

# Estimation Of Potential Evapotranspiration (PET) Using Standard Meteorological Data: A Case Study In The Watersheds Of Northern Algeria

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## Abstract

Accurately estimating potential evapotranspiration (PET) is essential for understanding hydrological processes, managing water resources, and supporting agricultural planning especially in semi-arid regions where meteorological data are often scarce. This study presents a simplified temperature-based model for estimating PET in the watersheds of northern Algeria. Reference annual and monthly PET values were obtained from the National Agency for Hydraulic Resources (ANRH) using the Penman-Monteith method. Through a detailed grapho-analytical analysis, empirical relationships were established between mean air temperature and PET, leading to the development of a new predictive formula. Model performance was evaluated at twelve meteorological stations using statistical indicators ( $R^2$ , RMSE, MAE, and MBE). Results show a high correlation between estimated and reference values ( $R^2_{adj} = 0.90 - 0.97$ ; RMSE = 0.1 - 0.32 mm), demonstrating the model's reliability and robustness under diverse climatic conditions. The proposed approach offers a practical alternative to data-intensive methods, facilitating PET estimation in data-scarce regions and supporting water management, irrigation scheduling, and climate adaptation strategies across northern Algeria and similar semi-arid Mediterranean areas.

**Keywords:** potential evapotranspiration; temperature-based model; Penman-Monteith; semi-arid climate; northern Algeria; water resource management.

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## 1. INTRODUCTION

Evapotranspiration (ET) is crucial for maintaining the water balance in a watershed and is vital for hydrological studies, water resource management, and irrigation planning [1, 2, 3]. Climate conditions, such as precipitation and actual evapotranspiration, as well as surface and subsurface characteristics, influence the streamflow. In large watersheds, infiltration losses are minimal, so river runoff is primarily determined by climate, as evapotranspiration is considered the primary mechanism of water loss [4].

Conversely, in smaller catchment areas, infiltration losses increase while evapotranspiration losses become relatively less significant [5]. Thus, ET is critical for the water balance of a catchment. Therefore, runoff analyses rely on data from potential evapotranspiration (PET) [6].

Numerous models exist for estimating potential evapotranspiration (PET), each requiring different data inputs. Review articles [2, 11, 12] outline the development of these models, detailing their hypotheses, definitions, and equations. The variety of models highlights the complexity of the evapotranspiration process and the dependency on local climatic conditions [13, 14]. They are usually classified into five categories: water balance, mass transfer, combination, radiation, and temperature-based models.

Among these, the Penman [15] and Penman-Monteith FAO-56 [16] models are reference standards to numerous institutions [17, 18]. These models provide reliable estimates of PET and reference evapotranspiration (ET<sub>o</sub>) under varying climatic conditions and are the most dependable methods for capturing global atmospheric changes [19, 20, 13]. However, the extensive data requirements for these models pose significant challenges, particularly when only limited data are available.

The variety and specificity of evapotranspiration estimation equations complicate the identification of the most suitable method for a given study. Moreover, many of these equations were originally developed for specific climatic regions and may not be directly applicable in other contexts [7, 2, 5, 11, 12]. As a result, much research has focused on evaluating and generalizing existing evapotranspiration models. These efforts seek to assess and compare the most widely used methods for estimating PET and ETo [21, 22, 10, 23, 24, 25, 26, 27, 28, 13, 29, 9].

The estimate of PET in Algeria is complex due to the country's diverse climate and geography [30, 31]. Researchers have developed methods tailored to specific regional conditions. Furthermore, the National Agency for Hydraulic Resources (ANRH) described an empirical formula using data from 45 climatological stations. The latter uses the Penman method in conjunction with temperature data to calculate monthly PET. It considers average monthly temperature, the month, and geographical location [32, 33]. However, its effectiveness is limited by a regional coefficient ( $K_r$ ), which restricts its application to areas far from the original stations [36].

In this context, this study develops a simplified mathematical expression to calculate the potential evapotranspiration across northern Algeria. The proposed approach relies on the ANRH formula using only air temperature. Given that air temperature data are widely available and reliable, this method provides a practical and robust solution for PET assessment. Moreover, it is anticipated that this simplified model will provide estimates near those obtained using the Penman model, offering a more physically accurate representation of evapotranspiration.

## 2. MATERIALS AND METHODS

### 2.1. Study Area and Data

Algeria is strategically located in North Africa, bordering the Mediterranean Sea to the north and extending southward to the Sahara Desert. It shares borders with Tunisia, Libya, Morocco, Mauritania, and the Western Sahara to the east, west, and southwest, while to the south, it is bordered by Niger and Mali. Covering an area of 2,381,741 km<sup>2</sup>, approximately 85% of Algeria is comprised of desert. This study specifically focuses on the northern region of Algeria, which spans 480,000 km<sup>2</sup> [32]. Geographically, the study area is defined by latitudes between 33° and 37° and longitudes between -2.2° and 8.6°, bordered to the north by the Mediterranean Sea and to the south by the Great Sahara. It encompasses 16 watersheds, numbered 01 to 17, excluding Basin 13, which represents the southern portion of the country.

Precipitation within this region exhibits significant variability, characterized by a pronounced gradient from north to south and a more subtle gradient from east to west [34]. The climate in northern Algeria is predominantly Mediterranean, with hot, dry summers and mild, rainy winters. In coastal areas, the rainfall is comprised between 400 and 1,500 mm compared to the high plateaus and the Saharan Atlas region, which are known for their semi-arid climate, where annual precipitation does not exceed 500 mm. The pre-Saharan and Saharan areas are classified as very arid, with annual rainfall averaging between 50 mm and 200 mm [35].

Algeria's territorial temperature fluctuates highly, with significant diurnal and sea-sonal variation. Indeed, the average daily temperature in January averages 11.5 °C, while in July, it oscillates between 25°C and 27°C. This variation is even higher in the high plateaus and the Saharan Atlas areas, with daily average temperatures in January ranging from 2°C to 9°C and in July.

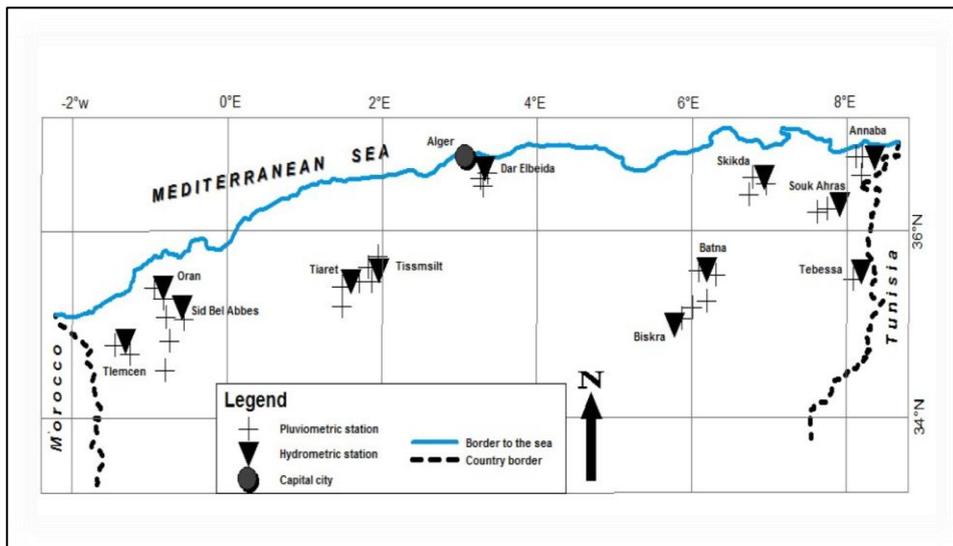


Figure 1. Location of northern Algeria (a) and altitude variations (b, c) across 12 watersheds.

2.2. Methodology

2.1.1. Potential Evapotranspiration Data

Interannual average data describing PET were collected from major meteorological stations and compiled in a map produced by the National Water Resources Agency (ANRH) in 2002. This data is needed to understand Algeria's environmental and climate conditions, which are important for areas like water management, agriculture, urban planning, and weather forecasting. The data helps us assess evapotranspiration, which is a key factor in evaluating water availability and managing water resources effectively in the region.

Moreover, monthly mean precipitation and temperature data were collected from websites, such as <https://www.infoclimat.fr/> for monthly data and <https://freemeteo.fr/> for daily data, for a period of 30 years (1985-2015). These meteorological data provide a strong foundation to analyze long-term climatic trends and variations. Thus, describing the region's climate dynamics.

The ANRH formula based on Penman's method served to derive the monthly potential evapotranspiration values. This approach is commonly employed in regions with limited meteorological data to calculate potential evapotranspiration.

By utilizing this data, the study offers a comprehensive assessment of potential evapotranspiration in the area over the 30 years. This information is valuable and can be applied for multiple purposes including water resource management, agriculture, and other sectors that rely on understanding of local climatic conditions.

2.2.2. Metrics of Performance

The study relied on the literature's statistical criteria [9, 13, 14, 19, 20] to compare and assess the performance of evapotranspiration (PET) models. These criteria are outlined in detail in the relevant sections of the study.

The metrics consider  $O_i$  and  $P_i$ , which represent the observed evapotranspiration dataset values and the evapotranspiration values calculated using the temperature-based models. The symbols  $P$  and  $O$  refer to the mean values of  $P_i$  and  $O_i$ , respectively, and  $n$  indicates the total number of data points or ordinates in the dataset.

Table 1. Statistical criteria used to evaluate the performance of the obtained potential evaporation model

| Criteria                               | Statistical formula   |
|--|---|
| Coefficient of determination ( $R^2$ ) | $R^2 = \frac{\sum_{i=1}^N (P_i - P) \times (O_i - O)}{[\sum_{i=1}^N (P_i - P)^2]^{0.5} [\sum_{i=1}^N (O_i - O)^2]^{0.5}}$ |
| Root Mean Square Error (RMSE)          | $RMSE = \sqrt{\frac{\sum_{i=1}^N (P_i - O_i)^2}{N}}$  |
| Mean Absolute Error (MAE)              | $MAE = \frac{\sum_{i=1}^N  P_i - O_i }{N}$  |

Mean Bias Error (MBE)

$$MBE = \frac{\sum_{i=1}^N (P_i - O_i)}{N}$$

O<sub>i</sub>: evapotranspiration values; P<sub>i</sub>: evapotranspiration values calculated from temperature-based models; P and O: average of P<sub>i</sub> and O<sub>i</sub>; n is the total number of ordinates

**2.2.3 Used Approach**

This current study relies on a graphical analysis to highlight to connexion between a crucial determinant, which is the mean air temperature in the evapotranspiration process and the PET itself both on an annual and monthly basis. The interannual mean PET data are directly sourced from the map presented in reference [37]. At the same time, the monthly PET values are derived using an empirical formula recommended by the National Agency for Hydraulic Resources (ANRH) (ANRH).

In Algeria, the ANRH has developed a region-specific empirical formula for estimating monthly potential evapotranspiration (PET). This formula is grounded on data collected from 45 climatological stations spread across the country. This formula uses data collected from 45 territorial climatological stations. The formula enables the estimation of monthly PET using the average monthly temperature, the month of the year, and the geographical location. The formula is as follows:

$$ETP_{ANRH} = k_r k_m (H - 187)(0.032t + 0.077) \tag{1}$$

With:

*k<sub>r</sub>*: regional coefficient,

*k<sub>m</sub>*: monthly coefficient,

*H*: Theoretical monthly sunshine duration (in hours per month), expressed as a function of Lambert Y values according to the formulas given in Table IV,

*t*: average monthly temperature for the month in question, expressed in C°.

Duration *H<sub>i</sub>* is linearly related to latitude *Y*: *H<sub>i</sub> = a<sub>i</sub>Y + b<sub>i</sub>* (2)

With: *Y*: latitude, in Lambert North-Algeria coordinates (in kilometres).

**Table 2.** Monthly parameters *a<sub>i</sub>* and *b<sub>i</sub>* given in the table below.

| Mois                        | 01     | 02     | 03     | 04     | 05     | 06     | 07     | 08     | 09     | 10     | 11     | 12     |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b><i>a<sub>i</sub></i></b> | 0,0218 | 0,0110 | 0,0012 | 0,0098 | 0,0201 | 0,0248 | 0,0230 | 0,0144 | 0,0031 | 0,0081 | 0,0185 | 0,0246 |
| <b><i>b<sub>i</sub></i></b> | 315    | 307    | 371    | 389    | 429    | 429    | 436    | 414    | 370    | 351    | 311    | 308    |

**Table 3.** The monthly coefficient values *k<sub>m</sub>*

| Mois                        | 01   | 02   | 03   | 04   | 05   | 06   | 07   | 08   | 09   | 10   | 11   | 12   |
|-----------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| <b><i>k<sub>m</sub></i></b> | 0.96 | 1.22 | 1.11 | 1.17 | 1.02 | 1.00 | 0.97 | 0.97 | 0.98 | 0.90 | 0.90 | 0.86 |

A high degree of consistency is observed between the study's findings and those obtained from Penman's formula. Considering that this study was based on data from 45 operational climatological stations, and the latter is based on average monthly temperatures [33]. This graphical analysis approach significantly improves our understanding of the temporal relationship between potential evapotranspiration (PET) and air temperature (annually and monthly). Indeed, this key tool enables an understanding of the temperature's influence on the evapotranspiration process within the region, which is essential for hydrological modeling, water resource management, and various other applications requiring a mastery of water transfer mechanisms in the environment.

Twelve meteorological stations strategically distributed across northern Algeria were considered in this analysis, including Dar El Beida, Oran, Tebessa, Tlemcen, Annaba, Tiaret, Souk Ahras, Sidi Bel Abbès, Skikda, and Tissemsilt. These stations represent a wide range of geographical areas across the region, providing a comprehensive database to assess climate variations. The study delivers a comprehensive view

of the spatial distribution of temperatures and potential evapotranspiration in this semi-arid region. The findings also depict regional variations and serve as valuable knowledge of the environmental dynamics. This analysis has important real-world applications in water management, environmental planning and agriculture. The data describing temperature and evapotranspiration variation is a key data to inform and guide national strategies for efficient water usage, a sustainable agricultural, and encourage sustainable practices to mitigate climate changes.

### 3. RESULTS

#### 3.1 Recovery of the Annual PET Series

Elevated temperature and limited precipitation are regarded as the main factors influencing the long-term average of potential evapotranspiration (PET) in semi-arid climate regions. These characteristics are unique to each specific locality. In these conditions when temperatures change, the potential for evapotranspiration changes as well, as higher temperatures rates are systematically associated with more potential evapotranspiration. The cartographic representation of temperature and potential evapotranspiration is a common practice to effectively apprehend the spatial distribution of climatic factors. This approach provides a more precise visualization of geographical variations, facilitating a more comprehensive understanding of temperature and evapotranspiration patterns across different regions within the semi-arid landscape. Such mapping is vital for accurately assessing local climatic conditions and determining the water requirements of these areas.

$$k_{t,i} = \frac{t_{a,i}}{t_o} \quad (3) \quad \text{and} \quad k_{PET,i} = \frac{PET_{a,i}}{PET_o} \quad (4)$$

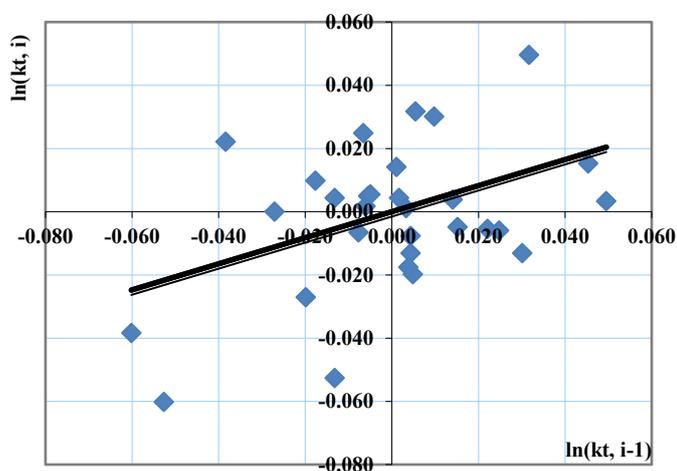
Where  $t_{a,i}$  is the average temperature for year  $i$  in  $^{\circ}\text{C}$ ;  $t_o$  is the mean interannual temperature in  $^{\circ}\text{C}$ ,  $PET_{a,i}$  is the potential evapotranspiration for year  $i$ , and  $PET_o$  is the mean interannual evapotranspiration in mm.

Given the preponderant influence of heat on potential evapotranspiration [4, 11, 13, 29, 31, 38, 40], in the physico-thermal conditions of a given locality, we seek the relationship between the moduli of PET and those of temperatures,  $k_{PET,i} = f(k_{t,i})$ . If we adopt a linear relationship, we obtain the equality of the two moduli:  $k_{PET,i} = k_{t,i}$ , hence the expression

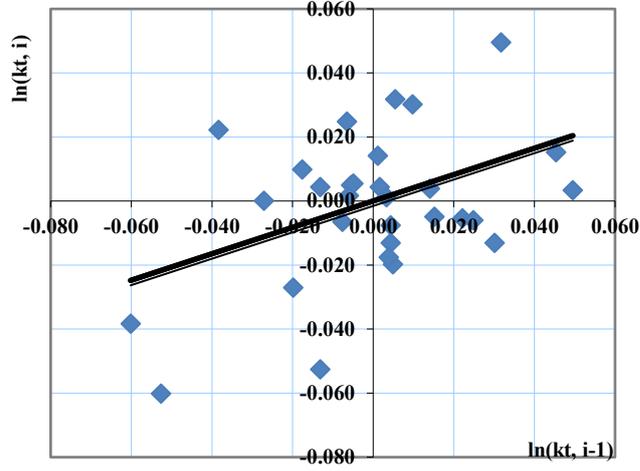
$$PET_{a,i} = k_{t,i}PET_o \quad (5)$$

However, autoregressive analysis of mean annual temperature time series revealed a fairly significant auto-correlation for practically all the stations examined (Fig. 1). By way of illustration, for all the stations examined, the graphical analysis of the dependence  $\ln(k_{t,i}) = f[\ln(k_{t,i-1})]$  has enabled us to obtain a type relationship:

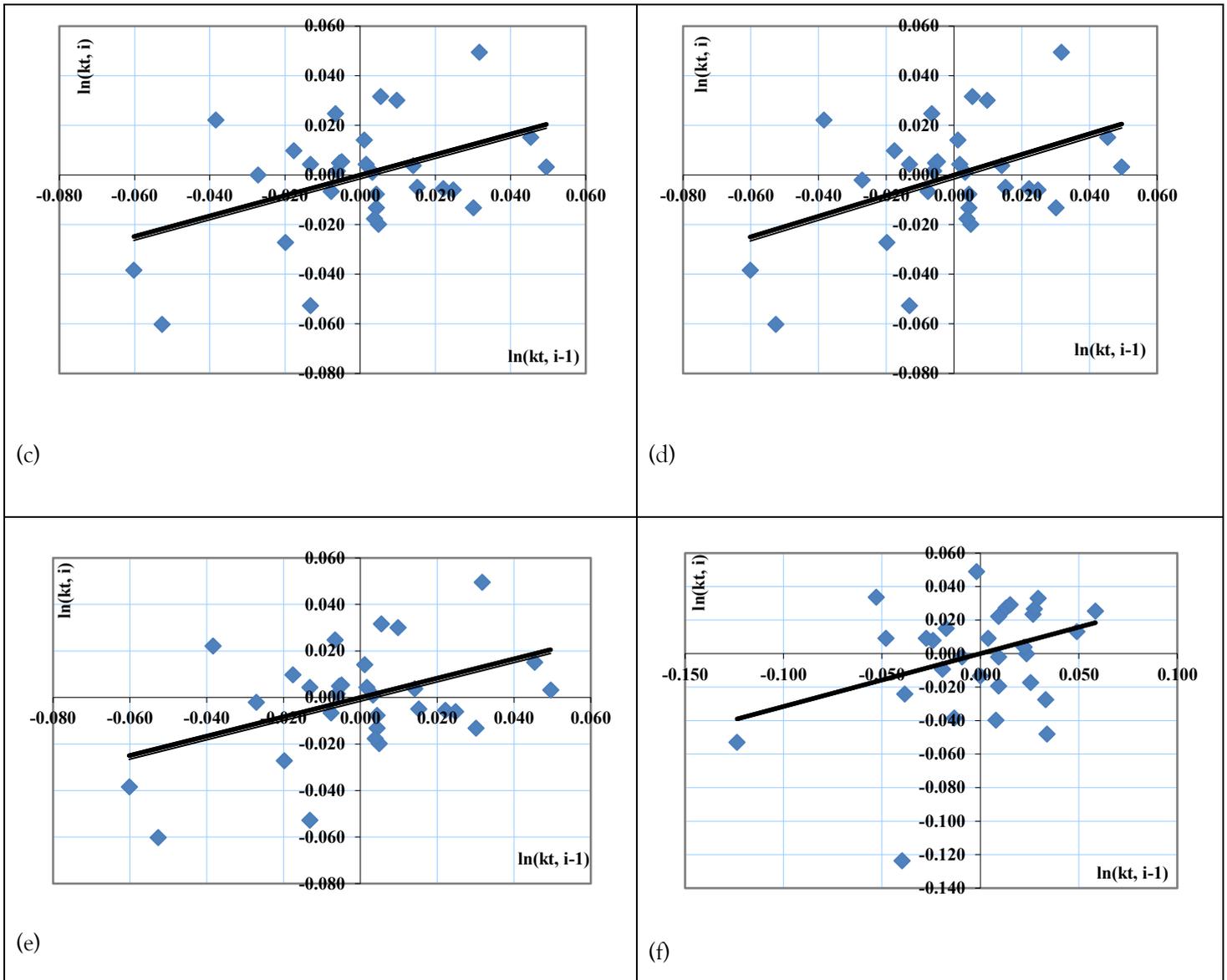
$$k_{t,i} = k_{t,i-1}^{\alpha} \quad (6)$$



(a)



(b)



**Figure 2.** Graphs of dependence for the stations of (a) Dar El Beida, (b) Annaba, (c) Oran, (d) Tlemcen, (e) Tebessa, and (f) Tiaret.

Below, we present the graph of this dependency (Fig. 1), which is expressed as:

$(k_{t,i}) = 0.61(k_{t,-1})$  with an auto-correlation coefficient  $r_1 = 0.61$ , thus:

$$k_{t,i} = k_{t,-1}^{0.61} \quad (7)$$

The conclusion is that potential evapotranspiration in a given year depends not only on the temperature of the current year but also, to a lesser extent, on the temperature of the previous year  $t_{a,-1}$  due to thermal inertia. Consequently, the proportionality coefficient  $k_{PET}$ , can be expressed as follows:

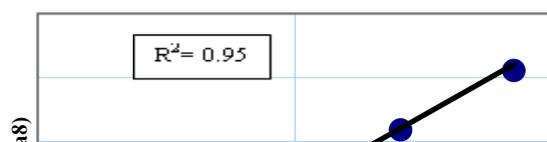
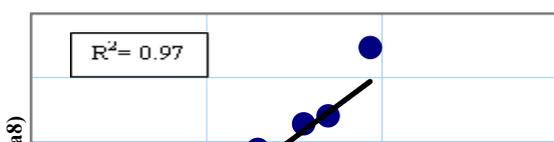
- For the current year  $i$ ,  $k_{PET,i} = \lesssim k_{t,i}^1$ , with an auto-correlation coefficient  $r_1$
- For the previous year  $i-1$ ,  $k_{PET,i} = \lesssim k_{t,i-1}^{\alpha_2}$ , with an auto-correlation coefficient  $r_2$

Since a linear relationship is assumed for the current year,  $\alpha_1 = 1$  and  $r_1 = 1$ . To account for the simultaneous influence of current and previous years' temperatures, the coefficient is expressed as an average:

$$k_{PET,i} = \frac{k_{t,i} + r_2 k_{t,i-1}^{\alpha_2}}{1 + r_2} \quad (8) \text{ or alternatively: } k_{PET,i} = \sqrt{k_i k_{i-1}^{\alpha_2}} \quad (9)$$

The value of potential evapotranspiration for a given year  $PET_{a,i}$  can thus be determined by multiplying the value of the interannual mean evapotranspiration  $PET_0$  by the proportionality coefficient  $PET_{a,i}$

$$PET = k_{PET,i} PET_0 \quad (10)$$



(a)

(b)

(b) (d)

**Figure 3.** Graphique de la dépendance  $k_{(PET, i)}$  et  $t_{m,i}$  pour les stations de (a) dar elbida , (b)Annaba , (c)Oran , (d)Tlemcen ,(e)Tebessaet (f)Tiaret.

Values of the same order were obtained for the Skikda station. A graphical analysis (Fig. 3) of the proportionality coefficient values  $k_{(PET, i)}$  calculated using expressions (8) and (9) reveals a strong correlation. Deviations from the mean value range from 0.02% to 0.90%. Using equation (10), we were able to reconstruct the annual potential evapotranspiration for all the stations examined in this research.

In this context, the climatic exponent  $n$  is determined empirically by analyzing historical data. The established relationship reflects how seasonal thermal variations affect evapotranspiration rates across different months. This monthly formulation enhances the precision of PET estimates, supporting applications in crop planning, hydrological modeling, and climate adaptation strategies.

### 3.2 Establishment of Monthly PET Series:

In a similar way, we consider that monthly potential evapotranspiration is mainly a function of the month's heat reserves  $P_{m,i}$  , represented by monthly mean temperatures  $t_{m,i}$ . We denote the monthly modulus of temperature for a given year by:

$$\tau_i = \frac{t_{m,i}}{t_{m,m,a}}$$

And the monthly modulus of potential evapotranspiration for the same year by:  $\rho_i = \frac{PET_{m,i}}{PET_{m,m,a}}$

Thus, the following relationship can be expressed:  $\rho_i = \tau_i^n$  (11)

Where:

- $t_{m,m,a}$  : mean monthly temperature for year  $i$
- $PET_{m,m,a}$ : mean monthly potential evapotranspiration for the same year

- n:climaticexponent

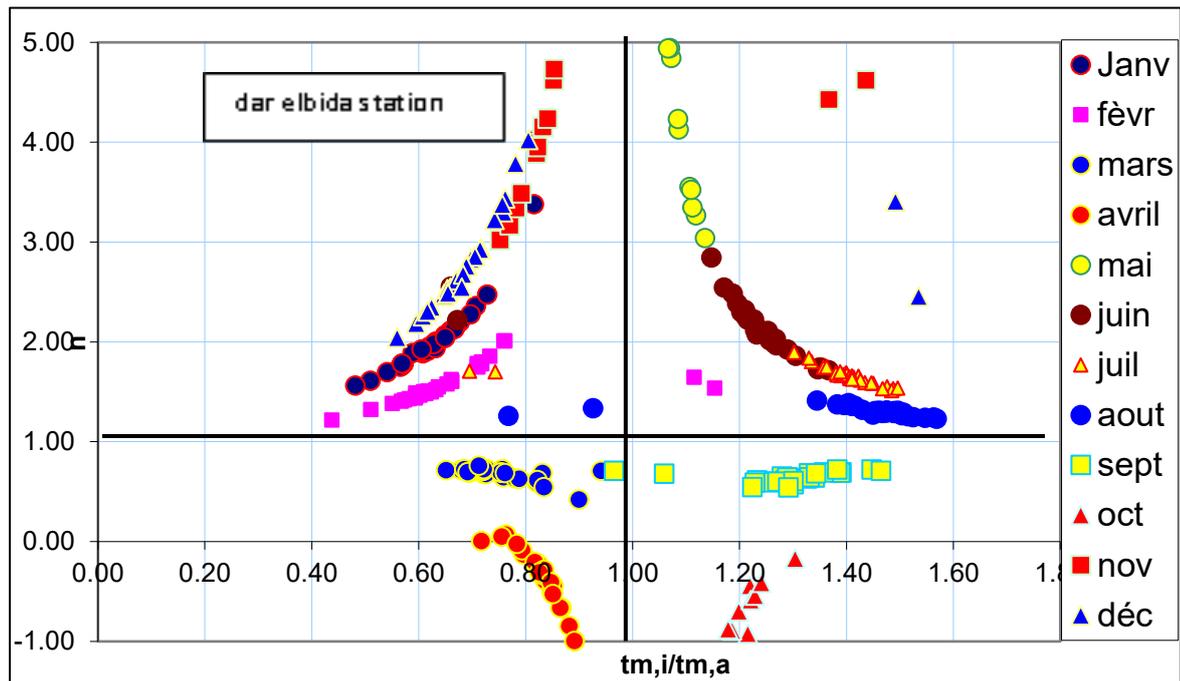


Figure 4. Dependency graph  $n = f\left(\frac{t_{m,i}}{t_{m,m,a}}\right)$  for Dar Elbida station

- For most of the weather stations examined, the dependency graphs  $n = f\left(\frac{t_{m,i}}{t_{m,m,a}}\right)$  are characterized by a specific scattering of points, for almost all months.
- However, for some weather station, the shape of these dependencies is virtually functional, as shown by the graph for the Tebessa and Tiaret stations (Fig. 6).

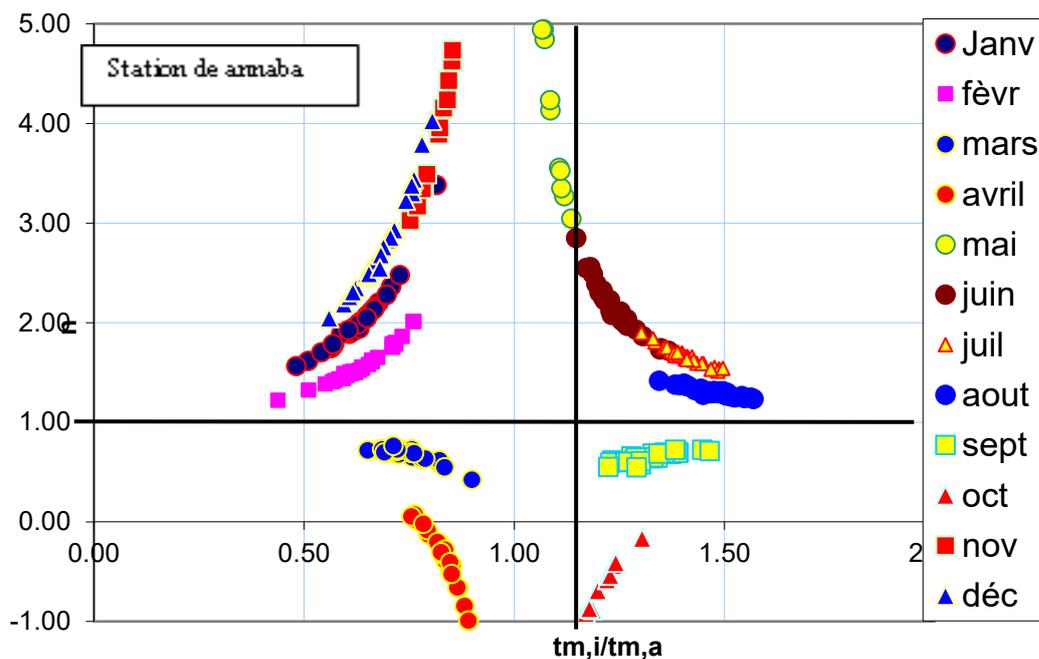


Figure5 : Dependency graph  $n = f\left(\frac{t_{m,i}}{t_{m,m,a}}\right)$  for Annaba station.

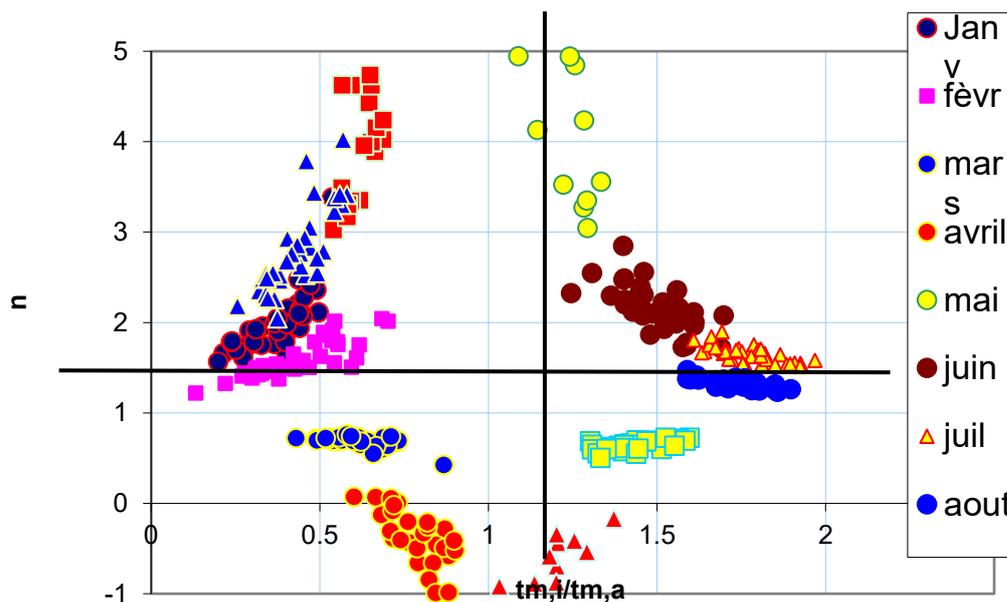


Figure6. Dependency graph  $n = f\left(\frac{t_{m,i}}{t_{m,m,a}}\right)$  for the Tebessa and Tiaret station.

The determination of the monthly exponent enables the calculation of potential evapotranspiration values for each month using the following formula:

$$PET_{m,i} = PET\left(\frac{t_{m,i}}{t_{m,m,i}}\right)^n \quad (12)$$

A graphical examination of the relationship between the exponent values and the annual temperature moduli ratios  $\frac{t_{m,i}}{t_{m,m,a}}$  for different months reveals that the data points exhibit hyperbolic and asymptotic behavior relative to the values  $\frac{t_{m,i}}{t_{m,m,a}} = 1$  and  $n = 1$  (Figures 4, 5, and 6).

This relationship is analytically represented by a homographic function expressed as:

$$n_i = \frac{\alpha\tau_i - \beta}{\tau_i - 1} \quad (13)$$

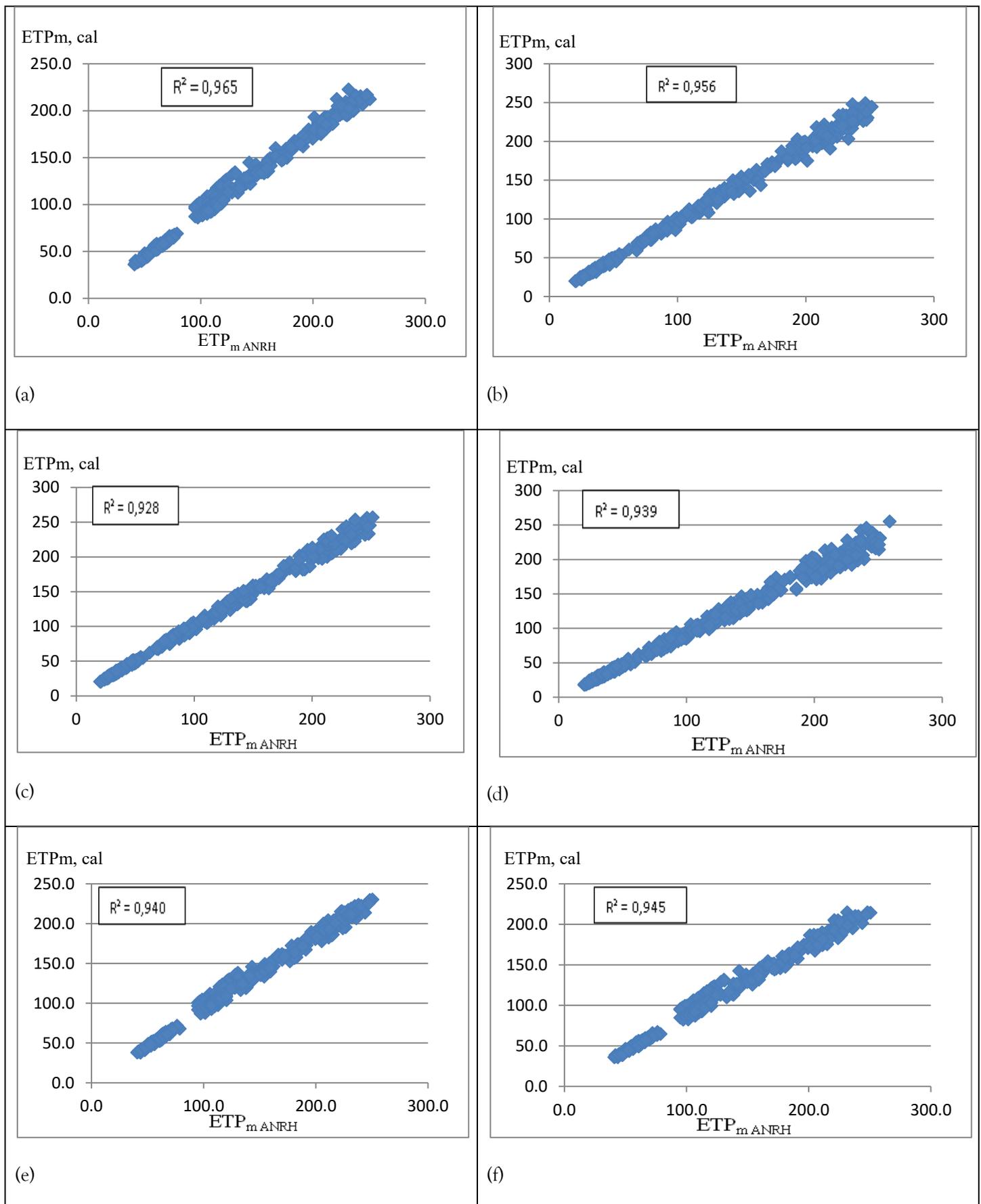
The graphical analysis of the function  $n \times (\tau_i - 1) = f(\tau_i)$  for the various months demonstrated a linear trend, which facilitated the determination of the parameters  $\alpha$  and  $\beta$  specific to each month.

Table 4. Monthly parameter values  $\alpha$  and  $\beta$

|          | 01    | 02    | 03    | 04    | 05    | 06    | 07    | 08    | 09    | 10    | 11    | 12    |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $\alpha$ | 0.426 | 0.589 | 0.844 | 0.937 | 0.966 | 0.940 | 0.926 | 0.901 | 0.878 | 0.743 | 0.521 | 0.423 |
| $\beta$  | 1.004 | 0.942 | 0.825 | 0.742 | 0.715 | 0.687 | 0.657 | 0.734 | 0.976 | 1.033 | 1.127 | 1.150 |

By utilizing the interannual mean potential evapotranspiration values, which can be sourced from the map provided by the National Agency for Hydraulic Resources (ANRH) (1977), it becomes feasible to estimate the specific annual values  $PET_{a,i}$ . These values are determined as a function of the temperature modulus ratio of the current year relative to the previous year, denoted as  $k_{a,i} = (k_{t,i}, k_{t,i-1})$ , through one of the two relationships expressed in equations (8) and (9).

### 3.3 Performance Analysis and Model Evaluation



**Figure 7.** Dependency graph  $ETP_{m,cal} = f(ETP_{m,ANRH})$  for the stations of (a) Dar El Beida, (b) Annaba, (c) Oran, (d) Tlemcen, (e) Tebessa, and (f) Tiaret.

The relation  $PET_{m,i} = PET_{m,m,a} \tau^n$ , with  $n_i = \frac{\alpha \tau_i - \beta}{\tau - 1}$  and  $\tau_i = \frac{t_{m,i}}{t_{m,m,a}}$ , is used to estimate monthly ETP values. The values of the parameters  $\alpha$  and  $\beta$  are given in Table 4.

To illustrate the application of this method, the monthly potential evapotranspiration values calculated over the period from 1986 to 2015 at the Dar El Beida, Annaba, Oran, Tlemcen, Tebessa, and Tiaret weather stations were compared with the values calculated using the ANRH method.

**Table 5.** Performance comparison of the model across six stations

| Station parameter    | darelbida | Annaba | Oran | Tlemcen | Tebessa | Tiaret |
|----------------------|-----------|--------|------|---------|---------|--------|
| (R <sup>2</sup> )    | 0.97      | 0.93   | 0.96 | 0.94    | 0.94    | 0.95   |
| (R <sup>2</sup> Adj) | 0,92      | 0,90   | 0,97 | 0,91    | 0,98    | 0,93   |
| (RMSE)               | 0,15      | 0,13   | 0,19 | 0,23    | 0,20    | 0,32   |
| MAE                  | 0,16      | 0,01   | 0,19 | 0,19    | 0,39    | 0,32   |
| MBE                  | 0,02      | -0,00  | 0,04 | 0,04    | 0,15    | 0,10   |

**Interpretation and Discussion :**

- **Coefficient of determination (R<sup>2</sup>):**

- Reflects the model's ability to explain data variability. Ideal value: 1.
- Best performance: Dar El Beida (0.97), indicating excellent accuracy.
- Lowest: Annaba (0.93), still very satisfactory.
- All stations scored above 0.90 → robust model.

- **Adjusted R<sup>2</sup> (R<sup>2</sup> Adj):**

- Accounts for number of predictors.
- Best: Tebessa (0.98), lowest: Oran (0.97).

- **Root Mean Square Error (RMSE):**

- Indicates mean deviation.
- Best: Annaba (0.13), worst: Tiaret (0.32).

- **Mean Absolute Error (MAE):**

- Best: Annaba (0.01), worst: Tebessa (0.39).

- **Mean Bias Error (MBE):**

- Closest to zero (best): Annaba (-0.00).
- Highest positive bias: Tebessa (0.15), followed by Tiaret (0.10).

These indicators confirm the model's high predictive performance and its robustness across diverse climatic zones.

**Table 6.** Comparison of actual and calculated ETP data across stations

| Station Parameter | darelbida | Annaba | Oran   | Tlemcen | Tebessa | Tiaret |
|-------------------|-----------|--------|--------|---------|---------|--------|
| ETPmin(ANRH)      | 40,9      | 20,2   | 24     | 39,7    | 44,1    | 38     |
| ETPmin(cal)       | 36,1      | 20,5   | 19,9   | 34,7    | 37,8    | 36,1   |
| ETPmax(ANRH)      | 250,6     | 251,4  | 248,9  | 249,1   | 231,6   | 220,5  |
| ETPmax(cal)       | 222,7     | 256,2  | 249,6  | 239,5   | 247,2   | 216,1  |
| Moy ETP(ANRH)     | 112,2     | 126    | 116    | 120     | 131,2   | 121    |
| Moy ETP(cal)      | 117,5     | 116,8  | 112,8  | 109,4   | 118,8   | 115,3  |
| Var ETP(ANRH)     | 2864,3    | 5407   | 5307   | 3725,9  | 3925,9  | 3405   |
| Var ETP(cal)      | 3079,8    | 5363,8 | 5009,2 | 3682,1  | 3324,1  | 2970,3 |

|                    |      |       |      |       |      |       |
|--------------------|------|-------|------|-------|------|-------|
| Ecart<br>ETP(ANRH) | 53,5 | 73,53 | 72,8 | 61,04 | 62,7 | 58,35 |
| EcartETP(cal)      | 55,5 | 73,2  | 70,8 | 51,79 | 57,7 | 54,5  |

These results show strong alignment between calculated and actual values, with minor deviations:

- **PET<sub>min</sub>**: Calculated values are slightly lower than measured ones in most cases, with good agreement in Annaba (20.2 vs 20.5).
- **PET<sub>max</sub>**: High concordance observed across all stations; highest values seen in Annaba.
- **Average PET**: Calculated means are close to observed values; highest at Tebessa (131.2 observed vs. 118.8 calculated).
- **Variance**: Observed values show slightly greater dispersion, but calculated values remain within acceptable ranges.
- **PET Difference**: Deviations are small, confirming the model's stability—smallest difference in Dar El Beida, largest in Annaba.

Overall, the comparison validates the model's ability to accurately replicate the spatial and temporal variability of potential evapotranspiration across northern Algerian watersheds.

#### 4. DISCUSSION

Understanding the interannual mean value of potential evapotranspiration (PET) is crucial for analyzing climate patterns and their impact on water resources in semi-arid regions. By utilizing the map provided by the Agence Nationale des RessourcesHydrauliques (1997), the interannual mean PET can be derived, accurately reflecting the prevailing climatic conditions of the region. Based on this mean value, it becomes possible to estimate specific annual values of potential evapotranspiration (PET) for any given year by relating the temperature of the current year to that of the previous year.

The relationship between temperature and evapotranspiration is central to understanding the annual variations in PET. As expressed in equations (8) and (9), the annual values of potential evapotranspiration can be predicted through a function that correlates the current year's temperature with that of the previous year. This approach takes into account the phenomenon of thermal inertia, recognizing that climatic variables often display continuity and dependency across time.

One of the primary advantages of this method lies in its dynamic character. It enables a year-to-year estimation of PET based solely on temperature data, which are readily available from most meteorological stations. This simplicity makes the model particularly effective for regions where comprehensive climatic datasets (e.g., solar radiation, humidity, wind speed) are lacking. In addition, it supports rapid assessments of the effects of climate variability on evapotranspiration, allowing for real-time or predictive management decisions.

The model's reliability has been confirmed through strong correlations between calculated and observed values across various statistical indicators, including  $R^2$ , RMSE, MAE, and MBE. These results validate its robustness and precision across a range of climatic contexts, especially within the diverse watersheds of northern Algeria.

Furthermore, the method's extension to monthly scales by introducing a climatic exponent (n) allows for a more granular understanding of seasonal PET dynamics. This improves the capacity to forecast crop water requirements, monitor drought evolution, and support irrigation planning.

In light of the above, it is evident that establishing a strong link between temperature and potential evapotranspiration enhances the precision of hydrological modeling. By integrating this model into water resource management strategies—particularly in semi-arid and arid environments—it becomes possible to anticipate water shortages, optimize water allocation, and mitigate the adverse impacts of climate change. This contributes to sustainable development goals in water-scarce regions and reinforces the necessity of climate-informed resource planning.

#### 5. Conclusion and Perspectives

The methodology developed for estimating potential evapotranspiration (PET) in this study is grounded in a scientifically sound and operationally practical approach that leverages the strong dependency of PET on air temperature—both at the annual and monthly scales. Given the scarcity of complete

meteorological datasets in many semi-arid and arid regions, including northern Algeria, the choice of using temperature as the sole input parameter enhances the accessibility and applicability of the model. At the annual level, the model reconstructs PET values using a proportionality coefficient  $k_{ETP,i}$ , which is a function of the temperature moduli of the current and previous years. This formulation incorporates the concept of thermal inertia and allows for the dynamic tracking of interannual variations in PET using only historical and current temperature data. The relationship is expressed as:  $ETP_{a,i} = k_{ETP,i}ETP_o$ . For monthly PET estimation, the model uses the following relationship:

$$PET_{m,i} = PET\tau_i^n$$

Where  $\tau_i = \frac{t_{m,i}}{t_{m,m,a}}$  is the monthly temperature modulus, and n is a climatic exponent modeled by a homographic function:  $n_i = \frac{\alpha\tau_i - \beta}{\tau_i - 1}$

The monthly approach adopted in this study enables a detailed representation of seasonal fluctuations in potential evapotranspiration, thereby supporting practical applications such as estimating agricultural water needs, optimizing irrigation schedules, and monitoring drought conditions.

The reliability of this method has been rigorously evaluated using data from multiple meteorological stations located in various climatic regions across northern Algeria. The results demonstrate that the model achieves high coefficients of determination ( $R^2$  exceeding 0.90), along with low RMSE and MAE values and minimal mean bias error (MBE), underscoring its precision and robustness. These findings suggest that the model can serve as a practical alternative to more intricate approaches like the Penman-Monteith model, particularly in situations where meteorological data are limited.

While the method generally produces consistent results, a slight underestimation of PET was noted during the hottest months. To address this, a monthly correction factor was implemented, calculated as the ratio of the reconstructed annual PET to the sum of the monthly PET values for the same year. This adjustment ensures that the sum of the monthly estimates matches the annual total, thereby improving both internal consistency and physical plausibility.

Overall, the model offers a significant improvement in estimating potential evapotranspiration using streamlined input data. By balancing scientific rigor with operational simplicity, it provides a versatile and adaptable framework. Its straightforward application makes it especially beneficial for hydrologists, agricultural planners, and water resource managers working in data-constrained environments.

From a research perspective, several avenues can further enrich and expand the applicability of the proposed model:

- **Integration with Remote Sensing Data:** By coupling the model with satellite-derived temperature and evapotranspiration products (e.g., MODIS, Landsat), its spatial resolution and regional scalability can be significantly enhanced.
- **Incorporation into Climate Models:** Linking this model with regional or global climate projection tools (e.g., CMIP6 outputs) can facilitate long-term forecasts of evapotranspiration in the context of climate change scenarios (RCPs/SSPs).
- **Adaptation for Operational Hydrology:** Embedding the model into decision-support systems for irrigation scheduling, reservoir management, and drought early warning systems would increase its value for practitioners and policymakers.
- **Application to Other Regions:** While the current study focused on northern Algeria, the framework is generalizable to other semi-arid Mediterranean basins with minimal calibration, which could promote broader applicability.
- **Use of Artificial Intelligence:** Incorporating machine learning and optimization algorithms (e.g., Random Forest, XGBoost, Genetic Programming) could help refine the parameter estimation process and reduce uncertainties.

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