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Article

Irrigation performance assessment of the date palm production system in Biskra region, Algeria

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Abstract: Knowing the water needs of the date palm is essential, not only for its optimal production, but also for the management of water resources. This study aims to evaluate the irrigation performance of the date palm production system in the region of Biskra, Algeria. Date palm water requirements were estimated using CROPWAT software and data. The results obtained show that in the study area, the water requirement estimated at 1,672 mm/year. Considering the efficiency of irrigation, water losses of up to 6,150 Mm3/ha in the same season could be avoided. The water productivity is about 0.40 kg/m3, for a yield of 70%. With the current scarcity of water resources, research should focus on the use of modern irrigation systems in agriculture to significantly improve water productivity and, more generally, the living conditions of farmers.

Keywords: crop water requirement; CROPWAT; water use efficiency; water productivity; Biskra

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1. Introduction

The date palm (*Phoenix dactylifera* L.) originates from the Middle East, Western India or Iraq, according to several authors [1-3]. It is a thermophilic species. Despite its regional and international importance and its dependence on irrigation or shallow groundwater for its survival, relatively little research has been published on the relationship between water and the irrigation requirements of date palm [4].

The annual water requirements of date palm trees in Algeria are between 1,500 and 3,500 mm [1]. In other regions of the world, the annual water requirements of date palm are estimated between 2,700 and 3,600 mm in the United States, around 2,230 mm in Egypt and between 2,500 and 3,200 mm in Iraq. In terms of water consumption, date palm is considered to be a relatively water-consuming crop, with annual consumption in California (United States of America) estimated at between 200 and 250 m^3 of water/tree [5], and between 59 and 80 m^3 of water/tree in Saudi Arabia [6].

The Algerian palm grove has about 18 million date palms, of which nearly 81.9% are productive. This heritage is spread over 16 regions mainly located in the south-eastern regions of the country. One of the most important regions is Biskra, with nearly 4,286,350 date palms, including 3,980,278 productive date palms, with a production of 4,077,881 quintals [7], representing 40.3% of the national date production. The palm grove represented about 33% of the total irrigated area in Biskra for the 2014-2015 season [8]. Between 2000 and 2015, the policy of developing date palm cultivation in Algeria led to an increase in the area occupied by this crop, from 24,745 to 42,911 ha. However, this increase in area is accompanied by an increase in the demand for irrigation water. Since the early 2000s, the Algerian government has provided considerable support and encouragement to farmers through subsidies to use localized irrigation methods that are more economical in the quantities of water used [9,10]. Increasing the efficiency of irrigation water is one of the economically viable solutions to overcome water scarcity [11].

However, surface irrigation (by submersion and by plank), which consumes more water, remains the most widespread. In Algeria, FAO statistics indicated a rate of 9% for drip and sprinkler irrigation methods, and 82% for the submersion method [12]. Therefore, it is important to know how to use irrigation to optimize yields, water use efficiency and, ultimately, to improve the benefits that producers can obtain from it [13].

Several techniques have been used to assess the water requirements of date palm in different countries. Abdul Salam and Al Mazrooei (2007), using FAO's CROPWAT software. They estimated the values for the potential annual evapotranspiration, actual evapotranspiration and net water requirements of date palm in Kuwait; these values were 2,883 mm/year, 2,685 mm/year and 2,553 mm/year respectively [14]. According to the study by Othman and Dahim (2016) on the irrigation water requirements of the main perennial crops (dates, citrus fruits and alfalfa) for 13 regions in Saudi Arabia, the reference evapotranspiration (ET_0) calculated using the Penman-Monteith equation [15], it is on average 2,255.5 mm/year, while the evapotranspiration of date palm (ETc) is 1,650 mm/year, and net irrigation requirements value is 1,562 mm/year [16]. Considering Djibouti's soil and climate conditions for the cool period (October to April), Said Ahmed (2015) estimated by the neutron probe method, the volumetric water requirements of the date palm at 0.130 m^3/day, with an irrigation frequency of once every 2 weeks [16]. Dewidar et *al.* (2015) estimated the volumetric water requirements of date palm using a non-automatic weighing lysimeter, between 0.087 and 0.297 m^3/day, with a daily average of 0.182 m^3 [17]. Delli and Mouhouche (2017) calculated virtual water by determining the water requirements of date palm cultivation in Algeria, using the FAO CROPWAT software [18].

This study aims to evaluate the irrigation performance of the date palm production system in Biskra region. To do this, the water requirements of the date palm are estimated, the efficiency of the water supply to the date palm is assessed, and finally, the water productivity of the irrigation systems in Biskra is assessed. This study will be used as a decision-making tool for planning activities and to effectively implement policies for the development of more efficient irrigation. The results will provide a key contribution to improving water resource management for the phoeniciculture sector, which is one of the economic pillars of Biskra region.

2. Materials and Methods

2.1. Presentation of the study area

The region of Biskra covers an area of 21,671 km^2. The entire region is divided into several agro-climatic zones (plain and steppe). The study area is located between latitudes 33.0° and 35.5° north and longitudes 4.0° and 7.0° east (Figure 1).

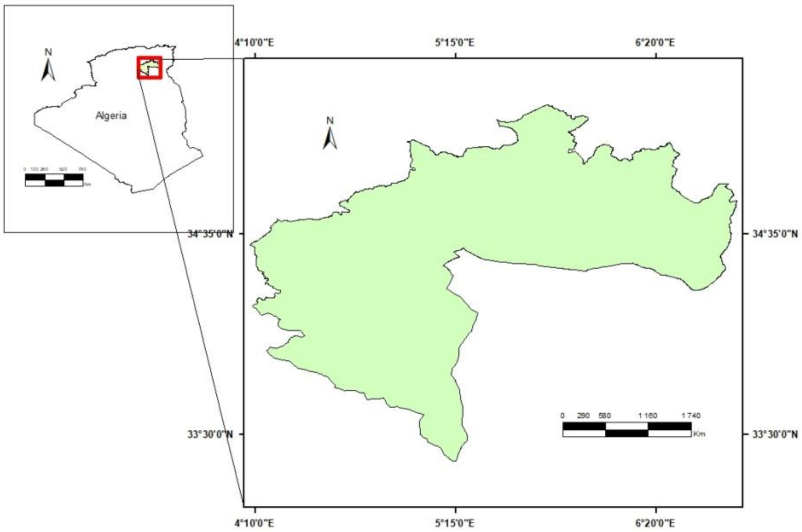

Figure 1. Location of the wilayah of Biskra.

Biskra region is a transition zone between several climatic phenomena, in particular the transition from the Mediterranean climate regime to the Saharan climate characterized by drying influences that prevail, for part of the year, over the northern Sahara [19]. The average minimum temperature for the coldest month is 12.8°C in January. The highest temperatures are recorded in June, July and August, with monthly averages reaching 34.7°C.

Sary (1976) created a map of annual amplitudes (degree of continentality), placing the Biskra region in a north-south corridor between iso-amplitudes above 22°C. Rainfall is autumn and winter, almost absent in summer. The monthly average values are low (12 mm), therefore, the annual average does not exceed 200 mm. Evaporation is high (2,734 mm) and exceeds rainfall throughout the year, hence the use of groundwater irrigation to meet the water requirements of the date palm tree [20].

In addition, geological and hydrogeological studies have highlighted the existence of several aquifers of very distinct importance due to their lithological composition, geological structure and operating facilities. These groundwater resources consist of four types of groundwater [21,22] :

- Groundwater, located at variable depths, from a few meters to about fifty meters, with easy and less expensive access;
- The Mio-pliocene sands aquifer and the deeper limestone aquifer are located at a depth of more than 50 meters and sometimes at a depth of 300 or 400 meters; they are exploited by drilling;
- The sandstone aquifer of the Continental interlayer where the aquifers are located, generally at very deep depths (more than 1 km).

2.2. Methods

The methodology of the study was based on an essential first step, namely the estimation of water requirements by calculating the evapotranspiration of date palms cultivation. The evapotranspiration was calculated based on the FAO Penman-Monteith equation [23] for which a reference evapotranspiration (ET_0) was first calculated and then adjusted using crop coefficients (Kc) to obtain the evapotranspiration of the crop concerned. Water requirements (net and gross) were estimated on the basis of evapotranspiration, effective rainfall and water application efficiency, using equations provided by the FAO study [24]. A second step to assess the irrigation performance of the date palm production system in Biskra was to study the irrigation efficiency, as well as the productivity of the irrigation water.

Data were collected at the Biskra weather station, covering a period from 1989 to 2015. The processing of meteorological data for the estimation of water requirements was done using the CROPWAT computer program, version 8.0. CROPWAT 8.0, is a software program promoted by FAO to calculate crop water requirements and irrigation requirements based on soil, climate and crop data (Figure 2). CROPWAT has been used in various studies on crop water requirements and optimization of irrigation water supply [25].

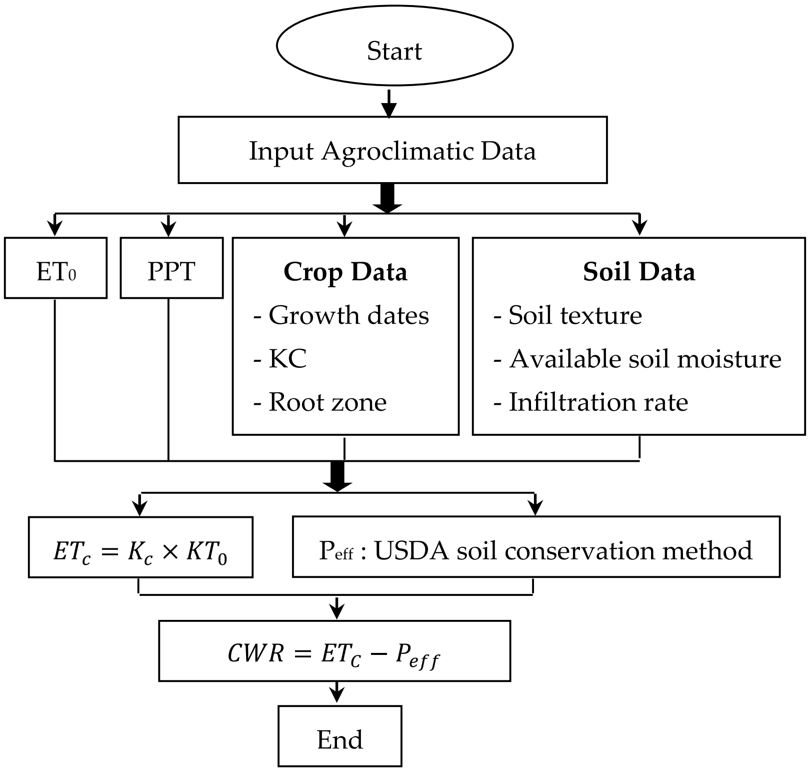

Figure 2. CROPWAT 8.0 flowchart (Muhammad et al., 2017).

Water application efficiency is defined as the ratio of actual evapotranspiration to water applied to the plot [26]. In this study, the 10% efficiency choice represents submersion irrigation, which is the most widely used in the area. Water productivity takes into account the need to maximize production per unit of available water in a context of increasing food demand and limited water resources [27]. It is also referred to as “water use efficiency” (WUE in kg/m^3, to be distinguished from the irrigation efficiency of water supply) and is expressed as the ratio between production (in kg) and applied water (in m^3) [28,29]. Water productivity depends on the irrigation system used.

Water productivity is the ratio of the net benefits from crop, forestry, fishery, livestock and mixed agricultural systems to the amount of water used to produce those benefits [27]. The considered water productivity indicators are crop water use efficiency (CWUE) [30].

$$CWUE = \frac{Y}{ETc}$$

Where CWUE represents the crop water use efficiency (kg/m³), Y represents the crop yield (kg/ha), and ETc represents the crop evapotranspiration in mm.

3. Results and discussion

3.1. Water requirements of the palm tree

Data analysis from the Biskra weather station (1989-2015) showed that the monthly maximum average temperatures are lower in January with an average temperature of 12.8°C (Figure 3 and Table 1). On the other hand, the hottest month of the year is July, when it reaches 34.7°C. The highest average rainfall is recorded in October with 20.6 mm and the lowest in July (2.3 mm), the annual average is 148 mm.

For humidity, the values generally range from 25% in July to 59% in December, with an annual average of 42%. The average monthly wind speeds show a relatively even distribution over the whole year, ranging from 4.4 to 2.6 m/s. The highest values are observed in June (4.4 m/s). In winter, the predominance of cold and humid winds from the North is recorded, whereas in summer the south winds are hot and dry (sirocco).

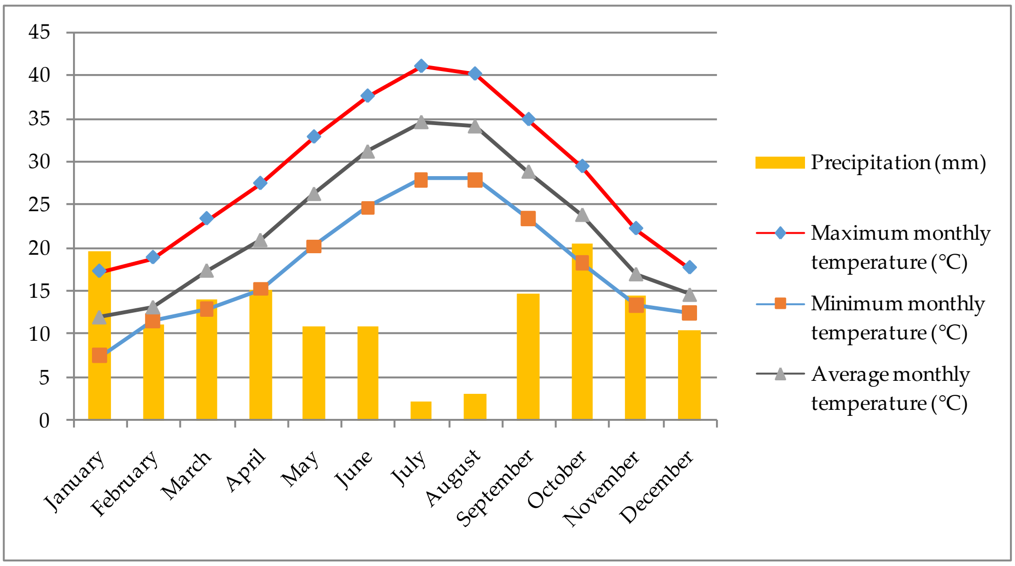

Figure 3. Monthly temperatures data in the wilaya of Biskra (1989-2015).

Table 1. Aggregated weather data by monthly time interval (1989-2015).

Month	Average temperature °C	Humidity %	Wind m/s	Insulation %	Radiation MJ/m²/day	Precipitation Mm
January	12.8	57	3.5	74	11.6	19.7
February	13.2	48	3.6	75	14.7	11.3
March	17.5	42	3.6	72	18.3	14
April	21.0	38	4.0	75	22.5	15.3
May	26.4	33	3.8	77	25.3	10.9
June	31.1	28	4.4	78	26.6	10.9
July	34.7	25	4.2	81	26.6	2.3
August	34.2	30	3.7	79	24.0	3.1
September	29.0	39	2.7	70	19.0	14.7
October	23.4	48	2.7	73	15.5	20.6
November	17.0	54	2.9	70	11.7	14.6
December	14.6	59	2.6	71	10.4	10.6

The calculation of the reference evapotranspiration (ET_0) indicated that it varies between 68.65 mm/month (December) and 339.74 mm/month (July). Annual ET_0 was estimated at 2,177 mm (Table 2). The average annual evapotranspiration is between 2,000 and 3,600 mm/year in the southern Algerian regions [18]. The high values of potential annual evapotranspiration are very much higher than precipitation, due to the arid nature of the study area. It should be noted that evapotranspiration can account for up to 85% of water losses from agricultural land in arid and semi-arid environments [31,32].

The average annual precipitation in the Biskra department is 148 mm. Precipitation is fairly unevenly distributed over the year. From May to the end of September, rainfall is scarce. Table 2 shows the effective rainfall value calculated using the U.S.D.A (United State Department of Agriculture) method. The highest monthly value of effective rainfall is obtained in January (19.1 mm); the lowest value is recorded in July (2.3 mm).

Results of crop evapotranspiration (ETc) revealed a total of 1,816.5 mm/year (Table 2). It was found that the monthly ETc values were 298 mm in July and 52.6 mm in December. The highest temperatures caused the highest evapotranspiration rates. Early work by Furr and Armstrong (1956) cited by Al-Omran, Eid and Alshammari, 2019) [33] estimated that the annual evapotranspiration of date palm was 1,300 to 1,600 mm. Evapotranspiration of date palm crops was theoretically estimated by Alazba (2001) using the Penman-Monteith equation at six different locations in Saudi Arabia, at 1,500 to 5,000 mm, depending on the location and differences in irrigation water quality [34].

Table 2. Monthly water requirements of date palm tree.

Month	ET_0 mm	ET_c mm	P_{eff} mm	Monthly requirements m^3/ha/an
March	143.75	130.8	13.6	1172
April	187.73	169.1	14.8	1543
May	245.92	223.4	10.8	2126
June	302.41	270.4	10.6	2598
July	339.74	298.2	2.4	2958
August	298.52	229.5	3.2	2262
September	192.25	146.4	14.3	1321
October	140.39	106.3	19.8	865
November	90.50	69.9	14.3	556
December	68.65	52.6	10.5	421
January	75.82	57.8	19	389
February	91.54	62.1	11.2	509
Total	2,177.22	1,816.5	145	1,6720

The estimated water requirements of date palm in Biskra showed that the total calculated was 16,720 m^3/ha/year and that the values varied between 42.1 mm/month in December and 295.8 mm/month in July, a significant variation. Water consumption per hectare is high in the hottest months 212.6 mm to 132.1 mm from May to September; this represents about 1,127 mm in summer, compared to 132 mm in winter (December to February). The months with high water requirements are June (260 mm), July (296 mm) and August (226 mm). A beginning of the decrease in potential evapotranspiration: 192 mm was recorded in September. The same period of high heat coincides with fruit growth and ripening, between 150 to 200 days between pollination and fruit maturity [4].

According to Zaid and Arias-Jiménez (2002), palm water requirements in Algeria range from 15,000 to 35,000 m^3/ha/year and in Biskra region. Delli and Mouhouche (2017) quantified these water requirements between 10,859 and 31,973 m^3/ha/year in the two Saharan and pre-Saharan bioclimatic levels respectively, while for Biskra, the value calculated was 19,160 m^3/ha/year.

In general, the amount of water delivered to the crop is less than the amount of water extracted from the source. Water losses in irrigation systems are related to the irrigation techniques used.

3.2. Efficiency

During the 2014-2015 season, the area under date palm cultivation was estimated at 42,911 ha. The estimated water requirements range from 7,174.71 Mm^3/year to 1,024.95 Mm3/year for irrigation system efficiencies of 10% and 70% respectively, or water losses of up to 6,149.75 Mm^3 for the same season. These water requirements, expressed by the number of date palms recorded in Biskra region, show "virtual" quantities of water per tree from 239 to 1,674 m^3/tree.

These results, compared to those of Alazba (2004), show that it is possible to irrigate an additional area or save water for other campaigns. The estimation of the actual annual water use by a date palm tree to be 137 m^3/tree in the eastern region to about 195 m^3/tree, in the central region of Saudi Arabia, for submersion irrigation, compared to 55 m^3/tree and 78 m^3/tree respectively for the two regions that use the drip irrigation system [34]. Mihoub et *al*. (2015) found that the use of the localized palm irrigation system would be more efficient than submersion irrigation, saving up to 50% of irrigation water. Thus, new water-saving irrigation techniques are required [35].

With an average supply cost of 0.40 euros per cubic meter of water, this corresponds to the cost of irrigation water without drinking water treatment [36], and the financial savings achieved over a campaign would be around 2459.9 million euros. Innovative irrigation is initially expensive but can be more profitable in the long term and can help to preserve water.

3.3. Water productivity

Few studies have been conducted on the water productivity of date palm. However, Carr (2013) proposed a reference figure of about 1.3 kg/m^3 of irrigation water. Productivity depends on the irrigation system applied. In Tunisia, for an efficiency of 70%, the water productivity varies from 0.42 to 0.59 kg/m^3/palm [37]. For Biskra region, the value of water productivity is 0.51 kg/m3 and ranks first in the country, representing more than 0.0196 m^3/1 kg of water [19]. The results are in the order of 0.40 kg/m^3. Productivity could be significantly improved through innovative irrigation techniques, thus creating added value per cubic meter of water used.

4. Conclusions

Water is essential for agricultural production and must be used to its full potential to produce efficiently and achieve high yields. Understanding food security and the adequacy of water supplies to meet future global irrigation water demands depends on the water demand by competing water users, the climatic forcing and how those are shaped by human activities, natural variability, and socio-economic [38]. Therefore, good water resource management for irrigation through the use of more efficient irrigation systems is necessary.

This study aims to optimize the performance of date palm irrigation systems, a highly strategic crop for Biskra region and for Algeria in general. The water consumption estimated in this study shows significant water losses.

For an efficiency of irrigation systems of 10% to 70%, water requirements are around 7,174.71 Mm^3/year and 1,024.95 Mm^3/year, respectively. Water requirements are approaching the global availability of renewable freshwater resources. Every drop of fresh water is becoming increasingly valuable and must be managed efficiently and intensively [39].

It is therefore necessary to underline the need for rational irrigation of Biskra palm groves through an efficient irrigation system, allowing optimal crop growth, but also good quality production and the sustainability of the oases.

References

1. Zaid, A., and Arias-Jimenez, E. Date Palm Cultivation. In *FAO Plant Production and Protection Paper*; FAO. Rome, Italy, 1999, pp.156-287.
2. Battesti, V., Gros-Balthazard, M., Ogéron, C., Ivorra, S., Terral, J., & Newton, C. Date palm agrobiodiversity (*Phoenix dactylifera* L.) in Siwa Oasis, Egypt: Combining ethnography, morphometry, and genetics. *Hum. Ecol.* **2018**, *46*, 529-546.
3. Ortiz-Uribe, N., Salomón-Torres, R., & Krueger, R. Date palm status and perspective in Mexico. *Agric.* **2019**, *9(3)*, 46.
4. Carr, M. The water relations and irrigation requirements of the date palm (*Phoenix dactylifera* L.): A review. *Exp. Agric.* **2013**, *49(1)*, 91-113.
5. The Political Ecology Of California Grown Dates. Available online: http://www-laep.ced.berkeley.edu/classes/la221/sp2001/la221dh/datepaper.html (accessed on 8 january, 2019)
6. Al-Amoud, A., Mohammad, F., Al-Hamed, S., & Alabdulkader, A. Reference evapotranspiration and date palm water use in the kingdom of Saudi Arabia. *Inter. Res. J. Agri. Sci. and Soil Sci.* **2012**, *2(4)*, 155-169.
7. Anonyme, A. Statistiques agricoles 2014-2015. Alger, Algérie: Ministère de l'Agriculture et du Développement Rural, 2015.
8. Anonyme, A. Bilan annuel de la phoeniciculture *2015*. Biskra, Algérie: Direction des Services Agricoles, 2015.
9. Naouri, M., Hartani, T., & Kuper, M. Mobility of rural youth and new forms of Saharan agriculture (Biskra, Algeria). *Cah. Agricultures* **2015**, *24(6)*, 379-386.
10. Bessaoud, O., Pellissier, J., Rolland, J., & Khechimi, W. Rapport de synthèse sur l'agriculture en Algérie, CIHEAM-IAMM : Montpellier, France, 2019; pp. 1-81.
11. Ahmed, T., Hashmi, H., Ghumman, A., & Sheikh, A. Performance assessment of surface and subsurface drip irrigation system for date palm fruit trees. *Agricul. Res.* **2012**, *7(10)*, 1542-1549.
12. AQUASTAT Database. Available online 31 december, 2003: http://www.fao.org/nr/water/aquastat/data/query/index.html?%20lang=en (accessed on july 25, 2018)
13. Payero, J., Tarkalson, D., Irmak, S., Davison, D., & Petersen, J. Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass. *Agric. Wat. Man.* **2009**, *96(10)*, 1387-1397.
14. Abdul Salam, M., & Al Mazrooei, S. Crop water and irrigation water requirements of date palm (*Phoenix dactylifera*) in the loamy sands of Kuwait. In III International Date Palm Conference, Leuven, Belgium, 2007.

15. Othman, A., & Dahim, M. Scenario Based Agriculture Land Use for Achieving Sustainable Irrigation Water Requirements in Saudi Arabia: A Case Study of Najran Region. *J. Curr. Res. Sci.* **2016**, *4(1)*, 1-17.
16. Ahmed, H. Etude de l'alimentation hydrique du palmier dattier (*Phoenix dactylifera* L.) dans le contexte pédoclimatique de la zone littorale de la République de Djibouti. Thèse de Doctorat, Université d'Orléans, Orléans, France, 2015.
17. Dewidar, A., Al-Fuhaid, Y., & Essafi, B. Lysimeter based water requirements and crop coefficient of surface drip-irrigated date palm in Saudi Arabia. *Inter. Res. J. Agric. Sci. and Soil Sci*. **2015**, *5 (7)*, 173-82.
18. Delli, R., & Mouhouche, B. Évaluation de l'Eau Virtuelle de la Phoeniciculture Algérienne pour sa Meilleure Utilisation. *Can. Biosys. Eng. J.* **2017**, *59*, 1-7.
19. Chabour, N. Hydrogéologie des domaines de transition entre l'Atlas saharien et la plateforme saharienne à l'Est de l'Algérie. Thèse de Doctorat. Université Constantine 1, Constantine, Algérie, 2006.
20. Sary, M. Géographie physique d'une haute plaine steppique algérienne : Le Hodna. Thèse de Doctorat. Université Louis Pasteur, Strasbourg, France, 1976.
21. Fabre, J. Le Sahara: un musée géologique. *Rche.* **1974**, *42(5)*, 140-152.
22. Bouziane, M., & Labadi, A. Les eaux profondes de la région de Biskra (Algérie). *Europ. J. Sci. Res.* **2009**, *25(4)*, 526-537.
23. Allen, Richard G., Luis S. Pereira, Dirk Raes, and Martin Smith. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. In *FAO Irrigation and Drainage Paper 56*; FAO: Roma, Italy, 1998; 300 (9).
24. Land, F. Irrigation Potential in Africa: A Basin Approach. In *FAO Land and Water Bulletin 4*; FAO: Roma, Italy, 1997.
25. Yawson, D. Climate Change and Virtual Water: Implications for UK Food Security. Doctoral thesis, Dundee, Scotland: University of Dundee, 2013.
26. Kambou, D., Xanthoulis, D., Ouattara, K., & Degré, A. Concepts d'efficience et de productivité de l'eau (synthèse bibliographique). *Biotech. Agro. Soc. Environ.* **2014**, *18(1)*, 1-13.
27. Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M., & Kijne, J. Improving agricultural water productivity: Between optimism and caution. *Agricul. Wat. Manag.* **2010**, *97(4)*, 528-535.
28. Cook, S., Gichuki F., and Turral, H. Agricultural Water Productivity: Issues, Concepts and Approaches. International Water Management Institute : Challenge Program on Water & Food, Basin Focal Project. Colombo, Sri Lanka, 2006; pp. 1-17.
29. Nhamo, L., Mabhaudhi, T., & Magombeyi, M. Improving water sustainability and food security through increased crop water productivity in Malawi. *Wat.* **2016**, *8(9)*, 411-422.
30. Asres, L., Singh, P., Derebe, M., & Yersaw, B. Evaluation of Water Productivity under Furrow Irrigation for Onion (*Allium cepa* L.) Crop. *Adv. in Agric.* **2022**, 1-8.
31. Chehbouni, A., Escadafal, R., Duchemin, B., Boulet, G., Simonneaux, V., Dedieu, G., & Sobrino, J. An integrated modelling and remote sensing approach for hydrological study in arid and semi‐arid regions: the SUDMED Programme. *Inter. J. Rem. Sens.* **2008**, *29*, 5161-5181.
32. Chirouze, Jonas. Estimation de l'évapotranspiration à l'aide de Données de Télédétection Dans Le Domaine Infra-Rouge-Thermique à Haute et Basse Résolution. Thèse doctorat, Université Paul Sabatier, Toulouse III, Toulouse, France, 2009.
33. Al-Omran, A., Eid, S., & Alshammari, F. Crop water requirements of date palm based on actual applied water and Penman–Monteith calculations in Saudi Arabia. *App. Wat. Sci.* **2019**, *9*, 69.
34. Alazba, A. Theoretical estimate of palm water requirements using Penman-Monteith model. In Annual Meeting, American Society of Agricultural and Biological Engineers, USA (2001).
35. Mihoub, A., Helimi, S., Sakher, M., El-Hafed, K., Koull, N., Lakhdari, K., Tidjani, B., Benazoui, A., Bensalah, L., & et , al. Date palm (*Phoenix dactylifera* L.) irrigation water requirements as affected by salinity in Oued Righ conditions, North Eastern Sahara, Algeria. *Asi. J. Cro. Sci.* **2015**, *7(3)*, 174-185.
36. Hervieu, B., & Thibault, H. Repenser le développement rural en Méditerranée. MediTerra : Presses de sciences po. **2009**, France, pp. 392.

37. Slimani, M., & Zayani, K. Apport d'eau, Développement et Rendement de Jeunes Palmiers Deglet Nour Dans La Parcelle Expérimentale d'Atilet-Nefzaoua (Tunisie). *Medit. J. Econ., Agri. Envi.* **1998**, *9(4)*, 58-62.
38. Hejazi, M., Edmonds, J., & Chaturvedi, V. Global irrigation demand—A holistic approach. *Irr. Dra. Sys. Eng.* **2012**, *1(2)*, 1-4.
39. Wada, Y., Flörke, M., Hanasaki, N., Eisner, S., Fischer, G., Tramberend, G., & Wiberg, D. Modeling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches. *Geosci. Mod. Dev.* **2016**, *9(1)*, 175-222.