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Branch:Hydraulics

Specialty: Water Resources

THEME

Determination of water plans evaporation in arid zone region of Ouargla

Prepared by:

- **Afaf ATTAB**
- **Nour el houda ATTAB**

Submitted to the jury composed of:

Meryem Marie ELFERGOUGUI	Lecturer	President
Dalila OULHACI	Lecturer	Examiner
Sofiane SAGGAI S	Professor	Supervisor

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إهـــــــــداء:

الحمد لله وكفى والصلاة على الحبيب المصطفى

وأهله و من وفى اما بعد

انطلاقا من قوله تعالى:

"وَقَضَى رَبُّكَ أَلاَّ تَعْبُدُواْ إِلاَّ إِيَّاهُ وَبِالْوَالِدَيْنِ إِحْسَاناً"

نهدي ثمرة عملنا و جهدنا هذه الى من لا يمكن للكلمات ان تفيهما حقهما الوالديَنا الكريمين حفظهما الله ورعاهما والى كافة افراد عائلتنا "عائـلة عطـاب"،

والى كل الأرواح الغالية علينا والى كل من علمنا حرفاً و ساندنا في اتمام هذا العمل من قريب او من بعيد.

كما نتمنى ان تكون هذه المذكرة ذات فائدة للعلم وطلبته.

***Acknowledgments*:**

In the name of God, the Most Gracious, the Most Merciful first and foremost

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Thank you

ملـــخص

يؤدي التبخر في سطح الماء الحر إلى فقدان كميات كبيرة من المياه في الطبيعة، لذلك من الضروري تقدير و معرفة هذه الكميات المفقودة، يهدف عملنا إلى مقارنة نتائج تقدير التبخر بعدة طرق مختلفة) مقياس التبخر بيش؛ مقياس كولورادو؛ المعادلة المقترحة من قبل بوطوطاو ج ؛ صيغة بانمن ,(حيث نسعى من خلال هذه الأطروحة إلى حل مشكلة عدم وجود أجهزة قياس التبخر أو نقص البيانات في محطات الأرصاد الجوية, ومن البدائل دمج طرق باستخدام عدد اقل من المتغيرات فقد أظهرت نتائج الدراسة التي تم الحصول عليها انه من بين ستة معادلات تم الاحتفاظ بأفضل ثلاثة منها مع التحقق من صحتها و هي : 1 (بيش =0.9105 بان – 8.2265) حيث الدلالة 0.335

و 2 (بوطاوطاو = 0.8561 بيش +3.9264) حيث الدلالة 0.278 و 3 (بانمان =1.2024 بان -9.7771) حيث الدلالة 0.278 فهي تمكننا من حساب قيمة التبخر بإحدى الطرق السابقة في غياب الأخرى.

الكلمات المفتاحية: التبخر، المسطحات المفتوحة، مناخ جاف،منطقة ورقلة.

Abstract

Evaporation in the open water surface leads to the loss of large amounts of water in nature, so it is necessary to estimate and know these lost quantities, our study aims to compare the results of the evaporation estimate in several different ways (evaporator Piche ; Colorado pan ; Boutoutaou formula ; Penman formula), where we seek through this thesis to solve the problem of the lack of evaporation gauges or lack of data at meteorological stations, One alternative is to integrate methods using fewer variables, and the results of the study obtained showed that out of six equations, the best three were retained with validation and is :

(1) E piche = 0,9105 **E** pan - 8,2265 sig = 0.335

(2) E Boutoutaou = 0,8561 **E** piche + 3,9264 sig= 0.278

(3) E penman = 1,2024 **E** pan - 9,7771 sig = 0.278

enabling us to calculate the evaporation value in one of the previous methods in the absence of the other.

Keywords: evaporation, free water surface, arid climate, Ouargla region.

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Introduction:

Water is the most abundant natural resource on Earth. It is one of the simplest human needs and indispensable in all daily activities. It also has a significant economic impact as it is used in agriculture, energy production and mining. (Daniel and Al,2019. Tian ad Al 2021), Where water constitutes 71% of the total surface area of the Earth, and according to the United States Geological Survey (USGS), the amount of water present on the Earth's surface is estimated at about 1,360 million km3**,(Abu Dhamidah D, 2021)** More than 97% of this water is salt water found in the oceans and the rest **(Bouzidi, 2019)**, About 35 million cubic kilometers of fresh water **(Eisenberg and Kauzmann, 1969).**

Water moves from the oceans to the atmosphere through evaporation **(Jones, 1992)** In hydrology, evaporation is of obvious practical interest **(Piri and al., 2009)**

Evaporation is the return of water vapor to the atmosphere by diffusion of water particles from soil, plants, water bodies, and other moist surfaces while the loss of water from vegetation is called transpiration.However, evaporation is often used to refer to the loss of water from the surfaces of free water bodies, as the latter is primarily responsible for the largest percentage of water loss from nature, that is why this type of evaporation was chosen for our study.

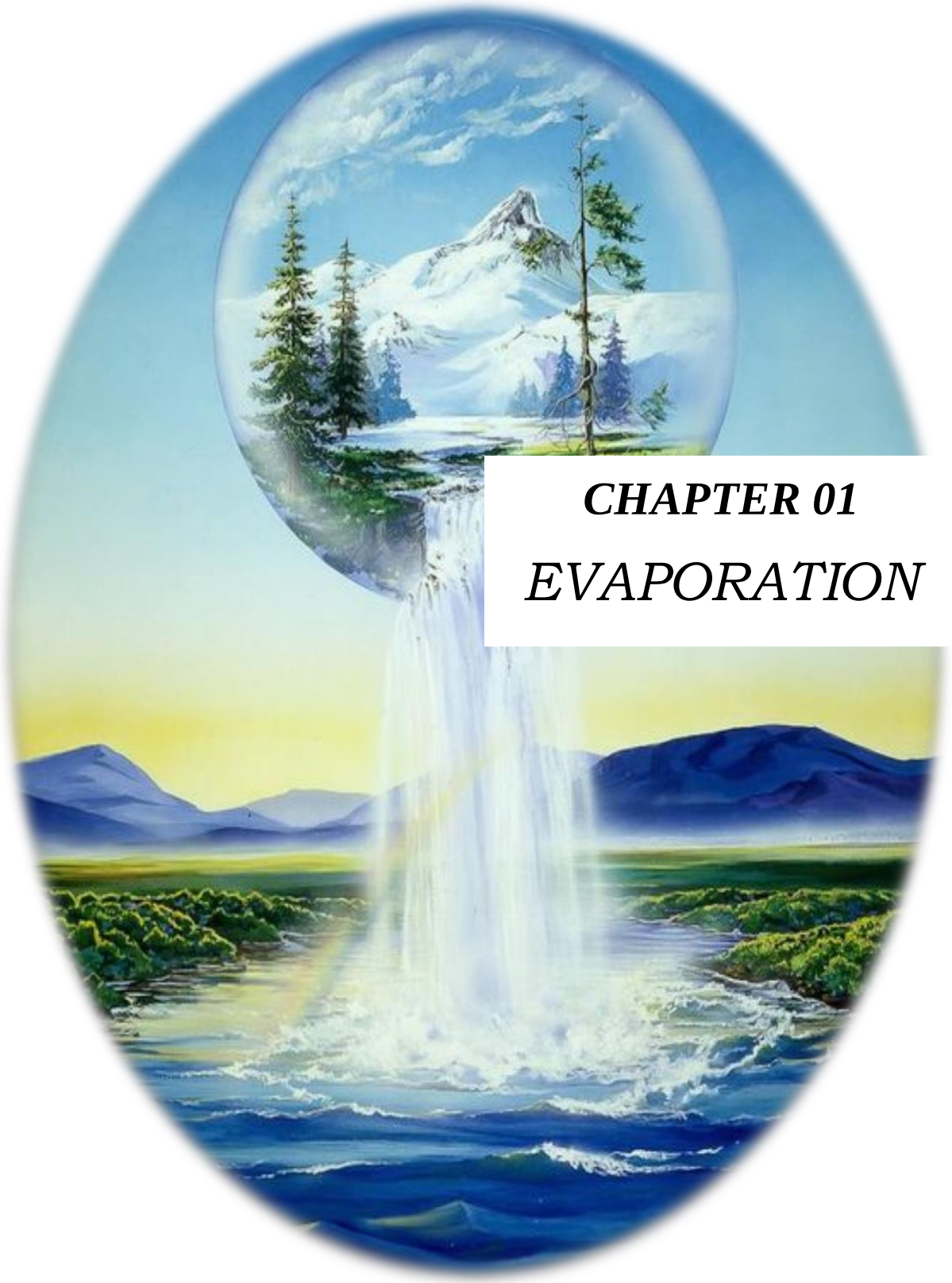
Most Arab states will suffer - in the future - from a severe water crisis, and evaporation is one of the real problems that drain water in hot areas, especially in Arab countries located in the arid and semi-arid regions. **(Hassan,Youssef, 2019)**

The Algerian desert regions suffer from the problem of evaporation compared to the northern regions, where the methods of measuring evaporation with any type of device have some defects that significantly reduce its value in geographical and other studies.

However, these methods give a general perception of evaporation.

In this thesis, we pay special attention to the problem of the lack of evaporation measuring devices in meteorological stations for the region of Ouargla, located in the southeast of Algeria, as the goal of our work is to determine the extent to which the methods of calculating and measuring evaporation are linked by deducing relationships to determine one of them in the absence of the other.

- Chapter I: Under the title Evaporation,this chapter addressed howevaporation is carried out and the factors affecting it and the devices used to measure it.
- Chapter II: Under the title of introducing the area where it addressed the site of the geographical location and the climate of the area and its climate
- Chapter III: Under the title of the result and the discussion where he addressed the analysis of the results obtained and discussed.



CHAPTER 01

EVAPORATION

Chapter 1 : EVAPORATION

1. Notion on evaporation:

For the water cycle to work, water has to get from the Earth's surface back up into the skies so it can rain back down. It is the invisible process of evaporation that changes liquid and frozen water into water-vapor gas, which then floats up into the skies to become clouds**.(John prafferty,2001)**

1.1 Concept of evaporation:

In general, evaporation is the phenomenon by which a substance is convertedfrom the liquid or solid phase into vapor **(Brutsaert, 1982).**

It is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. It is important in determining the water balance of watersheds, allowing prediction and estimation of runoff and groundwater recharge **(Allen, 1986).**Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in the atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration. In hydrology,evaporation estimation is divide into two categories evaporation from open water surfaces and evaporation from land.

1.2 Thermodynamics and physics of evaporation :

The process of evaporation involves the simultaneous exchange of heat and massfrom the evaporating surface to the surroundings **(Williams,1961)**

Heat (energy) is necessary for evaporation to occur. Energy is used to break the bonds that hold water molecules together, which is why water easily evaporates at the boiling point (212 ° F, 100 ° C) but evaporates much more slowly at the freezing point. Net evaporation occurs when the rate of evaporation exceeds the rate of condensation. A state of saturation exists when these two process rates are equal, at which point the relative humidity of the air is 100 percent. (Condensation, the opposite of evaporation).

1.3 Evaporation drives the water cycle:

The term evaporation refers to the change of state of a liquid into vapor. In the context of the hydrological cycle, evaporation is the transfer of water from the ocean and continents into the atmosphere. The vaporization of ocean water can be interpreted as the first step in the hydrological cycle and it ultimately regulates the input of water in the continents. Around 85% of the world's evaporation happens over oceans **(Mehta and al., 2005).** Over continents, the flux of evaporation is smaller but still represents around 60-70% of the volume of in-coming precipitation **(Lim and Roderick, 2009; Miralles andal , 2011b).** Both water bodies "e.g. lakes and rivers" and land surfaces contribute to continental evaporation.

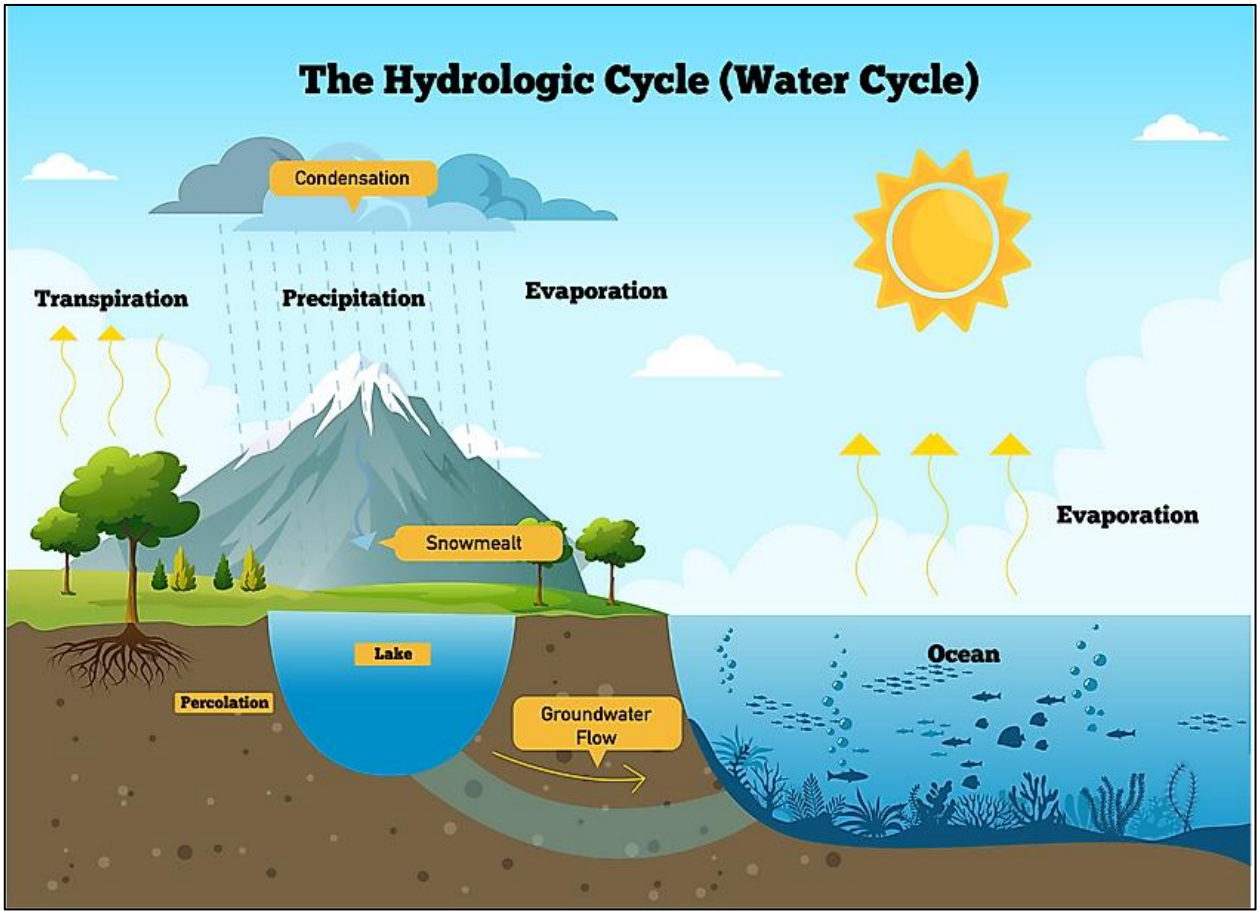


Figure n°01: The water cycle

2. Parameters influencing evaporation:

Evaporation mainly depends on two factors associated with meteorological factors ,the amount of heat available, the capacity of the air to store water but also factors physics related to evaporating surfaces.

2.1 Metrological parameters:(Williams , 1961)

Factors That Affect the Evaporation is:

2.1.1 Temperature (water and air):

As the temperature increases, the rate of evaporation also increases. Temperature and rate of evaporation are proportional to each other, The water molecules move rapidly when the water is heated,thismakes the molecules escape faster. Higher temperatures lead to increasing in vaporization asmore molecules get kinetic energy to convert into vapor.**(Abir el khozaala ,2021)**

2.1.2 Humidity:

The rate of evaporation decreases with an increase in humidity. Humidity and the rate of evaporation are inversely proportional to each other.As evaporation proceeds, the surrounding air becomes gradually saturated and the process will slow down and might stop if the wet air is not transferred to the atmosphere.

- **Relative humidity (RH):**

Relative Humidity is the dimensionless ratio of the actual vapor pressure tosaturation vapor pressure at the same temperature**.(Mukaddes Darwish ,1998)**

- **Absolute humidity** :

Absolute humidity is the quantity of water that the air contains (in pressure of steam). In other words: Absolute humidity=Relative humidity*****the amount of water saturation the higher the air is Hotter the more water vapor (or humidity) it can hold **(Ahmed AN, 2021).**

2.1.3 Wind:

Increase in wind speed results in increased evaporation. Wind speed and rate of evaporation are proportional to each other.The replacement of saturated air with drier air depends greatly on wind speed.

For wind, its effect exists, but is not significant like air temperature and humidity. Indeed, its role in this process of evaporation is the hunting of the humid air existing on the surface of the water, to allow new droplets of water to escape and be transformed into steam. 'water.**(Rainer f and Olaf h, 2021)**

2.1.4 Atmospheric pressure:

When the atmospheric pressure of the air is low, the air pushes less strongly on the surface of the water. It will then be easier for the water molecules to tear themselves away from the surface of the water to find themselves in the vapor state**.(Evren ozgur and Kocak kasim,2015)**

2.1.5 Solar radiation :

The evaporation process needs su_cient energy for the latent heat of vaporization**(Maidmet,1993)**. The main source of heat energy is solar radiation.According to**(Budyko, 1963).**

2.2 Physical parameters :

2.2.1 Water plan surface exposition :

As the surface area increases, the rate of evaporation increases. The surface area and rate of evaporation are proportional to each other. Vaporization increases with an increase in the surface area. (If the surface area is increased, then the amount of liquid exposed to air is larger. More molecules can escape with a wider surface area.).

2.2.2 Salinity:

water salinity on evaporation adds to the complexity of the challenge of quantifying evaporation **(Salhotra et al., 1985).** Increasing water salinity reduces evaporation since the dissolved salt ions lower the free energy of the water molecules, i.e., reduce the water activity, and hence reduce the saturation vapor pressure above the saline water at a given water temperature **(Harbeck, 1955; Lee, 1927; Salhotra and al.,**

1985; Stumm &Morgan,1981). Saltwater has another substance dissolved in it (salt), so its particles attach themselves to the water molecules, making them heavier and in need of more energy to escape the surface.

2.2.3 Depth:

Depth of the Body From Where Evaporation Occurs The water body from where the water is evaporated is the main factor in how evaporation occurs. Thus, if the depth of a pond is too much, the rate at which the water will be evaporated will be more.

The effect of the water depth on the seasonal distribution of evaporation can be considered as a result of the heat storage capacity of the water body which is, to a large extent, determined by its depth. In higher latitudes **(J Finch and R Hall ,2001)**the deeper the water table, the steeper was the falling rate of evaporation , The only thing depth will do is govern the duration of the event.

2.2.4 Turbidity:

Turbidity is a measure of the relative clarity of a liquid, Water temperature is an important determinant in many aquatic biological processes, where High turbidity increases the temperature of the water due to the absorption of sunlight by the molecules. That is, there is a direct relationship between turbidity and evaporation. The higher the temperature, the more intense the evaporation. **(Joseph M Mwangangi, 2007)**Evaporation from bare soil (content in soil water, capillarity, soil color and albedo).

3. Determinations of evaporation:

3.1Evaporation calculation:

There are many methods for calculating evaporation and they are called indirect methods; Evaporation from open water bodies often represents the largest loss in their local hydrologic budget, yetits quantification continues to be a theoretical and practical challenge in surface hydrology and micrometeorology **(Assouline & Mahrer, 1993, 1996; Assouline et al., 2016; Brutsaert,1982, 2005)**.There are several methods for calculating evaporation. Of the best known among:

3.1.1 Aerodynamic method (Dalton Formula) :(J. Dalton, 1802)

This method utilizes the concept of eddy motion transfer of water vapor from an Evaporating surface to the atmosphere.**(Safa M. Aldarabseh, 2020)**

Besides the supply of heat energy, the second factor controlling the evaporation rate from an open water surface is the ability to transport water vapor away from the evaporative surface. The transport rate is governedby the humidity gradient in the air near the surface and the wind speed across the surface. The recognition of these processes led Dalton to formulate the classical law of evaporation from a free water surface bearing his name:

E = B (eas **- e**a **)** **Where :** $B=\frac{0.622\,K^2\rho\alpha\,U2}{P\,\rho\,w\left(\ln\left(\frac{Z2}{Z0}\right)\right)^2}$

Where:

Ea = Evaporation estimated by aerodynamic method (m/s),

(multiply by [1000 mm/m *86400 s /day] to get in mm/day).

es = saturation vapor pressure at the ambient temperature T (Pa) .

ea = ed = actual vapor pressure estimated using dew point temperature Td or by multiplying es by the relative humidity Rh (Pa).

B = the vapor transfer coefficient (m Pa-1 s -1).

k = the Von Karman constant = 0.4.

u2 = the wind velocity (m/s) measured at height z2 (cm)

ρa = density of moist air (kg/m3).

ρa = density of water (kg/m3).

p = atmospheric pressure in Pa.

3.1.2 Energy Balance Method:

The energy-balance method for determining evaporation was suggested by Angstrom in 1920 **(Brutsaert, 1982)**. This method is based on the conservation of heatand energy within a body of water, and the method relies on the assumption that the ratiobetween the sensible and latent heat fluxes is compatible by means of measurable localmicroclimatic variables **(Bowen, 1926)**. In addition the energy-balance method requiresdata on changes in heat storage that are not always available, especially for large lakes**(Bolsenga, 1975).** This additional information can be obtained or filled in by means oflake water temperature or heat storage modeling **(Croley,1989, 1992; Henderson-Sellersand Davies, 1986; Hostetler and Bartlein, 1990).**

(Er = -dh/dt). Based on the continuity and energy equation, one can derive the energy balance equation for evaporation as :

$$E=\frac{1}{\mathbf{lv}\,\rho\mathbf{w}}(\mathbf{Rn}-\mathbf{Hs}-\mathbf{G})$$

Absorbed by evaporation:

where

lv = latent heat of vaporization (J/kg), **[lv** (kJ/kg) = 2500 - 2.36 T (°C) up to 40 °C**]**

ρw = water density **(kg/m^3),**

Rn = net radiation **(W/m²),**

Er = rate of evaporation **(m/s)**,

H_S=sensibl eheat flux (inW/m^2,to change liquid water temperature),

G = the ground heat flux (in W/m^2, to change underlying soil temperature),

3.1.3 Water-Budget Method :

The water-budget method has generally been used in estimating evaporation from lakes, ponds, and water reservoirs based on the inflow and outflow concepts. It is a very simple and direct method, but difficult in practical use. It is a direct measurement of evaporation losses from lakes, reservoirs, or ponds, and does not require knowledge of the evaporation process or input of climatological data. The water balance of the lake is a simple algebraic sum of water inputs minus water outputs. Due to

$$E = P - I_{vi} + I_{v0} \pm I_L \pm \Delta s$$

conservation of mass, the water balance must hold for any period "monthly, seasonally, or annually".**(Mukaddes D and al, 1998)**

where:

E is the amount of evaporation,

P is the precipitation over the lake,

I_{vi}, is the surface runoff into the lake,

I_{v0} is the surface runoff out of the lake,

I_L is the underground leakage into or out of the lake, and

Δs* is the change in water level of the lake during the period of study.

All variables in this Equation are in units of depth measured during the period ofobservations.

3.1.4 Penman Method:

Penman was a British physicist who derived a theoretical model of evaporation. Penman's first theoretical model was for open water evaporation and is shown in equations **(Penman,1948),(Tim Davie ,2008).**

The Penman method (1948), applied to open water, can be briefly described by the energy balance at the earth's surface, which equates all incoming and outgoing energy

fluxes, It's recommended by Food and Agriculture Organization , Penman used the energy budget method and the mass-transfer approach of Dalton to develop a functional combination equation for the calculation of evaporation. Penman's formula is **(Ponce, 1989)**:

H = Rn - λ E – G

where :

Rn = energy flux density of net incoming radiation (W/m²).

H = flux density of sensible heat into the air (W/m²).λE = flux density of latent heat into the air (W/m²).**G =** heat flux density into the water body (W/m²).

- The FAO-24 Penman method, the Penman-Monteith method, Kimberly-Penman, and Jensen-Wright are some of the well-known energy-budget methods which were developed by modification of the Penman equation.

3.2Evaporation measurement*:*There are many methods for measuring evaporation and they are called direct methods:

3.2.1 Hydrological devices (Pan Evaporation):

Pan evaporation is used to estimate the evaporation from lakes**(Tony M, 2007)**An evaporation pan is used to hold water during observations the determination of the quantity of evaporation at a given location. Such pans are of varying sizes and shapes, the most commonly used being circular or square.**(NOAA G, 2009)**The best-known pans are the "Class A" evaporation pan and the "Sunken Colorado Pan"[fao.org Chapter 3: Crop Water Needs.]. In Europe, India, and South Africa, a Symon's Pan (or sometimes Symon's Tank) is used. The main advantage of the bins is their economy and ease of installation; their disadvantage isthe difficulty of evaluating the effects of direct radiation and heat transfer through the walls.

a. Sunken Evaporation Pan (Symons Pan / Tank):

The Symons Pan / Tank is a standard instrument of the UK Met Office. It is a steel container 1.83 m (6 ft) on a side and 0.61 m (2 ft) deep, sunk into the ground with an above-ground rim of 0.076 - 0.1 m (3 - 4 in.) and is painted black internally. Its evaporation rate is lower than the Class A pan and conversion factors must be used.**(Mike Depledge, 2001)**

b. U.S. Weather Bureau Class A Land Pan Evaporimeter:

The United States Class-A pan is cylindrical design, 25.4 cm deep and 120.7 cm in diameter.

The bottom of the pan is supported by 3 to 5 cm above the ground level on an open-frame wooden platform, which enables air to circulate under the pan keeps the bottom of the pan above the level of water on the ground during rainy weather, and enables the base of the pan to be inspected with-out difficulty.**(Tim Davie ,2002)**

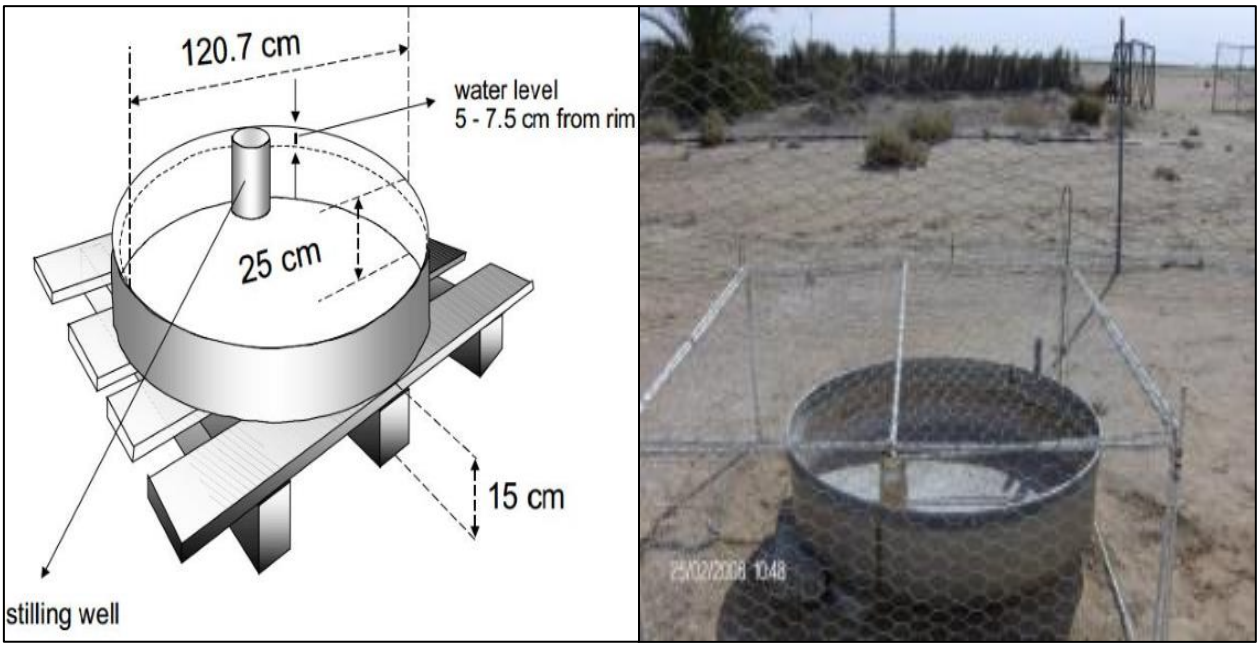


Figure n° 02:Class "A" evaporation pans

The pan itself is constructed of 0.8 mm thick galvanized iron, copper or monel metal, and is normally left unpainted. The pan is filled to 5 cm below the rim (which is known as the reference level). The water level is measured by means of either a hook gauge or a fixed-point gauge. The hook gauge consists of a movable scale and vernier fitted with a hook, the point of which touches the water surface when the gauge is correctly set. A stilling well, about 10 cm across and about 30 cm deep, with a small hole at the bottom, breaks any ripples that may be present in the tank, and serves as a support for the hook gauge during an observation. The pan is refilled whenever the water level, as indicated by the gauge, drops by more than 2.5 cm from the reference level.**(Cosandey C, Robinson M-- Armand Colin,2012).**

c. Sunken Colorado pan:

A type of evaporation pan that is 92cm square. It is made of an unpainted GI sheet, 46cm deep, about 1 m (3 ft) square and 0.5 m (18 in.) deep. This pan is sunk into the ground to within about 5 cm (2 in.) of its rim, and the water is maintained at about ground level. It is made of unpainted galvanized iron. The pan coefficient, on an annual basis, is about 0.8. ("AMS Glossary: Sunken Colorado Pan"*:26 /01/2012)*

There are variants of the Colorado ferry, including theORSTOM version**. (Vachala, 2008)**

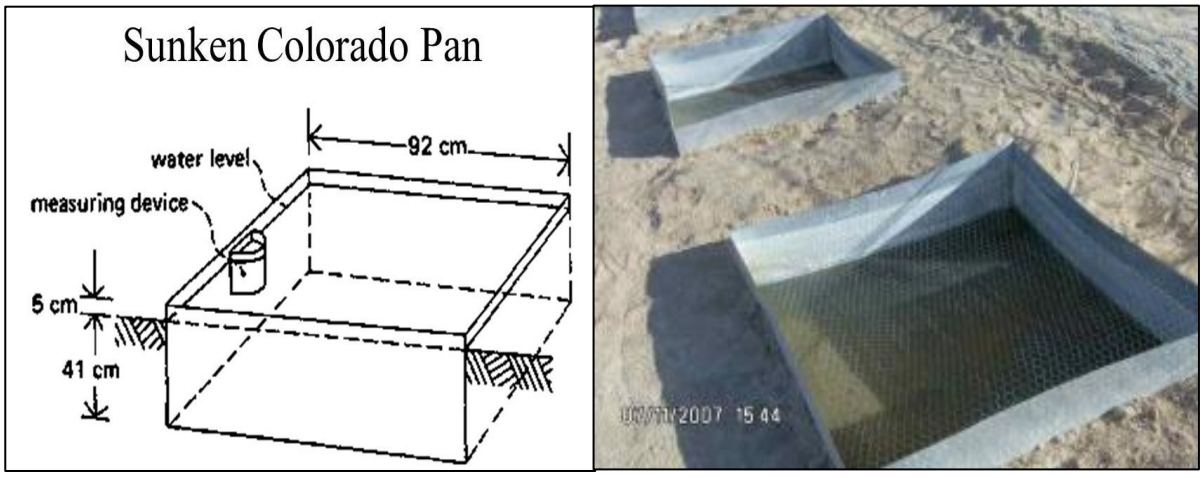


Figure n ° 03: AMS Glossary; Sunken Colorado Pan"(*Saggai ,2007)*

3.2.2 Meteorological devices:

a) Piche Evaporimeter :

It consists of a 32 cm long graduated tube of 1 cm inside diameter. It is closed at one end. The other end of the tube is open and has flat edge. There is a disk and clamp arrangement by which this end can be covered by a filter paper as shown in Fig n° 04.

The tube is filled up with distilled water. The open end is then covered by filter paper supported by the disk and the clamp. The evaporimeter is then hung in the inverted position. The water in the tube is soaked by the filter paper which moves rapidly outward through the paper and ultimately gets evaporated. The rate of loss of water from the tube gives the evaporation rate. This instrument is very sensitive to winds. **(A.laaboudi ,2019)**

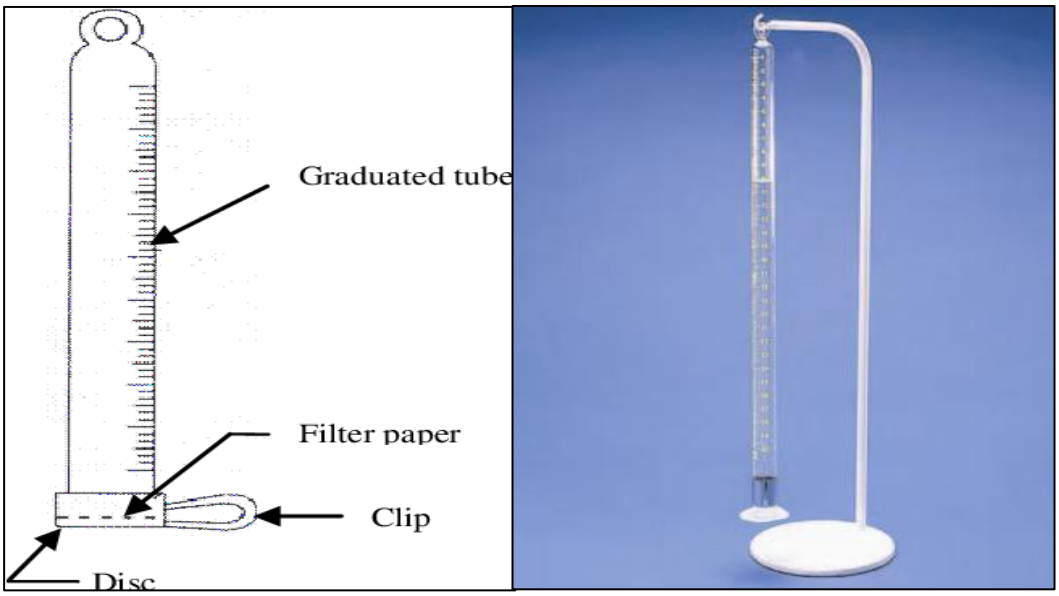
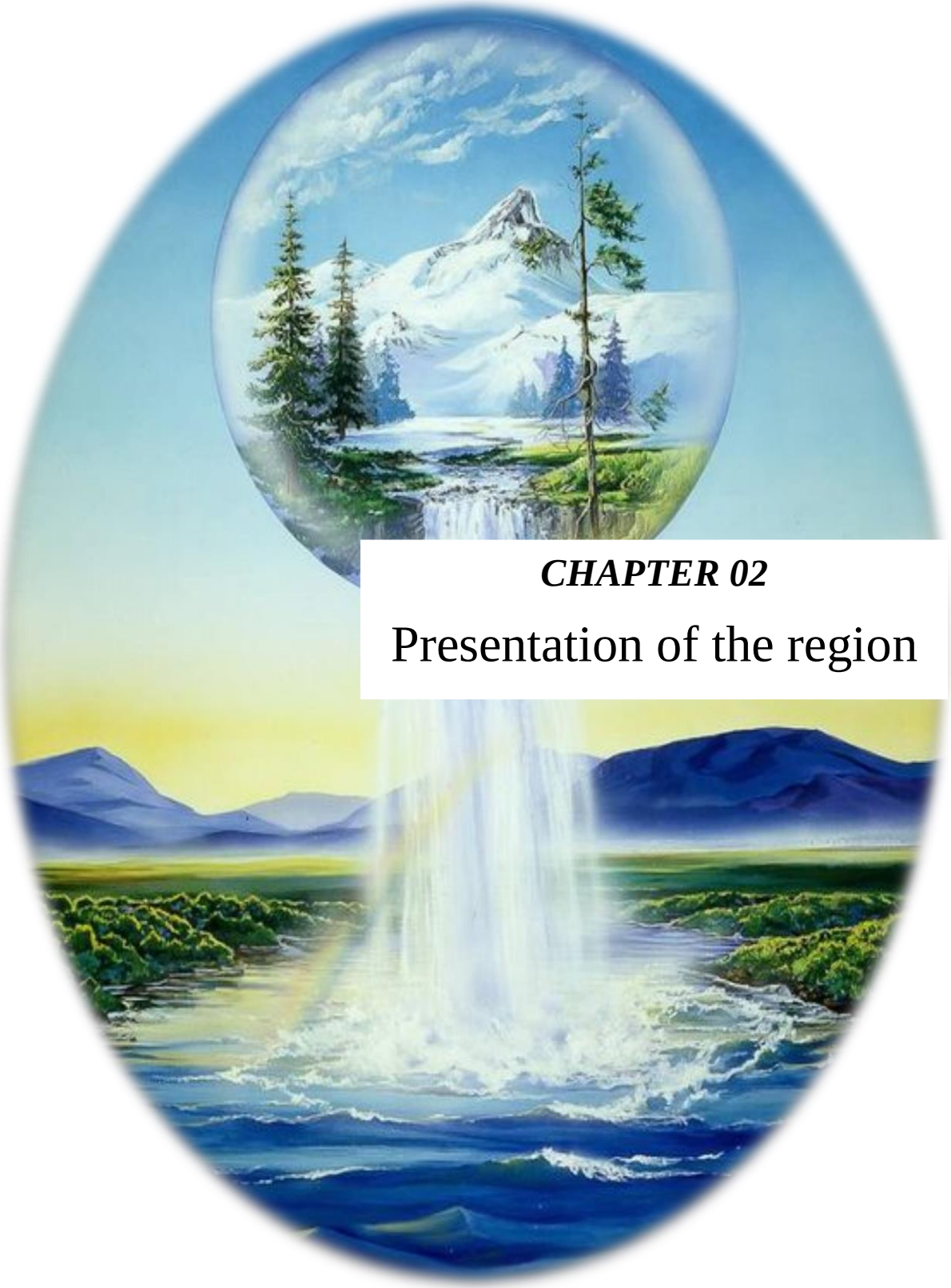


Figure n° 04: Piche Evaporimeter



CHAPTER 02

Presentation of the region

Chapter 02: Presentation of the region:

1. Geographical situation and climate :

1.1 Geographical location:

The study area is located in Algeria, specifically in the city of Ouargla, which is a low Covers 95 thousand hectares southeast of Algeria. Where this depression is located between latitude 31.9629 and longitude 5.34193 (°31'°57'46°N, 5°20'31°E). Its height is 141 meters above sea level**.(ONM Ouargla,2022)**

It includes administrative division No. 30, which consists of 6 administrative divisions (Ouargla, Nagosa, Hassi messaoud, El-Barma, El-Hijira, Sidi Khuwaylid) and 10 municipalities. It is a city of vast and varied nature, with many oases and sand dunes. It has a population of about 602,538 in 2022.

One of the most important economic activities that characterizes this region is its availability of the most important sources of energy in the country.

Figure n° 05 :Geographical location of city of ouargla

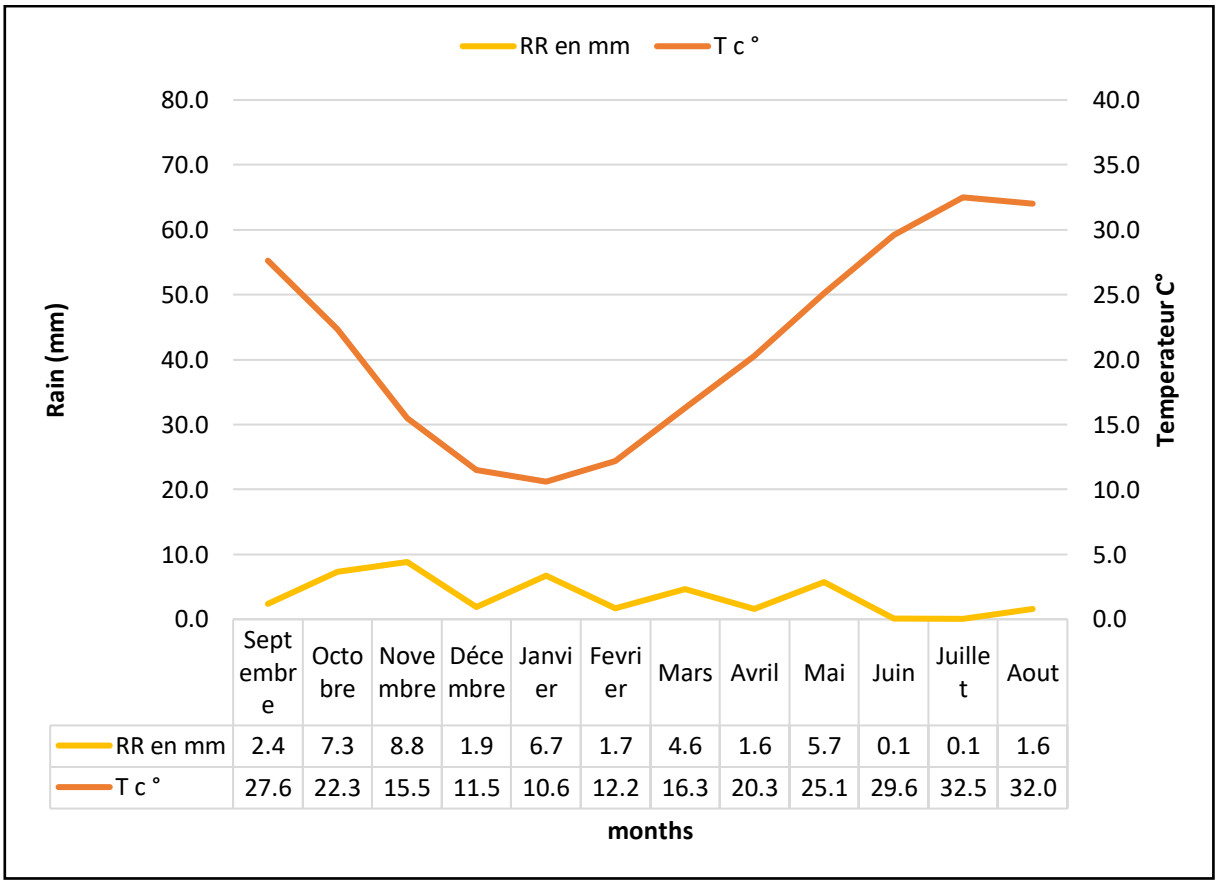
UTM coordinates: **X =** 710,000 m N, 730,000 m N, **Y =** 3,530,000 m E, and 360,000 m E

(Satouh and al. 2021; Bouselsal et al. 2015)

1.2 climate:

To study the climate of the Ouargla region, we drew an arc curve, which represents changes in temperature and precipitation in terms of time (last 10 years) .

_ ONM Ouargla _



	Septembre	Octobre	Novembre	Décembre	Janvier	Fevrier	Mars	Avril	Mai	Juin	Juillet	Aout
RR en mm	2.4	7.3	8.8	1.9	6.7	1.7	4.6	1.6	5.7	0.1	0.1	1.6
T c °	27.6	22.3	15.5	11.5	10.6	12.2	16.3	20.3	25.1	29.6	32.5	32.0

Figure n° 06 : Gaussen's ombrothermic diagram

The mean annual temperature is about 22.7 degrees Celsius and the mean annual precipitation is about 3.5 mm.

Since the precipitation curve is less than the temperature in most months of the Over a period of ten years, this studied region is characterized by irregular dryness hot climate in summer and mild in winter.In addition to the type of wind and currents **(Ozenda, 1991 and Rouvilois-Brigol, 1975).**

Therefore, Ouargla Province is considered an arid zone.

2. Geological and hydrogeological setting:

The Saharan platform includes the research area. This platform is made up of a Precambrian shield that rises over the sediments in Central and Western Sahara **(UNESCO, 1972)**. In the Ouargla area, only Mio-Pliocene terrains are exposed, and they are buried by a thin layer of Quaternary sediments (ergs, dunes). Mio-Pliocene continental formations built up the basin. On the eastern and western margins, there are red sands and soft sandstone with intersecting stratifications, limestone nodules, and limestone or gypsum layers. The aquifer system of the Ouargla basin is defined hydro geologically by the stacking of three aquifers from bottom to top.

The Quaternary detrital deposits such as sand, sandstone, and gravel, as well as gypsum and layers of limestone concretions, make up the superficial aquifer. (12-14 March 2019) (KHARROUBI Maha, BOUSELSAL Boualem2, and HADJ SAID Samia)

- The carbonated Senonian limestone layer and the Mio-Pliocene sand layer are both parts of the terminal complex aquifer.
- Albian and Barremian sands and sandstone clays make up the intercalary continental aquifer.
- Limestone with limestone or gypsum layers outcropping on the eastern and western sides. The Ouargla basin's aquifer system is characterized by the superposition of three aquifers from bottom to top

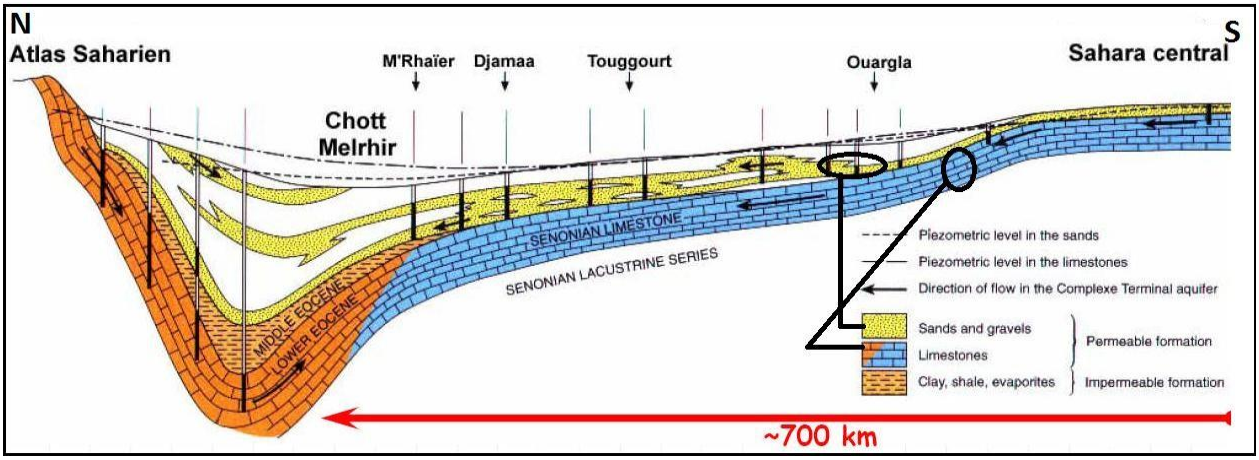


Figure n° 07: Hydrogeological section in the terminal complex aquifer.

(kharoubi ,2019)

3. Materials and methods:

1.1 Materials :

To ensure the follow-up of changes in the rate of evaporation in the region of Ouargla, we measured the following meteorological factors

wind; temperature; humidity; On a daily basis in the summer for 112 days This is because the evaporation process is at its peak during this season. Then the weekly average was calculated over 16 weeks where we use:

1.1.1 The weather shelter :

For shelter is an infrastructure accessory for temperature, humidity and evaporation of air in the atmosphere. Contains a moisture gauge, and three thermometers, one of which contains distilled water and gauze to determine air moisture, a lam thermometer, and a moisture meter for hair. The shelter consists of solid plastic material, consisting of a cage and a double roof with four slopes and four lists. The shelter is designed to ensure that the tools are ventilated and protected from direct, reflected or diffuse radiation and from bad conditions.

Figure n°08: picture of the weather shelter

(jules Richard,1975)

1.1.2 Anemometer :

A device that measures wind speed by the amount of wind pressure on a surface, such as a cup or a fan, or by using sound pulses.

A mechanical anemometer has a wheel with cups or a fan at the end of the wheel brake. One of them contains a magnet. Every time a magnet passes a key, it regis ters. This can give a very accurate reading of wind speed.

Figure n° 09 : Anemometer (Saggai ,2008)

- We also measured the value of evaporation using two different devices, an evaporimeter Piche,and an evaporimeter pan Colorado.

1.2 Methods: We used two methods to calculate evaporation:

1.2.1 The Penman formula : $\frac{700Tm/(100-A)+15(T-Td)}{(80-T)}$ **E= (mmday−1)**

1.2.2 The Boutoutaou D formula: **E** = 0,233 n (es – ea) (1 + 0,39 V)

I.2.1 The Penman formula : (Penman, H. L., 1948)

The Penman formula for the evaporation rate from a lake is simplified to the following:

$$E = \frac{700Tm/(100-A)+15(T-Td)}{(80-T)} (mmday-1)$$

Where:

T m = T + 0.006h,

h is the elevation (metres),

T is the mean temperature,

A is the latitude (degrees)

T d is the mean dew-point.

Values given by this formula typically differ from measured values by about 0.3 mm day −1 for annual means, 0.5 mm day −1 for monthly means, 0.9 mm day −1 for aweek and 1.7 mm day −1 for a day.

The formula applies over a wide range of climates. Monthly mean values of the term (T − T d) can be obtained either from an empirical table or from the following empirical relationship, provided precipitation is at least 5 mm month −1 and (T − T d)is at least 4°C: (T − T d) = 0, 0023 h +0, 37 T + 0,53 R + 0,53 Rann – 10.9° C

Where:

R is the mean daily range of temperature and **R ann** is the difference between the mean temperatures of the hottest and coldest months. Thus the evaporation rate can be estimated simply from values for the elevation, latitude and daily maximum and minimum temperatures.

I.2.2 Boutoutaou D formula:

The formula for calculating evaporation proposed by BOUTOUTAOU (1995) is as follows:

E = 0,233 n (es – ea) (1 + 0,39 V)

E : evaporation (mm),

V: wind speed (m/s),

$\mathbf{V_2}$: wind speed at a height of 2m;

$\mathbf{V_2}$ = 0,78 V

ea: water vapor pressure in the atmosphere (millibar),

(es - ea): saturation deficit in the atmosphere (millibar),

es: saturated water vapor pressure corresponding to the surface temperature evaporating (millibar),

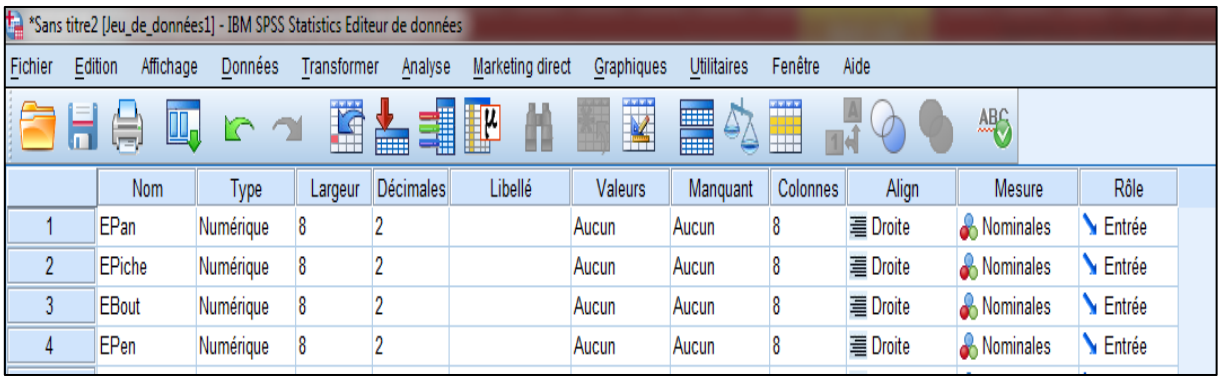
n: number of days in the month considered (for January n = 31, February n = 28 etc., for daily calculations n = 1); For daily calculations n =1) .

Several authors express the temperature of water as a function of the temperature of the surrounding air (Vuglinsky, 1991). The abacus or the following relationship; can be used to determine Algeria's climatic conditions**(Boutoutaou, 1995):**

tw = 1.39 t – 0.01 (t)2 – 1.62

t_w : Water temperature °C .

t : Air temperature °C.



	Nom	Type	Largeur	Décimales	Libellé	Valeurs	Manquant	Colonnes	Align	Mesure	Rôle
1	EPan	Numérique	8	2		Aucun	Aucun	8	Droite	Nominales	Entrée
2	EPiche	Numérique	8	2		Aucun	Aucun	8	Droite	Nominales	Entrée
3	EBout	Numérique	8	2		Aucun	Aucun	8	Droite	Nominales	Entrée
4	EPen	Numérique	8	2		Aucun	Aucun	8	Droite	Nominales	Entrée

Figure n°10: a capture of work in the program SPSS

I.3 SPSS :

SPSS is short for **S**tatistical **P**ackage for the **S**ocial **S**ciences,

Complex statistical data analysis. The SPSS software package was created to manage and analyze social science data. It was initially launched in 1968 by SPSS Inc. and was later acquired by IBM in 2009, Current versions (post-2015) have the brand name: IBM SPSS Statistics.

It is a sophisticated software used by social scientists and related professionals for statistical analysis. **(john Wiley, 2005)**

The software name originally stood for Statistical Package for the Social Sciences (SPSS),(Quintero, Dino; 30 September 2016) reflecting the original market, then later changed to Statistical Product and Service Solutions.**(Hejase, A.J& Hejase, H.J,2013)**

The original SPSS manual has been described as one of "sociology's most influential books" for allowing ordinary researchers to do their own statistical analysis.[9] In addition to statistical analysis, data management (case selection, file reshaping, creating derived data) and data documentation (a metadata dictionary is stored in the data file) are features of the base software.**(Nie, Bent and Hull, 1970)**

I.4 The study steps :

After completing the information gathering as a first step, (measuring temperature, humidity, wind speed, and evaporation using a Peach and Colorado evaporator). We have done organized this information in a way that allows us to read it more easel Then Calculation of evaporation using Penman and Boutoutaou equations and Draw two curves . The first is to include the four measured and computed evaporation values with temperature over a single time curve (16 weeks) and The second is to include the four measured and calculated evaporation values with humidity during one curve in terms of time (16 weeks). and we did then Calculate the standard deviation and use it to insert the error bar within the previous curve. Calculate the accumulation of each method separately, and use them to plot the correlation curves representing each method in terms of the other.

after that We will enter the evaporation data obtained in four ways into the spss program, from which we will extract the following:

Statistical studies (Descriptive statistics and the Box plot, multiple comparisons) In addition to Analyze and discuss previous results.

CHAPTER 03

Results and Discussions

CHAPTER 03: Results and Discussions

1. Results:

1.3 Effect of meteorological parameters on the rate of evaporation:

In fig: 11_ represents the changes in temperature and evaporation values in four different ways (two measurement methods, Pan Colorado and Piche, two methods of calculating Boutoutao and Penman formula), In terms of time, 16 weeks.

Where we observe through:

- The first eight weeks, an increase with a slight overlap in the intensity of evaporation in all ways, accompanied by an increase in the same pace in temperature, up to 29.2 °C.
- As for the second part of the curve, which starts from the ninth (8) week to the sixteenth (16) and last week we notice a significant rise in temperature accompanied by a clear rise and consistency in the intensity of evaporation in all the previous four methods.

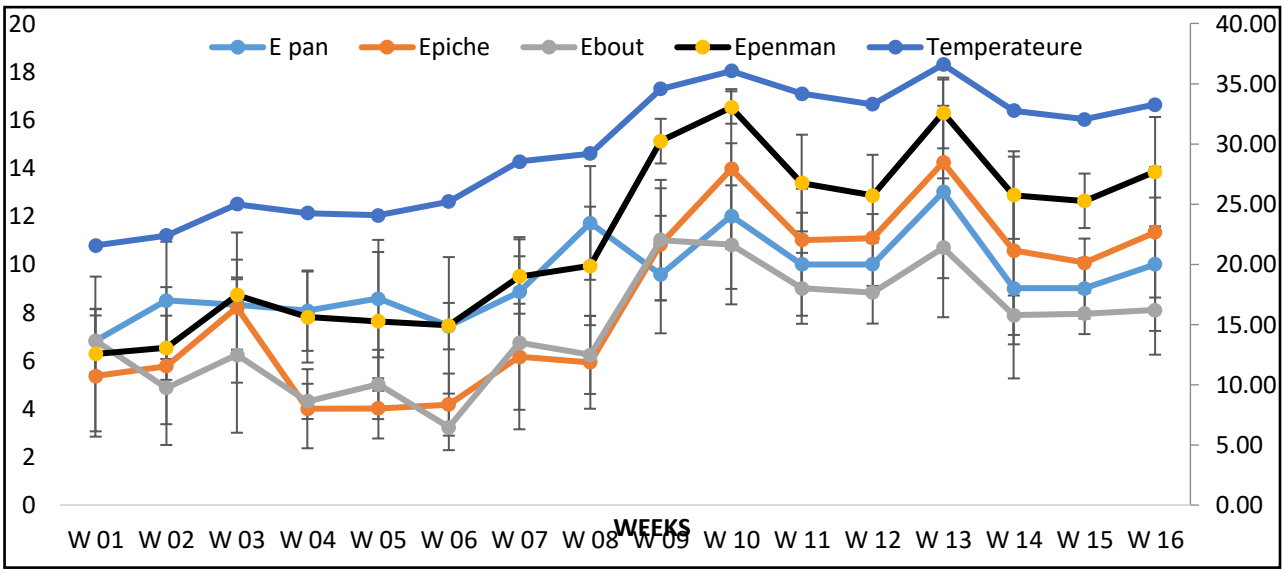


Figure n° 11: Changes in air temperature and evaporation values in several ways in terms of time.

1.1 Effect of meteorological parameters on the rate of evaporation:

In fig:12_ represents changes in moisture content and evaporation values in four 04 different ways (two measurement methods are Colorado and Pishe, two methods for calculating Boutoutao and Penman formula), In terms of time, 16 weeks.

Where we observe through:

- The first eight weeks, an increase with a slight overlap in the intensity of evaporation in all ways, accompanied by a decrease in the relative humidity of up to 41% .After that, the humidity reaches a maximum value of 57.5%.
- As for the second part of the curve, which starts from the ninth (08) week to the sixteenth(16) and last week ,we notice a significant decrease in humidity, reaching a minimum value of 25.3%, accompanied by a clear increase and consistency in the intensity of evaporation in all the previous
- four methods.

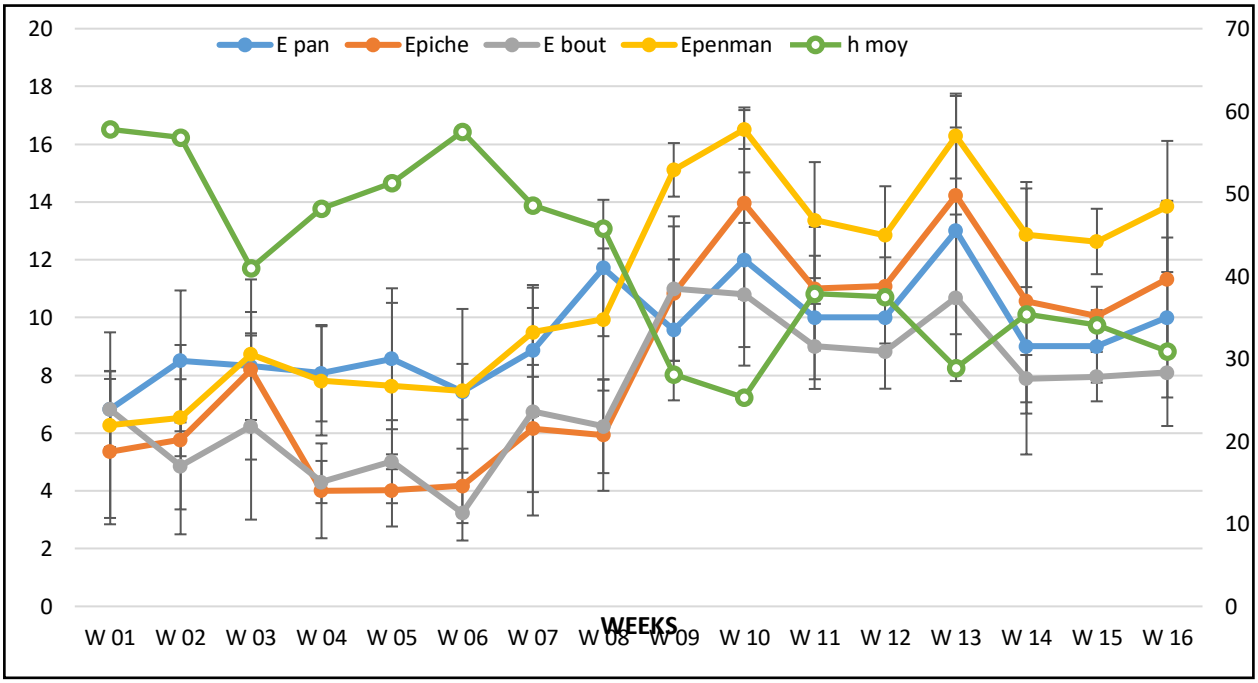
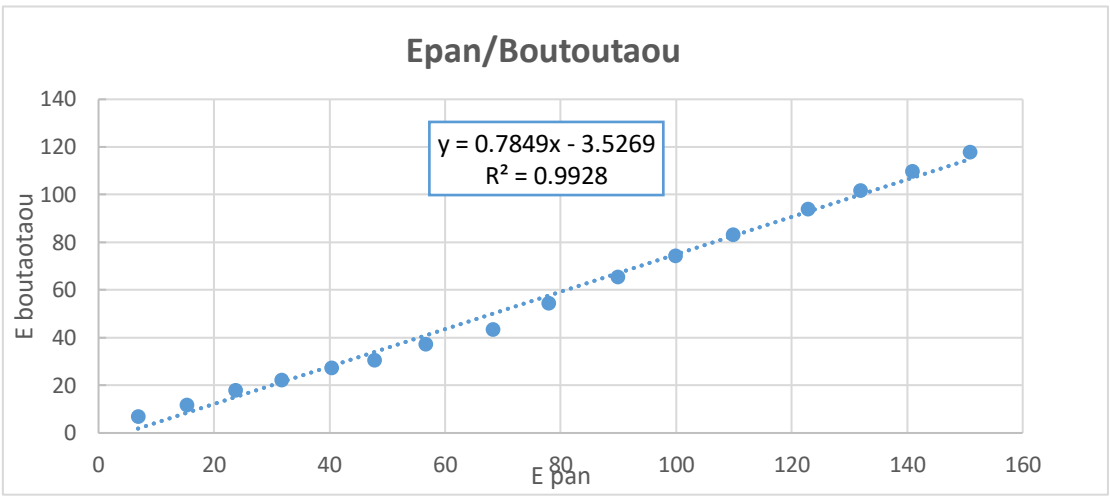
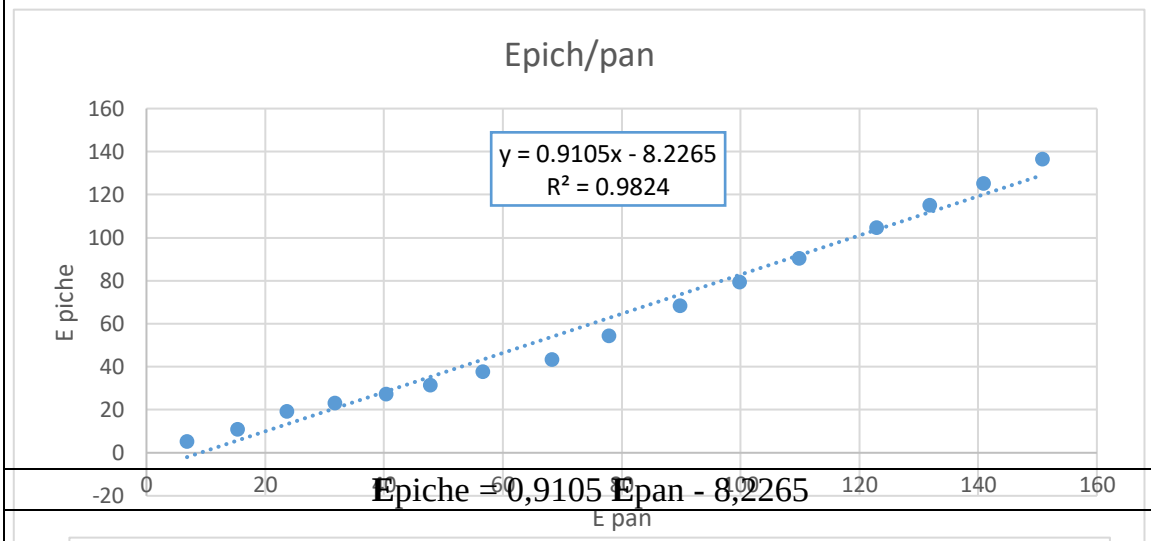


Figure n° 12: Changes in humidity and evaporation values in several ways in terms of time.

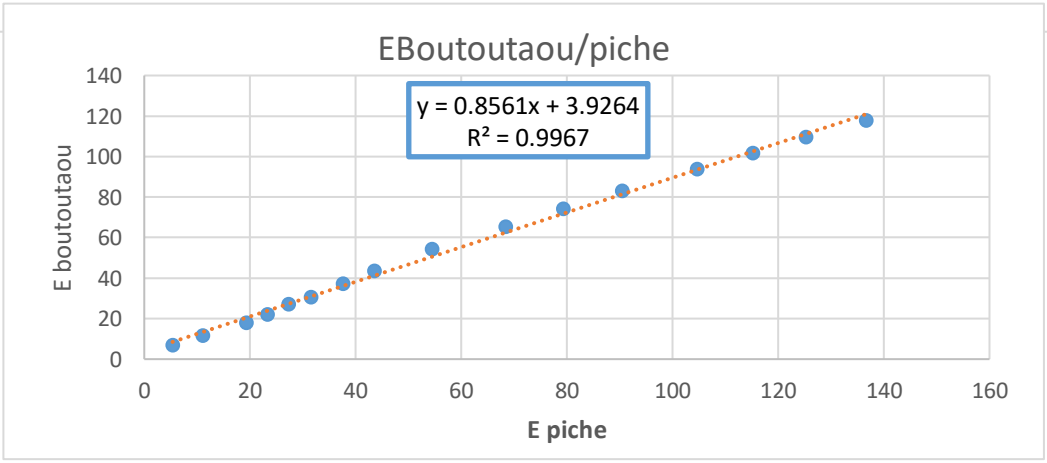
1.2 Correlation between measured and calculated evaporation results :



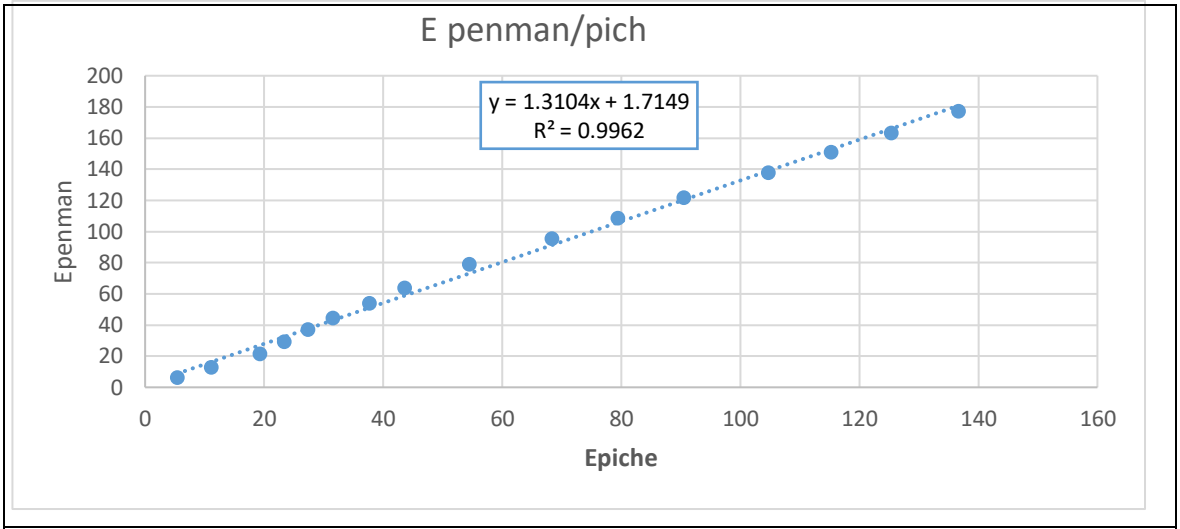
$$E_{Boutoutaou} = 0{,}7849 E_{pan} - 3{,}5269$$



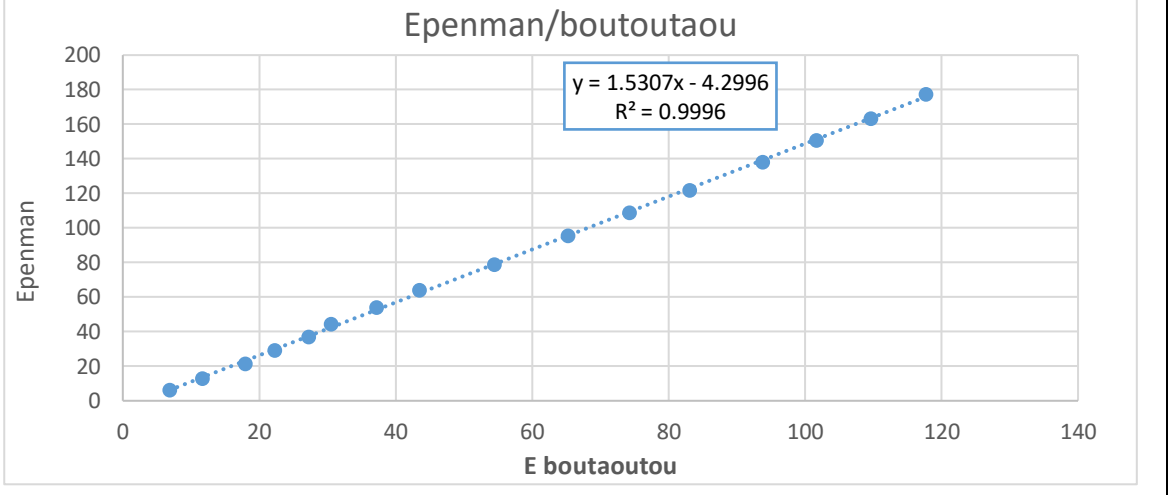
$$E_{piche} = 0{,}9105 E_{pan} - 8{,}2265$$



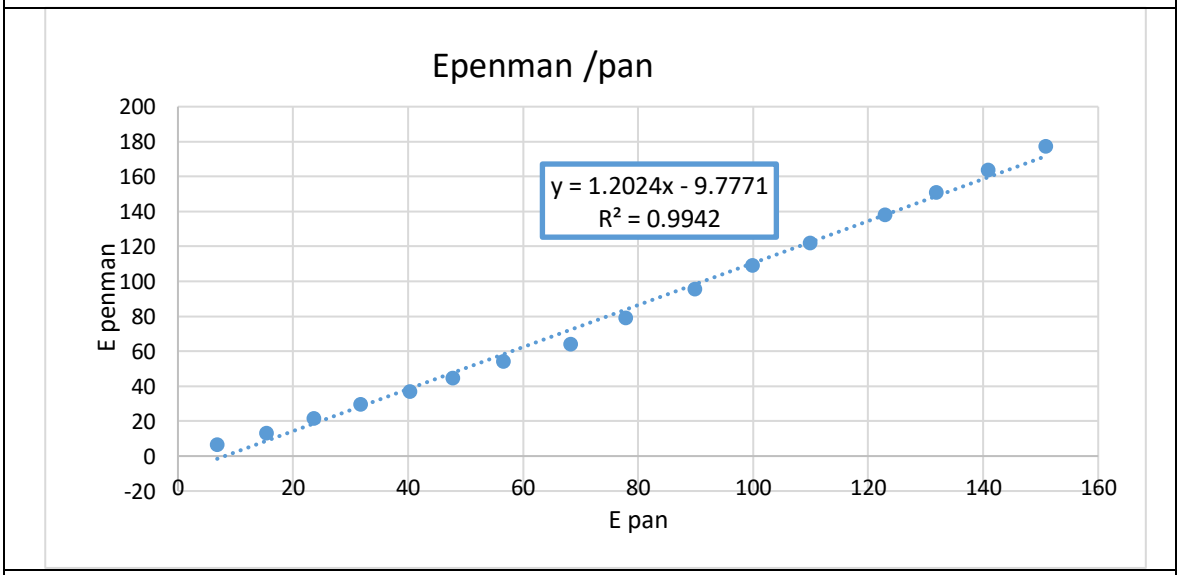
$$E_{Boutoutaou} = 0{,}8561\ E_{piche} + 3{,}9264$$



Epenman = 1,3104 **E** piche + 1,7149



E penman = 1,5307 **E**boutoutaou - 4,2996



Epenman = 1,2024 **E** pan - 9,7771

Figure n° 13:Correlation between the results of the chosen models and the measured evaporation

The previous six curves represent changes in the correlation between evaporation calculation and measurement methods.The first curve represents the extent of the relationship between the Pan equation and the Boutoutaou equation The second is between Ban and pich , the third is between piche and Boutoutaou , the fourth is between piche and Penman, the fifth is between Boutoutaou and Penman , and the sixth is between Boutoutaou and Penman .

Where it appears to us that, the correlation coefficients between all these relations equal 0.99, Except for the second in which the correlation coefficient is 0.98.

1.3statistical study :

1.3.1 Descriptive statistics:

		Statistics			Statistics
EPan	**N**	16	*EPiche*	**N**	16
	Minimum	7		**Minimum**	4
	Maximum	13		**Maximum**	14
	Mean	9,5		**Mean**	8,5
	Standard deviation	1,7127		**Standard deviation**	3,52136
	Variance	2,933		**Variance**	12,4
	Skewness	0,546		**Skewness**	0,089
EBoutoutaou	**N**	16	*EPenman*	**N**	16
	Minimum	3		**Minimum**	6
	Maximum	11		**Maximum**	17
	Mean	7,375		**Mean**	11,125
	Standard deviation	2,47319		**Standard deviation**	3,519
	Variance	6,117		**Variance**	12,383
	Skewness	-0,01		**Skewness**	0,123
N valide (liste)			**N**	**16**	
a. Unless otherwise stated, bootstrap results are based on 1000 bootstrap samples					

Tablen°01:Descriptive statistics results

1.3.2 Analysis :

Through the descriptive statistics table, we note that It contains three columns, where the first column represents methods to be employed (piche ,pan ; penman, boutoutaou) and the second column represent number of cases [N] and means ; (minimum), (maximum), (variance), and (Stad Deviation)

We note that the highest value of evaporation was recorded using the Penman equation which equals 17 (mm day−1), followed by Piche with a value of 14(mm day−1), then pan Colorado with a value of 13(mm day−1), and then with the Boutoutaou equation with a value of 11 (mm day−1).

The minimum value of evaporation amounted to 3(mm day−1), which was recorded by the Boutoutaou equation, then the value recorded by the evaporation scale piche = 4, then penman = 6(mm day−1), then the value 7 (mm day−1) measured by pan Colorado.

The mean and standard deviation of the evaporation values and the difference in pan Colorado are 9.5, 1.7, and 2.9 respectively.

As for the piche evaporation meter, its results are 8.5; 3.5; 12.4 respectively, as for the boutoutaou formula , the results are as follows 7.4; 2.5; 6.1, and in the end, they use an equation, while the result is as follows 11.1, 3.5; 12.4

But the Skewness Equal:

Pan: 0.5, Piche: 0.089, Boutoutaou : -0.1 , Penman :0.123

1.4 Box plot :

1.4.1 Definition:

Box plots **(Chambers, 1983)** are an excellent tool for conveying location andvariation information in data sets, particularly for detecting and illustratinglocation and variation changes between different groups of data.

1.4.2 Role:

A boxplot is a graph that gives you a good indication of how the values in the data are spread out. It can be used to determine the regions in which the sample values are more densely crowded and the regions in whichthey are more sparse.

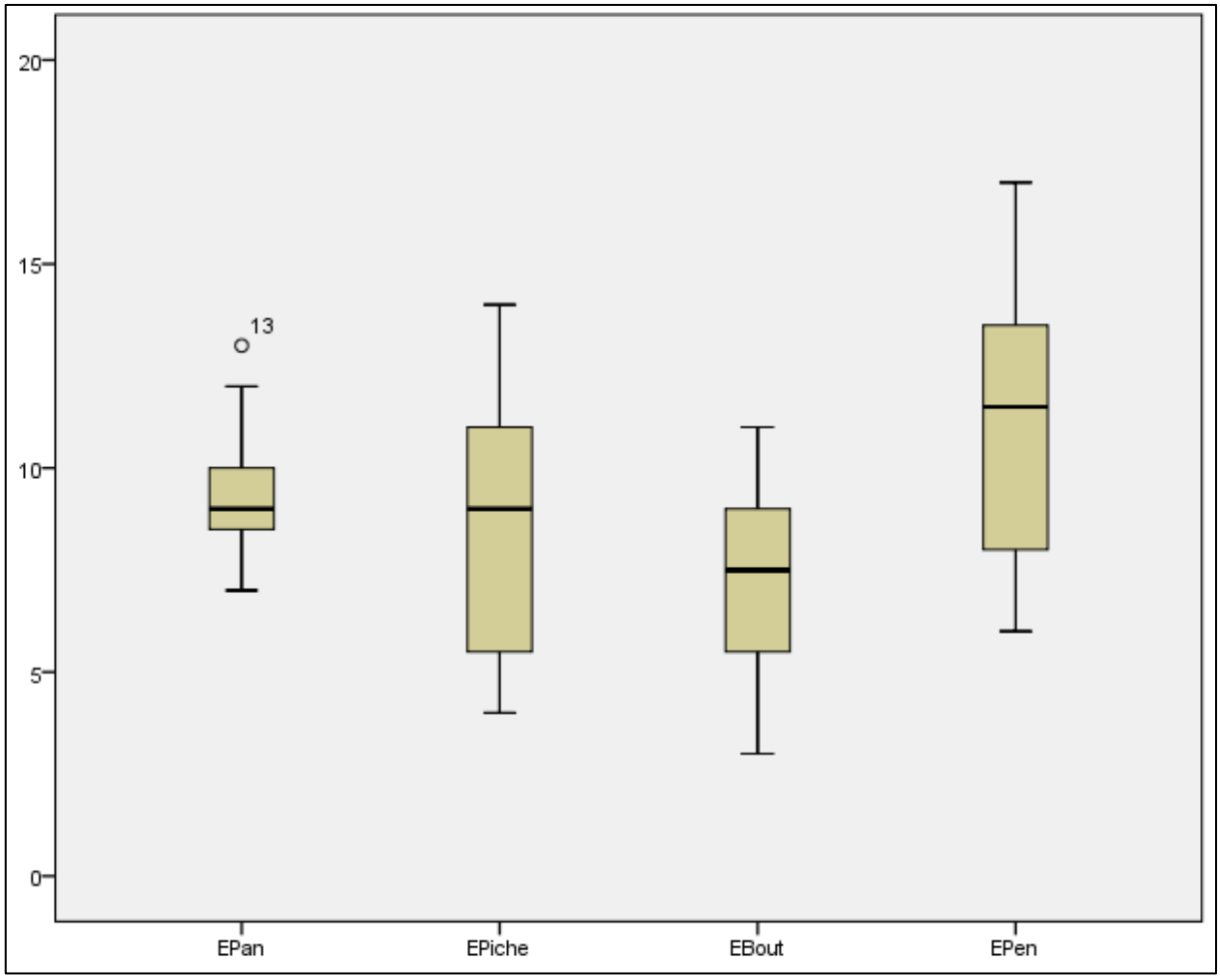


Fig n°14: Boxplot of the evaporation in (04) different ways

1.4.3 Analysis:

The drawing is a boxplot representing the distribution of evaporation values in several ways of measurement and calculation, where we note:

Pan , the evaporation data is more distributed in a small and intense area and is asymmetric towards minimum values and tends towards lower values

Also, the presence of the outlier is equal to 13.

Piche , the evaporation data are widely distributed in a longer and non-condensed region and are asymmetric towards maximum values and tend towards high values.
Boutoutaou, The evaporation data are distributed over a wide area in a region that is less long and more crowded than the previous one and is symmetrically distributed.

Penman ,Evaporation data is distributed over a wide area in a region that is longer and less dense and crowded than the previous one and is distributed almost symmetrically, tending towards maximum values.

1.5 ANOVA table:

1.5.1 Definition:

It is an abbreviation of the word "Analysis of variance"
Analysis of variance, (ANOVA) in SPSS, is used to examine the differences in mean values of the dependent variable associated with the effect of controlled independent variables, after taking into account the effect of uncontrolled independent variables.As shown in the following table:

Evaporation					
	Sum of squares	Df	Mean squar	F	Sig.
Between groups	121,500	3	40,500	4,788	*,005*
Withen groupes	507,500	60	8,458		
Total	629,000	63			

Table n°02 : Analysis of variance of evaporation

1.5.2 Analysis:

The following table presents the results of the analysis of variance ANOVA, the first column, the source of the variance between groups and within groups, and the source of the total variance, the second column shows the sum of squaresAnd the third column shows the degrees of freedom, the fourth column represents the mean of the squares of variance, the fifth column shows the value of F, which is the test statistic, and the sixth column shows the value of the statistical significance of the F test(SIG).

- If the result of the ***ANOVA*** test determines that there are statistically significant differences between the average groups, the reason for these differences must be known through multiple comparison tests.

1.6 Multiple comparaisons :

Dependent variable : Evaporation						
LSD						
(I) Mod	(J) Mod	Mean Difference (I-J)	Std Error	Sig.	Confidence Intervalle 95 %	
					Lower Bound	Upper Bound
Pan	Piche	1,00000	1,02825	,335	-1,0568	3,0568
	Boutoutaou	2,12500*	1,02825	,043	,0682	4,1818
	Penman	-1,62500	1,02825	,119	-3,6818	,4318
Piche	Pan	-1,00000	1,02825	,335	-3,0568	1,0568
	Boutoutao	1,12500	1,02825	,278	-,9318	3,1818
	Penman	-2,62500*	1,02825	,013	-4,6818	-,5682
Boutoutao	Pan	-2,12500*	1,02825	,043	-4,1818	-,0682
	Piche	-1,12500	1,02825	,278	-3,1818	,9318
	Penman	-3,75000*	1,02825	,001	-5,8068	-1,6932
Penman	Pan	1,62500	1,02825	,119	-,4318	3,6818
	Piche	2,62500*	1,02825	,013	,5682	4,6818
	Boutoutao	3,75000*	1,02825	,001	1,6932	5,8068
*. The mean difference is significant at the 0.05 level.						

2. Table n°03: LSD post hoc test for Evaporation

2.3.1 Definition:

The following illustrations explain the proper interpretation of SPSS output concerning Multiple Comparison procedures.

The multiple comparison procedures are used to determine which groups are significantly different afterobtaining a statistically significant result from an Analysis of Variance.

For this example, four groups were compared. The groups are identified in the output as pan, piche, and boutoutaou and penman.

The following illustration shows a sample output from an LSD post hoc test.

2.3.2 Analysis:

The table represents multiple comparisons to determine the extent to which the relationships between the studied methods match:

Whereas, the two most important columns are modes “I” and “J”, which compare each method with the other three methods.

We note that the first and the second row include a comparison of the relationships of Piche, Boutoutaou, and Penman, The third column represents the mean difference of the difference between the different relationships and the fourth column is for standard error. As for determining whether the two relationships pan and piche are different, refer to the value in the fifth column called (SiG) . The last column represents the confidence interval, which determines whether the mean difference value is acceptable or not.

3. Discussion:

2.1 Effect of meteorological parameters on the rate of evaporation:

The results obtained in field experiments confirmed for the first time the effect of meteorological factors on the evaporation rate by the measured and calculated methods.

2.1.1 temperature :

Where the curve in figure number 11 shows that the higher the temperature, the greater the value of evaporation in all methodes , and therefore we conclude that the

relationship between them is a positive one,This is due to the liberation of molecules through the breaking of hydrogen bonds due to temperature **(lenr S, 2017)**,where the Very high temperatures and prolonged intense insolation accelerate the process f evaporation and volatilization of water molecules **(Gaumann, 1971)**.

2.1.2 humidity :

As for the second atmospheric factor that affects evaporation referred to in curve number(fig:12).

It is the air humidity, which represents a mixture of two gases, dry air and water vapor **(Saggai and Boutoutaou,2011),** and it indicates that the lower the humidity, the higher the evaporation value, so we conclude that the relationship between them is an inverse relationship,This is explained by the fact that when the air is saturated with water vapor, it prevents the passage of sunlight to complete the evaporation process.

2.2 The correlation between the studied relationships:

Correlation measures how well a straight line passes through separate points when plotted on the “x,y” axis. If the correlation is positive, it means that when one variable increases, the other tends to increase. If the correlation is negative, this means that when one variable increases, the other tends to decrease. When the correlation coefficient is close to +1 , it means that there is a strong correlation, and the points (the cloud) are scattered along a straight line.

Where the correlation curves between the four relationships in the figures (13) show that the coefficient of determination between them is close to one (01), so it is strong in all cases and from it we can extract the following relationships:

E Boutoutaou = 0,7849Epan - 3,5269

E Boutoutaou = 0,8561 E piche + 3,9264

Epenman = 1,3104 E piche + 1,7149

E penman = 1,5307 Eboutoutaou - 4,2996

Epenman = 1,2024 E pan - 9,7771

Epenman = 1,3104 E piche + 1,7149

3.3 statistical studies :

The results obtained through spss programs are confirmed in the aforementioned tables "schedule n° 1, 2, 3"

3.3.1 Descriptive statistic :

The statistical description table shows whether the standard deviation values are acceptable or not, the SKEWNESS average is less than 1 in both the Colorado pan, piche, Penman, and Boutoutaou methods.

So it is in the natural state, and it is inclined to the right except for the Boutoutaou equation because it is negative.

3.3.2 ANOVA :

The one-way analysis of variance table " ANOVA" that sig value = 0.005, so it is less than0.05. Therefore, we reject the null hypothesis which states that all relationshipmeans are equal and we accept the alternative hypothesis is that there are at least two different means relationships, so a test should be done. Multiple comparisons.

3.3.3 Multiple comparisons:

This table shows whether or not the relationships between the methods are statistically significant because the second column contains mean challenge values which if accompanied by an asterisk * will be offset with a sig value less than 0.05 in the fourth column, so it is statistically significant.

But if the value of the average challenge is without a star *, then it will correspond to the sig value greater than 0.05, and this indicates that it is not significant. They are not acceptable and do not compensate for each other, namely:

Penman * Boutaou SIG = 0.043.

Then Piche * Penman SIG = 0.013.

followed by Pan * Boutaou SIG = 0.001.

As for the acceptable relationships that compensate each other, they are:

Pan and piche SIG = 0,335.

Pan and penman SIG= 0,119.

Piche and Boutoutaou SIG=0,278.

where the mean difference between the confidence interval and in all the previous relationships is the STD error constant and equal to 1.02825.

Conclusion:

The conclusion of our study should lead us to think very seriously about the problem of evaporation, especially in southern Algeria, specifically the Ouargla region, through a better management of water resources.

The main objective of this study was to develop a simple and suitable numerical model for a good estimation of the evaporation value. To achieve this goal, we compared the methods of measuring evaporation, namely, Pan Colorado and Piche, calculating it, which is the Penman and Boutoutaou equation in the event that there is a shortage of evaporation measurement devices or data. Meteorological stations and compensated.

We obtained six equations, each of which includes two methods from the previous methods. The obtained results showed that there are three correct equations in each one. Two methods can substitute each other in the absence of the other, which are (Boutoutaou and Piche), (Pan and Penman), (Pan and Piche), the degree of kinship varies between them ,the most closely statisticly related to them is :

E piche = 0,9105 **E** pan - 8,2265

then followed by (Boutoutaou and Piche): **E** Boutoutaou = 0,8561 **E** piche + 3,9264

The last in the order is (Pan and Penman):**E** penman = 1,2024 **E** pan - 9,7771

As for the remaining three equations, they are not valid and the methods in them cannot substitute each other, which are (pan and piche), (pan and penman), (piche and boutoutaou).

In the end, it must be said that due to our use of only four methods in the study, this makes our study not include all the possibilities, and we can know that our study is specific to dry areas only, meaning that each climatic region can have its own method to compensate for the lack of estimation of evaporation values.

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