Estimation of Barley (Hordeum Vulgare L.) Crop Water Requirements Using Cropwat Software in Ksar-Chellala Region, Algeria

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Abstract

This paper estimates the reference Evapotranspiration (ET0) and Water requirements of barley (Hordeum vulgare L.) in Ksar-Chellala region, Algeria, for one dry year by using CROPWAT software. Determination of Evapotranspiration (ET) is important in application such as irrigation design, irrigation scheduling, water resource management, hydrology and cropping systems modeling. Estimation of crop water requirements of barley (CWR_b) respected the methodology adopted by the service of development and management service of FAO, based on the use of software CROPWAT 8.0. The total water requirements for barley depend on a variety of target yields and crops management. The period of climatic data used is 23 years (1990-2012), the average rain in this period is 254 mm. The total rain of the dry year is 190 mm. The results of this study show, during the vegetative cycle of barley which is 6 months, the calculation of ET_0 is 453 mm, the potential water which was used by the crop barley is estimated at 281.4 mm, the efficiency of rainfall is 69 mm and a total water requirements of barley (CWR_b) equals to 211 mm, this amount distributed on three months coincided with important stages of development in barley. The supplementary irrigation in these conditions with optimal contents equals water requirements estimated by CROPWAT software that increases significantly grain yield of barely. Consequently, the gross irrigation water requirements ($GIWR$) of 1250000 ha which project to grow barley in the Algerian steppes regions are estimated at 3.77 billion and this for a dry year and a irrigation efficiency of 70%.

Keywords

Introduction

In agriculture, the irrigated areas in Algeria have evolved from 905300 ha in 2007 to 1.64 million ha in 2014. Algeria, an arid to semi-arid country, is characterized by a high population growth rate, making important increase in agricultural productivity to ensure food security. Agricultural development is strongly influenced by irrigation. Agriculture has become highly strategic, because water resources are highly sensitive to climatic conditions, and the soils are weakened by the aggressiveness of natural phenomena, in particular desertification. The country is vulnerable to climate change; it experienced more frequent droughts, increased desertification, greater wind and water erosion in recent years. As well as a decreased rainfall over the past 30 years that has affected dams, groundwater tables and salinization due to aquifer over-exploitation and drought (CEDARE, 2014).

Water resources management has been a challenge in Algeria due to precipitation shortage in recent years. Economically crops production has direct relationship with irrigation. Every plant has specific water supply and needs different amount in different time and in different soil depth (O`Shaughnessy et al., 2012), (Yavuz et al., 2015). However, irrigation scheduling has been based on the predicted crop water requirements (CWR). 'Crop water requirements' is defined as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit

plant growth and crop yield (Allen et al., 1998).

As the crop grows and extracts water from the soil to satisfy its evapotranspiration requirements (*ETc*), the stored soil water is gradually depleted. In general, the net irrigation water requirements (*NIWR*) is the amount of water required to refill the root zone soil water content back up to field capacity. This amount, which is the difference between field capacity and current soil water level, corresponds to the soil water deficit (Andales, Chávez, and Bauder, 2015).

Plant responses to water deficit are dependent on the amount of water lost, the rate of loss and the duration of the stressed condition (Bray, 1997).

The objective of a proper irrigation schedule is to supply the right amount of water before harmful stress occurs (optimum quantity and timing). It's very important to define a precise strategy when designing an irrigation system. Knowing the crop water requirements enables to determine the proper irrigation schedule at any given time; irrigation managers need to calculate the best time to irrigate, and how much water to use so that crops are economically productive, and water resources are managed in a sustainable manner. The calculation of seasonal and peak project supply required for a given cropping pattern and intensity includes the (*NIWR*) and other water needs including leaching of salts and efficiency of the distribution system Irrigation requirements are one of the principal parameters for the planning, design and operation of irrigation and water resources systems. Detailed knowledge of the (*NIWR*) and its temporal and spatial variability is essential for assessing the adequacy of water resources, to evaluate the need of storage reservoirs and to determine the capacity of irrigation systems. It is a parameter of prime importance in formulating the policy for optimal allocation of water resources as well as in decision-making in the day-to-day operation and management of irrigation systems (Savva and Frenken, 2002).

The spatial and temporal variation of rainfall in Ksar-Chellala region, resulting from topography and climate, makes that any action of agricultural intensification requires the recourse to the irrigation. According to several hydro geological studies in this area, the water resources mobilization is done in general by the means of drillings and/or wells feeding in the various groundwater systems which conceals a significant potential water resource.

Food and Agriculture Organization (FAO) developed software CROPWAT (Smith, 1992), which can deal with climate and crop information to determine the irrigation water requirements and also the efficiency and deficiency of the irrigation schedule. CROPWAT software includes a simple water balance model that allows the simulation of crop water stress conditions and estimations of yield reductions based on well established methodologies for determination of crop evapotranspiration (Smith, 1992) and yield response to water (Doorenbos and Kassam, 1979).

Simulation models, information systems and decision support systems can be relevant to support farmer's selection of water-use options, including crop patterns and irrigation systems, and to implement appropriate irrigation scheduling (Solinas, 2011). FAO software, such as CROPWAT, ET0 Calculator or AquaCrop, is nowadays widely used to calculate crop water and irrigation requirements and to develop irrigation schedules for different management conditions (Smith, 1992).

Barley is among the most important cereal in the world. It is one of the most ancient crops among the cereals and has played a significant role in the development of agriculture (Ullrich, 2011). Barley ranks fourth among cereals in terms of total world production. In 2009, around 54 million ha of barley were harvested, producing 152 million tons of grain at an average yield of 2.8 tons/ha (FAO, 2011)

Over the last 50 years, the average yield per hectare has increased noticeably (Pasquale, Theodore, Elias and Dirk, 2012).

Water is often the resource that most significantly limits barley yield, depending on severity of the deficiency. Seasonal evapotranspiration (*ETc*) of barley ranges from 100 to 500 mm. Barley is usually grown under rain fed situations. In some cases, however, full or partial irrigation may be applied, especially when barley is grown for malting or where double cropping is practised, with early-maturing barley followed by late-sown maize (or soybean). The seasonal water requirements for barley depend on target yield and crop management. Malt barley requires better water management than food barley to meet the standards set by the industry. During initial growth stages, crop water use ranges from 1 to 3 mm/ day, rising to 5 - 8 mm/day after canopy approaches complete cover (usually at the appearance of flag leaves), and remains high until the beginning

of canopy senescence. Although winter rainfall is sufficient in many climates to supply the full barley water requirements in the early vegetative phase, effective root zone soil moisture should not be depleted beyond 50 percent of total available water from emergence until flag leaf, after which depletions should probably not exceed 60 percent of the total available soil water until the soft dough stage. Normally, with adequate winter rainfall, border or flood irrigation of malt barley will require 2 to 3 irrigations on heavier soils corresponding with the critical growth stages. Light, sandy soils would require more frequent irrigations. Excessive soil moisture during the jointing and boot stage, coupled with high nitrogen fertility, may promote vegetative growth that could result in lodging as the crop develops. Excessive irrigation after the crop is well developed also promotes lodging (Pasquale, Theodore, Elias, Dirk, 2012). In Algeria and at the beginning of the nineteenth century, barley came at the head of cultures by its importance; it was intended for human consumption and was used as fodder complement. At present, barley ranks third in Algeria from the point of view of growing area and production. It represents currently the main animal food of sheep (Rahal-Bouziane, 2015).

However, sheep dominate in Algeria and are essentially concentrated in the steppe territory, employing 15 million head or more than 80% of the national total which is 18 million head and this according to the development office of the steppes (HCDS) in 2006, while livestock food requirements (feed grain) is: in 2005-2006, the year of low cereal prices, 60% of the feed requirements of sheep were provided by barley and 40% steppe rangelands. Cereal yields in the steppe are modest on land suitable for the cultivation of cereals, the yield varies from 03 to 05 qx/ha in poor years and from 08 to 12 qx/ha in a good year, through 05-08 qx/ha on average year. In 50 years the area under cereals (90% of barley) in the steppe has almost tripled from less than 1 million hectares in the sixties at 2.7 million hectares currently. According to HCDS until the end of 2005, 918 floodwater diversion works were rehabilitated or made, and thanks to these works, fodder production of 418 000 ha is possible today. The figures announced by the HCDS within the desertification fight days seminar held in Algiers in 2005, indicate the water engineering work shave involved only 30% of potential land which is favorable to spate irrigation (Bencherif S., 2011). Consequently, we can estimate the total area

that can be irrigated, which stands at 1250000 ha in the steppe regions with climatic and soil characteristics are almost similar to those of Ksar-Chellala region.

Finally, the aim of this study is to estimate Water requirements for barley in central steppe areas of Algeria by using CROPWAT software. In addition, to achieve a good yield, it is imperative to provide supplemental irrigation in this area and therefore we can estimate the water requirements of this large area.

Materials and methods

Study area

The agricultural region of Ksar-Chellala belongs to the central steppe areas of Algeria. The geographical coordinates of the weather station of Ksar-Chellala, are: the latitude 35°10, longitude 2°19, Altitude is 800 m above sea level, it is 3 km far from the study area. The precipitations' average during the period of climatic used data (23 years: 1990-2012) is 254 mm, Further series data of precipitation is representative of the last 30 years this is a sample spread. The climate of this region is characterized by subtropical dry semiarid Steppe (BSh): Low-latitude dry. Evaporation exceeds precipitation on average but is less than potential evaporation. Average temperature is more than 18°C (Peel, 2007).

Software used

This study is based on the methodology adopted by the Development and Management Service of FAO. It based on the use of software CROPWAT 8.0.

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. Estimation of the crop water requirements are derived from crop evapotranspiration (crop water use) which is the product of the reference evapotranspiration (ET_0) and the crop coefficient (Kc). The reference evapotranspiration (ET_0) is estimated based on the FAO Penman-Monteith method, using climatic data (Allen, 1998).

All calculation procedures used in CROPWAT 8.0 are based on two FAO publications of the Irrigation and Drainage Series, namely, No. 33 titled "Yield response to water" (Doorenbos and Kassam, 1979) and No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" (Allen,

1998). The development of irrigation schedules in CROPWAT 8.0 is based on a daily soil-water balance using various user-defined options for water supply and irrigation management conditions.

In addition, (Smith et al., 1992) reported that CROPWAT is a practical tool (software) used to help agro meteorologists, agronomists and irrigation engineers to carry out standard calculations for evapotranspiration and crop water use studies, and more accurate design and management for irrigation schemes.

In order to run properly, CROPWAT 8.0 needs some data inputs, namely: climatic and rainfall data, crop characteristics and soil features. As a starting point, and only to be used when local data are not available, CROPWAT 8.0 includes standard crop and soil data. When local data are available, these data files can be easily modified or new ones can be created. Likewise, if local climatic data are not available, these can be obtained from the climatic database, CLIMWAT, containing data from more than 5000 stations worldwide. After all inputs have been correctly introduced, the software gives some important outputs, such as reference evapotranspiration, effective rainfall (P_{eff}), *NIWR* and gross irrigation water requirements (*GIWR*). After *CWR* has been calculated, CROPWAT 8.0 can simulate different types of irrigation scheduling, mainly depending on the user desired option: by changing the Irrigation timing (irrigate at critical depletion, irrigate at user defined intervals, irrigate at given yield reduction, etc.) and Irrigation application (fixed application depth, refill soil to field capacity, etc..) the user can find the more suitable irrigation scheduling for the specific situation.

Calculation of reference evapotranspiration ET_0

Evapotranspiration (*ET*, normally expressed in mm/day) is the combination of two separate processes: evaporation (water lost from the soil surface) and transpiration (water lost from the crop). Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. When the crop is small, water is predominately lost by soil evaporation (at sowing, nearly 100% of *ET* comes from evaporation), but once the crop is well developed and completely covers the soil, transpiration becomes the main process (Allen, 1998). Weather parameters, crop characteristics, management and environmental aspects are factors influencing evaporation and transpiration.

The evaporation power of the atmosphere is expressed by the reference evapotranspiration (ET_0). ET_0 (expressed in mm/day) is defined as "the evapotranspiration rate from a reference surface, not short of water; the reference surface is a hypothetical grass reference crop with specific characteristics. It is called the reference crop evapotranspiration and is denoted as ET_0. The reference surface is a hypothetical grass with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23. The reference surface closely resembles an extensive surface of green, well-watered grass of uniform height, actively growing and completely shading the ground (Allen R.G., 1998). The principal weather parameters influencing evapotranspiration are radiation, air temperature, humidity and wind speed at 2m above ground level. A large number of empirical or semi-empirical equations have been developed for assessing reference crop evapotranspiration from meteorological data. Numerous researchers have analysed the performance of the various calculation methods for different locations. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the ET_0 (Allen, 1998). For daily, weekly, ten day or monthly calculations, the FAO Penman-Monteith equation requires:

Site location: altitude above sea level, latitude and longitude;

Air temperature (°C): maximum and minimum temperature or mean temperature;

Air humidity (%): maximum and minimum or mean relative humidity;

Radiation (MJ/m²/day or hours/day): net radiation or actual duration of bright sunshine;

Wind speed (m/s): wind speed at 2m above the ground level.

All meteorological data can be estimated using agro-meteorological stations; these stations are commonly located in cropped areas where instruments are exposed to atmospheric conditions, similar to those for the surrounding fields. In these stations, air temperature and humidity, wind speed and sunshine duration are typically measured at 2 m above ground level an extensive surface of grass or short crop. Where needed and feasible, the cover of the station is irrigated (Allen R.G., 1998).

Calculations of ET_0 are often computerized. Many software packages use the FAO Penman-Monteith equation to assess ET_0: nowadays, FAO ET_0 Calculator and CROPWAT are largely used. The selection of the time step with which ET_0 is calculated depends on the purpose of the calculation, the accuracy required and the time step of the climatic data available. In this work, daily time step has been utilized.

Estimation of the ET_0 was based on a 23 year climatic data (1990-2012). For the sunshine duration, this one is converted to solar radiation by the Ångström formula (Ångström, 1924). Pen-Mon equation was used in ET0 calculations with the following values for Ångström's coefficients: a = 0.25, b = 0.5.

Crop Water Requirements (*CWR*) are defined as the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease-free, growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment(Doorenbos and Pruitt, 1984). The water requirements of each crop are calculated taking into consideration the evapotranspiration rate; this depends mainly on climate, but also on growing season and crop development (Doorenbus and Pruitt, 1977). Crop evapotranspiration under standard condition (ET_c) is the sum of transpiration by the crop and evaporation from the soil surface. Prediction methods for *CWR* are used owing to the difficulty of obtaining accurate field measurements. The methods often need to be applied under climatic and agronomic conditions very different from those under which they were originally developed. To estimate ET_c a three-stage procedure is recommended (Doorenbus and Pruitt, 1977):Effect of climate on crop water requirements is given by ET0;Effect of the crop characteristics on *CWR* is given by the crop coefficient (*Kc*) which represents the relationship between reference evapotranspiration (ET_0) and crop evapotranspiration under standard condition (ET_c). Values of *Kc* vary with the crop; the main factors affecting its values are crop characteristics, crop planting or sowing date, rate of crop development and length of growing season; Effect of local conditions and agricultural practices on *CWR* includes the local effect of variations in climate over time, distance and altitude, size of fields, advection, soil water availability, salinity, irrigation and cultivation methods, for which local field data

are required.

The (*NIWR*) defined as: the amount of irrigation water that needs to be supplied to the crop to compensate all evapotranspiration losses (Savva and Frenken, 2002), are calculated using the soil water balance, which includes crop evapotranspiration, effective rainfall, groundwater contribution, stored soil water at the beginning of each period and leaching requirements.

Calculation of irrigation water requirements

Crop water requirements (*CWR*) for a given crop, *i*, are given by:

$$CWR_i = \sum_{t=0}^{T}(Kc_{i_t} \times ET_{0_t} - P_{eff_t}) - (Pe + Ge + Wb) + LR$$

(1)

$$\Leftrightarrow \quad CWR_i = \sum_{t=0}^{T}(ETc_t - P_{eff_t}) - (Pe + Ge + Wb) + LR$$

Where:

Kc_{i_t} is the crop coefficient of the given crop "*i*" during the growth stage "*t*" and where "*T*" is the final growth stage.

Pe = Effective dependable rainfall (mm);

Ge = Groundwater contribution from water table (mm): the contribution of the groundwater table to the soil water balance varies with the depth of the water table below the root zone, the soil type and the water content in the root zone (Savva and Frenken, 2002);

Wb = Water stored in the soil at the beginning of each period (mm): some water could be left in the soil from the previous irrigation or rainfall event, which can be used for the next crop. This amount can be deducted when determining the seasonal irrigation requirements;

LR = Leaching requirements (mm): an excess amount of water are applied during the irrigation, where necessary, for the purposes of leaching.

Not all dependable rainfall is effective and some may be lost through surface runoff, deep percolation or evaporation. Only a part of the rainfall can be effectively used by the crop, depending on its root zone depth and the soil storage capacity. Different methods exist to estimate the effective rainfall; one of the most commonly used is the USDA Soil Conservation Service Method;

Each crop has its own water requirements ET_c. Net irrigation water requirements (*NIWR*) in a specific

scheme for a given year are thus the sum of individual crop water requirements (CWR_i) calculated for each irrigated crop $_i$. Multiple cropping (several cropping periods per year) is thus automatically taken into account by separately computing crop water requirements for each cropping period. By dividing the area of the scheme (S. in ha), a value for irrigation water requirements are obtained and can be expressed in mm or in m³/ha (1 mm = 10 m³/ha).

$$NIWR = \frac{\sum_{i=0}^{n} CWR_i \times S_i}{S} \tag{2}$$

Where S_i is the area cultivated with the crop i in ha. Since culture and the growth cycle are known and the area of the scheme is dedicated only for barley:

and If Ge = 0, Wb = 0 and LR = 0,

equation (1) turns:

$$CWR_b = ETc - P_{eff} \tag{3}$$

And equation (2) turns:

$$NIWR = CWR_b \tag{4}$$

Gross irrigation water requirements (GIWR) are the amount of water to be extracted (by diversion, pumping) and applied to the irrigation scheme. It includes NIWR plus water losses:

$$GIWR = \frac{1}{E} NIWR \tag{5}$$

Where E is the global efficiency of the irrigation system.

Limited objective information on irrigation efficiency was available and estimations were based on several criteria:

• figures found in literature;
• type of crops irrigated;
• The level of intensification of the irrigation techniques.

If irrigation is the only source of water supply for the plant, the gross irrigation requirements will always be greater than the ET_c to compensate for inefficiencies in the irrigation system. If the crop receives some of its water from other sources (rainfall, water stored in the ground, underground seepage, etc.), then the irrigation requirements can be considerably less than the *CWR* (Savva and Frenken, 2002).

Climate data conversion

In general, climate data by the National Meteorological Service are standardized. Normally some conversions are required in order to adjust the data into the format accepted by CROPWAT 8.0. In our case, the wind is measured at 10 m, we must extrapolate it at 2 m (table 1), and because determining the reference evapotranspiration ET_0 is function of the wind at 2 m above the ground leveland in this case was used the formula of (Paulson,1970) (Equation 4).

$$u_2 = u_z \, 4.87 \, / \, ln \, (67.8 \, z_m \, 5.42) \tag{6}$$

Where:

u_2 = wind at 2 m,

u_z = wind at 10 m,

z_m = 10 m.

Table 1: Estimate of wind at 2 m

Month	Wind at 10 m (Km/day)	Wind at 2 m (Km/day)
January	276.2	163.9
February	311.0	184.5
March	374.6	222.2
April	365.3	216.7
May	315.5	187.1
June	303.5	180.1
July	268.6	159.3
August	350.4	207.9
September	237.8	141.1
October	235.1	139.5
November	303.0	179.7
December	297.2	176.3
Average	303.2	179.9

Source: own processing

Table 1: Estimate of wind at 2 m

Processing of rainfall data

For programming the irrigation water supply and management of barley crop, rainfall data dry year is used. An estimation of the respective rainfall data can be obtained by computing and plotting probabilities from the rainfall records. The different steps are:

1) Tabulate yearly rainfall totals for a given period;

2) Arrange data in descending order of magnitude;

3) Tabulate plotting position (Equation 7);

4) Plot values in the probability paper.

$$F_a = 100 \, m \, / \, (N + 1) \tag{7}$$

Where:

N = number of records,

m = rank number,

F_a = plotting position.

To plot values in the probability paper one has to choose the statistic model. Our choice is related to the law of Gumbel, since this model is frequently used in hydrology and climatology, to model the extreme events, in particular the annual rainfall. The function of distribution of the law of Gumbel is available on Equation 8. Thus we calculated the density of probability of the law of Gumbel (Equation 9).

$$F(x) = exp\ (-exp\ (-x-a/b)) \tag{8}$$

$$f(x) = 1/b\ exp\ (-exp(-x-a/b))\ exp\ (-x-a/b) \tag{9}$$

Finally we determined monthly values for the dry year according to Equation 10.

$$P_{idry} = Piav \times P_{dry}\ /\ P_{av} \tag{10}$$

Where:

P_{iav} = average monthly rainfall for month I,

P_{idry} = monthly rainfall dry year for month I,

P_{av} = average yearly rainfall,

P_{dry} = yearly rainfall at 80% probability of exceedance.

Crop data collection

We have taken the characteristics of the barley of the bulletin of FAO of irrigation and drainage N°46, (Smith, 1992), such as crop factors, rooting depth, critical depletion, yield response, crop height, (Table 2). For the length of the growth cycle and vegetal stage of barley is 170 days (FAO Irrigation and Drainage Paper No. 24)

Table 2: Essential information collected for barley crop

Soil Data Collection

The red sandy Loam characterizes all grounds of this area. The red sandy Loam is a medium ground. According to bulletin FAO N° 46, (Smith, 1992), its total available soil moisture is 1.4 mm/Cm.

Results and discussion

Calculation of reference ET_0

Calculation of ET_0 by CROPWAT 8.0 requires information on the meteorological station together with input climatic data: temperature, humidity, wind speed and sunshine duration (table 3).

Following this table that characterizes this area of study and during the vegetative cycle of barley, the highest average daily evapotranspiration ET_0 values are attained in March (3.14 mm/d) and in April (4.26 mm/d), it is a critical phase with regard to the culture of the barley, if we multiply these values by the number of days of each month, you can have the amount of water that has been evapotranspired, respectively during the month of March (97.3 mm) and April (127.8 mm). Consequently and in the absence of rains during this period must be applied to net irrigation dose during March of 973 m³/ha and during the month of April 1278 m3/ha.

Determination of normal, wet and dry year rainfall

Processing of rainfall data

An estimation of the respective rainfall data can be obtained by computing and plotting probabilities from the rainfall records. The different steps are:

1) Tabulate yearly rainfall totals for a given period (table 4);

Crop name BARLEY	Planting date: 01/11 Harvest : 19/04				
stage	Intial	Developement	Mi-season	Late season	Total
Stage days	35	50	45	40	170
Kc Values	0.30	-->	1.15	0.25	
Rooting depth (m)	0.30	-->	0.90	0.90	
Critical depletion (fraction)	0.60	-->	0.60	0.90	
Yield response (fraction)	0.20	0.60	0.50	0.40	1.00
Crop height (m)			0.90		

Source: own processing

Table 2: Essential information collected for barley crop.

Month	Min Temp (deg.C)	Max Temp (deg.C)	Humidity (%)	Wind (Km/d)	Sunshine duration (Hours)	Solar Rad (MJ/m²/d)	ET_0 (mm/d)
January	2.8	13	70	163.9	6	10.1	1.42
February	3.5	14.3	64	184.5	7	13.3	2.01
March	6.3	18.3	60	222.2	8.2	17.7	3.14
April	8.6	21.1	51	216.7	9.1	21.6	4.26
May	12.9	26.8	45	187.1	9.9	24.3	5.38
June	18	33.4	34	180.1	9.9	24.7	6.61
July	21.1	37.5	28	159.3	10.8	25.7	7.16
August	21	36.3	32	207.9	10.7	24.3	7.41
September	16.7	30	47	141.1	9.7	20.4	4.86
October	12.5	24.3	56	139.5	8.9	16.2	3.31
November	6.8	16.4	62	179.7	8.2	12.6	2.12
December	4.4	13.2	74	176.3	6.5	9.8	1.32
Averge	11.2	23.7	52	179.9	8.7	18.4	4.08

Source: own processing

Table 3: Calculation of reference evapotranspiration (ET0) for Ksar-Chellala weather Station.

Year	1999	2009	2003	1990	1996	2011	1994	1997	2010	2008	2007	
Rain (mm/year)	371	355	335	325	311	310	308	304	297	273	256	
Rank No	1	2	3	4	5	6	7	8	9	10	11	
Fa %	4.2	8.3	12.5	16.7	20.8	25	29.2	33.3	37.5	41.7	45.8	

Year	2004	2006	1992	2012	1993	2005	1991	1998	2001	1995	2000	2002
Rain (mm/year)	251	247	240	235	225	210	198	197	196	163	147	114
Rank No	12	13	14	15	16	17	18	19	20	21	22	23
Fa %	50	54.2	58.3	62.5	66.7	70.8	75	79.2	83.3	87.5	91.7	95.8

Source: own processing

Table 4: Statistical analysis of Ksar-Chellala rainfall.

2) Arrange data in descending order of magnitude;

3) Tabulate plotting position (Equation 3);

4) Plot values in the probability paper.

**Adjustment by the graphic method**

In the case of an adjustment according to the law of Gumbel, the graphic method rests on the use of a probabilistic paper of Gumbel Figure 1. We deferred the data points to be adjusted in a system of axes, in X-coordinate places from there the values possible of the density of probability of the law of Gumbel, in Y-coordinate places from there the total annual rain. Then to plot the straight line which passes best by these points. It is noted that the arithmetic mean 254 mm coincides with the value with 50% of exceedance probability which as of 254 mm. Without passing by the statistical tests, we can confirm graphically

that the law of Gumbel adjusts better the series of rain data. Thus we can estimate the exceedance probability which it is advisable to give to each rain value.

Calculate year values at 20, 50 and 80% of exceedance probability: P80 = 190 mm, P50 = 254 mm, and P20 = 317 mm. Similarly values for dry, normal and wet years can be determined. Results are given in the Table 5.

Effective rainfall

To account for the losses due to runoff or percolation, a choice can be made of one of the four methods given in CROPWAT 8.0 (Fixed percentage, Dependable rain, Empirical formula, USDA Soil Conservation Service). In general, the efficiency of rainfall will decrease with increasing rainfall. For most rainfall values below 100 mm/month, the efficiency will be
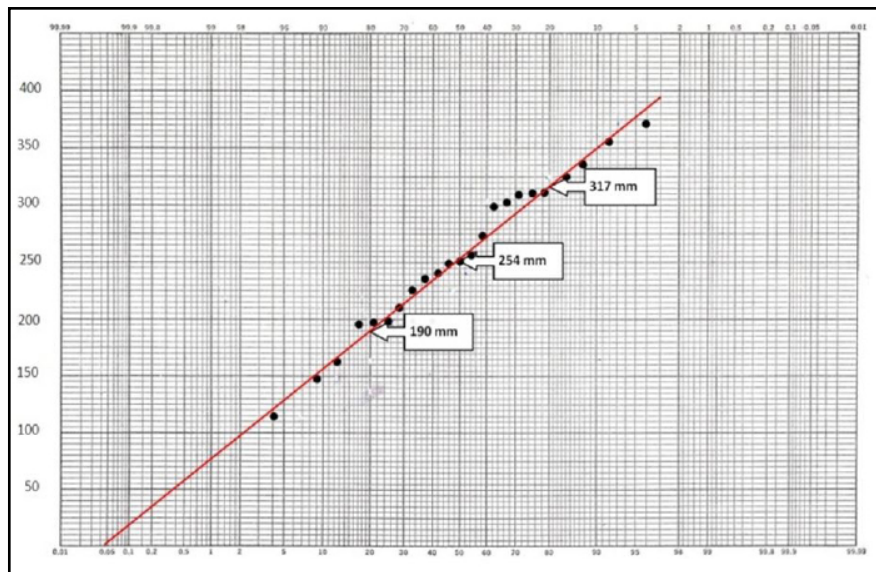
Source: own processing

Figure 1: Probabilistic paper of Gumbel.

	Jan	Fev	Mar	Avr	Mai	Juin	Juil	Août	Sept	Octo	Nov	Dec	year
Normal year	16.2	19.4	20.7	24.1	28.7	11.2	8.9	11.3	32.2	36.9	23.0	21.6	254.3
Dry year	12.1	14.5	15.5	18.0	21.5	8.4	6.7	8.4	24.1	27.6	17.2	16.2	190.2
Wet year	20.2	24.2	25.9	30.1	35.8	14.0	11.1	14.1	40.2	46.1	28.7	27.0	317.4

Source: own processing

Table 5: Monthly values for the normal, dry and wet year.

	Jan	Fev	Mar	Avr	Mai	Juin	Juil	Août	Sept	Octo	Nov	Dec	year
Rain dry year	12.1	14.5	15.5	18.0	21.5	8.4	6.7	8.4	24.1	27.6	17.2	16.2	190.2
Effrain	9.7	11.6	12.4	14.4	17.2	6.7	5.3	6.8	19.3	22.1	13.8	12.9	152.2

Source: own processing

Table 6: Effective rain is 80 % of actual rain.

approximately 80%. In our case we chose the fixed percentage (80%) (Table 6).

Crop water requirements of barley CWR_b calculations

The calculation of the CWR_b was based on the climatic data and the information of crop and soil. The CWRb (Table 7) are the difference between the crop evapotranspiration ET_c and the effective rainfall of dry year. The table 7 is illustrated by figure 2.

The total water requirements of barley CWRb are equal to 211 mm. The highest CWR_b was attained in the month of March (81.8 mm) and which represents 39 % of total CWR_b it represents there productive stage, which is a critical phase with regard to the culture of the barley. While the lowest CWR_b was attained in the month

of December (8.4 mm), which represents a vegetative phase of dormancy.

If we assured a supplementary irrigation during February, March and the beginning of April and by respecting the doses of irrigation, we can increase significantly grain yield of barely in this region.

So following these results the Gross irrigation water requirements *GIWR* of 1250000 ha which are projecting to grow barley can be estimated in the Algerian steppe regions and this for a dry year. If we fix the irrigation system efficiency to 70%, these needs are estimated at:

$NIWR = CWR_b$ = 211 mm/m² = 2110 m³/ha

$$GIWR = \frac{2110}{0.70} \times 1250000 = 3\,767\,857\,143\ m^3$$

Month	Decade	Stage	Kc coeff	ET$_c$ mm/day	ET$_c$ mm/dec	Effrain mm/dec	CWR$_b$ mm/dec
Nov	1	Init	0.3	0.75	7.5	5.3	2.2
Nov	2	Init	0.3	0.63	6.3	4.3	2.1
Nov	3	Init	0.3	0.56	5.6	4.3	1.3
Dec	1	Deve	0.33	0.52	5.2	4.5	0.7
Dec	2	Deve	0.48	0.63	6.3	4.4	1.9
Dec	3	Deve	0.66	0.89	9.8	4	5.8
Jan	1	Deve	0.83	1.16	11.6	3.5	8.1
Jan	2	Deve	1	1.42	14.2	3	11.2
Jan	3	Mid	1.14	1.84	20.2	3.3	16.9
Feb	1	Mid	1.15	2.08	20.8	3.7	17.2
Feb	2	Mid	1.15	2.31	23.1	3.9	19.2
Feb	3	Mid	1.15	2.74	21.9	4	18
Mar	1	Mid	1.15	3.17	31.7	4	27.7
Mar	2	Late	1.02	3.21	32.1	4.1	28
Mar	3	Late	0.79	2.77	30.5	4.4	26.1
Apr	1	Late	0.55	2.15	21.5	4.6	16.9
Apr	2	Late	0.34	1.45	13	4.3	8.2
				Total	281.4	69.5	211.4

Source: own processing

Table 7: Crop water requirements of barley.
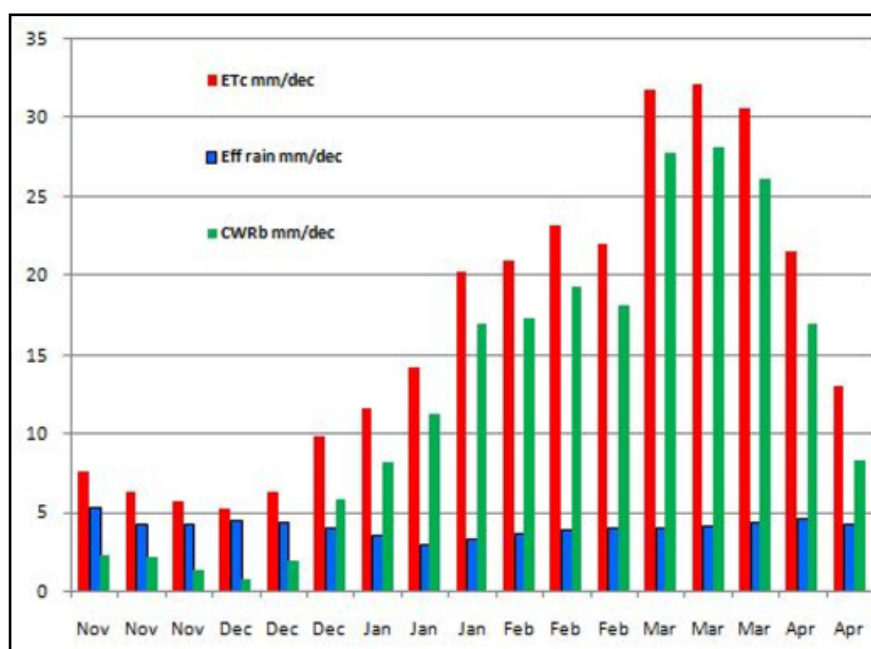
Source: own processing

Figure 2: Crop water requirements of barley *CWR$_b$* in Ksar-Chellala region.

Conclusion

The Sustainable Water Management helps ensure a more stable production. Improving irrigation efficiency is very important for farmers to have a more correct use of water and for this reason, before thinking of irrigation as a water source, they must establish whether irrigation is really necessary or not in their specific environmental conditions. For this purpose, a preliminary analysis is very useful.

The planning stage of an irrigation project design actually implies a survey of all factors which could influence *CWR* (climate, soil and crop itself).

Then *CWR* need to be compared with available water coming from the rain (effective rainfall) and from the soil (initial soil water available). In case of a water deficit, the technician can evaluate the possibility of introducing irrigation, assessing if the water source will be able to cope with all aspects of demand. This survey is of paramount importance in order to establish if irrigation is effectively needed or not.

The first three parameters that must be taken into account in an investigation so described are: climate, soil and crops. If effective rainfall during the period is insufficient to cover the entire crop cycle, taking into account the infiltration rate of the soil and its permeability, the construction of the irrigation system is imperative. This kind of situation is quite normal in the case of an arid climate with a light soil; relative humidity and rainfall are low.

Following this study, the determination of the CWR_b requires several stages in particular the collection of the climatic data and their processing by the prescribed methods, in particular the method adopted by the FAO. Further to this approach, we were able to estimate the CWR_b in the region of Ksar-Chellala for dry year.

The total of the CWR_b is 211.4 mm, CWR_b of February, March and April equal 161.3 mm which represents 76% of the total CWR_b, and also represents stages of flowering, beginning of grain-filling period and physiological maturity. If we assure a supplementary irrigation during February, March and the beginning of April and by respecting the doses of irrigation, we can increase significantly grain yield of barely in this region.

Finally, the underground water potentials of steppe regions are limited and cannot meet the needs of this large area which amounts to 1250000 ha, whose gross irrigation water requirements (*GIWR*) are estimated at 3.77 billion and this for a dry year and a irrigation efficiency of 70%. So the steppe regions (30 million ha) receive an average amount of effective rainfall for a dry year 152 mm equivalent to 40.56 billion m^3/yr. So if one gets only 10 % of this volume falling from the sky we can meet the needs of this area without affecting the underground water potentials. So it is imperative to be based on the technical spate.

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References

[1]   Andales, A. A., Chávez, J. L., Bauder, T. A. (2015) "Irrigation Scheduling: The Water Balance Approach", Fact Sheet No. 4.707, Crop Series Irrigation, Colorado State University Extension, 11/93. Revised 1/15. [Online] Available: http:// www.ext.colostate.edu. [Accessed 30 April 2016].

[2]   Ångström, A. (1924) "Solar and terrestrial radiation. Report to the international commission for solar research on actinometric investigations of solar and atmospheric radiation". *Quarterly Journal of the Royal Meteorological Society*, Vol. 50, No. 210, pp. 121-126. E-ISSN 1477-870X. ISSN 0035-9009.

[3] Bencherif, S. (2011) "L'élevage pastoral et la céréaliculture dans la steppe algérienne", thèse de doctorat, Agro Paris Tech, Institut des Sciences et Industrie du Vivant et de l'Environnement (AgroParisTech), p. 269, pastel-00586977, version 1 - 19, Apr 2011 [Online] Available: http://pastel.archivesouvertes.fr/docs/00/58/69/77/PDF/These_bencherif.pdf. [Accessed: Mai 25, 2016].

[4] CEDARE (2014) North Africa Regional Water Sector M&E Rapid Assessment Report, Monitoring & Evaluation for Water in North Africa (MEWINA) Project, Water Resources Management Program.

[5] Bray, E. A. (1997) "Plant responses to water deficit", *Trends in Plant Science*, Vol. 2, No 2, pp. 48-54, ISSN 1360-1385. DOI: http://dx.doi.org/10.1016/S1360-1385(97)82562-9.

[6] Doorenbus, J. and Pruitt, W. O. (1977) "Guidelines for predicting Crop water requirements, Irrigation and Drainage", FAO, Paper No. 24.

[7] Doorenbos, J. and Kassam, A. H. (1979) "Yield Response to Water, Irrigation and Drainage", FAO, Paper No. 33.

[8] O'Shaughnessy, S., A., Evett, S. R., Colaizzi, P. D. and Howell, T. A. (2012) "A crop water stress index and time threshold for automatic irrigation scheduling of grain sorghum", *Agricultural Water Management*, May 2012, Vol. 107, pp. 122-132. ISSN 0378-3774. DOI: 10.1016/j.agwat.2012.01.018.

[9] Pasquale, S.,Theodore, C. H., Elias, F. and Dirk, R. (2012) "Crop yield response to water", FAO, Paper No. 66, pp. 134-141. ISBN 978-92-5-107274-5.

[10] Paulson, C. A. (1970) "The Mathematical Representation of Wind Speed and Temperature Profiles in the Unstable Atmospheric Surface Layer", *Journal of Applied Meteorology*, No. 9, pp. 857–861. DOI 10.1175/1520-0450(1970)009<0857:TMROWS>2.0.CO;2

[11] Peel, M. C., Finlayson, B. L. and McMahon, T. A. (2007) "Updated world map of the Köppen-Geiger climate classification", Hydrology and Earth System Sciences, No 11, pp. 1633-1644. [Online] Available: http://www.hydrol-earth-syst-sci.net/11/1633/2007/. [Accessed 20 Oct 2015]. DOI 10.5194/hess-11-1633-2007.

[12] Rahal-Bouziane, H. (2015) "Genetic diversity of traditional genotypes of barley (Hordeum vulgare L.) in Algeria by pheno-morphological and agronomic traits", *African journal of agricultural research*, Vol. 10, No. 31, pp. 3041-3048. ISSN 1991-637X. DOI 10.5897/AJAR2015.9513.

[13] Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. (1998) "Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements", FAO, Irrigation and drainage paper No. 56. ISBN 92-5-104219-5.

[14] Solinas I. (2011) "Information Technology in Irrigation and Drainage Course, Power-Point presentations". Florence, Italy.

[15] Savva, A. P. and Frenken, K. (2002) "Crop Water Requirements and Irrigation Scheduling. Irrigation Manual Module 4", Water Resources Development and Management Officers, FAO, Sub-Regional Office for East and Southern Africa, 2002, Harare, Zimbabwe.

[16] Smith, M. (1992) "A computer program for irrigation planning and management. Irrigation and Drainage", FAO, Paper No. 46.

[17] Ullrich, S. E. (2011) "Significance adaptation production and trade of barley", In: B*arley Production, Improvement and Uses*, Ed. Ullrich John Wiley & Sons Inc., Ames, IA, USA. pp. 3-13.

[18] Yavuz, D., Seymen, M., Yavuz, N., and Türkmen, O. (2015) "Effects of irrigation interval and quantity on the yield and quality of confectionary pumpkin grown under field conditions", *Agricultural Water Management*. September 2015, Vol. 159, pp. 290-298. ISSN 0378-3774. DOI 10.1016/j.agwat.2015.06.025.