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Estimation of Water Requirements with a View to Wind-Powered Pumping for the Optimal Irrigation of Date Palms at the Initial Growth Stage in the Sahel of Burkina Faso

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Abstract

This study aims to estimate the irrigation water requirements of a young date palm plantation located in Dori, within the Sahelian region of Burkina Faso. The Cropwat 8.0 software, based on the FAO Penman-Monteith method, was used to estimate reference evapotranspiration, effective rainfall, and crop irrigation water requirements from climatic, soil, and crop data. Simulations carried out for a 1-hectare plantation revealed that reference evapotranspiration ranged from 1.68 mm/day in December to 5.55 mm/day in June, while crop coefficients varied between 0.40 and 0.50. The annual water requirement of the date palm plantation exceeded 2559 mm, corresponding to a pumping demand of more than 23,196 m^3 of water per year. These findings provide a scientific basis for the design and sizing of efficient drip irrigation systems and contribute to the sustainable development of date palm cultivation across the African Sahel.

Keywords

Date Palm, Sahel, Evapotranspiration, Irrigation, Water Requirements

1. Introduction

The Sahel is an arid zone threatened by climate change, which leads to major social and environmental vulnerability. Agriculture in Sahelian countries must cope with these changes in order to ensure food security for their growing populations.

The use of plant species with high phenological plasticity, such as the date palm, is one of the responses to difficult pedoclimatic conditions to which few plants are adapted.

The date palm tolerates drought well, but it has very high irrigation water requirements for its development and for satisfactory production [1]. However, under arid conditions or in the case of a prolonged dry season, irrigation is necessary to compensate for the transpiration deficit of crops and evaporation from the soil surface resulting from insufficient or irregular rainfall. Water applications must be sufficient to meet all the needs of the date palm and to compensate for losses due to infiltration and evaporation at the soil surface [2].

Date palm water requirements are largely determined by the evaporation phenomenon, the intensity of which depends, on the one hand, on meteorological data and, on the other hand, on the plant's own requirements and its vegetative stage [3].

The evaluation of date palm water requirements takes into account palm evapotranspiration and the crop coefficient, which depends on the stage of palm development and the climatic conditions of the cultivation area [4].

Evapotranspiration depends on radiant solar energy and atmospheric turbulence, which are two phenomena directly related to temperature, air humidity, wind, and sunshine duration [5].

Evapotranspiration is one of the most difficult components of the hydrological cycle to quantify because of its complexity within the soil-earth-plant system [6]. Its estimation is important for irrigation programs, planning, and water resources management [7].

Several studies on evapotranspiration have been conducted in West Africa. In Senegal, [8] also evaluated the TURC method using annual data from five stations. [9] evaluated, calibrated, and then validated six methods for estimating reference evapotranspiration in the Senegal River delta, using daily data from the Saint-Louis and Ndiaye stations.

In Burkina Faso, [10] worked on methods for estimating actual evapotranspiration in the Kou watershed. [11] evaluated twenty methods for estimating daily reference evapotranspiration.

Among evapotranspiration estimation methods, the Penman-Monteith (FAO-PM) method has been recommended by the FAO as the standard method [12]. [8] showed that the performance of the FAO-PM method lies in the large number of meteorological variables it integrates: temperature, solar radiation, relative humidity, and wind speed. In Benin, [13] used the Penman-Monteith method to calculate potential evapotranspiration at hourly and daily scales on four sites in the upper Ouémé basin. More recently, [9] used the Penman-Monteith and [14] methods to estimate evapotranspiration at the country scale.

Evaluating date palm water requirements will make it possible to determine the irrigation water requirement while taking rainfall at the date palm cultivation site into account.

The localized irrigation technique known as "drip irrigation" was chosen in this study in order to preserve water resources [1]. The use of subsurface drip irrigation is efficient in further saving irrigation water. It has the advantage of delivering water near the roots, thereby improving irrigation performance [15]. Water-use efficiency in a subsurface drip irrigation system can exceed 95% if it is well designed [16].

The objective of this study is to evaluate the water requirements and the quantities of water that must be pumped for drip irrigation of young date palms at the initial stage of cultivation in Dori, located in the Sahelian zone in northeastern Burkina Faso, West Africa.

2. Materials and Methods

The objective of this study is to estimate, using simulation software, the water requirements of young date palms and the volume of water that must be pumped to meet irrigation demands during periods of insufficient or no rainfall under sandy soil conditions.

2.1. Presentation of the Study Site

Dori is a town in northeastern Burkina Faso, the capital of the department of the same name, in Séno Province and in the Liptako Region. The municipality of Dori covers an area of approximately 2532 km^2, with a population of 46,521 inhabitants [17]. The Dori site corresponds to the following geographical coordinates: 0˚30 west longitude and 14˚03 north latitude.

The climate of the Sahel is characterized by two seasons: a dry season lasting 8 to 9 months (from November to June) and a wet season lasting 3 to 4 months (from June to September) [18]. The dry season is subdivided into two sub-seasons: dry and cold, and dry and hot. This Sahelian-type climate is hot and dry from March to June, rainy from July to October, and cold and dry from November to February. It is characterized by long periods of drought [19]. During the year, the temperature generally ranges from 16 to 41˚C and is rarely below 13˚C or above 44˚C. Rainfall is irregular and lasts only about 3 months. It is approximately 567 mm/year, with strong evapotranspiration approaching 3 meters [20]. The average daily incident solar radiation in Dori is mainly constant, at around 5.7 kWh/m^2/day [21]. Four soil types exist in Dori: soils on aeolian sands, deep clayey soils or eutrophic brown soils, deep alluvial soils, and medium- and shallow-depth soils [22].

2.2. Climatic Data of the Site

The data used in this study were provided by the National Directorate of Meteorology of Burkina Faso [5]. They consist of observational records of air temperature, relative humidity, wind speed, sunshine duration, and rainfall collected at the Dori meteorological station over a 10-year period, from 2004 to 2013. The measurements were recorded daily at 3-hour intervals.

The climatic data entered into the software are the values presented correspond to the monthly averages calculated from the provided data which summarized in **Table 1**.

Table 1. Climatic data for the Dori site.

Month	Minimum temperature (˚C)	Maximum temperature (˚C)	Air humidity (%)	Wind speed (km/h)	Sunshine (hours)	Rainfall (mm)
January	16	32	0	17	9	0
February	19	35	0	17	8.5	0
March	23	39	2	16	8.1	0
April	27	41	15	13	9	8
May	29	41	40	15	9.3	14
June	28	38	78	15	9.5	48
July	26	35	95	13	10	105
August	25	33	99	12	9.5	133
September	25	35	98	10	9.9	74
October	25	38	50	10	9.1	11
November	20	36	1	13	9.9	0
December	17	32	0	15	9.1	0

It can be seen that in Dori, the highest minimum temperature is observed in May, at 29˚C. The maximum temperature of 41˚C is recorded in April and May. As for relative air humidity, the highest value (99%) is measured in August. The highest wind speed (17 km/day) is obtained in January and February. The highest number of sunshine hours is 10 hours at the Dori site, recorded in July.

2.3. Date Palm

The date palm is scientifically known as *Phoenix dactylifera*. It is a monocotyledonous plant of the Arecaceae family, originally from humid tropical regions [15], but over time some species have adapted to hot, semi-arid, or arid climates. The date palm is a single-stem species composed of a stipe surmounted by a crown of fronds. **Figure 1** shows the date palm variety selected in this study.

Figure 1. Photograph of a variety of young date palms.

The root system of the date palm is arranged in bundles of roots, sometimes with branches. Figure 2 shows the root system of the date palm.

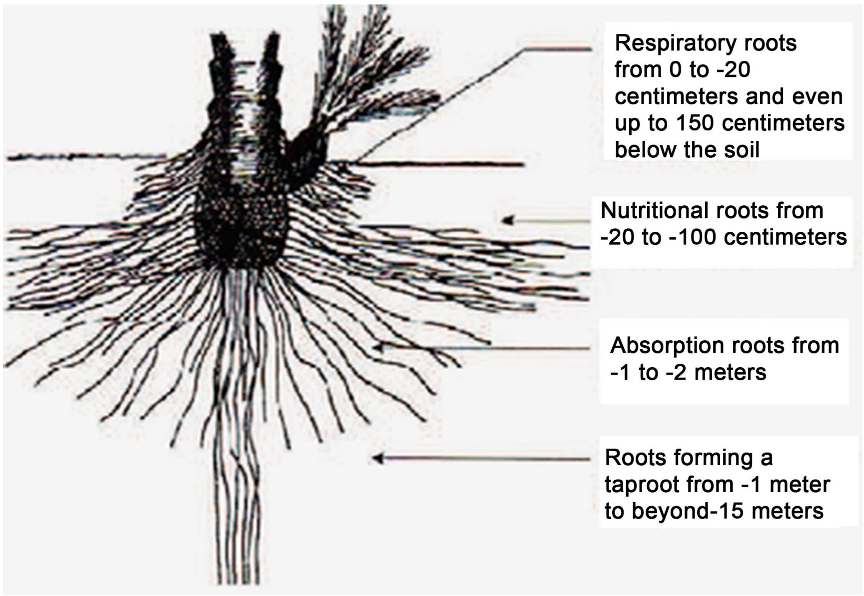

Figure 2. Types of date palm roots [2].

The root system of young date palms consists of four types of roots. The respiratory roots extend from 0 to 20 cm below the soil surface; this zone contains pneumatodes, small mealy or wart-like outgrowths that are essential for plant aeration. The nutrient roots are located between 20 and 100 cm depth, where a high density of fine roots is found. The water absorption roots extend from 100 to 200 cm depth and are responsible for absorbing moisture and mineral nutrients. Finally, the anchorage roots penetrate deeper into the soil, sometimes exceeding 6 m depending on soil conditions, and form a dense root network that provides structural support and stability to the palm [2]. The roots may extend up to 25 m around the palm tree and up to 17 m deep if water requirements are not met at the level of the nutritional roots. Root density and depth allow the date palm to withstand water stress and drought conditions.

Water consumption for date palm irrigation varies considerably depending on the palm variety, climatic conditions, seasons, and soil types [23]. The Penman model, based on knowledge of evapotranspiration, is adopted for estimating date palm water requirements.

2.4. Presentation of the Simulation Tool

For the calculation of irrigation water requirements of the date palm at the Dori site, the Cropwat 8.0 software developed by the FAO is used. This software makes it possible to calculate crop water requirements and irrigation requirements from climatic and crop data. These data can be entered directly into Cropwat or imported from other applications. The program also makes it possible to establish irrigation schedules for different management conditions and to calculate the water supply of irrigated perimeters for various cropping patterns [24].

The most important factors for model parameterization are the water flux, consisting of evapotranspiration and precipitation, as well as the crop coefficient of the plant (K_c) [25]. The meteorological data required for model parameterization are air temperature, air humidity, wind speed, precipitation, and evapotranspiration. In addition, Cropwat determines date palm water requirements based on the duration of each phase and the period of the year.

The results displayed by the software include the climatic table, the date palm water requirements table, and the irrigation schedule table. The climatic table gathers all climatic data that can be entered into the software. It should be noted that only one value per month is calculated. The date palm water requirements table includes all crop- and rainfall-related data. In this table, the values of reference evapotranspiration, the proportion of the area occupied by the crop type, and the evolution of K_c as a function of date can also be recorded. The irrigation schedule table gathers all soil characteristics: total available water, readily available water, rainfall, actual evapotranspiration of the plant, etc.

2.5. Theoretical Approach

The estimation of irrigation water requirement takes into account date palm evapotranspiration, soil, and rainfall at the cultivation site [26].

2.5.1. Calculation of Date Palm Evapotranspiration

Evapotranspiration is the quantity of water vapor transferred to the atmosphere through transpiration of the date palm via its stomata and through evaporation from the soil surface [27]. For the date palm, transpiration represents 32% of the total received radiation and 53% of the net radiation [28]. Two concepts should be clearly identified in this regard: reference evapotranspiration and maximum evapotranspiration [29].

Reference evapotranspiration corresponds to a characterization of the evaporative power of the atmosphere at a given place and at a specific time of the year and does not take into account crop characteristics or soil factors [27]. There are many empirical formulas for estimating reference evapotranspiration. The Penman-Monteith method is recommended by the FAO as the reference model because of its performance under different climatic conditions [30]. It is given by relation (1):

$$ET_0 = \frac{0.408\Delta\left(R_n - G\right) + \gamma \frac{900}{T+273} U_2\left(e_0 - e_a\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \tag{1}$$

where: ET_0 is daily reference evapotranspiration, R_n is net radiation at the crop surface, G is soil heat flux, T is the mean air temperature measured at 2 m above the ground, U_2 is wind speed at 2 m above the ground, e_0 and e_a are the saturated and actual vapor pressures of the air at 2 m above the ground, respectively, Δ is the slope of the vapor pressure curve, and γ is the psychrometric constant.

2.5.2. Date Palm Crop Coefficient

The crop coefficient (K_c) is the ratio of the maximum evapotranspiration of a crop during a given period of its vegetative cycle, that is, under optimal conditions, to the reference evapotranspiration. The crop coefficient is given by expression (2):

$$K_c = K_s K_{cb} + K_e \tag{2}$$

where: K_c is the date palm crop coefficient, K_{cb} is a crop coefficient, K_e is an evaporation coefficient, and K_s is a water stress reduction coefficient.

In Burkina Faso, the crop coefficients (K_c) of date palm follow the standard values established for Sahelian conditions and vary according to the four main growth stages of the crop. During the initial growth stage (young palms/establishment phase), the crop coefficient ranges from 0.30 to 0.50 [31]. These average values should be adjusted to account for the hot, dry, and windy climatic conditions prevailing in Burkina Faso.

2.6. Date Palm Water Consumption and Irrigation Requirements

Maximum evapotranspiration can be estimated from reference evapotranspiration corrected by a coefficient called the crop coefficient at different stages of palm development [15]. Date palm water consumption is given by Equation (3) [23].

$$ET_M = K_c \times ET_0 \tag{3}$$

where: ET_M is maximum evapotranspiration, K_c is the date palm crop coefficient, and ET_0 is daily reference evapotranspiration.

The irrigation requirement is the volume of water needed to compensate for the deficit between, on the one hand, potential evaporation and, on the other hand, effective rainfall during the period of palm growth and the change in soil water content. The Dori site is located in a livestock-producing area where sheep and cattle constitute the predominant livestock. The sandy soil is amended with cattle manure, which modifies soil water dynamics, particularly the rate at which water infiltrates into the soil. According to [32], the application of organic amendments (sheep and cattle manure) has a significant effect on most soil properties, especially its water-holding capacity. According [33], the total porosity of the amended sandy soil is 43.7%.

Knowledge of irrigation requirement makes it possible to determine the irrigation dose and frequency by adjusting requirements to local conditions. Water requirements are obtained from a water balance according to relation (4):

$$\text{Water requirement} = ET_M - \text{Effective rainfall} \tag{4}$$

Several methods are available in Cropwat for estimating effective rainfall. These include the Fixed Percentage method, which assumes that effective rainfall is a constante fraction of total rainfall (typically about 80%); the FAO Formula method, which is based on a water balance approach using a two-part linear equation according to the amount of rainfall ; and the Rainfall Probability method, a probabilistic approach that is particularly suitable for arid and semi-arid regions [34]. These methods estimate the proportion of rainfall that is effectively stored within the crop root zone and is therefore available for crop use, excluding losses due to surface runoff and deep percolation.

By default, Cropwat applies the empirical method developed by the USDA Soil Conservation Service (USDA-SCS), in which effective rainfall (P_{eff}) is automatically estimated from the measured total rainfall (P_{tot}) using two different equations [35].

For monthly rainfall less than or equal to 250 mm, effective rainfall is calculated using Equation (5):

$$P_{eff} = P_{tot} \times \frac{125 - 0.2 P_{tot}}{125} \tag{5}$$

For monthly rainfall greater than 250 mm, effective rainfall is calculated using Equation (6):

$$P_{eff} = 125 + 0.1 P_{tot} \tag{6}$$

2.7. Evaluation of the Quantity of Drip Irrigation Water

An empirical relationship exists between the quantities of water required for surface irrigation and those to be applied in the case of localized irrigation, expressed by Equation (7) [36]:

$$Q_l = Q_g \times \left(k_0 + 0.90\,p\right) \tag{7}$$

where: Q_l is the water volume for localized irrigation, Q_g is the water volume for surface irrigation, p is the fraction of soil covered by the plant canopy, and k_0 is the oasis effect coefficient.

According to the FAO-56 methodology, the fraction of soil covered by the canopy (p) during the initial growth stage (young plants) ranges from 0.10 to 0.30, while the oasis coefficient (k_0) typically varies between 1.05 and 1.25. Under the Sahelian climatic conditions and drip irrigation system considered in this study, the canopy cover fraction (p) was set to 0.20, and the oasis effect was incorporated into the adjustment of the crop coefficient (K_c).

3. Results

The calculation of water requirements was carried out for an area of one (1) hectare of date palms at the initial stage. This is equivalent to 120 date palms spaced 10 meters apart. The calculation of reference evapotranspiration, crop coefficient, and water requirements are performed using version 8.0 of the FAO Cropwat software. Running this program required parameters related to climate, soil, and the date palm.

3.1. Values of Solar Radiation and Reference Evapotranspiration

The values of solar radiation and reference evapotranspiration are given in **Table 2**.

Table 2. Solar radiation and evapotranspiration.

Month	Solar radiation (MJ/m²/day)	Reference evapotranspiration (mm/day)
January	19.5	1.77
February	20.4	2.06
March	21.3	2.8
April	23.4	3.94
May	23.7	5
June	23.7	5.55
July	23.7	5.43
August	23.9	5.23
September	24.1	5.32
October	21.6	4.25
November	21	2.15
December	19.0	1.68
Average	22.11	3.77

The month of June records the highest daily average reference evapotranspiration (ET_0) value (5.55 millimeters per day), with solar radiation of 23.7 MJ/m^2/day. The lowest reference evapotranspiration value (1.68 millimeters per day) is obtained in December, with solar radiation of 19.0 MJ/m^2/day. It is observed that the daily average values of reference evapotranspiration and solar radiation in November, December, January, and February are very close. These four months constitute the cold dry season of the year. From March onward, the daily average values of reference evapotranspiration increase very rapidly to reach their maximum value in June. During this period, the solar radiation value remains practically constant. The reference evapotranspiration values then decrease to reach their minimum value in December.

Figure 3 shows the evolution of the daily average value of solar radiation and reference evapotranspiration as a function of the months of the year at the Dori site.

This curve shows that monthly reference evapotranspiration in Dori is practically equal to 2 mm for the months of November, December, January, and February. It increases during March, April, May, and June, reaching a maximum of 5.55 mm in June. It then decreases during July, August, September, and October.

3.2. Effective Rainfall Values

As rainfall data are loaded into Cropwat 8.0, effective rainfall is automatically calculated. Table 3 gives the values of rainfall recorded at the site and the values of effective rainfall calculated by Cropwat.

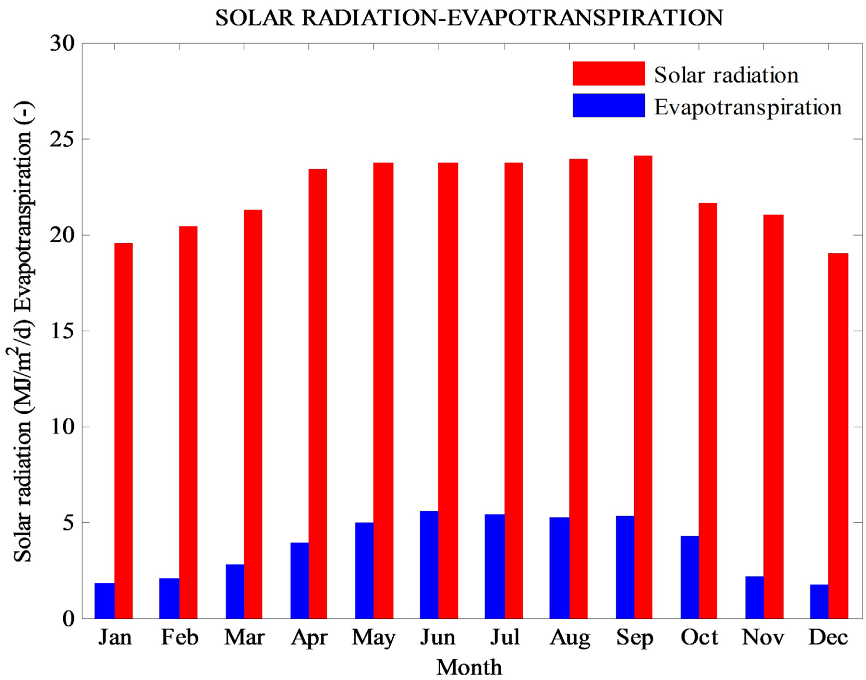

Figure 3. Curve showing the evolution of solar radiation and reference evapotranspiration in Dori.

Table 3. Daily average rainfall at the Dori site.

Month	Rainfall (mm)	Effective rainfall (mm)	Difference (mm)
January	0	0	0
February	0	0	0
March	0	0	0
April	8	7.9	0.1
May	14	13.7	0.3
June	48	44.3	3.7
July	105	87.4	17.6
August	133	104.7	28.3
September	74	65.2	8.8
October	11	10.8	0.2
November	0	0	0
December	0	0	0
Average	393	334	59

Figure 4 shows the evolution of rainfall depths and effective rainfall at the Dori site.

It can be observed that the amount of rainfall received has practically the same values as effective rainfall during the months from January to May and in October. From June to September, the gap between rainfall recorded at the site and effective rainfall calculated becomes large. The greatest difference is obtained in August, with a value of 28.3 millimeters/day (Table 3).

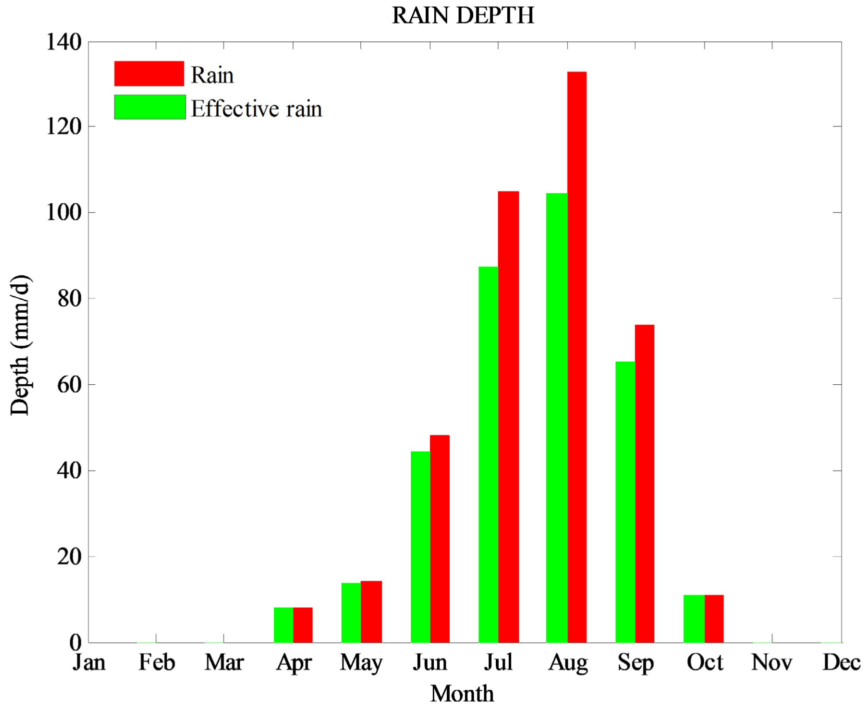

Figure 4. Curve showing the evolution of rainfall depths and effective rainfall at the Dori site.

3.3. Values of Date Palm Crop Coefficients at the Dori Site

Table 4 gives the values of date palm crop coefficients provided by Cropwat.

Table 4. Date palm crop coefficient values.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
K_c (-)	0.4	0.4	0.5	0.5	0.5	0.5	0.45	0.45	0.45	0.45	0.4	0.4

The value of the date palm crop coefficients at the Dori site is 0.4 for the months of November, December, January, and February, corresponding to the cool dry season, 0.50 for the months of March, April, May, and June, corresponding to the hot dry season, and 0.45 for the remaining months, corresponding to the rainy season. These crop coefficient values are consistent because this is the initial stage of date palm cultivation.

3.4. Irrigation Water Requirements for a One-Hectare Date Palm Plantation

The values of date palm water consumption, irrigation requirement, and the quantity of water to be supplied at the Dori site for a one-hectare plantation comprising 120 date palms are summarized in Table 5.

Table 5. Water consumption and water requirements of date palms.

Month	Monthly consumption (mm/month)	Net irrigation requirement (mm/month)	Quantity of water to be supplied (mm/month)
January	87.084	87.084	91.667
February	101.352	101.352	106.686
March	172.200	172.200	181.263
April	242.310	234.410	246.747
May	307.500	293.800	309.263
June	341.325	297.025	312.658
July	300.550	213.150	224.369
August	289.480	184.780	194.506
September	294.462	229.262	241.328
October	235.237	224.437	236.250
November	105.780	105.780	111.347
December	83.656	82.656	87.006
Total	2560.936	2225.936	2343.09

Figure 5 shows the evolution of date palm water requirements at the Dori site.

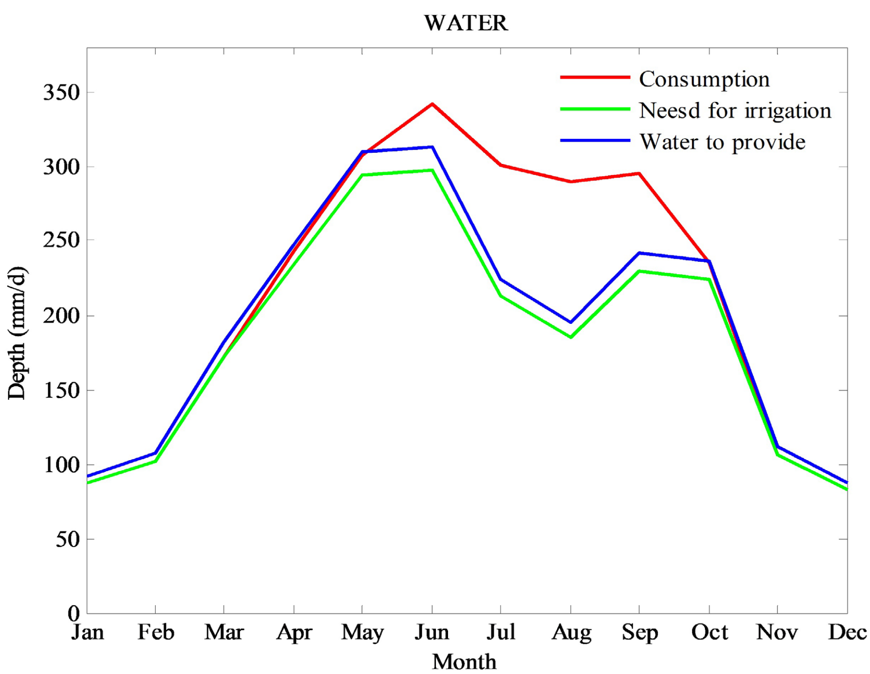

Figure 5. Curve showing the evolution of date palm water requirements.

According to the results in **Table 5**, water consumption increases in the same way as reference evapotranspiration. This increase is observed particularly during the period from March to September. During this period, the date palm becomes active, and this period coincides with the hot season. Total date palm water consumption at the Dori site exceeds 2559.936 millimeters per year. The lowest monthly irrigation requirement occurs in December, at 82.656 millimeters per month. It increases from January to June and reaches its maximum value in June, with a requirement of 297.025 millimeters of water. Thereafter, the irrigation requirement decreases to reach its minimum value of 82.656 millimeters per month in December. The quantity of water to be supplied to date palms increases in the same way as the irrigation requirements. The quantity of water to be supplied to date palms reaches 2343.09 millimeters per year.

3.5. Quantity of Water to Be Pumped for Date Palm Irrigation

Table 6 gives the monthly quantities of water to be pumped for drip irrigation of one (1) hectare of date palms.

Table 6. Quantities of water to be pumped.

Month	Quantity of water to be pumped (mm/month)	Quantity of water to be pumped (m^3/month)
January	100.834	907.506
February	117.355	1056.194
March	199.389	1794.505
April	271.422	2442.799
May	340.189	3061.705
June	343.923	3095.313
July	246.805	2221.252
August	213.956	1925.607
September	265.461	2389.151
October	259.875	2338.875
November	122.482	1102.339
December	95.707	861.362
Total	2577.398	23196.608

The minimum quantity of water to be pumped at the Dori site occurs in December, with a value of 95.70 mm/month. The highest value is recorded in June, with a value of 343.92 mm/month. The average quantity of water to be pumped is 214.783 mm/month. The quantity of water to be pumped increases from January to June, when it reaches its maximum value. It then decreases to reach its minimum value in December. The total quantity of water to be pumped is 23,196 cubic meters per year. The quantity of water to be pumped is rather high, since the Dori site is located in a Sahelian zone where evapotranspiration is very high.

4. Discussion

The results obtained highlight strong seasonal variability in reference evapotranspiration (ET_0) at the Dori site, with a maximum observed in June (5.55 mm/day) and a minimum in December (1.68 mm/day). This variation is consistent with Sahelian climatic conditions characterized by high temperatures and strong solar radiation during the hot season, thereby promoting an increase in evapotranspiration. These observations are in agreement with previous work conducted in arid areas by [11] as well as [9], who showed that ET_0 is strongly correlated with solar radiation intensity and high temperatures.

The date palm crop coefficients (K_c), ranging from 0.4 to 0.5, reflect relatively moderate water consumption at the initial stage of development. This range of values is comparable to those reported in the literature by [19] for young date palm plantations, where the still limited leaf area reduces transpiration losses. However, these values could change significantly with the growth of the plant canopy, implying a progressive increase in the water requirements of the young date palm.

The annual water consumption estimated at more than 2559 mm per year highlights the importance of the water requirements of the date palm even at the initial stage, despite its recognized capacity as a drought-resistant plant. This confirms that, although tolerant of arid conditions, the date palm requires sufficient water supply to ensure optimal growth and satisfactory yield. This finding is also supported by several studies, notably [24], indicating that prolonged water stress can severely limit productivity.

Furthermore, the quantity of water to be pumped, estimated at more than 23,196 m^3/year for one hectare of cultivation, highlights the scale of the water resources required for effective irrigation in the Sahelian context. This requirement poses major challenges in terms of water resource availability and the energy cost of pumping. In this context, the use of wind-powered pumping appears to be a relevant and sustainable solution, particularly in areas where access to conventional energy is limited.

Moreover, the low contribution of rainfall in covering water requirements, typical of the Sahelian climate, reinforces dependence on irrigation. This justifies the use of simulation tools such as Cropwat 8.0 for rational water management, enabling optimization of water applications according to the real requirements of crops such as date palm cultivation.

Finally, these results, which are consistent with those of [1] [15] [21], have important implications for sizing pumping systems and irrigation infrastructure. A precise estimation of water requirements will make it possible not only to ensure adequate irrigation, but also to minimize losses and improve the overall efficiency of the system.

5. Conclusions

The objective of this study is to evaluate the water requirements and the quantities of water that must be pumped for drip irrigation of young date palms at the initial stage of cultivation in Dori, located in the Sahelian zone in northeastern Burkina

Faso, West Africa.

Cropwat 8.0 software, developed by the FAO, was used to calculate reference evapotranspiration, crop coefficient, and the water requirements of date palms. The program input parameters are those related to climate, soil, and the date palm. The calculation of irrigation requirements was carried out for one (1) hectare containing 120 date palms at the initial stage. The results showed that the highest daily average reference evapotranspiration value, 5.55 millimeters per day, was recorded in June, and the lowest value, 1.68 millimeters per day, was obtained in December. The values of the date palm crop coefficients at the Dori site vary between 0.4 and 0.5. Total date palm water consumption at the Dori site exceeds 2559 millimeters per year. The total quantity of water to be pumped is 23,196 cubic meters per year. The maximum, minimum, and average values of the quantity of water to be pumped are useful for calculating the pumping flow rate and for sizing the water pumping system required for optimal drip irrigation of date palms. These results will serve as a reference for estimating the quantities required for date palm irrigation in the Sahel of Burkina Faso and throughout the Sahelian zone in Africa.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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