. The climatic data used after homogenization (average monthly temperatures min and max in °C, average monthly precipitation in mm, average monthly relative humidity in %, average monthly wind speed in m/s and average monthly sunshine duration in hour/d) are collected from the National Meteorological Office [26]. It is well known that mild warming can be advantageous for crop photosynthesis and growth. However, photosynthesis is negatively affected by high temperature, as crop transpiration and soil moisture evaporation are enhanced, and crop growth is inhibited. Climatic warming accelerates evaporation from vegetation and may further inhibit crop photosynthesis [33]. The evapotranspiration values calculated by the FAO formula (penman-Monteith) is presented in Table 1 and reported in Figure 10. Variation of the Monteith method to the Penman method involves the use of a plant resistance parameter [10]. The expression of this equation is:

$$ET_0 = C * \left(w * R_n + (1 - w) * F(u) * (ea - ed)\right) \quad (2)$$

Where: ETO (mm day -1) reference evapotranspiration ,W weighting factor reflecting the effect of radiation one different temperature and altitude, Rn net radiation at the crop surface, F (U) (milliards) wind-related function, ea: saturation vapor presses at the average temperature of the air, ed (milliards) average of actual vapor presses of the air, expressed , (ea - ed) and C correction factor to compensate for daytime and night weather conditions.

According to the table below (Table 1), we observed that the average evapotranspiration of reference (ET0) is 4,36 mm. In january, it was observed that the lowest value of ET0 was 1.43 mm / day when precipitation was highest during the rainy season while the maximum value of ET0 was 8.48 mm and this in july (month of peak in the dry season).According to [2] ET0 was least during the period when the wet season was at its peak and highest when the dry season was at its peak. The increasing temperatures and low relative humidity are due to the increasing in the evapotranspiration during the dry season of the year.

Low values of ET0 in the wet season, especially in the short rainy season in January,

November and December could have been resulted in high rainfall occurrences together with low temperatures and high relative humidity. The ET0 is low in the rainy season in July and August. This season is characterized by higher temperatures, average relative humidity and sunshine hours, but low wind speed in km/day, which could be the reason behind this low in ET0. According to [1] the low ET0 was due to the high relative humidity. ET0 is influenced by climatic parameters including relative humidity of air, solar radiation, temperatures and wind. Therefore, consequently ET0 is a climatic parameter that varies with the seasons as the other climatic parameters vary.

Table 1. *potential evapotranspiration calculated with Cropwat at the station of Ain Skhouna (1989-2015)*

Month	Temperature C°		Humidity %	Wind (km/ day)	Sunshine (hours)	Radiation (MJ/m2 / day)	ET0 (mm/ day)
	Min	Max					
January	0.10	12.00	74	247	5.50	9.4	1.43
February	0.40	13.30	68	293	6.80	12.8	2.07
March	3.10	17.00	62	316	7.30	16.4	3.1
April	5.70	20.20	60	346	8.30	20.3	4.13
May	9.70	26.00	56	321	9.50	23.7	5.51
June	14.30	31.70	47	326	10.40	25.4	7.22
July	17.10	35.70	39	321	11.30	26.4	**8.48**
August	17.20	35.00	43	312	10.20	23.5	7.7
September	14.40	29.40	56	291	8.30	18.5	5.32
October	10.10	24.10	61	266	7.70	14.6	3.66
November	4.80	17.20	67	283	6.30	10.5	2.29
December	1.20	12.90	74	263	5.40	8.6	1. 47
Average	8.20	22.9	59	299	8.1	17.5	4.36

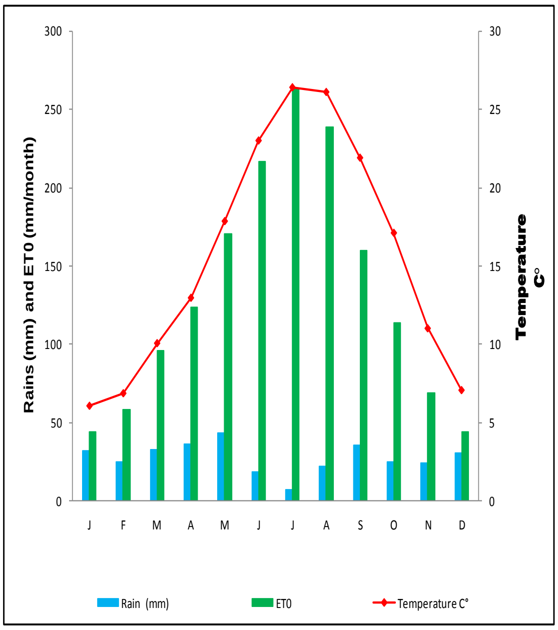

Figure 10. *Tendencies combined of ET0, temperature and precipitations, station of Ain Skhouna*

III.5.Water Balance

Using Cropwat software, we established the irrigation schedules for the main irrigated crops in the plain. We used a simple technique of management called the Water Balance which allows to check the soil, water reserve (RFU) and to control the water supply by irrigation, on the one hand, if it is sufficient to not empty the RFU and on the other hand, if it is not too important to avoid saturating the soil therefore water losses by runoff. The water balance makes it possible to analyze, at the end of the season, all of the needs and inputs and to keep the trace of deficit and surplus periods [4,5]. To determine the consumption of each crop it is necessary to calculate the basic value the PET (Potential Evapotranspiration) and to obtain the consumption of the culture (ETM), we must multiply the values of the PET by a crop coefficient values Kc, which is a determining parameter of evapotranspiration and the crop's water requirements [22] varying according to the stage and type of each crop. The estimation of this parameter was made by applying the formula given below:

$$B = Kc * ETP - (Pe + X * RFU) \quad (3)$$

Where PET (mm) the potential evapotranspiration of reference, Kc the crop Coefficient for each

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culture, EP (mm) effective pluviometry, RFU (mm) the reserve easily liable to wear out of the ground, available at the beginning of period, X Percentage liable to wear out of the initial reserve, counts held the depth of rooting reached.

The results obtained are summarized in the table 2 and the total volumes of water to be brought to the Zana-Gadaïne plain is reported in Table 3.

Table 2. *Water Balance (Needs for the water cultures) (m3/ha/ month)*

Month	Janv.	Fev.	March.	April.	May.	Jun.	July.	August.	Sept.	Oct.	Nov.	Dec.
Soft and hard wheat	0	213	797	1087	0	-	-	-	-	-	0	0
Sorghum	-	-	-	-	124	1921	2952	2413	1340	-	-	-
Alfalfa		0	499	777	1080	2203	2295	1864	1420	781	367	
Green Barley	0	-	-	-	-	-	-	-	-	0	363	388
Maize	-	-	-	-	0	1857	2821	-	-	-	-	-
Vetch - Oats	227	460	-	-	-	-	-	-	202	781	456	205
Arboriculture	-	-	0	0	1449	2419	2952	1935	1499	781	-	-
Vegetable	-	0	434	963	1251	-	-	-	-	-	-	-
Tobacco	-	0	347	1087	978	-	-	-	-	-	-	-
Tomato	-	-	0	535	1558	2289	2111	-	-	-	-	-

Table 3. *Total volume to bring (m3/month)*

culture	Volume to be brought (m3/ha/month)	Area (ha)	V*S	%
Alfalfa	11284.61	1940	21892137.6	24.73
Arboriculture	11036.58	933	10297129.1	11.63
Sorghum	8749.47	4040	35347866.9	39.93
Tomato	6493.09	32	207778.8	0.23
Maize	4677.64	40	187105.6	0.21
Vegetable	2648.09	70	18536.6	0.02
Tobacco	2411.60	16	38585.6	0.04
Vetch-Oats	2330.49	950	2213965.5	2.50
Soft and hard wheat	2096.82	5340	11197034.8	12.65
Green Barley	750.54	9490	7122605.6	8.05
Total	$52.5 * 10^3$	22851	$88.5 * 10^6$	100

An estimate of the average area-distributed irrigation needs are given in Tables 2 and 3. The results show that sorghum, alfalfa and durum and common wheat have higher irrigation needs. However, it should be noted that these crops are spread over large agricultural areas.

III.6. The Need of Water

The water requirements calculated by Cropwat for crops grown on the Zana-Gadaïne plain are shown in Figure 11.

During the months of the dry season the irrigation requirements are higher. This could be resulted in severe conditions of dry and consequently the low relative humidity resulting from insufficient rainfall and high temperatures that resulted in high rates of evapotranspiration [9]. Found that evaporation rates were high with humidity of the soil decreasing severely during the period when temperatures were at their highest, which indicate a high irrigation water requirement. Farmers used several agricultural areas irrigated by pumping [30]. The irrigation methods used are basins, furrows and pumping through flexible and draining pipes. The farmers that used methods of hosepipe and furrow tended to irrigate more water than required because these technologies will mostly have low application efficiency than the pumped systems where one is capable to easily control the quantity of water applied [29].Excessive irrigation can have negative effects on yield and quality of the crop because of the increased spread of diseases and pests, lower fertility caused by leaching of nutrients and minerals and accumulation of salts on the soil surface as a result of evaporation, among other effects [3].

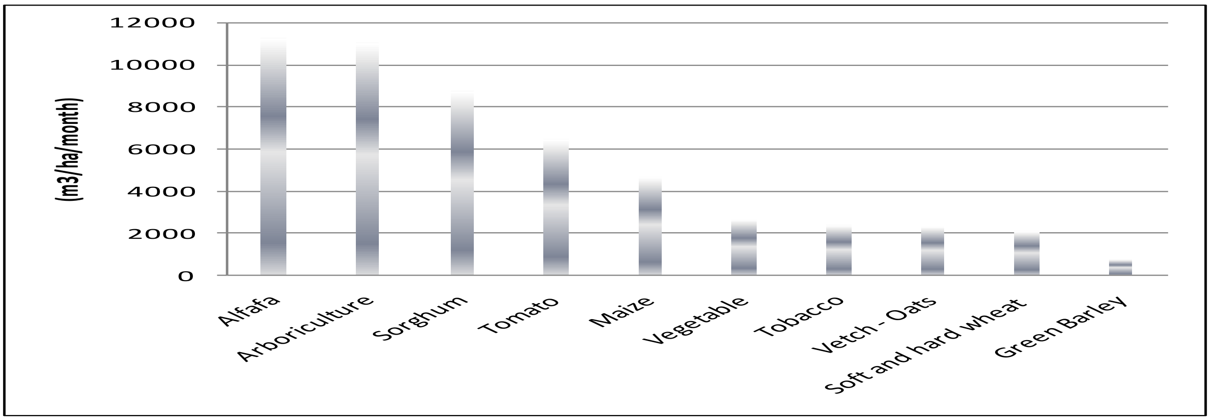

Figure 11.*Needs for the water of the cultures (m 3 / ha/ month)*

Tomato, Tobacco, potato, maize and sorghum are developed in the period from February to September; this is mainly due to the increase in the yield coefficient during the foliage stage. The period from February to September is the season of summer and of spring, which also corresponds to the highest period of Et0. Other crops such as durum wheat, alfalfa, green barley and vetch oats are annual crops which are characterized by its resistance to the drought and its high productivity (Figure 12).

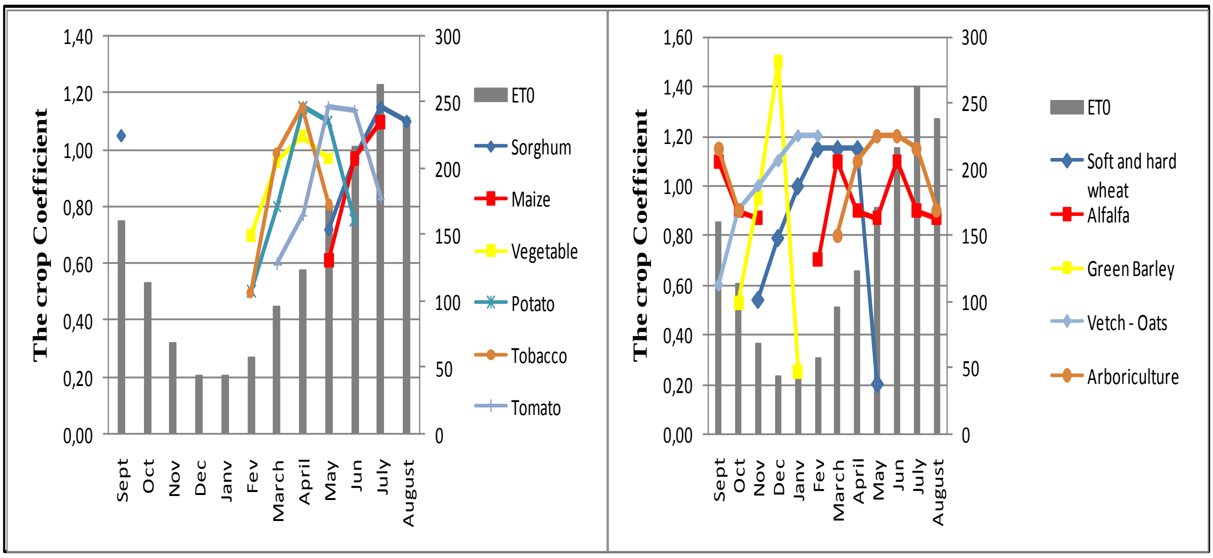

Figure 12. *Variation of the crop coefficient (kc) according to ET0*

III.7.Determination of the module of watering

The amount of water that must be poured onto one hectare of ground each time that watering is practiced which was given by [13,25]. The factors influencing the watering module require the knowledge of:

- Technics of watering.
- General state of the ground and its slope.
- The permeability of the ground

$$qi = \frac{\alpha i \, * \, di}{3.6 \, * \, ti \, * \, T} \tag{4}$$

Where: qi (l/s/ha) the modulates of watering. α i: Percentage of occupation of the culture compared to the totality of irrigated surface, di((m 3 / ha) Proportion watering of the period considered, ti (days), duration of the amount corresponding to the di, T(hours/days) duration of daily watering day to plow

$$Ti = \frac{di}{ei} \text{ (days)} \tag{5}$$

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Where: ei (m3 /ha/days) the maximum of the evapotranspiration per day to plow.

$$ei = \frac{10 * ETP * Kc\ (month)}{N\ (nbre\ days)} \quad (6)$$

The results obtained are summarized in the table below (Table 4).

Table 4.*Modules of waterings (l/s/ha)*

Month	Janv.	Fev.	March.	April.	May.	Jun.	July.	August.	Sept.	Oct.	Nov.	Dec.
Soft and hard wheat	-	0.05	0.07	0.09	-	-	-	-	-	-	-	-
Sorghum	-	-	-	-	0.11	0.20	0.27	0.24	0.16	-	-	-
Alfalfa	-	-	0.05	0.05	0.06	0.11	0.10	0.09	0.08	0.04	0.03	-
Green Barley	-	-	-	-	-	-	-	-	-	-	0.15	0.15
Maize	-		-	-	-	0.20	0.26	-	-	-	-	-
Vetch - Oats	0.01	0.02	-	-	-	-	-	-	0.02	0.02	0.02	0.01
Vegetable	-	-	0.05	0.07	0.09	-	-	-	-	-	-	-
Tobacco	-	-	0.0003	0.0005	0.0005	-	-	-	-	-	-	-
Tomato	-	-	-	0.0007	0.0014	0.0019	0.0016	-	-	-	-	-
Arboriculture	-	-	-	-	0.04	0.0747	0.09	0.0398	0.031	0.024	-	-
Total	0.011	0.065	0.161	0.210	0.312	0.582	**0.724**	0.370	0.290	0.091	0.188	0.158

IV. Conclusion

The water needs of a crop, the recovery of losses by evapotranspiration and allowing optimum water consumption for a potential crop yield in given climatic conditions is a thorny subject. In a context of water resources development in a semi-arid climate, this allows to adjust the needs as possible over time. At the end of this work, we can conclude that the choice of the method of calculation of ET0 depends on the climatic parameters available. The Penman-Monteith formula is used. The ET0 calculation allowed us to estimate the needs of the main crops grown on the plain. The water needs of alfalfa, apricot, sorghum tomato, maize, vegetable, tobacco, oat vetch, common and durum wheat and green barley crops are high and are not generally covered by the rainfall recorded in the region (net rain deficit). This water deficit can be met by irrigation water pumped from the basement when the water supply in the soil is insufficient. High irrigation water values of the main crops in the Zana-Gadaïne plain are stressed during dry periods as a result of extreme drought conditions and, consequently, the drop in relative humidity as a direct result of insufficient rainfall and high temperatures. Annual groundwater withdrawals for agricultural purposes are estimated at 62 million m3/year, but calculations of water requirements for irrigated crops in the plain are estimated at 88 million m3/year for an irrigated area of about 22851 hectares, from which a deficit for agriculture of 15 m3/year is deducted which is not fully covered by rainfall.The water requirements and the irrigation conditions necessary for the crops were estimated; the highest were alfalfa, arboriculture and sorghum at 22%, 21% and 17% respectively (annual crops), maize at 12%, tomato at 9%, while the lowest were vegetables , tobacco, Vetch - Oats, Soft and hard wheat and green barley at 5% for each crop.To ensure a better productivity-water ratio, while supporting the rationalization of the use of the vital resource, it is imperative to ensure the following recommendations:

- The inputs must be rationalized on the basis of knowledge of the real needs of the cultures;
- Improve cultivation practices, the choice of optimum sowing (or planting) date;
- Continue the diffusion of economical irrigation techniques, while providing a professional training for irrigators.

V. References

1. Abdalla, N.M.; Zhang, X.; Ishag. A.; Gamareldawla, H. Estimating reference evapotranspiration using CROPWAT model at Guixi Jiangxi Province. *State Key Laboratory of Hydrology and Water Resources and Hydraulic Engineering, Hohai University, China, 15. URL: http://www. paper.edu.cn* (2010).
2. Adeniran, K.A.; Amodu, M.F.; Amodu, M. O.; Adeniji, F.A.Water requirements of some selected crops in Kampe dam irrigation project. *Australian Journal of Agricultural Engineering* 1(4) (2010) 119-125.

3. Al-Ghobari, H.M. The impact of excessive irrigation water and fertilizers on the environment and groundwater quality in arid regions. *WIT Transactions on Ecology and the Environment* 162 (2012) 313-323.
4. Allen, R.G.;Pereira, L.S.;Raes, D.; Smith, D. Crop evapotranspiration. Guides for computing crop water requirements.*FAO Irrig. Drain, Italy* 56 (1998) 300.
5. Allen, R.G.; Pereira, L.S.;Howell, T.A.; Jensen, M.E.Evapotranspiration information reporting: I. Factors governing measurement accuracy. *Agric. Water Manage* 98(6) (2011) 899-920.
6. Athamena, A.; Menani, M.R.Nitrogen flux and hydrochemical characteristics of the calcareous aquifer of the Zana plain, northeast of Algeria. *Arabian Journal of Geosciences* (2018) 11 :356.
7. Athamena ,A. Flux azoté : origine et devenir dans les eaux souterraines, cas de la plaine de Zana, Est Algérien. *Thèse de doctorat, Université de Batna 2* (2018).
8. Battista, P.Calculation of the irrigation requirements of crops in «Applied Meteorology and Climatology». Lecture notes of the Agrometeorology and Agroclimatology course of the Faculty of Agriculture-University of Florence, Ed. G. Maracchi, Florence (2000) 230-250.
9. Blaney, H.F.; Criddle, W.D.Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data. U.S. Department of Agriculture Soil Conservation Service TP 96, Washington D.C (1950).
10. Burman, R.; Pochop, L.O. Evaporation, Evapotranspiration and climatic dated. Elsever Science B.V (1994) 278.
11. Cemagref.Guide practises irrigation, 2nd édition, édition cemagref-dicova bets (1992) 294.
12. C.G.G.Étude géophysique de la plaine de Bourehzel. Direction des études du milieu et de la recherche hydraulique. Ministère des ressources en eau. Algérie (1972).
13. Doorenbos.;Pruitt.Les besoins en eau des cultures, bulletin F.A.O d'irrigation et de drainage n°24, édition F.A.O, Rome(1975)197.
14. Drouiche, A. ;Nezzal, F.;Djema, M.Variabilité interannuelle des précipitations dans la plaine de la Mitidja en Algérie du Nord. Interannual variability of precipitation in the Mitidja plain in Northern Algeria, Revue des sciences de l'eau / Journal of Water Science 32(2) (2019)165-177.
15. F.A.O.Management of gypsiferous soils. Bulletin n°62, F.A.O Rome (1990) 81.
16. Faye, C.;Sané, T. ;Diéye, E.H.B. Variation spatiale et temporelle des précipitations de 1971 à 2010 dans le bassin versant du Sine Saloum (Sénégal), Algerian J. Env. Sc. Technology 6(2) (2020) 1310-1322.
17. Guiraud, R. Evolution post-Triasique de l'avant-pays de la chaine alpine en Algérie d'après l'étude du bassin du Hodna et des régions voisines (1975) 48-60-78.
18. Hallaire, M.r.The Problem of the potential of water in the ground and the availability of water for the vegetation. Ann. Physiol. Veg 2 (1960)119-130.
19. Hiez, G.L'homogénéité des données Pluviométriques Cah. ORSTOM. sér. hvdro., vol. XIV, n°2, Université de Fortalezza (Brésil)(1977) 129-172.
20. L'Hote, Yann.Mesure et étude des précipitations en hydrologie deust- Génie Hydro Sanitaire et Aquacole (1993).
21. Maule, C.; Helgalson, W.;McGinn, S.;Cutforth, H. Estimate of standardized reference simple evapotranspiration one the Canadian Prairies using models with limited weather dated. Canadian Society for engineering in agricultural food and biological system, CSAE/SCGR Meeting Winnipeg, Manitoba. (2005) 26-29.
22. Merdaci, S.; Masmoudi, A.L'apport de la télédétection pour l'estimation du coefficient cultural Kc de la culture d'orge (Hordeum vulgare) en région aride (Biskra Algérie), Algerian J. Env. Sc. Technology 6(3)(2020)1484-1490.
23. Menani, M.R.Étude hydrogéologique de la plaine d'El Madher : géologie, climatologie, hydrogéologie et modélisation des écoulements souterrains. Thèse de doctorat nouveau régime Université de Nancy 1, France 410.
24. Monteith, J.L.Evaporation and the environment in the state and movment of toilets in living room organisms, 19 thSymposiom. Ploughshare. For Exp. Biol., Swansea Cambridge Univer Press (1965) 205-234.
25. Ollier, CH.; Poirée, M.Irrigation les réseaux d'irrigation théorique, technique et économie des arrosages, 6ème édition Eyrolles Paris (1983)5-45.
26. O. N. M. Données climatologiques de la station d'Ain Skhouna.
27. Penman, H.L.Natural Evaporation from Open Water, Bare Soil and Grass, Proceedings of the Royal Society, Series A 193 (1948). 120-148.
28. Richards, L.A.Diagnosis and improvement of saltworks and alkali soils. Agric. Handbook 60, USDA, Washington D.C (1954)160.
29. Roth, G.; Harris, G.;Gillies, M.;Montgomery, J.;Wigginton, D. Water-use efficiency and productivity trends in Australian irrigated cotton: a review.Crop and Pasture Science 64(12) (2014). 1033-1048.
30. Shouqin, Z.;Weihua, Z.;Jiake, L.;Chaofu, W. Temporal variation of soil water and its influencing factors in hilly area of Chongqing, China. International Journal of Agricultural and Biological Engineering 7(4) (2014) 47.
31. Thornthwaite, C.W.;Holzman, B.Measurement of Evaporation from Land and Water Surfaces,U.S. Dept. of Agriculture Technical Bulletin n°817,Washington D.C.(1942).
32. Vila, J.M.La chaine Alpine d'Algérie orientale et des confins Algéro-Tunisiens. Thèse de Doctorat es Science naturelle, Univ. Pierre et Marie Curie Paris VI (1980) 665.
33. Xiao, GJ.;Guo, Zq.;Zhang, Q.; Hu, Yb.;Wang, JG.; Cao, J.;Qiu, Zj.Warming affects water use, yield and crop quality of a potato-broad bean-winter wheat rotation system in semi-arid regions of China, The Journal of Agricultural Science (2020)1-15.

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