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Research Article

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Assessment of deficit irrigation efficiency. Case study: Middle Sebou and Innaouene downstream

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Abstract: Future projection shows that the availability of freshwater per capita will decrease to 560 m^3/year by 2030 in Morocco. In this realm of adopting efficient irrigation, alternatives become a priority to overcome water shortage. The presented study aims to investigate theoretically the likelihood of improving irrigation efficiency at the plot level of the Middle Sebou and Innaouene downstream perimeter using 75% of the total irrigation water requirement (IWR), based on the successful results obtained by the Moroccan National Institute for Agronomic Research. The methodology consists of the extraction of monthly evaporation data from MODIS16A2 and process it under Google Earth Engine (GEE); data that are used in the second part of the study, which aims to assess the efficiency of deficit irrigation on a plot of 2,500 olive tree, using three main indexes; olive three height (cm), Stomatal conductance (mmol H_2O m^{-2} s^{-1}), and olive tree growth (cm). The results show that 0.75 of full irrigation could save 17% of the total water used, reducing the water irrigation supply by an average of 5 Mm^3, with a slight decreasing of the olive production, estimated as 0.5 t/ha. Furthermore, water use efficiency and water productivity have been enhanced under deficit irrigation by respectively 0.25 kg/m^3 and 0.54 Dh/m^3. In economic terms, the result shows that with deficit irrigation, the decision-maker, or the farmer, could save about 5 million m^3 per year, which is a boost to the global economy if the method is transposed and applied to other Moroccan regions and also a support for the new agricultural strategy called Generation Green.

Keywords: remote sensing, evapotranspiration, deficit irrigation, irrigation water use efficiency, cloud computing, big data analytics

1 Introduction

1.1 Agriculture in Morocco

Agriculture is the main engine of Moroccan's economic evolvement. It contributes to the production of the National Gross Domestic Product by 20% and also creates job opportunities especially in rural areas.

1.2 The Moroccan green plan

Launched in 2008, the Green Morocco Plan strategy aims to accelerate growth, reduce poverty, and ensure long-term agriculture sustainability by implementing 500 projects for an investment budget of 147 billion dirhams over ten years. The main objectives of the MGP by 2020 are:
- The creation of 1–1.5 million additional jobs
- The reduction of poverty by multiplying by 2–3 times the income of nearly 3 million rural people
- The increase of the Gross Domestic Product Agricultural (GDP) from +60 to 90 billion dirhams; the doubling of exports
- The sustainable management of resources (water-saving from 20 to 50%)
- Limiting the impact of climate change and preserving natural resources

Moreover, the plan aims to reach 4,50,000 ha of irrigated agriculture by 2035. Along with the agricultural investment, the Moroccan government plans to build five more dams to alleviate water resource pressure.

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Note that 80% of Moroccan water resources are consumed by agriculture. The National Program for Water-Saving in Irrigation is one of the transversal actions adopted to mitigate the effects of water resource scarcity and improve the efficiency of water use in irrigation (Tanouti 2017). It consists of shifting to drip irrigation on the plot with subsidies reaching 100% for small farmers (Molle and Sanchis-Ibor 2019), over an area of 5,50,000 ha. This latter is a worldwide alternative used toward saving water (Postel et al. 2001; Lundqvist et al. 2008). As an example, Turkey's government offers subsidies of 50–75% of the cost of water-saving irrigation technologies (Molle and Sanchis-Ibor 2019). The Rural Development Policies in Italy covers up to 60% of the cost of water-saving irrigation technologies (Molle and Sanchis-Ibor 2019). The Shock Plan in Spain offers subsidies up to 60% for drip irrigation (Lopez-Gunn et al. 2012). Algeria's government covers 100% of drip irrigation investment (Tanouti 2017). Also, in Tunisia, the National Program for Water-Saving covers 40–60% of the cost of water-saving irrigation technologies (Frija et al. 2016).

However, the increase in water supply and shifting to drip irrigation are still far to maintain sustainable agriculture under the current hydrological conditions (Tanouti 2017). A study carried out by Berbel et al. (2014) on the Rebound Effect of Water-Saving Measures shows that the impact of drip irrigation on water-saving is uncertain, and it depends on the agricultural systems and basin or aquifer characteristic (Hussain and Abed 2019; Solangi et al. 2019). Perry et al. (2009) highlighted the agronomic constraints and hydrological realities concerning the application of advanced water-saving technologies. The study shows that water-saving technologies are limited to saving water consumption. Tanouti (2017) showed that Moroccan water-saving policy at the plot scale runs in contrast with climate change projections and hydrologic realities. Farmer irrigation practice is a significant problem that creates impediments to water-saving (Cordier et al. 2020; Dokić et al. 2020; Fenu and Malloci 2020), even in developed countries (Burt 2004; Levidow et al. 2014). Likewise, Morocco encountered the same problem with the paradigm shift of farmers (Benouniche et al. 2014a, 2014b; Molle and Tanouti 2017). Another issue that affects water consumption is expansion, intensification, and crop change (WWF 2015; Sese-Minguez et al. 2017; Tanouti 2017).

Deficit irrigation is a solution that may go along with drip irrigation to ensure water-saving. It takes into account hydrological conditions, mainly actual evapotranspiration and crop phenology. The technique was applied on different types of crop worldwide and was highly recommended by several types of research on boosting water-saving efficiency at the plot level taking into account the hydrological conditions. Fereres and Soriano (2007) showed that regulated deficit irrigation provides a significant performance in fruit trees in terms of water-saving and farmer's income. Chai et al. (2016) showed that regulated deficit irrigation can improve water use efficiency, with a highlight of the plants responding under deficit irrigation. Mandal et al. (2020) performed deficit irrigation using a simulation-optimization framework for the irrigation water supply of a check dam in the Kondepi IWMP area. The results show that deficit irrigation can enhance water-saving efficiency and improve yield productivity. Ozer et al. (2020) carried out a study on black cumin using deficit irrigation and showed that deficit irrigation can save irrigation water supply by 40%. Sabri et al. (2017) conducted a study about date palm over the period 2012–2014 in a plot of 14 ha in Errrachidia and found that deficit irrigation based on 60–100–80% water regime could save 14% of water irrigation supply. El Jaouhari et al. (2018) conducted a study in Imouzzer Kander region located in Morocco to assess the deficit irrigation efficiency on an apple orchard. This study shows that the water regime provides an excellent performance regarding the apple fruit. Wahba (2017) used water management simulation Model DRAINMOD-S over 20 years to assess the sustainable use of agricultural drainage water used for irrigation in the North-West Delta of Egypt. Best results were found in yield managed with deficit irrigation combined with controlled drainage. Deficit irrigation was also applied to olives trees (Fernandes-Silva et al. 2018). Razouk (2016) showed over a field experiment conducted by the Moroccan National Institute for Agronomic Research in the region of Meknes about deficit irrigation applied to olive trees; the level of yield and vegetative growth of the olive tree is not significantly affected by the deficit irrigation at 75 and 50% of the evapotranspiration during the critical phases: April, July, August.

The Middle Sebou and Innaouene downstream economy is basically relied on agricultural activity, especially olive crops; however, this latter is facing serious water issues; a compilation of pollution, inundation, and erosion compounded by climate change impacts threat the water availability in long term; to deal with this drawback, deficit irrigation is a conducive alternative that could alleviate it by solving the nexus of water irrigation amount-crop yield. No similar studies were applied to this region before and this article will be a first reference and a stepping stone for future researches.

In this context, the presented study aims to investigate theoretically the likelihood of improving irrigation efficiency at the plot level using 75% of the total irrigation water, based on the successful results obtained by the Moroccan National Institute for Agronomic Research. The approach could be transposable on the overall country and any region that has the same climate characteristics.

The first part displays a brief introduction of the study area and underlines the used methodology. In the second part, the actual evapotranspiration (AET) was estimated, using Modis Evaporation product over the period 2008–2019 within Google Earth Engine (GEE) Could-Computing Environment. 2,500 ha of olive crop yield was assessed under full drip irrigation supply and 75% of full drip irrigation supply over five years ranged from 2008 to 2019. The last part focuses on water use efficiency and water productivity assessment over the same period.

2 Study area

The Middle Sebou and Innaouene downstream perimeter are located in the Sebou watershed on the banks of the Inaouen and Sebou River in Morocco. The Middle Sebou and Inaouen downstream perimeter is 60 km far away from the Fez city. The perimeter is characterized by a chain of Ouljas plots lying along 100 km with the Sebou and Inaouen River along. The Hydro-Agricultural Development Project of the Perimeter of the Middle Sebou and Inaouen downstream is an extension of the first part of the hydro-agricultural project in the downstream of Idris I dam with an annual water allocation of 24 Mm^3 (6,000 m^3/ha to the plot) (Figure 1).

Ethical approval: The conducted research is not related to either human or animal use.

3 Methodology

In this study, deficit irrigation was applied to a plot of 2,500 ha of olive trees, localized along with Ouljas in the Middle Sebou and Inaouen downstream perimeter. In this plot, the irrigation water was supplied by a drip irrigation system with two lateral lines per bed with 2.5–3 m spacing, and 16 mm thick, using a turbulent flow dripline, with emitters spaced by 0.75 m and a discharge rate of 4 L h^{-1}. The study consists of two irrigation strategies applying 100 and 75% of the irrigation water requirement (IWR), performed in monthly intervals for a period ranged from 2008 to 2019. Besides, the crop water requirement was calculated for 100% evapotranspiration and 75% evapotranspiration, using the water balance equation (Villalobos et al. 2016). The deficit irrigation consists of the irrigation water requirement (IWR) reducing to 75% during April, June, July, August,

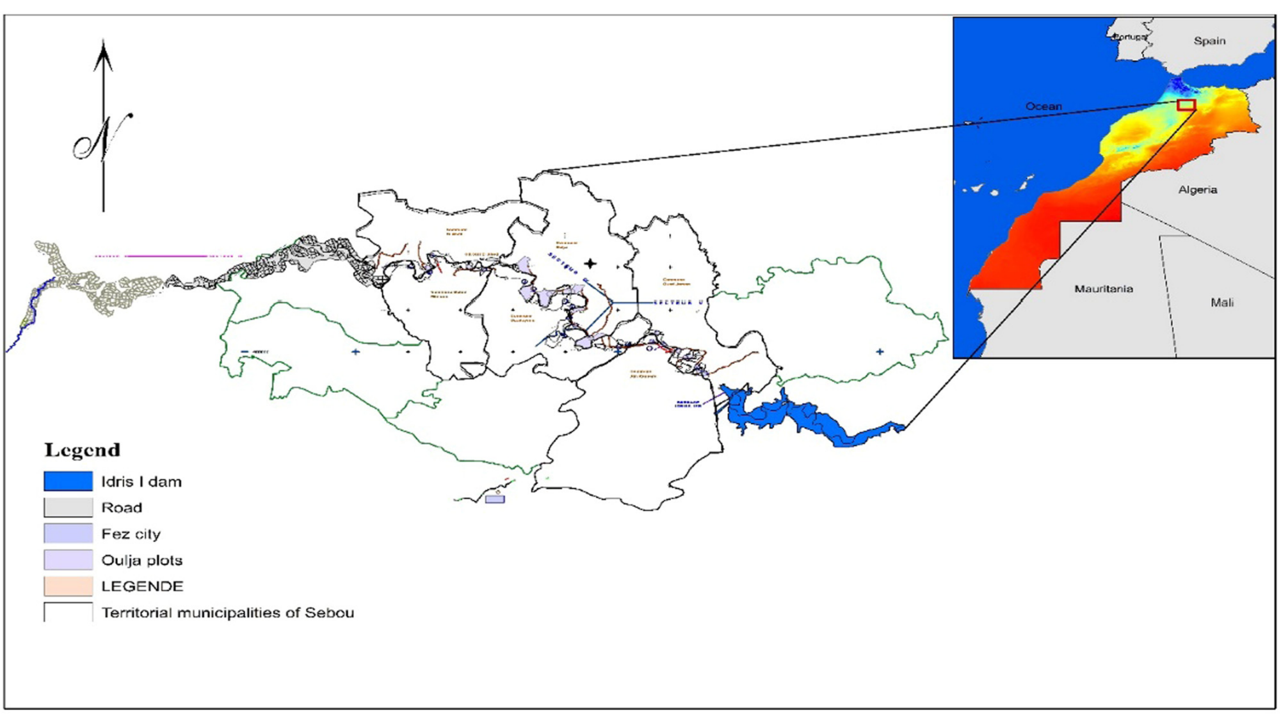

Figure 1: The Middle Sebou and Innaouene downstream perimeter.

Table 1: Monthly crop coefficient for olives trees (Masmoudi et al. 2004)

Crop coefficient	Months											
	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
K_c	0.50	0.50	0.65	0.60	0.55	0.50	0.45	0.45	0.55	0.60	0.65	0.50

September, October, and November. Olive evapotranspiration was calculated using the actual evapotranspiration (AET) (Pascual-Seva et al. 2016), crop coefficient (K_c) (Abdelkhalik et al. 2019), and reduction coefficient (K_r) (FAO 1998). The actual evapotranspiration (AET) was retrieved from MODIS16A. Besides, in this study, we used the same crop coefficient (K_c) and reduction coefficient (K_r) proposed by Masmoudi et al. (2004) (Tables 1 and 2). The crop coefficient (K_c) reflects the variation of plant activity and soil surface water status. Besides, the reduction coefficient (K_r) (Conseil Oleicole International 1997) takes into account the percentage of variations of soil cover related to planting density. In the current study, we chose 0.7 as a reduction coefficient (K_r) value for olive trees.

3.1 Hydroclimatic data

Idriss I rain gauge station has been used to calculate water crop requirement for 100% evaporation and 75% evapotranspiration over the period 2008–2019. Precipitation data were provided by the Hydraulic Basin Agency of Sebou, over the same period.

3.2 Evapotranspiration

In this study, the monthly actual evapotranspiration (AET) data were retrieved over the period 2008–2019,

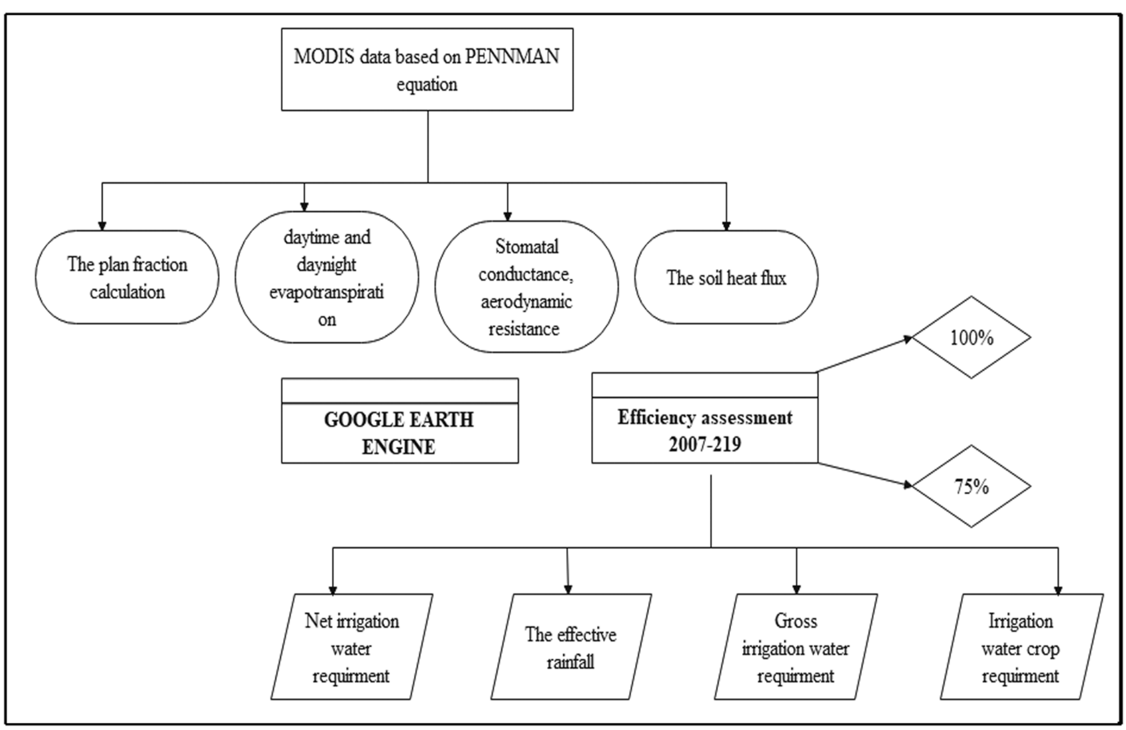

Table 2: The reduction coefficient values corresponding to the vegetation land cover (Conseil Oleicole International 1997)

The vegetation land cover	The reduction coefficient (K_r)
More than 50%	1.00
40–50%	0.90
35–40%	0.80
30–35%	0.75
Less than 30%	0.70

using MOD16A2 sensor, with a spatial resolution of 500 m, freely available on https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/products/MOD16A2/. The MOD16 algorithm is based on the Penman-Monteith equation (Aguilar et al. 2018). Penman-Monteith equation is composed of four equations:

- The plan fraction calculation
- The calculation of daytime and nighttime evapotranspiration
- The calculation of the soil heat flux
- The calculation of stomatal conductance, aerodynamic resistance, and resistance of the boundary layer.

$$\lambda \cdot E_T = \frac{\Delta \cdot A_c + \rho \cdot C_p \cdot (e_{sat} - e) \cdot F_c / r_a}{s + \gamma \cdot (1 + r_s / r_a)}$$

$$\lambda \cdot E_s = \frac{\Delta \cdot A_{soil} + \rho \cdot C_p \cdot (1 - F_c) \cdot (e_{sat} - e) / r_{as}}{s + \gamma \cdot r_{tot} / r_{ras}} \cdot \left(\frac{RH}{100}\right)^{(e_{sat} - e)/200}$$

$$A_c = F_c \cdot A$$

$$A_{soil} = (1 - F_c) \cdot A - G$$

where $\lambda \cdot E_T$ (W m^{-2}) is the latent heat flux of foliage transpiration, $\lambda \cdot E_s$ (W m^{-2}) is the latent heat flux of evaporation of the soil at a daily scale; Δ is the slope of the curve that relates the water vapor pressure to the temperature (Pa K^{-1}); e (Pa) is the actual water vapor pressure, and e_{sat} (Pa) is the saturated vapor pressure; A (W m^{-2}) is the net radiation, partitioned for soil (A_{soil}) and vegetation (A_c); G (W m^{-2}) is the soil heat flux; ρ (kg m^{-3}) is the air density; C_P (J kg^{-1} K^{-1}) is the specific heat capacity of air; F_c is the fraction of the plant cover; r_a (s m^{-1}) is the aerodynamic resistance; r_s (s m^{-1}) is the surface resistance; r_{tot} (s m^{-1}) is the total of the aerodynamic resistance; RH (%) is the relative humidity, and γ is the psychometric constant (Pa K^{-1}).

The extraction of monthly evaporation data from MODIS16A2 was conducted using Google Earth Engine (GEE). Google Earth Engine (GEE) is a cloud computing platform for big data analysis and processing (Kumar and Mutanga 2018). Google Earth Engine (GEE) archives satellite and geographic information system vector and raster data (Mutanga and Kumar 2019). Many studies have used Google Earth Engine (GEE) to extract MODIS data, to perform Landcover Mapping and for Agricultural Applications and Disaster Management and Earth Sciences (Campos-Taberner et al. 2018; He et al. 2018; Parente and Ferreira 2018; Poortinga et al. 2018).

The data retrieving method has been coded in Google Earth Engine (GEE) which can be freely used at https://code.earthengine.google.com/?scriptPath=users%2Fisel hassnaoui%2FIsmailelhassnaoui%3Aismailelhassnaoui

3.3 Crop data

This study focused on a plot of 2,500 ha of olive trees along with Ouljas in the Middle Sebou and Inaouen downstream perimeter.

The net water requirement was calculated, assuming that there are no losses during irrigation (equation 3). On the other hand, the gross water requirement was calculated, including the excess of water irrigation supply (Pomares 2007) (equation 4). Furthermore, the sufficient rainfall (P_e) (Abdelkhalik et al. 2019) (equation 2) was estimated based on the recorded precipitation by Idriss I rain gauge station, including irrigation water losses. Moreover, the irrigation water requirement (IWR) is considered equal to the gross water requirement (equation 5).

Evapotranspiration:

$$ET_c = K_c \times K_r \times ET_0 \tag{1}$$

The effective rainfall:

$$P_e = P \times \eta \tag{2}$$

Net irrigation water requirement:

$$NIWR = ET_c - P_e \tag{3}$$

Gross irrigation water requirement:

$$GCR = \frac{NIWR}{E_f} \tag{4}$$

Irrigation water requirement:

$$IWR = GCR \tag{5}$$

where ET_c is the crop evapotranspiration (mm) which represents crop water requirement, K_c: crop coefficient, K_r: reduction coefficient, P_e is the effective precipitation, which is the amount of precipitation that I stored in the soil (mm), P: the recorded rainfall data (mm), η: the percentage of precipitation that soaks into the ground, which is estimated to 80%, GCR: The gross crop requirement (mm), E_f: the irrigation efficiency of 0.90, IWR: the irrigation water requirement (mm).

3.4 Olive yield

The Assessment of the impact of deficit irrigation on crop yield was based on the study conducted by the National Institute of Agronomic Research, on Saiss covering the same study area. This latter assessed the behavior of olive trees with a density of 154 trees/ha under full irrigation requirement and 75% of full irrigation requirement. The agro-physiological parameters and biochemicals of olive trees show that no significant difference was recorded between the full irrigation requirement and 75% of full irrigation requirements in terms of olive tree growth and development as well as no physiological disturbance. Also, olive production was barely affected by water availability, which is estimated as 0.5 t/ha (INRA 2019) (Figures 2–4).

3.5 Water use efficiency and water productivity

Irrigation water use efficiency (IWUE) was calculated as the ratio between the marketable yield harvested (kg/ha) and the total volume of water applied (m^3 per ha). Economic productivity is defined as the value derived per unit of water used, which indicates how much economic output is produced per cubic meter of fresh water abstracted (in Dirham (Dh) per m^3). In the Saiss area, the average production costs and the average margins data are highlighted in Table 3.

Ethical approval: The conducted research is not related to either human or animal use.

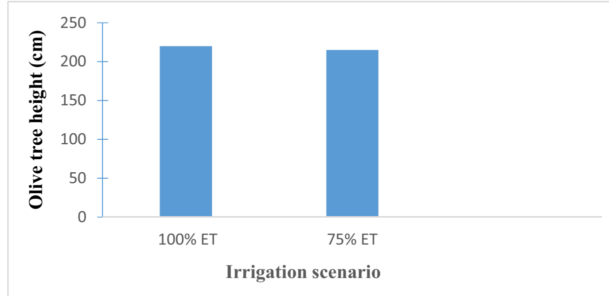

Figure 3: Effect of irrigation scenario on the height of the olive trees (INRA 2019).

4 Results and discussion

4.1 Evapotranspiration

Figure 5 shows the monthly evapotranspiration data retrieved from MODISA16, using Google Earth Engine (GEE), over the period 2008–2019, in the Middle Sebou and Inaouen downstream perimeter. The temporal variation of the evapotranspiration along each year is evident, mostly when we compare the rainy months against the driest ones. The peak evapotranspiration data are observed during the rainy months, especially March, April, and May, to some extent. However, the minimum evapotranspiration values are observed during the driest months, especially in July and August. During the period ranging from 2008 to 2019, the highest evapotranspiration was observed in March 2017 with 904.47 mm. However, the minimum evapotranspiration value was observed in July 2016, with 25.24 mm. The mean value of evapotranspiration during the same period is 220 mm, with a standard deviation of 167.38. The variation of evapotranspiration values from March to May is not significant because the precipitation from January to April keeps the soil moisture content. During the period ranging from August to December, vegetation presents the

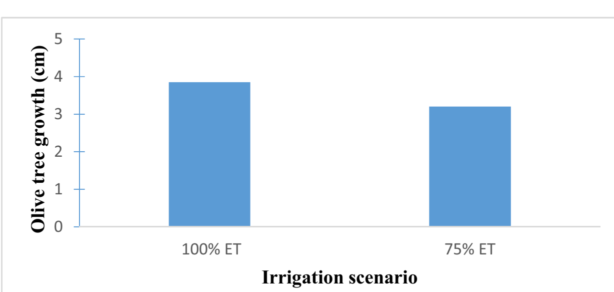

Figure 2: Growth of young branches of olive tree within the irrigation scenarios (INRA 2019).

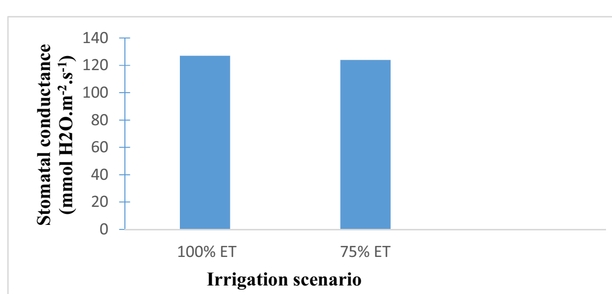

Figure 4: Effect of irrigation scenario on conductance stomatic leaves of olive trees (INRA 2019).

Table 3: The Average production costs and the average margins of the olive trees irrigated by drip irrigation in the Saiss region (Source: Regional directorate of agriculture of Fes-Meknes)

The average production costs and the average margins	
Parameters	**Olive trees irrigated by drip irrigation**
Phytosanitary products (Dh/ha)	1,600
Fertilizer (Dh/ha)	1,200
Workforce without harvest (Dh/ha)	1,950
Workforce with harvest (Dh/ha)	850
Fuel for irrigation (Dh/ha)	2,200
Other expenses (Dh/ha)	500
Total of variable expenses (Dh/ha)	8,300
Yield (t/ha)	6
Expenses (Dh/kg)	1.38
Selling price (Dh/kg)	3.5
Turnover (Dh/ha)	21,000
Margin (Dh/ha)	12,700
Margin (Dh/kg)	2.12

lowest evapotranspiration values, due to the highest fractions of the available energy used as sensible heat fluxes (*H*) (Antônio et al. 2013; Yang et al. 2016). Evapotranspiration is strongly correlated with surface soil moisture (Kurc and Small 2004). In arid and semiarid regions, the evapotranspiration is limited by soil moisture (Rodriguez-Iturbe 2000). Shen et al. (2017) found that transpiration is high where the climate is more humid, and there is a great canopy. Moreover, Shen et al. (2017) show that the peak of evapotranspiration retrieved by MODIS sensor, over in Australian Semiarid and Arid Basins, occurred in January to May. Hence, under dry conditions, the vegetation closes its stomata, limiting its transpiration and photosynthesis. The same result was found by Antônio et al. (2013).

4.2 Deficit irrigation

Figure 6 points out the variety of gross water requirement per hectare over the period 2008–2019. The visual examination of Figure 6 shows that the peak of the gross water requirement per hectare is observed during the rainy months, especially March, April, and May, in some extent; however, the minimum gross water requirement values are observed during the driest months, especially in July and August. During the period ranging from 2008 to 2019, the highest gross water requirement was observed in March 2017 with 457.3 mm. However, the minimum gross water requirement value was observed in July 2016, with 8.9 mm. The mean value of gross water requirement during the same period is 97.1 mm, with a standard deviation of 81.91. Figure 7 presents the variation of the irrigation water crop requirement per hectare over the period 2008–2019. As expected, the peak of the irrigation water crop requirement per hectare is observed during the rainy months, especially March, April, and May, to some extent. However, the minimum irrigation water crop requirement values are observed during the driest months, especially in July and August. During the period ranging from 2008 to 2019, the highest irrigation water crop requirement was observed in March 2017 with 440.5 mm. However, the graph shows there is some months where the rainfall covers more than the gross water requirement, with an observed maximum

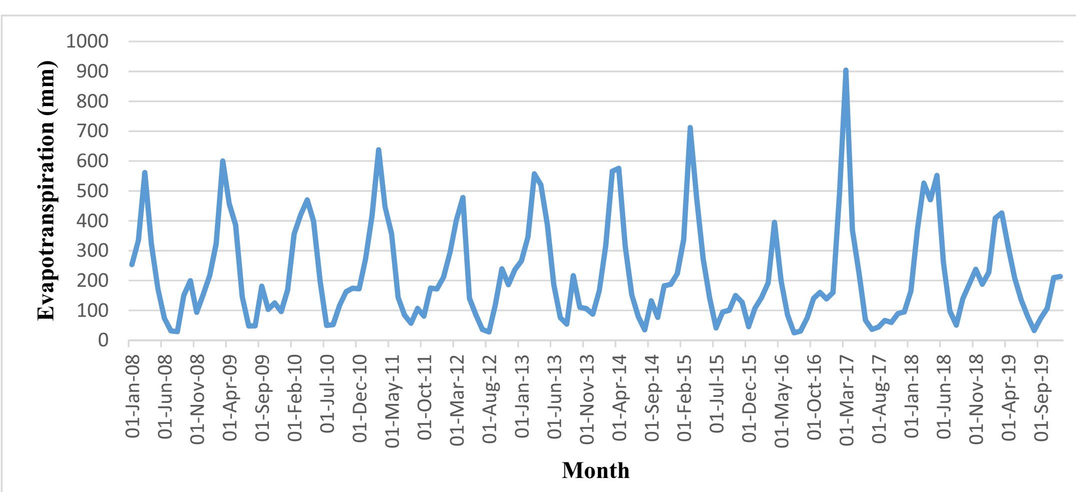

Figure 5: Monthly Evapotranspiration derived from MODISA16 over the period 2008–2019.

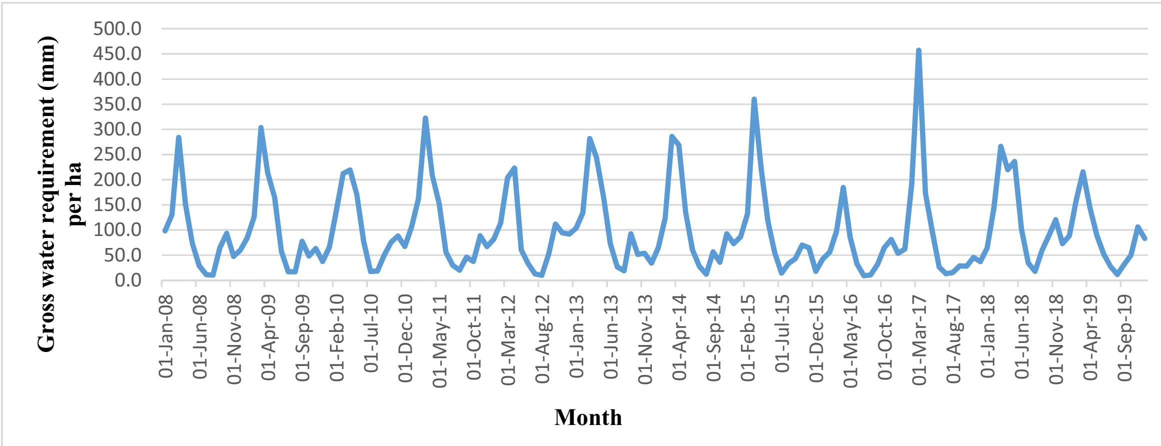

Figure 6: Gross water requirement (mm) per ha, over the period 2008–2019.

surplus of 162.4 mm, in October 2018. Covering the gross water requirement through rainfall provides enough water storage in the olive trees' root zones, which can maintain their continuous vegetative developments. The fact that the rainfall covers more than the gross water requirement in some months can urge the decision-makers or the farmers to firstly not irrigate during these months and to think about rainfall harvesting, to overcome crop water requirement during the drought periods.

Furthermore, the mean value of gross water requirement during the same period is 65.4 mm, with a standard deviation of 78.66. Moreover, the visual examination of Figure 8 shows that deficit irrigation could reduce the irrigation water requirement (IWR), especially during April, June, July, August, September, October, and November. Indeed, during the period ranging from 2008 to 2019, the highest irrigation water requirement (IWR), for the 2,500 ha, under deficit irrigation was observed in March 2017 with 11 million m^3 per month; the graph shows there is some months where the rainfall covers more than the gross water requirement, with an observed maximum surplus of 5.2 million m^3 per month, in October 2018. The mean value of irrigation water requirement (IWR) under deficit irrigation during the same period is 1.2 million m^3 per month, with a standard deviation of 2. Figure 9 presents the amount of water-saving over the period ranging from 2008 to 2019. Applying deficit irrigation can afford water-saving up to 0.4 million m^3 per month, with an annual average of 5 million m^3. The water-saving based on deficit irrigation, conducted over the current study, goes hand in hand with the previous study, which recommended deficit irrigation (Fereres and Soriano 2007; Chai

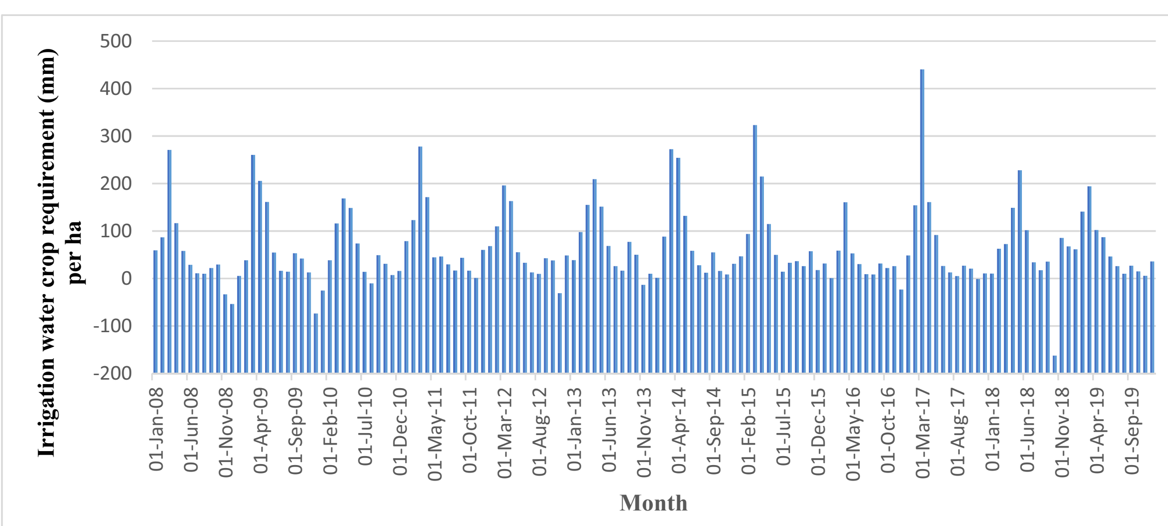

Figure 7: Irrigation water crop requirement (mm) per ha, over the period 2008–2019.

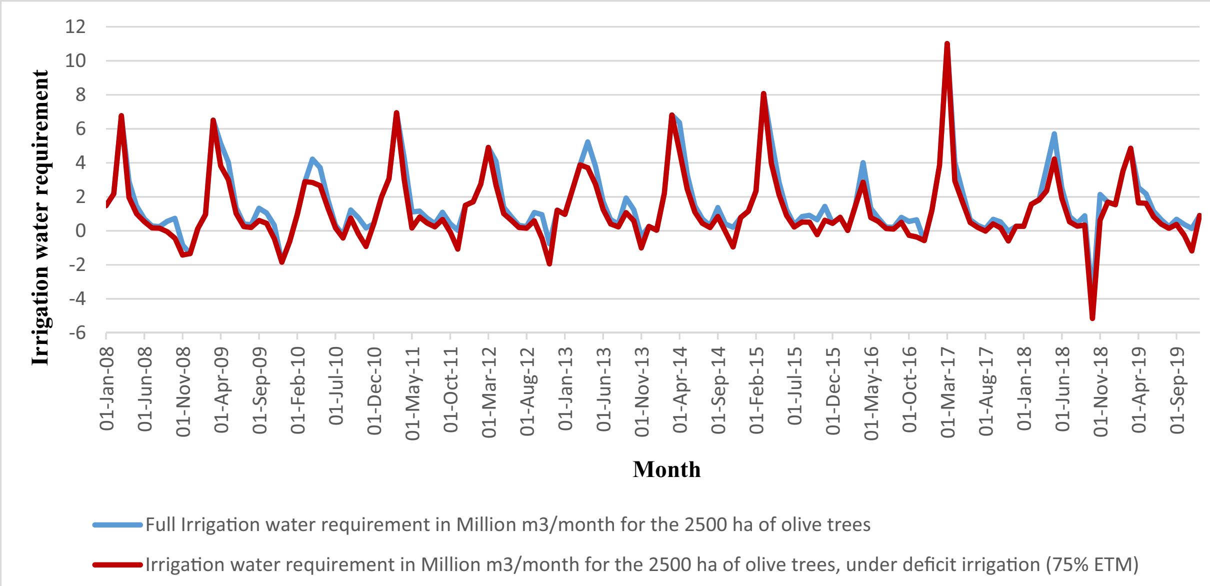

Figure 8: Irrigation water requirement (IWR) variation under full irrigation supply and deficit irrigation, over the period 2008–2019.

et al. 2016; Marra et al. 2016; Tinoco et al. 2016; Sabri et al. 2017; Wahba 2017; El Jaouhari et al. 2018; Anabela Fernandes-Silva et al. 2018; Abdelkhalik et al. 2019; Mandal et al. 2020; Ozer et al. 2020).

4.3 Water use efficiency and water productivity

Figure 10 points out the annual variety of water use efficiency per hectare over the period 2008–2019 under full irrigation supply and deficit irrigation. The visual examination of Figure 10 shows that the peak of the water use efficiency per hectare for full irrigation supply and deficit irrigation is respectively 1.46 and 2.28 kg/m^3. However, the minimum water use efficiency per hectare values for both scenarios is respectively 0.58 and 0.63 kg/m^3. The mean value of water use efficiency per hectare for both scenarios is respectively 0.81 and 1.06 kg/m^3, a standard deviation respectively of 0.24 and 0.46. As expected, deficit irrigation can enhance the water use efficiency by an average of 0.25 kg/m^3.

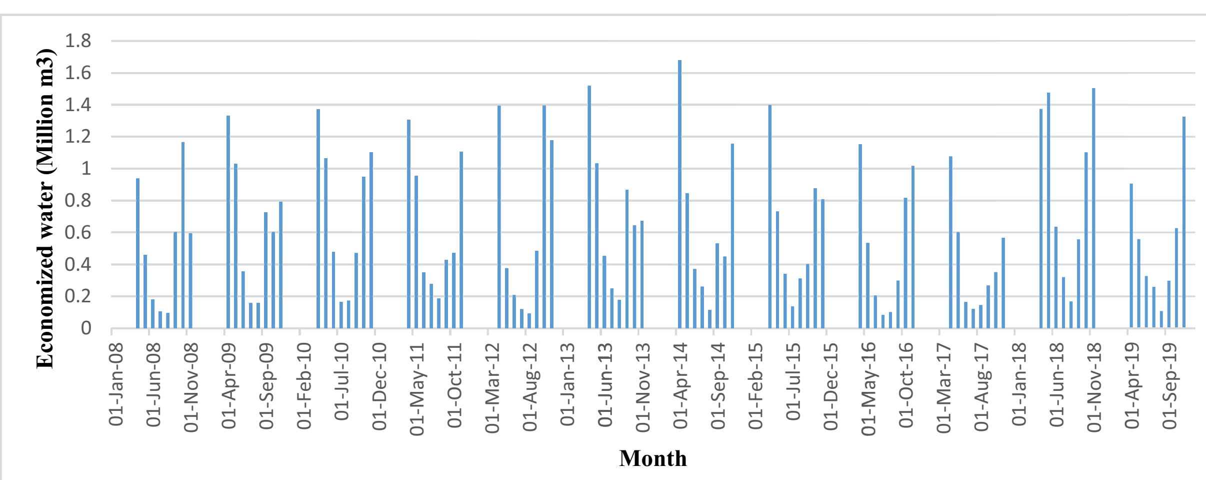

Figure 9: Economized water from the applied deficit irrigation over the period 2008–2019.

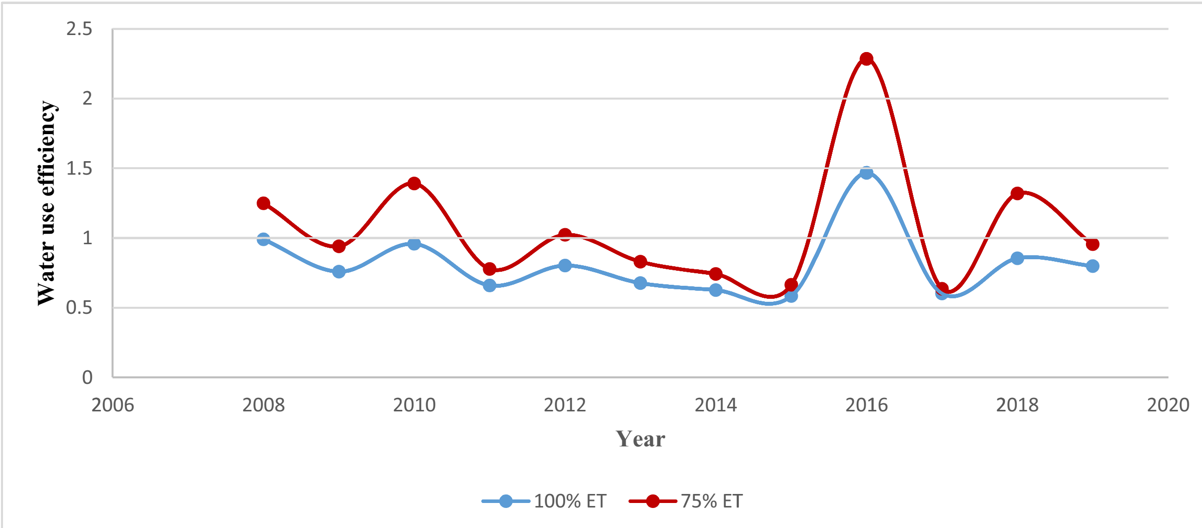

Figure 10: Water use efficiency under full irrigation supply and deficit irrigation, over the period 2008–2019.

Figure 11 points out the annual variation of water productivity per hectare over the period 2008–2019 under full irrigation supply and deficit irrigation. The visual examination of Figure 11 shows that the peak of the water productivity per hectare for full irrigation supply and deficit irrigation is respectively 3.10 and 4.84 Dh/m^3. However, the minimum water productivity per hectare values for both scenarios is respectively 1.23 and 1.34 Dh/m^3. The mean value of water productivity per hectare for both scenarios is respectively 1.72 and 2.26 Dh/m^3, with a standard deviation respectively of 0.52 and 0.97. As expected, deficit irrigation can enhance the water productivity by an average of 0.54 Dh/m^3.

5 Conclusion

The climate change predictions expose an overall rising trend in the temperature and a decreasing trend in the rainfall and relative humidity over the four studied decays (IPCC); it also uncovers the intra-seasonal fluctuation – humid and rainy in the winter and dry in the summer, the autumn and the spring are considered as transition season where the temperature is moderated. Then, the agriculture productivity during the hydrologic year, especially that under current climate changes the evapotranspiration, did not assure the complete return of water to the hydrological cycle. One of the most efficient

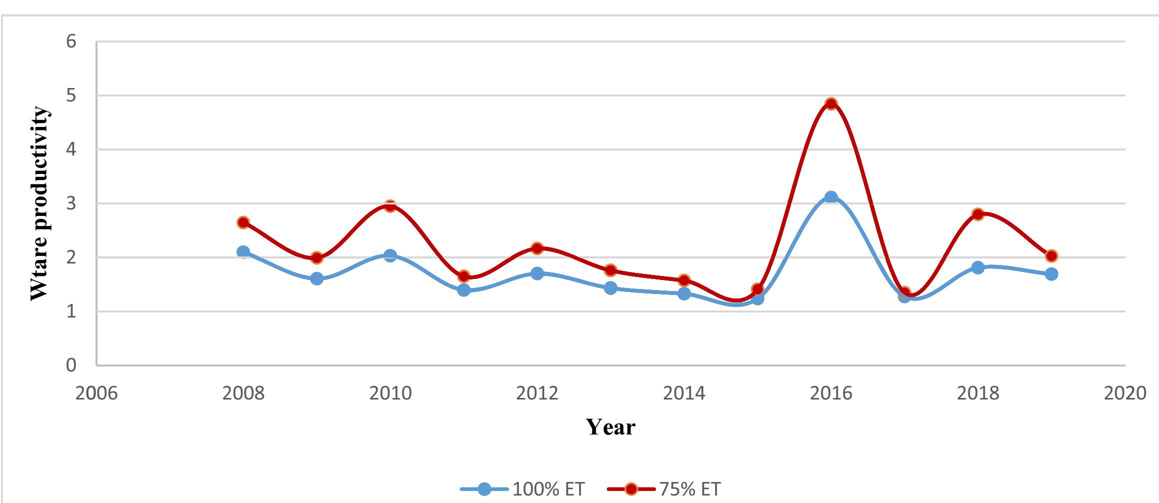

Figure 11: Water productivity under full irrigation supply and deficit irrigation, over the period 2008–2019.

adaptation strategies is deficit irrigation. The presented study proposed an integral approach to tackle climate change issues; the first part of the paper is focused on the extraction of monthly evaporation data from MODIS16A2 under Google Earth Engine (GEE), data that are used in the second part of the study, which aims to assess the efficiency of deficit irrigation on a plot of 2,500 olive tree; this theoretical study is applied on the Middle Sebou and Innaouene downstream perimeter. The irrigation water requirement (IWR) was estimated between the evapotranspiration and adequate rainfall (P_e). The assumption was the ability of the deficit irrigation to economize water and provide a good crop in terms of quality and quantity.

The study first deals with the problem of data acquisition; the evapotranspiration parameters are mandatory for carrying out the study; the problem encountered with these data is the absence of the monitoring station that provides temperature, and even if available, the spatial and temporal resolution are low; the processing of MODIS data under the Google Earth Engine (GEE) provides the required data. The obtained results show that under deficit irrigation condition, 17% of the total used water could be saved, and then reduce the water irrigation supply by an average of 5 Mm^3; a slight decrease in olive production was noted and estimated as 0.5 t/ha. The obtained result is aligned with the previous study carried out about the deficit irrigation. For instance (Liu et al. 2013), assessed the crop water demand and discussed the suitable irrigation system for two different regions, Tibet and China; the results claim that sustainable irrigation systems may be more successful to deal with water deficit drawbacks. Another study was processed by Zhou et al. (2018). It aims to compare two irrigation systems, gun irrigation and drip irrigation on potatoes yield; the results underline that the drip irrigation provides a significant result in terms of water-saving compared to the gun irrigation which, moreover, causes the nitrate leaching and reintroduces the agriculture process in the circle; pollutants generator- damaged sector. Other study was carried out on the same; it aims to evaluate the agro-physiological response of potato in the plain of Sais (Morocco); the used methodology consists of implementing an experimental plot and applying three irrigation regimes, the 100, 75, and 50% of crop evapotranspiration; the obtained results claimed that the best agronomic water use efficiency was recorded for irrigated treatments at 75% of ET_c (El Bergui et al. 2020).

Theoretically, the obtained results are satisfactory; however, to transpose the paradigm to practice and guarantee a successful deficit irrigation, a good knowledge of the physiologic characteristic of the crop and also the soil texture is required. Every type of crop has specific needed amount of water; the available water of a plant refers to a difference between water content at field capacity and water content at permanent wilting point which is the minimum amount of water that a plant requires to wilt; then, if the provided water is below this value, the plant losses turgidity and wilt. Concerning the soil, in a sandy soil most of percolated water is infiltrated, and the loam soil generally disposes of the greater water capacity due to its texture. Moreover, to adopt the DI as a global strategy, an inventory of the crop more suitable to DI should be established, according to the Food and Agriculture Organization; crops that are less sensitive to the DI are those with a short growing season with high tolerance to drought. The application of the technique on crops that need a humid condition and high water amount during all the growth cycle maybe less to no suitable for it.

The current study goes hand-in-hand with the Morocco Green Plan of water-saving. The deficit irrigation is a good alternative to enhance irrigation water efficiency taking into account the hydrologic conditions, especially evapotranspiration. In economic terms, the result shows that with deficit irrigation, the decision-maker, or the farmer, could save about 5 million m^3 per year, which is a boost to the global economy if the method is transposed and applied to other Moroccan regions.

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