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Optimization of Surface Irrigation through Infiltration Modeling for Environmental Protection in the Ouargla Region

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Dedications

To my beloved parents,

who sacrificed everything so that I could reach this day, whose prayers never ceased and whose love never faded , no words can ever express my gratitude for all you have done for me.

To all my friends and colleagues,

who shared with me the journey of studying and learning, and made the hard days easier with their presence.

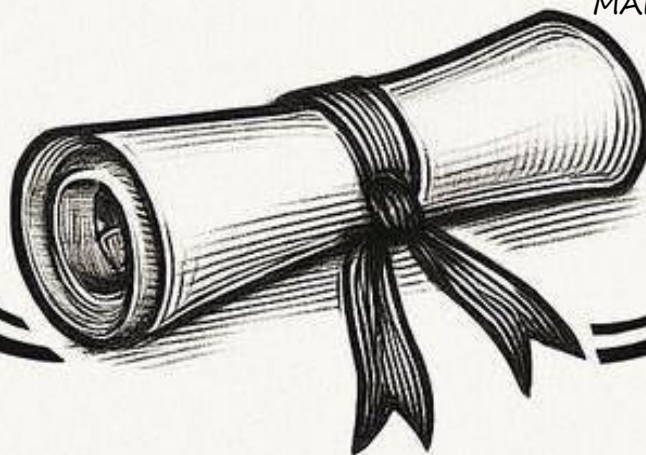
To all my professors,

who lit the candle of knowledge in our minds an guided us with wisdom and dedication.

To everyone

who believed in me this work is dedicated to you.

MAROUA



ملخص : يُعدّ الماء مورداً حيوياً وأساسياً للحياة البشرية، لا سيما في المناطق القاحلة وشبه القاحلة كمناطق ورقلة، التي تواجه تحديات كبيرة في إدارة مواردها المائية. ويُعتبر القطاع الزراعي أكبر مستهلك للمياه في المنطقة (70%)، يؤدي نقص الوعي وسوء استخدام موارد المياه إلى تفاقم هذه المشكلة. يُعدّ الري السطحي الطريقة الأكثر شيوعاً في حوض ورقلة، إلا أنه يعاني من انخفاض الكفاءة. يأخذ نموذج رياضي قائم على طريقة كوستياكوف توزيع المياه وحجمها وحركتها ومعدل التسرب على طول الأرض، أُجريت حسابات رياضية لتحديد معدل تسرب المياه على أربعة ألواح بأطوال ومعدلات تدفق مختلفة، لدورات الري: 35 دقيقة للوح الأول، 18 دقيقة للثاني، 27 دقيقة للثالث، و28 دقيقة للرابع. الهدف من هذه الدراسة هو إنشاء تطبيق هاتفي مبني على هذه الطريقة من أجل تحسين توقيت الري ومعدلات تدفق المياه من خلال تحديد معدل التسرب، مما يُساهم في الحد من الإفراط في استخدام المياه، وتقليل جريان المياه السطحية، وحماية المياه الجوفية، والحفاظ على التوازن البيئي في المنطقة.

الكلمات المفتاحية: المياه، السقي السطحي، التسرب ، تطبيق هاتفي، ورقلة

Summary: Water is a vital and essential resource for human life, especially in arid and semi-arid regions like Ouargla, which faces significant challenges in managing its water resources. The agricultural sector is the largest consumer of water in the region (70%), and a lack of awareness and misuse of water resources exacerbate this problem. Surface irrigation is the most common method in the Ouargla basin, but it suffers from low efficiency. A mathematical model based on the Kostiakov method considers water distribution, volume, movement, and seepage rate along the land. Mathematical calculations were performed to determine the water seepage rate on four panels of varying lengths and flow rates for irrigation cycles: 35 minutes for the first panel, 18 minutes for the second, 27 minutes for the third, and 28 minutes for the fourth. The aim of this study is to develop a mobile application based on this method to optimize irrigation timing and water flow rates by determining the seepage rate. This will contribute to reducing water overuse, minimizing surface runoff, protecting groundwater, and maintaining the ecological balance in the region.

Keywords: water, surface irrigation, infiltration, mobile application, Ouargla

Résumé : L'eau est une ressource vitale pour la vie humaine, notamment dans les régions arides et semi-arides comme Ouargla, qui doit relever d'importants défis en matière de gestion de ses ressources hydriques. Le secteur agricole est le plus gros consommateur d'eau de la région (70 %), et le manque de sensibilisation et la mauvaise utilisation de cette ressource aggravent ce problème. L'irrigation de surface est la méthode la plus courante dans le bassin d'Ouargla, mais son efficacité est faible. Un modèle mathématique basé sur la méthode de Kostiakov prend en compte la distribution, le volume, le mouvement et le taux d'infiltration de l'eau sur le terrain. Des calculs mathématiques ont été effectués pour déterminer le temps d'infiltration de l'eau sur quatre parcelles de longueurs et de débits différents pour des cycles d'irrigation : 35 minutes pour la première, 18 minutes pour la deuxième, 27 minutes pour la troisième et 28 minutes pour la quatrième. L'objectif de cette étude est de développer une application mobile basée sur cette méthode afin d'optimiser le calendrier d'irrigation et les débits d'eau en déterminant le taux d'infiltration. Ceci contribuera à réduire la surconsommation d'eau, à minimiser le ruissellement de surface, à protéger les eaux souterraines et à maintenir l'équilibre écologique de la région.

Mots-clés : eau, irrigation de surface, infiltration, application mobile, Ouargla

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General Introduction

General Introduction

Resources are among the scarcest natural resources in arid and semi-arid regions. Data from the Food and Agriculture Organization of the United Nations (FAO) indicates that approximately 3.2 billion people live in agricultural areas suffering from high to very high water scarcity (UN-Water, 2020) .

The Middle East and North Africa (MENA) region is the most water-insecure region in the world, driven by a range of factors, including population growth and increasing food demand (Food and Agriculture Organization,2011b) . The agricultural sector remains a vital socio-economic sector in most MENA countries, consuming **85%** of the region's available freshwater resources. It is the sector most affected by water scarcity, which negatively impacts food security (FAO,2021) .

Surface irrigation is the most dominant method in the global agricultural landscape , particularly in desert regions and specially in the Ouargla basin, due to its simplicity and low cost . However, this traditional method masks several significant problems, namely uncontrolled deep infiltration , which leads to substantial water loss, soil salinization, and a rise in the groundwater level, causing it to rise to the surface. These problems result in escalating environmental degradation and a decline in agricultural production.

To address these issues, the infiltration calculation method (Kostiakov method) emerged to control the amount of infiltration water, as well as irrigation time and water flow.

Based on the above, this study focuses on the following questions:

- To what extent can infiltration modeling be used?
- How can the calculation method be improved?
- How can modern technologies be integrated into the calculation to improve the efficiency of surface irrigation and reduce its negative environmental impacts in desert regions?
- How can controlling infiltration parameters contribute to reducing the environmental degradation of soil and groundwater?

General Introduction

The aim of this work is to determine the soil infiltration rate by providing known water flow rate and irrigation time. Developing a method for determining the infiltration rate, water flow rate, and irrigation time requires programming the method and converting it into a mobile application for ease of use and speed, thus replacing traditional methods. To achieve this, the work plan is summarized as follows:

- Chapter I : Theoretical Framework: Provides general information about water resources and an overview of surface irrigation.
- Chapter II : Explains the Kostiakov method and its calculation rules.
- Chapter III : Presents and interprets the results.
- Chapter IV : Explains the programming language used (Python), the programming steps, and the final mobile application.
- We conclude with a general summary and some recommendations.

Chapter I

Surface Irrigation

I. Introduction :

The use of the term irrigation, of scholarly origin, was popularized at the beginning of the century, a time when large hydraulic equipment was developed to meet water shortages, allow the intensification of agriculture and generate a new agricultural revolution (Marzouk, Y,1989). Since the 1960s , the practice of irrigation has led to a considerable increase in global food production, particularly in developing countries (Food and Agriculture Organization,2002)(Rosegrant, M.W. et al,2002)(Seckler, D. et al,1999) .

Indeed, depending on the species and varieties cultivated, the land, and the techniques used, irrigation can increase production by two to five times (and even ten times in arid zones) (Plauchu, V,2013) .

It must also lead to environmental preservation, particularly of agricultural land, and to water conservation for irrigation, which in turn translates into energy savings (Ollier, C. and Poirée, M,1983) .

Irrigation methods applied to wastewater are comparable to those used with conventional water. When applied correctly, these irrigation techniques reduce wastewater-related health problems and ensure good agricultural yields, while controlling environmental risks. The overriding imperative is to increase water use efficiency and find an irrigation method requiring minimal capital investment or expensive equipment.

With agriculture consuming approximately **70%** of the world's freshwater resources, the need for innovative water conservation technologies is becoming increasingly critical, particularly in water-scarce environments (Food and Agriculture Organization,2011b) (Food and Agriculture Organization,2011a) (Zegait, R. et al,2025) .

However, choosing an irrigation technology suited to a given context depends on a complex, sometimes conflicting, combination of physical, technical, and socioeconomic factors . Indeed, economic considerations, soil and climate conditions, and farming practices vary across regions, so an irrigation system deemed effective in one country may prove unsuitable in another (Food and Agriculture Organization,1997) (Keller, A. and Keller, J,2003) .

In arid and semi-arid regions, the limited availability of water resources is one of the main factors limiting the development of sustainable agriculture. These regions are characterized by low, irregular, and poorly distributed rainfall, which significantly reduces the reliability of

rainfed agriculture and makes irrigation essential to ensure agricultural production (Food and Agriculture Organization,2011b) (Food and Agriculture Organization,2011a) .

In this context, irrigated agriculture plays a vital role in food security and the economic development of arid zones. However, increasing pressure on water resources necessitates more rational and efficient management of irrigation water. Improving water use efficiency is therefore a priority in order to limit losses through evaporation, runoff, and deep percolation, while ensuring adequate water supply to the root zone of crops (Allen, R.G. et al,1998) .

Thus, the adoption of water-efficient irrigation techniques adapted to the climatic and soil conditions of arid and semi-arid regions constitutes an essential strategy to optimize the use of water resources, improve agricultural productivity and ensure the sustainability of production systems (Snyder, R.L. and Haman, D.Z,2017) .

1. Concepts and Functioning :

Bed irrigation is a trickle irrigation method . It is a traditional agricultural technique where water is applied in small furrows dug between rows of crops. The water flows by gravity along the furrows and gradually infiltrates the soil, reaching the root zone of the plants (Allen, R.G. et al,1998) .

The system operates on a few simple principles: water is introduced at the top of each furrow, and its flow rate is controlled to ensure uniform infiltration. Moisture is distributed laterally and vertically, allowing the roots to efficiently absorb water (Kendy, E. and Pala, M.2005) (**Photo I.01**) .



Photo I.01 : Surface irrigation .

2. Surface irrigation advantages and disadvantages :**2.1. Surface irrigation offers several advantages :**

- It allows for significant water savings compared to sprinkler irrigation because losses through evaporation and deep percolation are limited (Mohamed, Z.E. et al,2026) .
- It is also simple and inexpensive , requiring no complex pumping systems. This technique is suitable for sandy or silty soils and can reduce erosion if the slope is gentle and the flow rate controlled (Maas, E.V. and Hoffman, G.J,1977) .

2.2. Surface irrigation disadvantages :

This method has limitations .

- Irrigation uniformity can vary depending on the length and slope of the ditches, and manual labor is required for their construction and maintenance.
- In very clayey soils, infiltration is slow, which can lead to puddles and promote root diseases (Pallas, J,2004) .
- Water management can be tricky if the slope of the land is too steep, leading to uneven infiltration (Kendy, E. and Pala, M,2005) .

Controlled runoff (surface irrigation) is primarily used for vegetable crops such as tomatoes, carrots, and lettuce, as well as for some cereal crops like maize and wheat (Allen, R.G. et al,1998) (Pallas, J,2004) . This technique is generally adopted on farms with limited mechanization, where investments in irrigation equipment remain limited. It is particularly well-suited to arid and semi-arid regions, characterized by limited water availability and climatic conditions that promote high evaporation (Kendy, E. and Pala, M,2005) .

In desert environments, characterized by very low rainfall, often less than 100 mm/year, and very high potential evapotranspiration, irrigation is an essential factor for agricultural production and the sustainability of palm groves (Food and Agriculture Organization,2002) (Allen, R.G. et al,1998) (Maas, E.V. and Hoffman, G.J,1977) .

Date palm (*Phoenix dactylifera L.*) cultivation dominates oasis agricultural systems and plays a crucial role in the organization of agricultural space, notably by creating a microclimate favorable to the development of associated crops, such as market garden crops, fodder crops, or cereals, grown under its canopy (Pallas, J,2004) (Food and Agriculture Organization,2002b).

Irrigation using raised beds around palm trees ensures water supply to the root zone while maintaining the moisture levels in the topsoil necessary for intercropping (Bengezi, F. et al,2017) . However, the effectiveness of this technique is highly dependent on soil physical characteristics, plot leveling, and irrigation timing. Inadequate control of these parameters can lead to significant water losses and contribute to soil salinization problems (Bengezi, F. et al,2017) (Tixier, P,2010) .

In North African oasis farming systems, water management has historically relied on collective practices and traditional hydraulic infrastructure that allows for the gravity-fed distribution of irrigation water. According to (Al-Karadsheh, E. et al,2015) , surface irrigation remains the dominant technique in oases, particularly through the use of basins, raised beds, or furrows. These methods, adapted to small-scale, low-mechanization farms, allow water to be distributed among the plots via a network of canals and irrigation.

Channels. However, their effectiveness depends on flow control, plot leveling, and the social organization of water distribution.

The oases of the Algerian Sahara are also characterized by traditional irrigation systems based on ancient hydraulic infrastructure, notably foggaras and networks of distribution canals (Choukr-Allah, R,2014) . show that these systems constitute forms of socio-hydraulic organization enabling collective and sustainable management of water resources in an arid environment. Water drawn from underground aquifers is distributed by gravity to agricultural plots and used for irrigating palm groves and associated crops.

The date palm also has relatively high water requirements compared to other crops adapted to arid regions. According to (Kuper, M. et al.2009) , these requirements vary depending on climatic conditions, soil type, and the irrigation system used. In desert regions, water is generally applied in basins or raised beds around the palms to promote infiltration into the root zone. Proper management of irrigation frequency and quantity is essential to optimize production and limit water losses through evaporation or deep drainage.

3. Performance and results of bed irrigation :

“In a field trial on maize in arid zones, three furrow irrigation methods were compared: alternating furrow irrigation (AFI), fixed furrow irrigation (FFI), and conventional all-furrow irrigation (CFI). The results showed that, although the forward water distribution did not differ significantly between treatments, AFI maintained high maize yield levels even with up to a **50 %** reduction in the amount of water applied . Furthermore, AFI increased water use efficiency (WUE) by maintaining good yields while reducing water application compared to the conventional system” (Idda, S. et al,2021)

"Furrow irrigation is widely used in surface agriculture due to its low cost and lack of energy requirements, but it often suffers from water use performance far below -that of pressure systems. A series of field experiments conducted on cracked soil compared different irrigation treatments applied to eggplant cultivation. The results showed that **reducing furrow length and modifying furrow shape significantly improves irrigation efficiency and water productivity** . Among the techniques tested, *surge flow* irrigation showed the best performance, followed by fixed furrow irrigation, alternating irrigation, the cutback method, and finally continuous flow. This indicates that intelligent management of furrow shape and water flow can significantly optimize water use in furrow systems." (Abdul Salam, M. and Al-Mazrooei, S,2007)

"An evaluation of furrow irrigation performance on a large sugar estate in Ethiopia showed that current practices exhibited poor performance in terms of application efficiency and deep percolation losses , primarily due to inadequate determination of the inlet flow rate and shut-off time. By adjusting these management variables (flow rate and duration), a significant improvement in application efficiency was observed , although distribution uniformity remained relatively unaffected. These results demonstrate the importance of precise management to optimize the performance of traditional surface irrigation systems." (Kang, S.Z. et al,2000)

“In a maize experiment, different furrow irrigation systems (conventional, alternating, fixed) combined with three different irrigation levels showed significant variations in yield and water use efficiency. The highest grain yield (7.99 t/ha) was obtained under conventional furrow irrigation at 100% ET_c. However, the highest efficiency indices (CWUE, FWUE) were obtained under a more limited regime (50% ET_c), indicating that a controlled reduction in water can often lead to better productivity per unit of water applied .” (Karim, K. and Karim, K,2020)

Comparative studies have shown that the use of systems such as *ridge-furrow supplementary irrigation* can improve water productivity and winter wheat yields in semi- arid regions like the Loess Plateau in China. In this system, mounds and furrows structure the flow, improve the microclimate -and water absorption, and increase both efficient water use and plant biomass compared to unstructured practices (YitaYadeta, B. et al,2022) .

4. Physical description of surface irrigation :

The evaluation and management of irrigation systems have been the subject of numerous reference works. The fundamental principles were widely disseminated by (Gebreselassie, M. et al,2023) , whose work remains an essential basis for understanding irrigation practices. The analytical aspects of border irrigation *were* subsequently explored in greater depth by (Yu, F. and Singh, V.P,1989) , who developed a conceptual framework describing the different phases of water flow. Methodologically, (Israelsen, O.W. and Hansen, V.E,1962) proposed a systematic evaluation of bed irrigation, included in the OTA inventory of technologies adapted to arid and semi-arid zones. For his part, (Hart, W.E. and Reynolds, W.N,1965) produced an internal technical report compiling detailed data for evaluating this irrigation method, although it was not officially published. Finally, (Ley, T.W. and Clyma, W,1980) the provides a practical guide for farmers and managers, enabling them to diagnose and improve the efficiency of irrigation systems at the farm level.

During surface irrigation, a continuous flow of water is directed from the head of a ditch, i.e., the highest point of the field, by gravity across the soil surface towards the lower side (YitaYadeta, B. et al,2022) (Elliott, R.L,1980) (Merriam, J.L. and Keller, J,1978) (Alzba, A.A. and Fangmeier, D.D,1995) (Alzba, A.A. and Strelkoff, T,1994) (Blair, A.W. and Smerdon, E.T,1988a) .

Irrigation is carried out in four phases in **(figure I.01)** :

- Advancement phase .
- Storage or maintenance phase .
- Depletion or exhaustion phase .
- Recession phase .

4.1. Advancement phase : During such a flow, some of the water flowing over the surface of the land infiltrates the soil, while the rest continues to flow, wetting new parts of the land to be irrigated downstream as it advances. The advance continues downstream until the wetting front reaches the lower edge of the land.

4.2. Storage or maintenance phase : Storage begins to form superficially if the current flow is obstructed, as is the case with closed boards. The storage or maintenance phase begins when the excavator front reaches the downstream end, and water continues to flow onto the ground until a sufficient quantity of water is introduced to meet the site's high water requirements. This phase continues until the incoming flow ceases.

4.3. Depletion or exhaustion phase : The depletion phase of runoff irrigation begins as soon as the flow is stopped until the moment when the water begins to disappear upstream of the board.

4.4. Recession phase : The recession phase corresponds to the period during which the water disappears into the board and the receding water front continues downstream until it reaches the end.

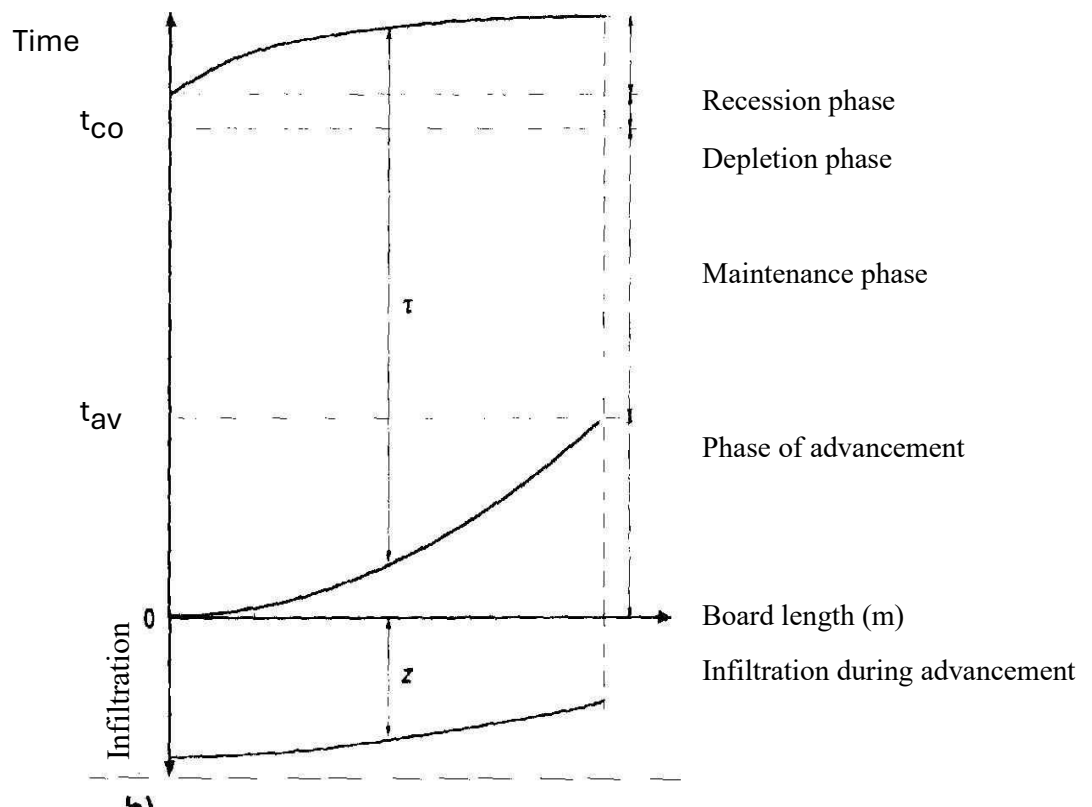


Figure I.01: Irrigation phases: curves of advance, recession, and infiltrated water depths .

II. Conclusion chapter I:

Through this chapter [I] we learned that the agricultural sector uses the largest percentage of water resources and that surface irrigation is the most widespread method among farmers, especially in arid and semi-arid regions, and what are the advantages and disadvantages of this method, in this method irrigation is carried out in four phases (Advancement phase - Storage or maintenance phase - Depletion or exhaustion phase - Recession phase) .

Chapter II

Metodology

I. Introduction:

This chapter focuses on describing and defining field experiments, collecting necessary information, presenting the methodology used in studying surface irrigation, and the mathematical modeling of the Kostiakov method.

II. Methodology:

1. method irrigation (field operation) :

First, you need to go to the site to conduct the experiment and collect all the data necessary for the calculations.

- Number and length of boards .
- Water flow rate entering the boards .
- Calculation of the time along the boards at different intervals (12 watering) .
- Calculation of the slope .
- The roughness coefficient .

We need this data in the study we are conducting in order to calculate water infiltrated into the soil.

During the period (**November – January**) **2025/2026** .

NOTE : I did not conduct the experimental part here , I only recorded the experimental results.

We have four board , Length of each board is :

- Board number (01) : **L = 65 m** .
- Board number (02) : **L = 50 m** .
- Board number (03) : **L = 65 m** .
- Board number (04) : **L = 65 m** .

To calculate the flow rate at the start of the board , a hole is dug, a container is placed in it, and the water is turned on while timing the process (**Photo II.05**). The flow rate varies from one board to another.

- Board number (01) : $F = 2 \text{ (l/s)}$.
- Board number (02) : $F = 6 \text{ (l/s)}$.
- Board number (03) : $F = 6 \text{ (l/s)}$.
- Board number (04) : $F = 5 \text{ (l/s)}$.

The slope S_0 of the earth is **0.001** and The roughness coefficient n It is determined according to the type of soil is **0.03570** .

To measure time advisement , markers are placed (**Photo II.03**) along the board every 10 m (**Photo II.04**) .

2. Materials Used :

- Pipes .
- Valves.
- Plastic film .
- Tape measure .
- Stopwatch .
- Graduated rulers .
- Stakes .



Photo II.01: Plastic film.



Photo II.02 : Valves.



Photo II.03 : Stakes.



Photo II.04 : markers along the board
..



Photo II.05 : Determining the flow rate.



Photo II.06 : Pipe connection .



Photo II.07 : board before watering.



Photo II.08 : board after watering .

III. Calculation methodology :

1. Determination of the infiltrated dose using the volume balance model :

Kostiakov empirical infiltration equation takes the form of a power term in an algebraic equation explicitly linking the cumulative infiltration depth (Z) , to the infiltration time (t) (Blair, A.W. and Smerdon, E.T,1988b) (Hartley, D.M,1992) . It is widely used due to its simplicity and its ability to fit most infiltration data (Fok, Y.-S,1986) . It is expressed by the equation (Kostiakov, A.N,1932) :

$$Z (t) = k \times t^a \quad (l/m) \dots (01)$$

$Z(t)$: represents the cumulative infiltration .

(K) and (a) are adjustment coefficients:

(K) : infiltration constant ($l/m \cdot min$) .

And

(a) : infiltration exponent .

The cumulative volume infiltrated $V(t)$ into the board during the advancement phase at time t is calculated as follows:

$$V(t) = \frac{K}{(a+1)} (t_{irr}^{a+1} - (t_{irr} - t_{ad})^{a+1}) \dots (02)$$

The instantaneous infiltration rate $I(t)$ is derived from this formula because the cumulative infiltration rate is the time integral of the instantaneous infiltration rate $I(t)$:

$$I(t) = \frac{1}{E} \times \frac{K}{(a+1)} \times (t_{irr}^{a+1} - (t_{irr} - t_{ad})^{a+1}) \quad \dots (03)$$

$V(t)$: is the infiltrated volume (l/m) .

$I(t)$: is the infiltrated water height (mm) .

t_{irr} : is the feeding duration (min) .

t_{ad} : is the advancement phase duration (min) .

E : is the spacing between the boards (m) .

Several parameters are necessary for developing a mathematical model for shallow irrigation, and their interaction determines the yield from both a technical and economic perspective. For this model, the parameters are:

Soil infiltration characteristics : a and K

Roughness coefficient : n

Average slope of the bed bottom in the direction of flow : S_0

Board length : L

Gap between boards : E

Inflow rate : F (l/s)

Application time : t_{irr} (min)

The different steps in determining the infiltration law are:

- Determination of the advance law .
- Determination of surface storage volumes.
- Determination of cumulative infiltrated volumes.
- Determination of the coefficients of the infiltration law.

2. Advancement law:

There are several advance laws traditionally used in furrow irrigation; the most common is of the power type:

$$x(t) = p \times t^r \dots (04)$$

t : represents the advance time (min) at point x (m).

p and r : are constant empirical coefficients.

Determining the advance law involves fitting the field measurements to this law. The fitting can be performed using the two-point method :

The two-point method : This method involves adjusting p and r based on only two measurements, for example when $x = L$ and $x = \frac{L}{2} = L_1$ amounts to solving the following system:

$$L_1 = p t_{L_1}^r \dots (06)$$

$$L = p t_L^r \dots (07)$$

The solution to this system of equations (4) and (5) is straightforward. The only data required are the transit times at the center and at the end of the board.

$$r = \frac{\log(\frac{L_1}{L})}{\log(\frac{t_{L_1}}{t_L})} \dots (08)$$

$$p = \frac{L}{t_L^r} \dots (09)$$

3. Stored volumes:

The amount of water that can be stored depends mainly on soil texture: it increases with clay content and decreases with sand content. That is, the finer the soil particles, the greater the ability to store water.

It also depends on the soil's moisture status at the time of irrigation that is, dry soil will absorb more water than moist soil.

At the end of the advance phase, the volume of water stored on the surface must be determined by measuring the water level, which is not always easy to do. In such cases—that is, when measuring this volume is imprecise or impossible—it can be estimated using empirical formulas .

$$V_S = \left(\frac{x}{0.305} \right) \times \left((2.947) \times \left(F \frac{n}{S_0^2} \right)^{0.753} - 0.0217 \right) \dots (10)$$

$V_S(x)$: is the stored volume (l) at the point where the water arrives at point (m) .

n : is the roughness coefficient .

S_0 : is the longitudinal slope of the flume in (m/m) .

F : is the flow rate at the inlet of the flume (l/s) .

4. Observed cumulative infiltration volumes:

The cumulative volumes infiltrated during the advance phase are calculated by subtracting the cumulative volumes that have drained off as runoff from the volumes stored on the surface.

These volumes are determined using the volume balance method, which implicitly assumes that the infiltration characteristics are the same across the entire section (or at least across the

portion of the section bounded by the flow measurement weirs). These volumes will subsequently be used to determine the infiltration law.

The balance method : The water balance method is a method used to determine the amount of water infiltrated by the soil. This method is simple and directly applicable.

We write the volume balance equation as a function of time :

$$V_C(t) = F \times t_{ad} \times 60 \dots (11)$$

$$V_i(t) = V_S(t) - V_O(t) - V_C(t) \dots (12)$$

$V_C(t)$: is the incoming volume which is a function of the flow rate at the head and the maintenance time at 60. $F \cdot t$ (l) .

$V_i(t)$: is the infiltrated volume (l) .

$V_S(t)$: is the estimated stored volume at the surface using formula **(10)** .

$V_O(t)$: is the volume drained by overflow, determined at the moment the water is stopped at the inlet of the board. However, for the experiment under study, the boards are closed the drained volumes are therefore zero.

F : flow (l/s) .

t_{ad} : Advancement time (min) .

5. Coefficients of the infiltration law:

There are several methods for determining the infiltration constant **K** and the time exponent **a**. The most commonly used is that of based on the two-point method analogous to that used to calculate the coefficients of the advance law. They propose an approximation to simplify the integral required in the volume balance: a Kostiakov type infiltration law (Haghiabi, A.H. et al,2011) (Gray, D.M,1972) .

$$V(t) = \frac{f}{a+1} \times (K \cdot t^a) \quad \dots (13)$$

$$f = \frac{(a+r)-(a \times r)-1}{r+1} \quad \dots (14)$$

$$\frac{V_L}{L} = \frac{F}{a+1} \times K \times t_L^a \quad \dots (15)$$

$$\frac{V_{L/2}}{L/2} = \frac{F}{a+1} \times K \times t_{L/2}^a \quad \dots (16)$$

f : is the Kiefer correction factor .

r : is determined by the two-point method applied .

(V_L) and (V_{L_1}) are the infiltrated volumes observed at times (t_L) and (t_{L_1}) , The values of K and a are calculated from the following four equations :

$$a = \frac{\log(\frac{\alpha}{\beta})}{\log(\frac{t_L}{t_{L_1}})} \quad \dots (17)$$

$$K = \frac{\alpha \times (a+1)(r+1)}{((a+r)-(a \times r)+1) \times t_L^a} \quad \dots (18)$$

With $\alpha = \frac{V_L}{L} \quad \dots (19)$

And $\beta = \frac{V_{L_1}}{L_1} \quad \dots (20)$

In the end The formulae of infiltrated :

$$I(t) = \frac{1}{E} \times \frac{K}{a+1} \times \left(t_{irr}^{(a+1)} - (t_{irr} - t_{ad})^{(a+1)} \right) \dots (21)$$

$I(t)$:is the infiltrated water depth (mm) .

t_{irr} :is the duration of the inflow (min) .

t_{ad} :is the duration of the advance phase (min) .

E :is the spacing between the boards (m) .

K and a are calculated from the following equations (17) (18) .

IV. Conclusion chapter II :

Using the Kostiakov method presented in Chapter II, and once the observation parameters (inlet flow rate, roughness coefficient, longitudinal slope of the board, and travel time) are estimated, the progression law, surface storage volumes, cumulative infiltrated volumes, and infiltration law coefficients are determined, which allows the theoretical infiltration along the board to be deduced.

Chapter III

The Calculations and Results

I. Introduction:

In this chapter [III] , we will calculate the infiltrated rate starting from the water advance times and drawing the graph .

II. the calculations and result:

1. the rate of advancement:

Table III.01 : Time it takes for water to advance along the board **01**.

L (m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	4	7	12	16	24	33	35
$t_{ad\ 2}$ (mn)	0	4	6	11	16	23	33	34
$t_{ad\ 3}$ (mn)	0	3	5	10	15	22	32	34
$t_{ad\ 4}$ (mn)	0	2	5	9	15	22	31	34
$t_{ad\ 5}$ (mn)	0	2	5	9	15	22	31	33
$t_{ad\ 6}$ (mn)	0	2	5	9	14	22	30	33
$t_{ad\ 7}$ (mn)	0	2	5	9	14	21	30	31
$t_{ad\ 8}$ (mn)	0	2	5	9	13	21	30	32
$t_{ad\ 9}$ (mn)	0	2	5	9	13	20	29	31
$t_{ad\ 10}$ (mn)	0	2	4	9	13	19	28	30
$t_{ad\ 11}$ (mn)	0	2	4	8	12	18	27	29
$t_{ad\ 12}$ (mn)	0	2	4	8	12	18	27	29

Table III.02 : Time it takes for water to advance along the board **02**.

L (m)	0	10	20	30	40	50
$t_{ad\ 1}$ (mn)	0	2	5	7	10	15
$t_{ad\ 2}$ (mn)	0	2	5	7	10	15
$t_{ad\ 3}$ (mn)	0	2	5	7	10	15
$t_{ad\ 4}$ (mn)	0	2	4	6	9	14
$t_{ad\ 5}$ (mn)	0	2	4	6	9	14
$t_{ad\ 6}$ (mn)	0	2	3	6	8	13
$t_{ad\ 7}$ (mn)	0	2	3	6	8	13
$t_{ad\ 8}$ (mn)	0	2	3	6	9	14

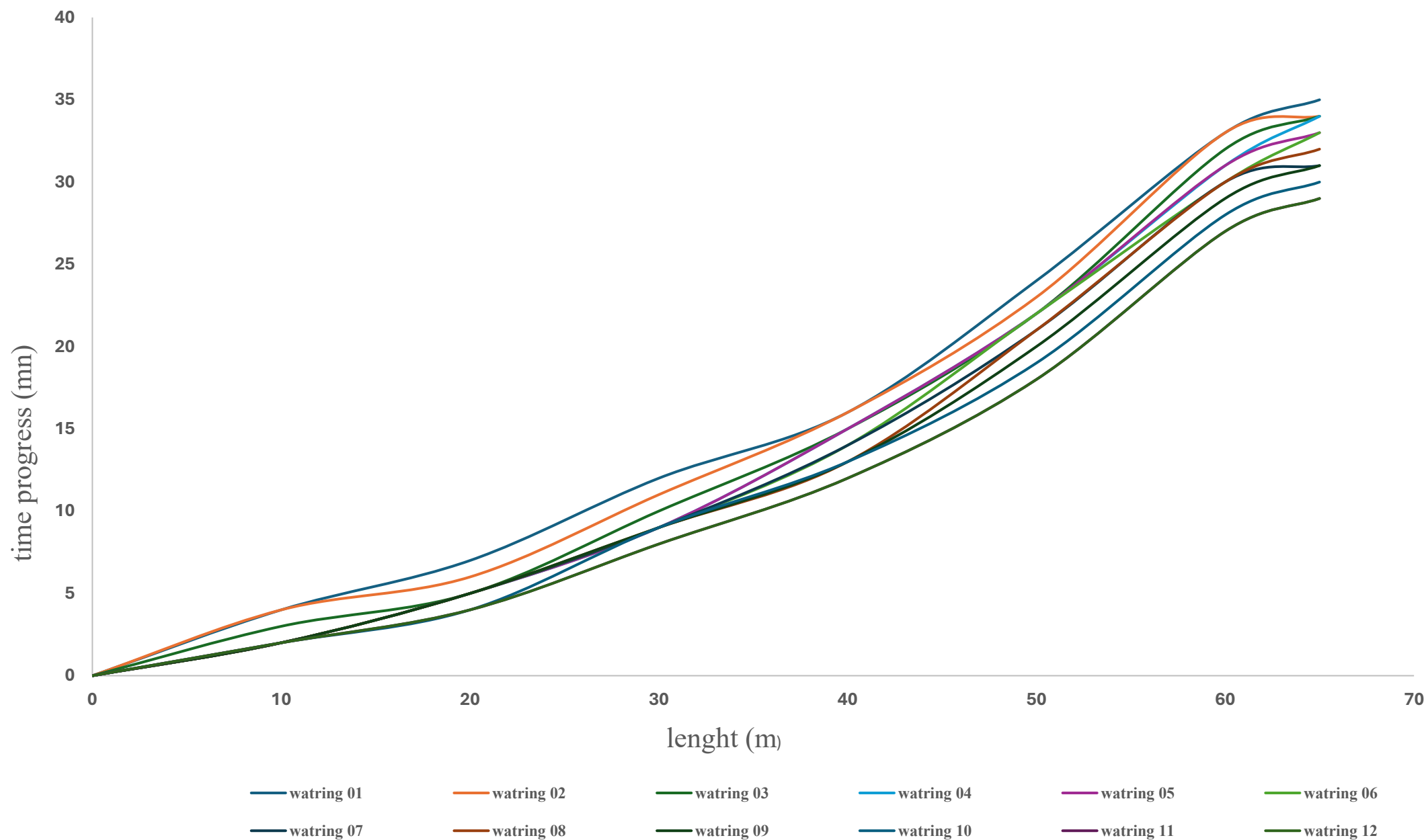
$t_{ad\ 9}$ (mn)	0	2	3	6	8	13
$t_{ad\ 10}$ (mn)	0	2	3	6	7	12
$t_{ad\ 11}$ (mn)	0	2	3	5	7	12
$t_{ad\ 12}$ (mn)	0	2	3	5	7	12

Table III.03 : Time it takes for water to advance along the board **03**.

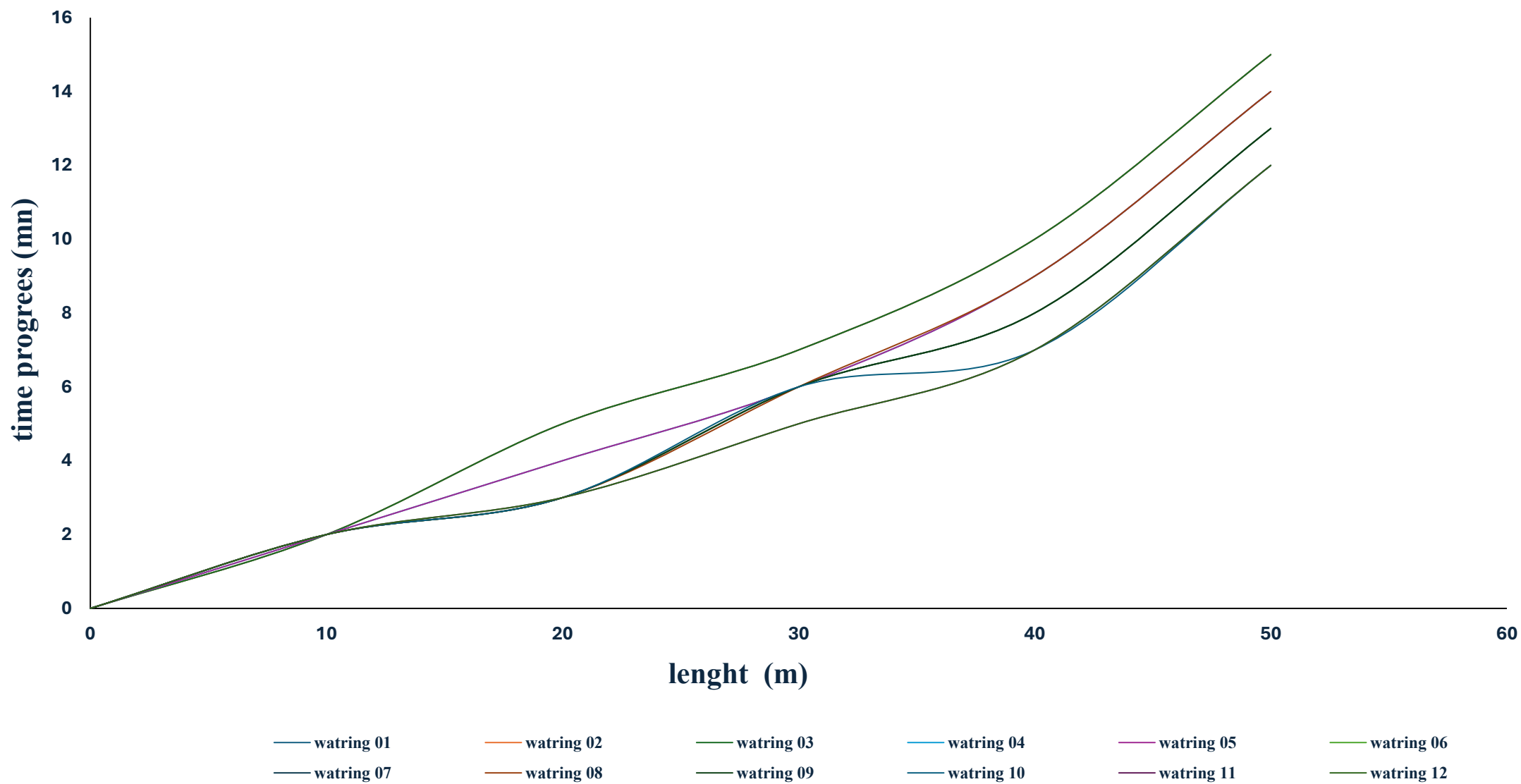
L (m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	2	5	7	11	16	23	27
$t_{ad\ 2}$ (mn)	0	2	4	7	10	16	22	27
$t_{ad\ 3}$ (mn)	0	2	4	7	10	15	21	25
$t_{ad\ 4}$ (mn)	0	2	4	5	9	15	21	24
$t_{ad\ 5}$ (mn)	0	2	4	6	9	11	16	22
$t_{ad\ 6}$ (mn)	0	2	4	5	8	10	14	20
$t_{ad\ 7}$ (mn)	0	2	4	5	7	10	13	17
$t_{ad\ 8}$ (mn)	0	2	3	5	7	9	12	17
$t_{ad\ 9}$ (mn)	0	2	3	5	7	9	12	16
$t_{ad\ 10}$ (mn)	0	2	3	5	7	8	11	16
$t_{ad\ 11}$ (mn)	0	2	3	5	8	9	11	15
$t_{ad\ 12}$ (mn)	0	2	3	5	8	9	10	14

Table III.04 : Time it takes for water to advance along the board **04**.

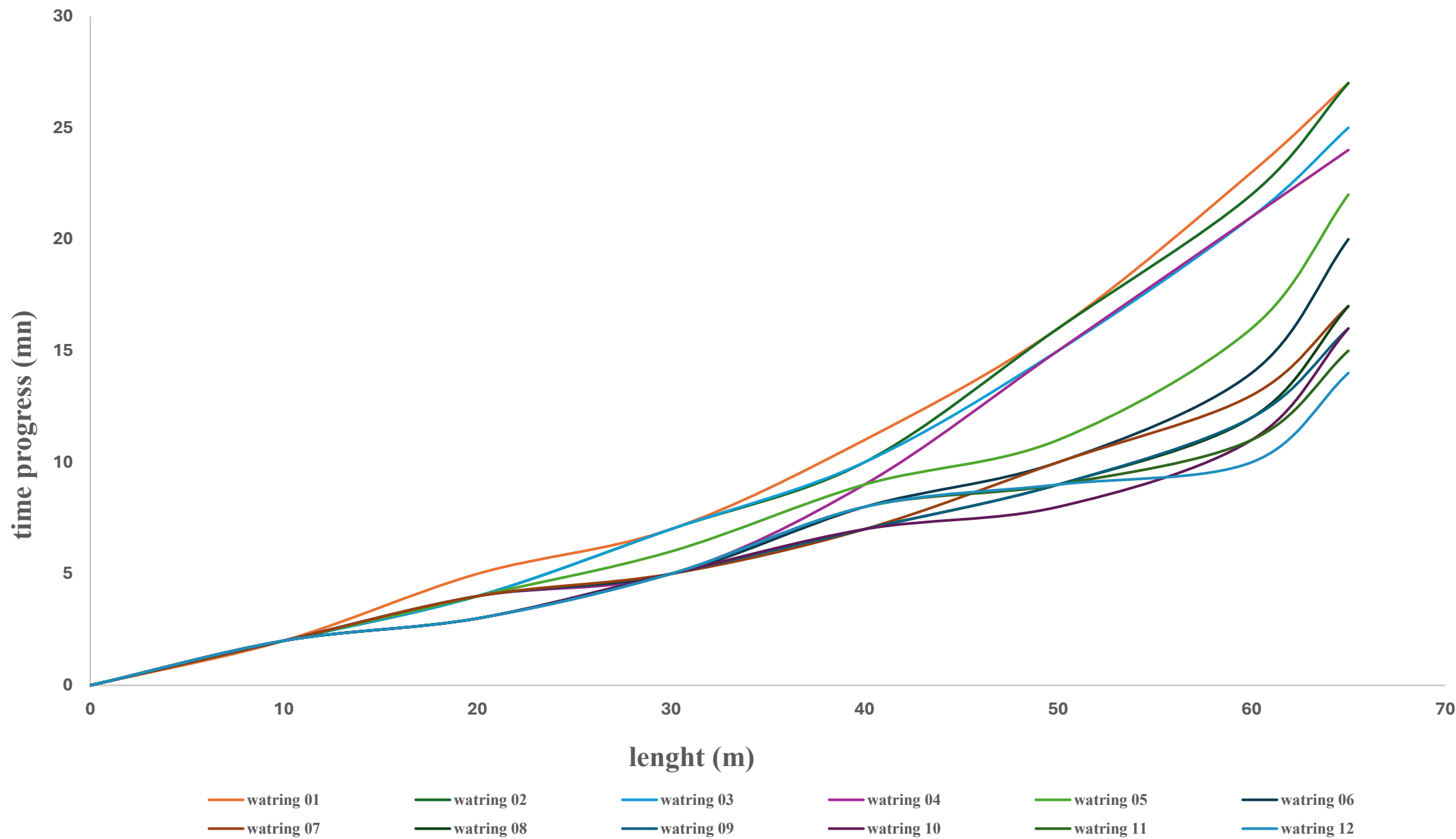
L (m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	3	6	9	13	18	24	28
$t_{ad\ 2}$ (mn)	0	2	5	9	13	18	23	27
$t_{ad\ 3}$ (mn)	0	2	4	9	12	16	22	25
$t_{ad\ 4}$ (mn)	0	2	4	8	12	16	22	24
$t_{ad\ 5}$ (mn)	0	2	4	8	10	14	20	23
$t_{ad\ 6}$ (mn)	0	2	3	6	9	12	18	20
$t_{ad\ 7}$ (mn)	0	2	3	5	9	12	17	19
$t_{ad\ 8}$ (mn)	0	2	3	5	8	12	17	19
$t_{ad\ 9}$ (mn)	0	2	3	6	8	12	16	18
$t_{ad\ 10}$ (mn)	0	2	3	6	8	12	16	18
$t_{ad\ 11}$ (mn)	0	2	4	5	7	11	15	17
$t_{ad\ 12}$ (mn)	0	2	3	5	7	11	13	15



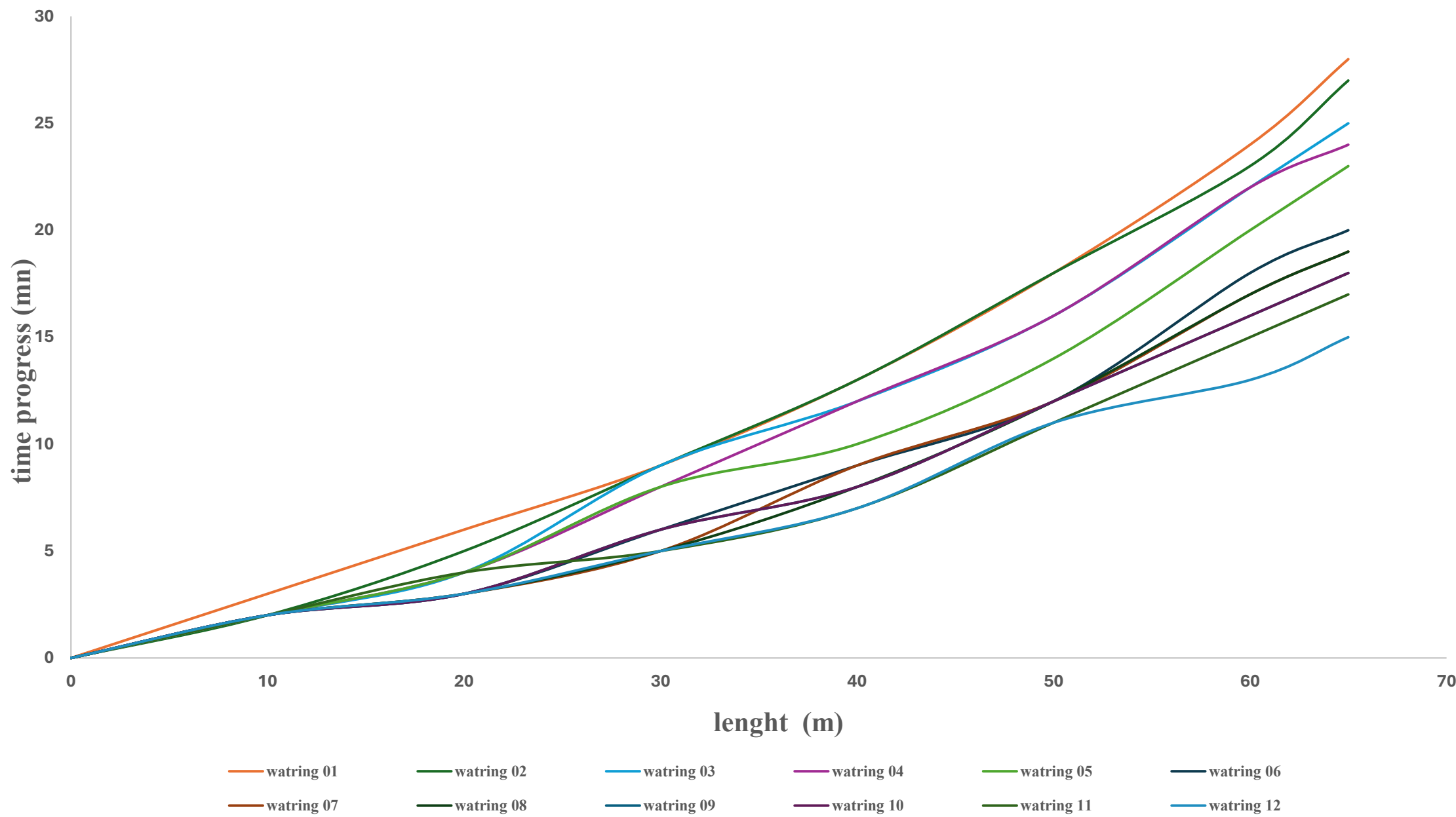
Graph III.01 : time progress along the board 01 .



Graph III.02 : time progress along the board 02 .



Graph III.03 : time progress along the board 03 .



Graph III.04 : time progress along the board 04 .

The curve represents the advance time (**in minutes**) over the length of the board (**in meters**) for 12 watering (**Graph III.01**) . The curve shows that the water advance time increases regularly with the length of the bed and that the flow rate is similar in all irrigation processes, with a progressive slowing of the water advance speed due to leaks in the soil.

The curve represents the time it takes to advance (**in minutes**) along the length of the board (**in meters**) for 12 watering (**Graph III.02**). All the curves at the beginning (from 0 to 10) have the same progression. Then, the curves converge along the entire length of the board, with a constant flow rate.

The curve represents the time it takes to advance (**in minutes**) along the length of the board (**in meters**) for 12 watering (**Graph III.03**). All the curves converge at the time of the advance along the board, with a constant flow rate. During the first watering, the time is longer, then it gradually decreases.

The curve represents the time it takes for the plants to advance (**in minutes**) along the length of the board (**in meters**) for 12 watering (**Graph III.04**). All the curves converge to show the time spent watering the bed at a constant flow rate. At the end of the board, the time between watering is longer and less frequent. Compared to the beginning and middle of the bed, the time between watering is shorter.

2. Determine the adjustment coefficients:

Determine the adjustment coefficients (**r , p**) in all board (**1-2-3-4**) of the law of progress according to the formulas **(8) (9) in chapter [II]** . The times of progress along board **(01)** at points $L = 65 \text{ m}$; $L_1 = 30 \text{ m}$ **(6) (7) in chapter [II] , (Table III.05) :**

$$L_1 = p t_{L_1}^r \dots (06)$$

$$L = p t_L^r \dots (07)$$

$$r = \frac{\log(\frac{L_1}{L})}{\log(\frac{t_{L_1}}{t_L})} \dots (08)$$

$$p = \frac{L}{t_L^r} \dots (09)$$

Table III.05 : Determine the adjustment coefficients in the board **01** .

Board 01	F (l/s)	L (m)	T L (mn)	L1 (m)	T L1 (mn)	r	p
m 1	2	65	35	30	12	0,7223093	4,984464
	2	65	34	30	11	0,6851694	5,8021750
	2	65	34	30	10	0,6318070	7,0034857
	2	65	34	30	9	0,5817237	8,3563335
m 2	2	65	33	30	9	0,5950896	8,1144930
	2	65	33	30	9	0,5950896	8,1144930
	2	65	31	30	9	0,6251724	7,5954787
	2	65	32	30	9	0,6095254	7,8611520
m3	2	65	31	30	9	0,6251724	7,5954787
	2	65	30	30	9	0,6421987	7,3165755
	2	65	29	30	8	0,6003706	8,6086004
	2	65	29	30	8	0,6003706	8,6086004

The times of progress along board **(02)** at points = 50 m ; $L_1 = 30$ m **(6)(7)** in chapter [II]
(Table III.06) :

Table III.06 : Determine the adjustment coefficients in the board **02**.

Board 02	F (l/s)	L (m)	T L (mn)	L1 (m)	T L1 (mn)	r	p
m 1	6	50	15	30	7	0,670251645	8,141283965
	6	50	15	30	7	0,670251645	8,141283965
	6	50	15	30	7	0,670251645	8,141283965
	6	50	14	30	6	0,602887895	10,18552186
m 2	6	50	14	30	6	0,602887895	10,18552186
	6	50	13	30	6	0,660672923	9,183702219
	6	50	13	30	6	0,660672923	9,183702219
	6	50	14	30	6	0,602887895	10,18552186
m 3	6	50	13	30	6	0,660672923	9,183702219
	6	50	12	30	6	0,736965594	8,010332732
	6	50	12	30	5	0,583488138	11,72952832
	6	50	12	30	5	0,583488138	11,72952832

The times of progress along board **(03)** at points = 65 m ; $L_1 = 30$ m **(6)(7) in chapter [II]**
(Table III.07) :

Table III.07 : Determine the adjustment coefficients in the board **03**.

Board 03	F (l/s)	L (m)	T L (mn)	L1 (m)	T L1 (mn)	r	p
m 1	6	65	27	30	7	0,5727643	9,8419064
	6	65	27	30	7	0,5727643	9,8419064
	6	65	25	30	7	0,6073925	9,2005753
	6	65	24	30	5	0,4929121	13,570330
m 2	6	65	22	30	6	0,5950896	10,328838
	6	65	20	30	5	0,5577386	12,225839
	6	65	17	30	5	0,6318070	10,851933
	6	65	17	30	5	0,6318070	10,851933
m 3	6	65	16	30	5	0,6647374	10,291761
	6	65	16	30	5	0,6647374	10,291761
	6	65	15	30	5	0,7037877	9,6648410
	6	65	14	30	5	0,7509472	8,9584245

The times of progress along board **(04)** at points = 65 m ; $L_1 = 30$ m **(6)(7) in chapter [II]**
(Table III.08) :

Table III.08 : Determine the adjustment coefficients in the board **04**.

Board 04	F (l/s)	L (m)	T L (mn)	L1 (m)	T L1 (mn)	r	p
m 1	5	65	28	30	9	0,6812366	6,7151592
	5	65	27	30	9	0,7037877	6,3905325
	5	65	25	30	9	0,7568041	5,6878296
	5	65	24	30	8	0,7037877	6,942846
m 2	5	65	23	30	8	0,7321508	6,5452031
	5	65	20	30	6	0,6421987	9,4927808
	5	65	19	30	5	0,5791679	11,811367
	5	65	19	30	5	0,5791679	11,811367
m 3	5	65	18	30	6	0,7037877	8,5009590
	5	65	18	30	6	0,7037877	8,5009590
	5	65	17	30	5	0,6318070	10,851933
	5	65	15	30	5	0,7037877	9,6648410

3. Determination of the stored volume and infiltrated volume and incoming volume :

Determination of the volumes of surface storage ,stored volume (V_S), infiltrated volume (V_i), and incoming volume (V_C), with the formulas (10) (11) (12) in chapter [II] ., all of the board (1-2-3-4) in (Table III.09) (Table III.10) (Table III.11) (Table III.12):

$$V_S = \left(\frac{x}{0.305} \right) \times \left((2.947) \times \left(F \frac{n}{s_0^2} \right)^{0.753} - 0.0217 \right) \dots (10)$$

$$V_C(t) = F \times t_{ad} \times 60 \dots (11)$$

$$V_i(t) = V_S(t) - V_O(t) - V_C(t) \dots (12)$$

Table III.09 : Determine the volumes (V_S), (V_i), (V_C) in the board 01.

L (m)	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	4	7	12	16	24	33	35
F (l/s)	2	2	2	2	2	2	2
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	480	840	1440	1920	2880	3960	4200
VI	302,303177	484,606354	906,909532	1209,2127	1991,51588	2893,81906	3044,9706
$t_{ad\ 2}$ (mn)	4	6	11	16	23	33	34
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	480	720	1320	1920	2760	3960	4080
VI	302,303177	364,606354	786,9095324	1209,2127	1871,51588	2893,81906	2924,9706
$t_{ad\ 3}$ (mn)	3	5	10	15	22	32	34
VS	177,69682	355,39364	533,0904676	710,78729	888,48411	1066,18093	1155,02934
VC	360	600	1200	1800	2640	3840	4080
VI	182,303177	244,60635	666,9095324	1089,2127	1751,51588	2773,81906	2924,97065
$t_{ad\ 4}$ (mn)	2	5	9	15	22	31	34
VS	177,69682	355,393645	533,0904676	710,78729	888,48411	1066,1809	1155,0293
VC	240	600	1080	1800	2640	3720	4080
VI	62,3031774	244,606354	546,9095324	1089,2127	1751,51588	2653,81906	2924,97065

t _{ad 5} (mn)	2	5	9	15	22	31	33
VS	177,69682	355,39364	533,0904676	710,78729	888,48411	1066,18093	1155,02934
VC	240	600	1080	1800	2640	3720	3960
VI	62,3031774	244,606354	546,9095324	1089,21271	1751,51588	2653,81906	2804,97065
t _{ad 6} (mn)	2	5	9	14	22	30	33
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	240	600	1080	1680	2640	3600	3960
VI	62,3031774	244,606354	546,909532	969,212709	1751,51588	2533,81906	2804,97065
t _{ad 7} (mn)	2	5	9	14	21	30	31
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	240	600	1080	1680	2520	3600	3720
VI	62,303177	244,606354	546,909532	969,212709	1631,51588	2533,81906	2564,97065
t _{ad 8} (mn)	2	5	9	13	21	30	32
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	240	600	1080	1560	2520	3600	3840
VI	62,303177	244,606354	546,909532	849,212709	1631,51588	2533,81906	2684,97065
t _{ad 9} (mn)	2	5	9	13	20	29	31
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	240	600	1080	1560	2400	3480	3720
VI	62,3031774	244,606354	546,909532	849,212709	1511,51588	2413,81906	2564,97065
t _{ad 10} (mn)	2	4	9	13	19	28	30
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,1809	1155,0293
VC	240	480	1080	1560	2280	3360	3600
VI	62,303177	124,606354	546,90953	849,21270	1391,51588	2293,81906	2444,97065
t _{ad 11} (mn)	2	4	8	12	18	27	29
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,18093	1155,02934
VC	240	480	960	1440	2160	3240	3480
VI	62,303177	124,60635	426,90953	729,21270	1271,51588	2173,8190	2324,9706
t _{ad 12} (mn)	2	4	8	12	18	27	29
VS	177,69682	355,39364	533,09046	710,78729	888,48411	1066,1809	1155,0293
VC	240	480	960	1440	2160	3240	3480
VI	62,303177	124,60635	426,90953	729,21270	1271,5158	2173,8190	2324,9706

Table III.10 : Determine the volumes (V_S) , (V_I) , (V_C) in the board **02**.

L (m)	10	20	30	40	50
$t_{ad\ 1}$ (mn)	2	5	7	10	15
F (l/s)	6	6	6	6	6
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1800	2520	3600	5400
VI	312,6859293	985,3718585	1298,057788	1970,743717	3363,429646
$t_{ad\ 2}$ (mn)	2	5	7	10	15
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1800	2520	3600	5400
VI	312,6859293	985,3718585	1298,057788	1970,743717	3363,429646
$t_{ad\ 3}$ (mn)	2	5	7	10	15
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1800	2520	3600	5400
VI	312,6859293	985,3718585	1298,057788	1970,743717	3363,429646
$t_{ad\ 4}$ (mn)	2	4	6	9	14
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1440	2160	3240	5040
VI	312,6859293	625,3718585	938,0577878	1610,743717	3003,429646
$t_{ad\ 5}$ (mn)	2	4	6	9	14
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1440	2160	3240	5040
VI	312,6859293	625,3718585	938,0577878	1610,743717	3003,429646
$t_{ad\ 6}$ (mn)	2	3	6	8	13
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	2160	2880	4680
VI	312,6859293	265,3718585	938,0577878	1250,743717	2643,429646
$t_{ad\ 7}$ (mn)	2	3	6	8	13
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	2160	2880	4680
VI	312,6859293	265,3718585	938,0577878	1250,743717	2643,429646
$t_{ad\ 8}$ (mn)	2	3	6	9	14
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	2160	3240	5040

VI	312,6859293	265,3718585	938,0577878	1610,743717	3003,429646
$t_{ad\ 9}$ (mn)	2	3	6	8	13
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	2160	2880	4680
VI	312,6859293	265,3718585	938,0577878	1250,743717	2643,429646
$t_{ad\ 10}$ (mn)	2	3	6	7	12
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	2160	2520	4320
VI	312,6859293	265,3718585	938,0577878	890,743717	2283,429646
$t_{ad\ 11}$ (mn)	2	3	5	7	12
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	1800	2520	4320
VI	312,6859293	265,3718585	578,0577878	890,743717	2283,429646
$t_{ad\ 12}$ (mn)	2	3	5	7	12
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354
VC	720	1080	1800	2520	4320
VI	312,6859293	265,3718585	578,0577878	890,743717	2283,429646

Table III.11 : Determine the volumes (V_s) , (V_i) , (V_c) in the board **03**.

L (m)	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	2	5	7	11	16	23	27
F (l/s)	6	6	6	6	6	6	6
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1800	2520	3960	5760	8280	9720
VI	312,6859293	985,3718585	1298,057788	2330,743717	3723,429646	5836,115576	7072,45854
$t_{ad\ 2}$ (mn)	2	4	7	10	16	22	27
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	2520	3600	5760	7920	9720
VI	312,6859293	625,3718585	1298,057788	1970,743717	3723,429646	5476,115576	7072,45854
$t_{ad\ 3}$ (mn)	2	4	7	10	15	21	25
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	2520	3600	5400	7560	9000
VI	312,6859293	625,3718585	1298,057788	1970,743717	3363,429646	5116,115576	6352,45854
$t_{ad\ 4}$ (mn)	2	4	5	9	15	21	24

VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	1800	3240	5400	7560	8640
VI	312,6859293	625,3718585	578,0577878	1610,743717	3363,429646	5116,115576	5992,45854
t _{ad 5} (mn)	2	4	6	9	11	16	22
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	2160	3240	3960	5760	7920
VI	312,6859293	625,3718585	938,0577878	1610,743717	1923,429646	3316,115576	5272,45854
t _{ad 6} (mn)	2	4	5	8	10	14	20
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	1800	2880	3600	5040	7200
VI	312,6859293	625,3718585	578,0577878	1250,743717	1563,429646	2596,115576	4552,45854
t _{ad 7} (mn)	2	4	5	7	10	13	17
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1440	1800	2520	3600	4680	6120
VI	312,6859293	625,3718585	578,0577878	890,743717	1563,429646	2236,115576	3472,45854
t _{ad 8} (mn)	2	3	5	7	9	12	17
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1080	1800	2520	3240	4320	6120
VI	312,6859293	265,3718585	578,0577878	890,743717	1203,429646	1876,115576	3472,45854
t _{ad 9} (mn)	2	3	5	7	9	12	16
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1080	1800	2520	3240	4320	5760
VI	312,6859293	265,3718585	578,0577878	890,743717	1203,429646	1876,115576	3112,45854
t _{ad 10} (mn)	2	3	5	7	8	11	16
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1080	1800	2520	2880	3960	5760
VI	312,6859293	265,3718585	578,0577878	890,743717	843,4296463	1516,115576	3112,45854
t _{ad 11} (mn)	2	3	5	8	9	11	15
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1080	1800	2880	3240	3960	5400
VI	312,6859293	265,3718585	578,0577878	1250,743717	1203,429646	1516,115576	2752,45854
t _{ad 12} (mn)	2	3	5	8	9	10	14
VS	407,3140707	814,6281415	1221,942212	1629,256283	2036,570354	2443,884424	2647,54146
VC	720	1080	1800	2880	3240	3600	5040

VI	312,6859293	265,3718585	578,0577878	1250,743717	1203,429646	1156,115576	2392,45854
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Table III.12 : Determine the volumes (V_S) , (V_i) , (V_C) in the board **04**.

L (m)	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	3	6	9	13	18	24	28
F (l/s)	5	5	5	5	5	5	5
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	900	1800	2700	3900	5400	7200	8400
VI	545,0278464	1090,055693	1635,083539	2480,111385	3625,139232	5070,167078	6092,681001
$t_{ad\ 2}$ (mn)	2	5	9	13	18	23	27
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	1500	2700	3900	5400	6900	8100
VI	245,0278464	790,0556927	1635,083539	2480,111385	3625,139232	4770,167078	5792,681001
$t_{ad\ 3}$ (mn)	2	4	9	12	16	22	25
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	1200	2700	3600	4800	6600	7500
VI	245,0278464	490,0556927	1635,083539	2180,111385	3025,139232	4470,167078	5192,681001
$t_{ad\ 4}$ (mn)	2	4	8	12	16	22	24
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	1200	2400	3600	4800	6600	7200
VI	245,0278464	490,0556927	1335,083539	2180,111385	3025,139232	4470,167078	4892,681001
$t_{ad\ 5}$ (mn)	2	4	8	10	14	20	23
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	1200	2400	3000	4200	6000	6900
VI	245,0278464	490,0556927	1335,083539	1580,111385	2425,139232	3870,167078	4592,681001
$t_{ad\ 6}$ (mn)	2	3	6	9	12	18	20
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1800	2700	3600	5400	6000
VI	245,0278464	190,0556927	735,0835391	1280,111385	1825,139232	3270,167078	3692,681001
$t_{ad\ 7}$ (mn)	2	3	5	9	12	17	19
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1500	2700	3600	5100	5700
VI	245,0278464	190,0556927	435,0835391	1280,111385	1825,139232	2970,167078	3392,681001

t _{ad 8} (mn)	2	3	5	8	12	17	19
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1500	2400	3600	5100	5700
VI	245,0278464	190,0556927	435,0835391	980,1113854	1825,139232	2970,167078	3392,681001
t _{ad 9} (mn)	2	3	6	8	12	16	18
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1800	2400	3600	4800	5400
VI	245,0278464	190,0556927	735,0835391	980,1113854	1825,139232	2670,167078	3092,681001
t _{ad 10} (mn)	2	3	6	8	12	16	18
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1800	2400	3600	4800	5400
VI	245,0278464	190,0556927	735,0835391	980,1113854	1825,139232	2670,167078	3092,681001
t _{ad 11} (mn)	2	4	5	7	11	15	17
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	1200	1500	2100	3300	4500	5100
VI	245,0278464	490,0556927	435,0835391	680,1113854	1525,139232	2370,167078	2792,681001
t _{ad 12} (mn)	2	3	5	7	11	13	15
VS	354,9721536	709,9443073	1064,916461	1419,888615	1774,860768	2129,832922	2307,318999
VC	600	900	1500	2100	3300	3900	4500
VI	245,0278464	190,0556927	435,0835391	680,1113854	1525,139232	1770,167078	2192,681001

4. Determine the coefficients:

Determine the coefficients (**a** , **k** , **α** , **β**) of which all the board with the formulas (17) (18) (19) (20) in chapter [II] in (Table III.13) (Table III.14) (Table III.15) (Table III.16) :

$$a = \frac{\log(\frac{\alpha}{\beta})}{\log(\frac{t_L}{t_{L_1}})} \quad \dots (17)$$

$$K = \frac{\alpha \times (a+1)(r+1)}{((a+r)-(a \times r)+1) \times t_L^a} \quad \dots (18)$$

$$\alpha = \frac{V_L}{L} \quad \dots (19)$$

$$\beta = \frac{V_{L_1}}{L_1} \quad \dots (20)$$

Table III.13 : Determine the coefficients k , a , α , β in the board 01.

Board 01	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4
F (l/s)	2	2	2	2	2	2	2	2	2	2	2	2
L (m)	65	65	65	65	65	65	65	65	65	65	65	65
L1 (m)	30	30	30	30	30	30	30	30	30	30	30	30
t L	35	34	34	34	33	33	31	32	31	30	29	29
TL1	12	11	10	9	9	9	9	9	9	9	8	8
V L	3044 ,970 65	2924 ,970 65	2924 ,970 65	2924 ,970 65	2804 ,970 65	2804 ,970 65	2564 ,970 65	2684 ,970 65	2564 ,970 65	2444 ,970 65	2324 ,970 65	2324 ,970 65
V L1	906, 9095 32	786, 9095 32	666, 9095 32	546, 9095 32	546, 9095 32	546, 9095 32	546, 9095 32	546, 9095 32	546, 9095 32	546, 9095 32	426, 9095 32	426, 9095 32
α	46,8 4570 24	44,9 9954 85	44,9 9954 85	44,9 9954 85	43,1 5339 47	43,1 5339 47	39,4 6108 7	41,3 0724 08	39,4 6108 7	37,6 1493 31	35,7 6877 93	35,7 6877 93
β	30,2 3031 77	26,2 3031 77	22,2 3031 77	18,2 3031 77	18,2 3031 77	18,2 3031 77	18,2 3031 77	18,2 3031 77	18,2 3031 77	18,2 3031 77	14,2 3031 77	14,2 3031 77
a	0,40 9190 03	0,47 8292 57	0,57 6245 79	0,67 9814 91	0,66 3192 76	0,66 3192 76	0,62 4395 51	0,64 4812 37	0,62 4395 51	0,60 1604 21	0,71 5687 09	0,71 5687 09
k	14,4 5690 47	11,3 0585 64	8,22 6918 49	5,82 8396 71	6,04 3897 36	6,04 3897 36	6,56 4952 09	6,28 7569 02	6,56 4952 09	6,88 3049 69	4,67 6427 21	4,67 6427 21

Table III.14 : Determine the coefficients k , a , α , β in the board 02.

Board 02	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4
F (l/s)	6	6	6	6	6	6	6	6	6	6	6	6
L (m)	50	50	50	50	50	50	50	50	50	50	50	50
L1 (m)	30	30	30	30	30	30	30	30	30	30	30	30
t L	15	15	15	14	14	13	13	14	13	12	12	12
TL1	7	7	7	6	6	6	6	6	6	6	5	5

V L	3363 ,429 646	3363 ,429 646	3363 ,429 646	3003 ,429 646	3003 ,429 646	2643 ,429 646	2643 ,429 646	3003 ,429 646	2643 ,429 646	2283 ,429 646	2283 ,429 646	2283 ,429 646
V L1	1298 ,057 788	1298 ,057 788	1298 ,057 788	938, 0577 878	938, 0577 878	938, 0577 878	938, 0577 878	938, 0577 878	938, 0577 878	938, 0577 878	578, 0577 878	578, 0577 878
α	67,2 6859 293	67,2 6859 293	67,2 6859 293	60,0 6859 293	60,0 6859 293	52,8 6859 293	52,8 6859 293	60,0 6859 293	52,8 6859 293	45,6 6859 293	45,6 6859 293	45,6 6859 293
β	43,2 6859 293	43,2 6859 293	43,2 6859 293	31,2 6859 293	31,2 6859 293	31,2 6859 293	31,2 6859 293	31,2 6859 293	31,2 6859 293	31,2 6859 293	19,2 6859 293	19,2 6859 293
a	0,57 8983 375	0,57 8983 375	0,57 8983 375	0,77 0535 348	0,77 0535 348	0,67 9257 827	0,67 9257 827	0,77 0535 348	0,67 9257 827	0,54 6488 04	0,98 5682 663	0,98 5682 663
k	19,8 7231 082	19,8 7231 082	19,8 7231 082	11,6 8813 296	11,6 8813 296	13,6 5260 172	13,6 5260 172	11,6 8813 296	13,6 5260 172	16,7 7543 387	6,21 8403 61	6,21 8403 61

Table III.15 : Determine the coefficients k , a , α , β in the board 03.

Board 03	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4
F (l/s)	6	6	6	6	6	6	6	6	6	6	6	6
L (m)	65	65	65	65	65	65	65	65	65	65	65	65
L1 (m)	30	30	30	30	30	30	30	30	30	30	30	30
t L	27	27	25	24	22	20	17	17	16	16	15	14
TL1	7	7	7	5	6	5	5	5	5	5	5	5
V L	7072 ,458 54	7072 ,458 54	6352 ,458 54	5992 ,458 54	5272 ,458 54	4552 ,458 54	3472 ,458 54	3472 ,458 54	3112 ,458 54	3112 ,458 54	2752 ,458 54	2392 ,458 54
V L1	1298 ,057 788	1298 ,057 788	1298 ,057 788	578, 0577 878	938, 0577 878	578, 0577 878	578, 0577 878	578, 0577 878	578, 0577 878	578, 0577 878	578, 0577 878	578, 0577 878

α	108, 8070 545	108, 8070 545	97,7 3013 139	92,1 9166 985	81,1 1474 677	70,0 3782 369	53,4 2243 908	53,4 2243 908	47,8 8397 754	47,8 8397 754	42,3 4551 6	36,8 0705 446
β	43,2 6859 293	43,2 6859 293	43,2 6859 293	19,2 6859 293	31,2 6859 293	19,2 6859 293	19,2 6859 293	19,2 6859 293	19,2 6859 293	19,2 6859 293	19,2 6859 293	19,2 6859 293
a	0,68 3110 516	0,68 3110 516	0,64 0066 656	0,99 7945 577	0,73 3674 356	0,93 0941 516	0,83 3285 567	0,83 3285 567	0,78 2619 487	0,78 2619 487	0,71 6709 692	0,62 8594 462
k	16,2 5791 598	16,2 5791 598	17,6 6162 965	5,76 9393 67	12,2 7419 545	6,57 7589 487	7,77 7057 324	7,77 7057 324	8,42 0114 384	8,42 0114 384	9,28 0872 245	10,4 7376 204

Table III.16: Determine the coefficients k , a , α , β in the board 04.

Board 04	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4	1_1	1_2	1_3	1_4
F (l/s)	5	5	5	5	5	5	5	5	5	5	5	5
L (m)	65	65	65	65	65	65	65	65	65	65	65	65
L1 (m)	30	30	30	30	30	30	30	30	30	30	30	30
t L	28	27	25	24	23	20	19	19	18	18	17	15
TL1	9	9	9	8	8	6	5	5	6	6	5	5
V L	6092 ,681 001	5792 ,681 001	5192 ,681 001	4892 ,681 001	4592 ,681 001	3692 ,681 001	3392 ,681 001	3392 ,681 001	3092 ,681 001	3092 ,681 001	2792 ,681 001	2192 ,681 001
V L1	1635 ,083 539	1635 ,083 539	1635 ,083 539	1335 ,083 539	1335 ,083 539	735, 0835 391	435, 0835 391	435, 0835 391	735, 0835 391	735, 0835 391	435, 0835 391	435, 0835 391
α	93,7 3355 387	89,1 1816 925	79,8 8740 002	75,2 7201 54	70,6 5663 079	56,8 1047 694	52,1 9509 233	52,1 9509 233	47,5 7970 771	47,5 7970 771	42,9 6432 31	33,7 3355 387
β	54,5 0278 464	54,5 0278 464	54,5 0278 464	44,5 0278 464	44,5 0278 464	24,5 0278 464	14,5 0278 464	14,5 0278 464	24,5 0278 464	24,5 0278 464	14,5 0278 464	14,5 0278 464

a	0,47 7721 6	0,44 7575 04	0,37 4263 086	0,47 8382 289	0,43 7743 502	0,69 8465 936	0,95 9285 974	0,95 9285 974	0,60 4052 584	0,60 4052 584	0,88 7441 742	0,76 8380 565
k	25,8 5193 22	27,3 7922 462	31,2 9058 738	22,4 6235 959	24,1 1579 981	10,6 8821 405	4,83 2501 764	4,83 2501 764	11,5 8762 036	12,0 5092 991	5,46 7167 859	6,56 8971 026

5. Determination the infiltrated water height:

Determination of the infiltrated water height $I(mm)$ using 4 board (1-2-3-4) where each watering and tracing curve represents the infiltrated water height with the formulas (21) in Chapter [II] in (Table III.17) (Table III.18) (Table III.19) (Table III.20):

$$I(t) = \frac{1}{E} \times \frac{K}{a+1} \times (t_{irr}^{(a+1)} - (t_{irr} - t_{ad})^{(a+1)}) \dots (21)$$

Table III.17: Determination of the infiltrated water height $I(mm)$ in the board 01.

$E = 8$, $t_{ir} = 44$ min

L (m)	0	10	20	30	40	50	60	65
$t_{ad 1}$ (mn)	0	4	7	12	16	24	33	35
I (mm)	265	232	207	169	140	87	37	28
$t_{ad 2}$ (mn)	0	4	6	14	16	23	33	34
I (mm)	257	223	206	145	131	86	33	28
$t_{ad 3}$ (mn)	0	3	5	12	15	22	32	34
I (mm)	263	236	218	161	138	91	37	28
$t_{ad 4}$ (mn)	0	2	5	9	15	22	31	34
I (mm)	269	249	222	186	138	90	41	28
$t_{ad 5}$ (mn)	0	2	5	9	15	22	31	33
I (mm)	255	236	209	176	130	83	36	28
$t_{ad 6}$ (mn)	0	2	5	9	14	22	30	33
I (mm)	255	236	209	176	137	83	41	28
$t_{ad 7}$ (mn)	0	2	5	9	14	21	30	31

I (mm)	227	210	186	155	119	76	32	28
$t_{ad\ 8}$ (mn)	0	2	5	9	13	21	30	32
I (mm)	241	223	197	165	135	82	36	28
$t_{ad\ 9}$ (mn)	0	2	5	9	13	20	29	31
I (mm)	227	210	186	155	126	82	36	28
$t_{ad\ 10}$ (mn)	0	2	4	9	13	19	28	30
I (mm)	213	197	182	145	118	81	36	28
$t_{ad\ 11}$ (mn)	0	2	4	8	12	18	27	29
I (mm)	207	190	174	144	116	79	35	27
$t_{ad\ 12}$ (mn)	0	2	4	8	12	18	27	29
I (mm)	207	190	174	144	116	79	35	27

Table III.18 : Determination of the infiltrated water height $I(mm)$ in the board 02.

$$I(t) = \frac{1}{E} \times \frac{K}{a+1} \times \left(t_{irr}^{(a+1)} - (t_{irr} - t_{ad})^{(a+1)} \right) \dots (21)$$

E = 8 , tir = 22 min

L (m)	0	10	20	30	40	50
$t_{ad\ 1}$ (mn)	0	2	5	7	10	15
I (mm)	207	178	137	113	79	33
$t_{ad\ 2}$ (mn)	0	2	5	7	10	15
I (mm)	207	178	137	113	79	33
$t_{ad\ 3}$ (mn)	0	2	5	7	10	15
I (mm)	207	178	137	113	79	33
$t_{ad\ 4}$ (mn)	0	2	4	6	9	14
I (mm)	196	165	137	111	77	32
$t_{ad\ 5}$ (mn)	0	2	4	6	9	14
I (mm)	196	165	137	111	77	32
$t_{ad\ 6}$ (mn)	0	2	3	6	8	13
I (mm)	182	155	142	106	85	40
$t_{ad\ 7}$ (mn)	0	2	3	6	8	13
I (mm)	182	155	142	106	85	40

$t_{ad\ 8}$ (mn)	0	2	3	6	9	14
I (mm)	196	165	151	111	77	32
$t_{ad\ 9}$ (mn)	0	2	3	6	8	13
I (mm)	182	155	142	106	85	40
$t_{ad\ 10}$ (mn)	0	2	3	6	7	12
I (mm)	161	139	128	98	89	47
$t_{ad\ 11}$ (mn)	0	2	3	5	7	12
I (mm)	181	150	135	108	84	37
$t_{ad\ 12}$ (mn)	0	2	3	5	7	12
I (mm)	181	150	135	108	84	37

Table III.19 : Determination of the infiltrated water height $I(mm)$ in the board **03**.

$$I(t) = \frac{1}{E} \times \frac{K}{a+1} \times \left(t_{irr}^{(a+1)} - (t_{irr} - t_{ad})^{(a+1)} \right) \dots (21)$$

$E = 8$, $t_{ir} = 34$ min

L(m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	2	5	7	11	16	23	27
I (mm)	456	412	349	309	236	156	68	31
$t_{ad\ 2}$ (mn)	0	2	4	7	10	16	22	27
I (mm)	456	412	369	309	254	156	79	31
$t_{ad\ 3}$ (mn)	0	2	4	7	10	15	21	25
I (mm)	395	356	318	264	214	140	68	32
$t_{ad\ 4}$ (mn)	0	2	4	5	9	15	21	24
I (mm)	390	344	301	281	206	116	51	29
$t_{ad\ 5}$ (mn)	0	2	4	6	9	11	16	22
I (mm)	321	285	251	218	173	145	85	32
$t_{ad\ 6}$ (mn)	0	2	4	5	8	10	14	20
I (mm)	283	247	213	196	152	125	79	29
$t_{ad\ 7}$ (mn)	0	2	4	5	7	10	13	17
I (mm)	208	179	153	140	117	85	58	29
$t_{ad\ 8}$ (mn)	0	2	3	5	7	9	12	17
I (mm)	208	179	166	140	117	95	66	29

$t_{ad\ 9}$ (mn)	0	2	3	5	7	9	12	16
I (mm)	183	157	145	123	102	82	57	29
$t_{ad\ 10}$ (mn)	0	2	3	5	7	8	11	16
I (mm)	183	157	145	123	102	92	65	29
$t_{ad\ 11}$ (mn)	0	2	3	5	8	9	11	15
I (mm)	158	136	125	105	78	70	55	29
$t_{ad\ 12}$ (mn)	0	2	3	5	8	9	10	14
I (mm)	142	123	114	97	73	66	59	34

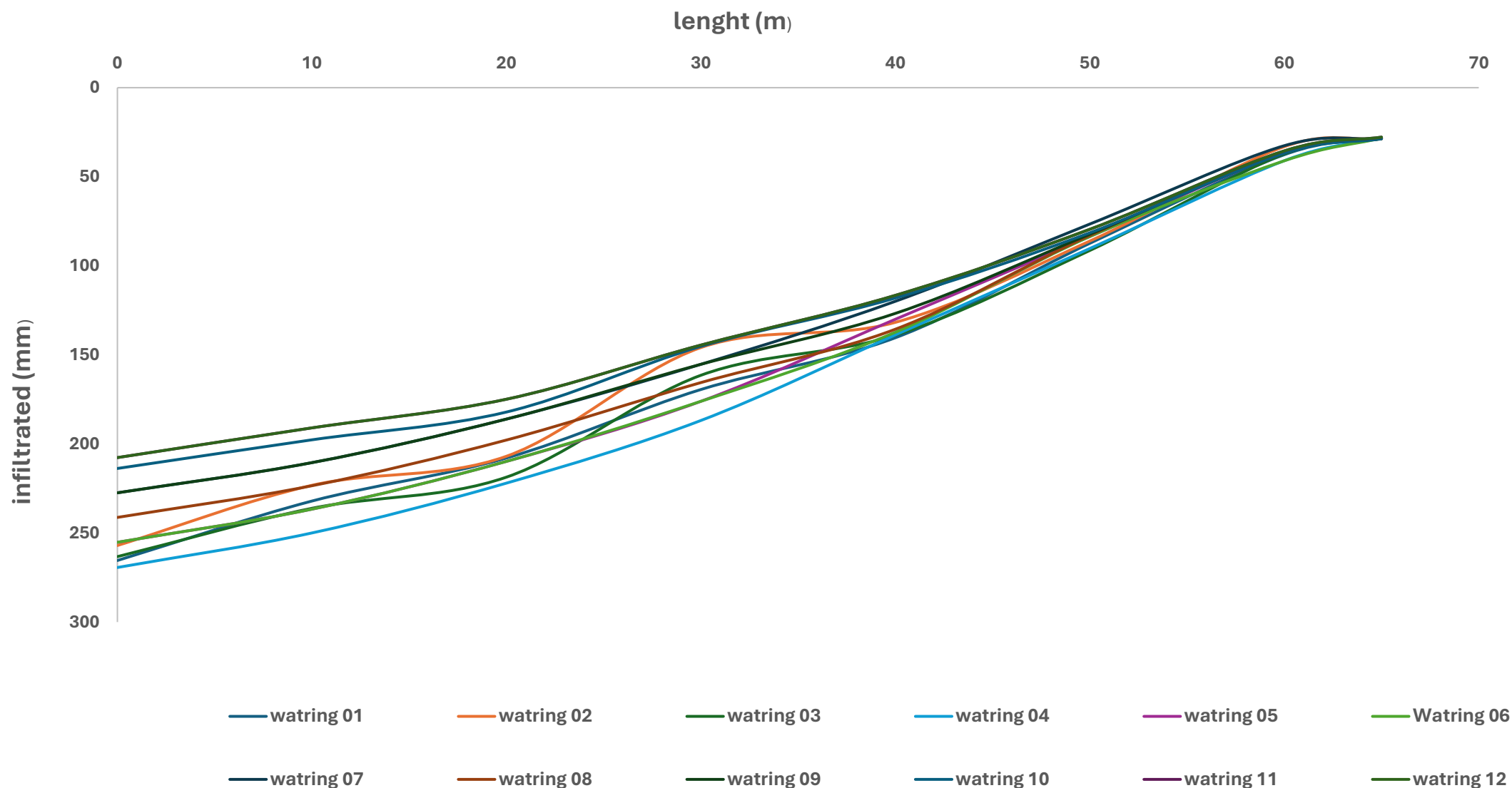
Table III.20 : Determination of the infiltrated water height $I(mm)$ in the board **04** .

$$I(t) = \frac{1}{E} \times \frac{K}{a+1} \times \left(t_{irr}^{(a+1)} - (t_{irr} - t_{ad})^{(a+1)} \right) \dots (21)$$

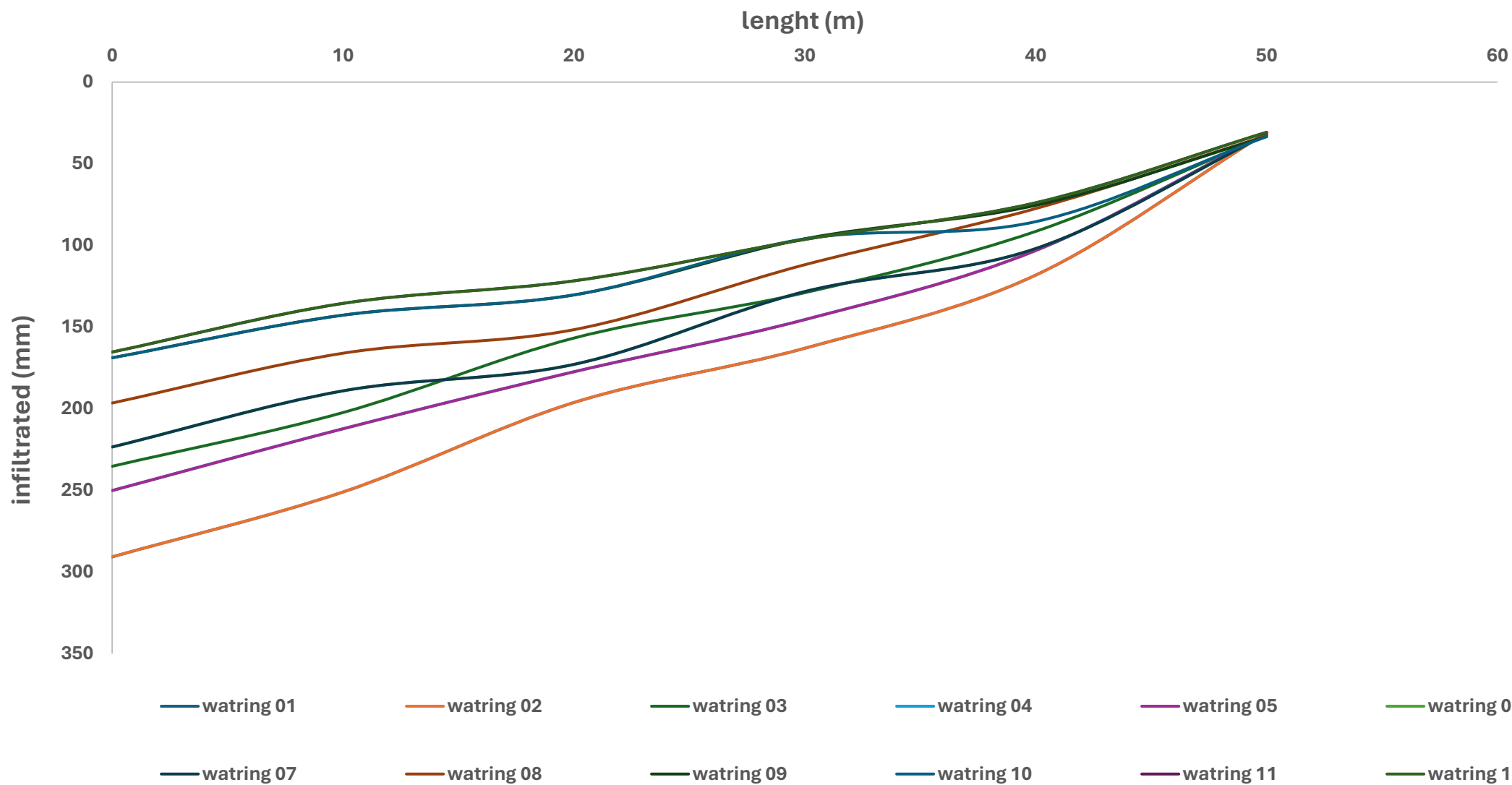
E = 8 , tir = 34 min

L(m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	3	6	9	13	18	24	28
I (mm)	400	349	300	254	196	131	65	30
$t_{ad\ 2}$ (mn)	0	2	5	9	13	18	23	27
I (mm)	373	340	294	235	180	119	66	31
$t_{ad\ 3}$ (mn)	0	2	4	9	12	16	22	25
I (mm)	318	291	263	199	162	117	58	33
$t_{ad\ 4}$ (mn)	0	2	4	8	12	16	22	24
I (mm)	304	275	248	195	147	104	48	33
$t_{ad\ 5}$ (mn)	0	2	4	8	10	14	20	23
I (mm)	278	252	226	178	155	112	57	34
$t_{ad\ 6}$ (mn)	0	2	3	6	9	12	18	20
I (mm)	239	212	199	161	127	96	46	32
$t_{ad\ 7}$ (mn)	0	2	3	5	9	12	17	19
I (mm)	226	196	182	156	109	79	40	28
$t_{ad\ 8}$ (mn)	0	2	3	5	8	12	17	19
I (mm)	226	196	182	156	120	79	40	28
$t_{ad\ 9}$ (mn)	0	2	3	6	8	12	16	18
I (mm)	178	157	147	119	101	69	42	30

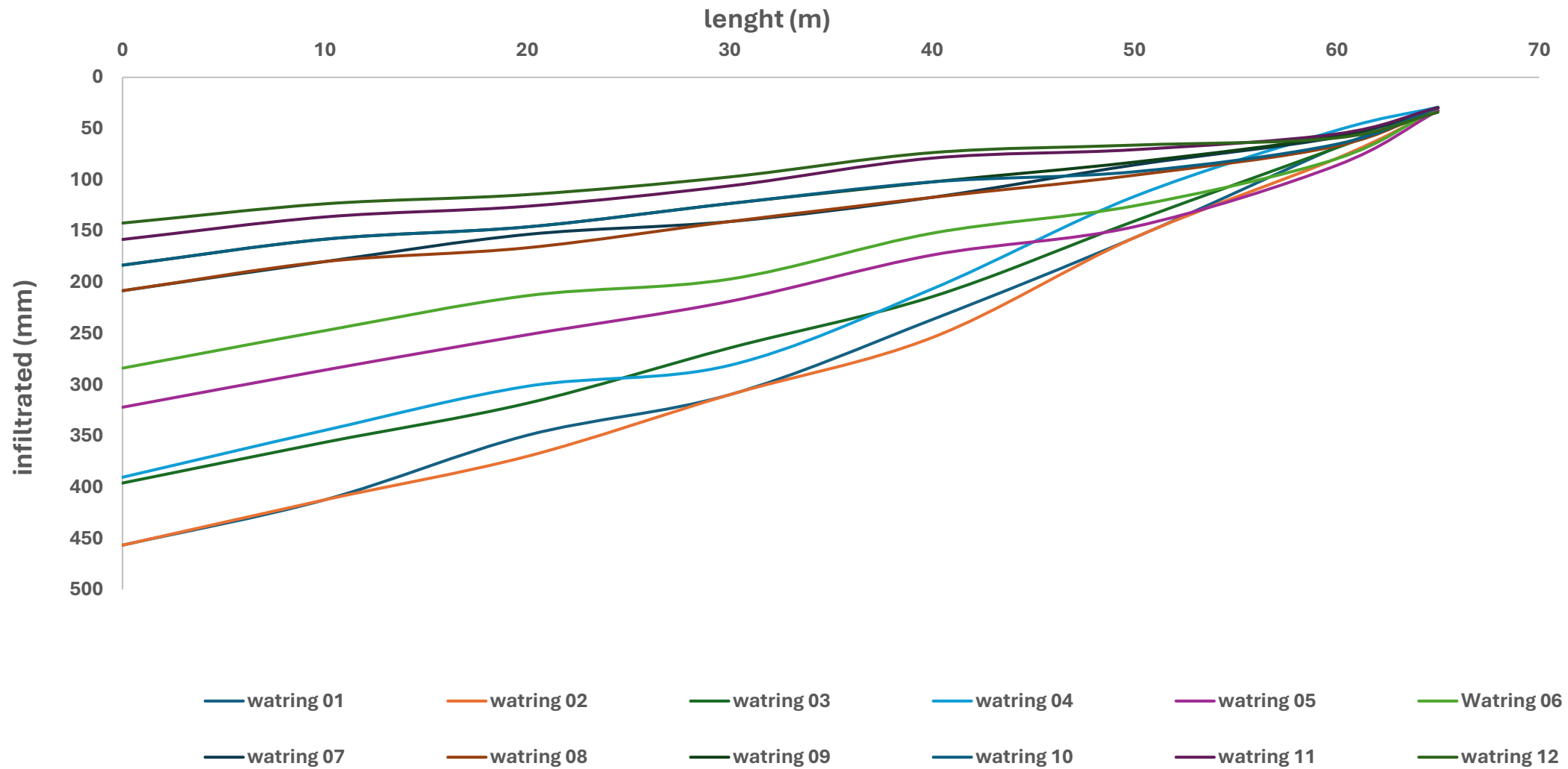
$t_{ad\ 10}$ (mn)	0	2	3	6	8	12	16	18
I (mm)	185	164	153	124	105	72	43	31
$t_{ad\ 11}$ (mn)	0	2	4	5	7	11	15	17
I (mm)	195	169	145	134	113	76	45	33
$t_{ad\ 12}$ (mn)	0	2	3	5	7	11	13	15
I (mm)	147	128	118	101	84	55	43	32



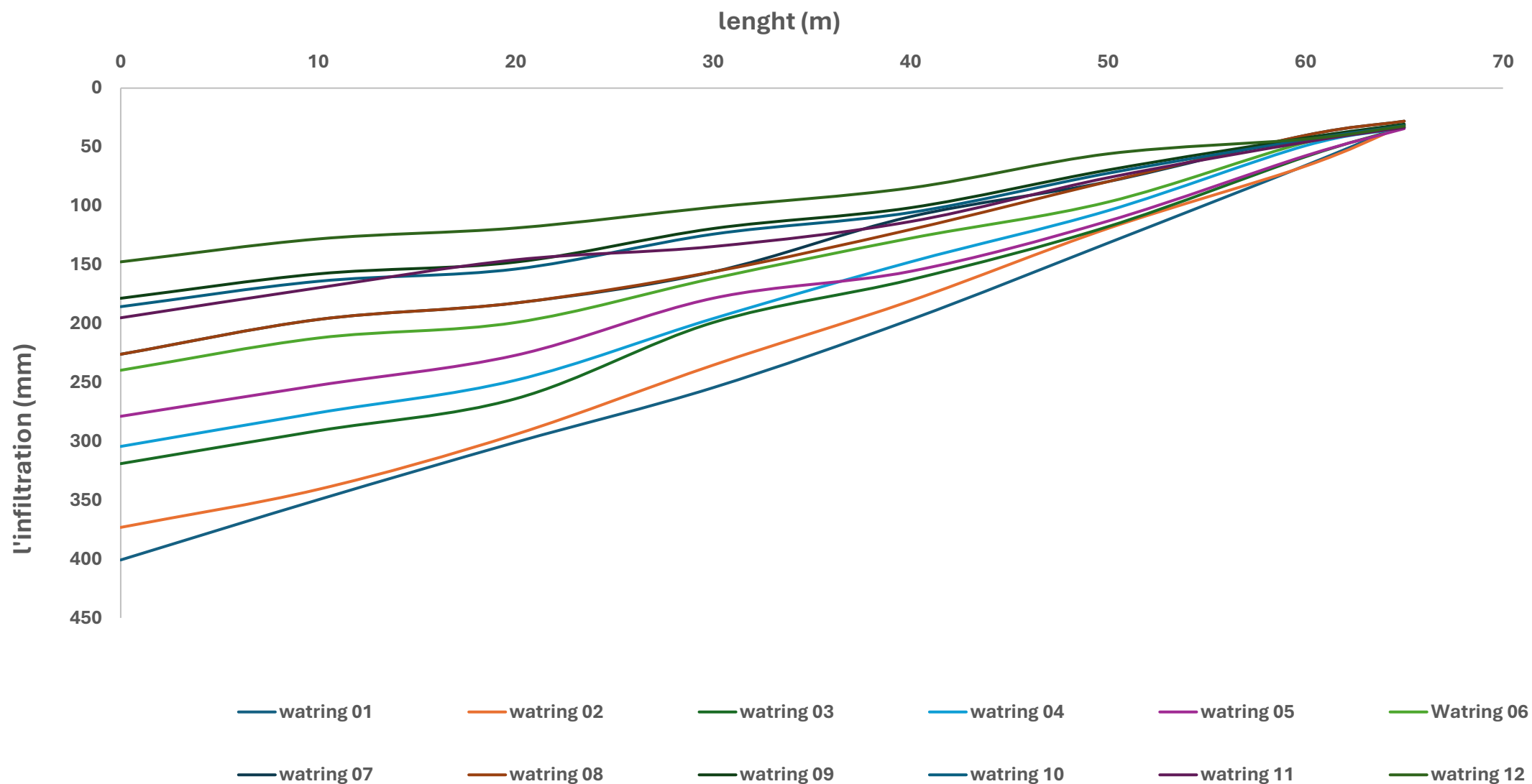
Graph III.05 : the infiltrated water height I (mm) in the board **01**.



Graph III.06 : the infiltrated water height I (mm) in the board **02** .



Graph III.07 : the infiltrated water height I (mm) in the board **03** .



Graph III.08 : the infiltrated water height I (mm) in the board **04**.

The graph shows the rate of water infiltration along the entire length of board (01) (Graph III.05) , Water infiltration into the soil is highest at the beginning of the board and gradually decreases toward the end of the board , while the irrigation time is constant .

The graph shows the rate of water infiltration along the entire length of board (02) (Graph III.06) , Water infiltration into the soil is highest at the beginning of the board ,in the end of the board ,water infiltration stabilizes , and the irrigation time varies with each watering .

The graph shows the rate of water infiltration along the entire length of board (03) (Graph III.07) , Water infiltration into the soil is highest at the beginning of the board , and in the end of the board ,water infiltration stabilizes .

The graph shows the rate of water infiltration along the entire length of board (04) (Graph III.08) , Water infiltration into the soil is highest at the beginning of the board , and The infiltrated is gradually subsiding , and in the end of the board ,water infiltration stabilizes .

6. Difference between upstream and downstream water levels:

Difference between upstream and downstream water levels in all the board (1-2-3-4) in the Table III. 21) (Table III. 22) (Table III. 23) (Table III. 24) :

Table III. 21 : Difference between upstream and downstream water levels in the board 01 .

NEV					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
2	65	44	237,0705516	89,3150645	3,647239256
2	65	44	228,2569728	88,8110666	3,511645736
2	65	45	234,6878041	89,1452063	3,610581601
2	65	46	241,1685026	89,535961	3,710284656
DEC					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
2	65	45	226,8837006	88,9012172	3,490518471
2	65	45	226,8837006	88,9012172	3,490518471
2	65	43	198,8238048	87,4218043	3,058827767
2	65	44	212,7730593	88,2000716	3,273431682

JAN					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
2	65	43	198,8238048	87,4218043	3,058827767
2	65	42	185,0213485	86,5532191	2,846482285
2	65	42	179,9008306	86,6281844	2,767705085
2	65	42	179,9008306	86,6281844	2,767705085

Table III.22 : Difference between upstream and downstream water levels in the board **02** .

NEV					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
6	50	25	259,8486244	89,38641738	5,196972487
6	50	25	259,8486244	89,38641738	5,196972487
6	50	23	202,4606813	86,06665826	4,049213625
6	50	24	218,5500156	87,38875201	4,371000313
DEC					
Flow(l/s)	Lenght (m)	Time (mn)	H up-H do(mm)	H up-H do%	(H up-H do)/L
6	50	24	218,5500156	87,38875201	4,371000313
6	50	23	191,2693869	85,61497034	3,825387737
6	50	23	191,2693869	85,61497034	3,825387737
6	50	22	163,7256243	83,32192448	3,274512487
JAN					
Flow (l/s)	Lenght(m)	Time (mn)	H up-H do(mm)	H up-H do%	(H up-H do)/L
6	50	21	135,4100017	80,22238905	2,708200033
6	50	21	135,4100017	80,22238905	2,708200033
6	50	21	134,5416212	81,4084809	2,690832425
6	50	21	134,5416212	81,4084809	2,690832425

Table III.23 : Difference between upstream and downstream water levels in the board **03** .

NEV					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
6	65	34	424,639143	93,005686	6,532909892
6	65	34	424,639143	93,005686	6,532909892
6	65	32	363,1952	91,7306605	5,587618457

6	65	33	361,16371	92,5421028	5,556364772
DEC					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
6	65	30	289,392165	89,8884738	4,452187152
6	65	29	254,165916	89,5580533	3,910244854
6	65	26	178,453102	85,6995796	2,745432341
6	65	26	178,453102	85,6995796	2,745432341
JAN					
Flow (l/s)	Lenght(m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
6	65	25	153,637459	83,8171059	2,363653218
6	65	25	153,637459	83,8171059	2,363653218
6	65	24	128,832625	81,4332731	1,982040383
6	65	24	108,052492	75,967991	1,662346033

Table III.24 : Difference between upstream and downstream water levels in the board **04** .

NEV					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do (mm)	H up-H do%	(H up-H do)/L
5	65	34	369,901831	92,2946666	5,690797395
5	65	33	341,492107	91,5224678	5,253724725
5	65	31	285,598387	89,5320602	4,393821333
5	65	31	270,630277	88,9190943	4,163542722
DEC					
Flow (l/s)	Lenght (m)	Time (mn)	H up-H do(mm)	H up-H do%	(H up-H do)/L
5	65	30	244,373193	87,660069	3,759587581
5	65	29	206,80993	86,2938585	3,18169123
5	65	29	197,996725	87,5826167	3,046103464
5	65	29	197,996725	87,5826167	3,046103464
JAN					
Flow(l/s)	Lenght (m)	Time (mn)	H up-H do(mm)	H up-H do%	(H up-H do)/L
5	65	27	147,868737	82,8338692	2,274903641
5	65	27	153,780994	82,8338692	2,365861452
5	65	28	161,637909	82,8548398	2,48673706
5	65	26	115,344137	78,1542371	1,774525178

According to the tables (21 -22 -23 -24), the longer the irrigation time , the lower the variance, while its percentage increases. Therefore, the greater the irrigation, the better the infiltration distribution and the higher the average flow rate.

Thus, both the flow rate and the irrigation time determine the average infiltration.

III. Conclusion:

This chapter III , after all the calculations using Kostiakov method, shows that the advance curves are not linear and have the shape of a power curve. We see that the advance time decreases after each watering. The decrease in water advance time during successive irrigations is mainly explained by the progressive reduction in the soil's infiltration capacity, due to the increase in its initial moisture content. This condition promotes faster surface irrigation , thus reducing the time needed to reach the end of the board. In other words: The wetter the soil, the less water it absorbs, therefore the water advances faster.

Chapter IV

Programming

I. Introduction :

In this chapter [IV] , we will address the practical application of the Kositakov method using the Python language because it is the easiest and fastest and is available on several desktops, with the aim of preparing a programming environment and converting it from a computational method to an application.

II. Programming :

1- Definition of Programming :

Programming is the process of giving instructions to a computer, which then translates and executes them using programming languages as an intermediary. We use programming :

- To solve problems and save time and effort.
- To build tools such as mobile apps and websites.

There are many programming languages : (Python – JavaScript – Java – C++ ...) In my project , I use Python language .

2- Development Environment Python :

In general, Python is a multipurpose programming language that can be used in many situations. But there is not one programming language which is best in all kind of situations, so it is important that you know about and have skills in different languages (Lutz, M,2013) .

Python Packages With Python you don't get so much out of the box. Instead of having all of its functionality built into its core, you need to install different packages for different topics (Lutz, M,2013) .

It contains many libraries, each of which is used for a specific purpose like (flet , kivy , tekinder , streamlit ...) .

An Editor is a program where you create your code (and where you can run and test it) , like PyCharm (**Photo IV.01**) (Lutz, M,2013) .

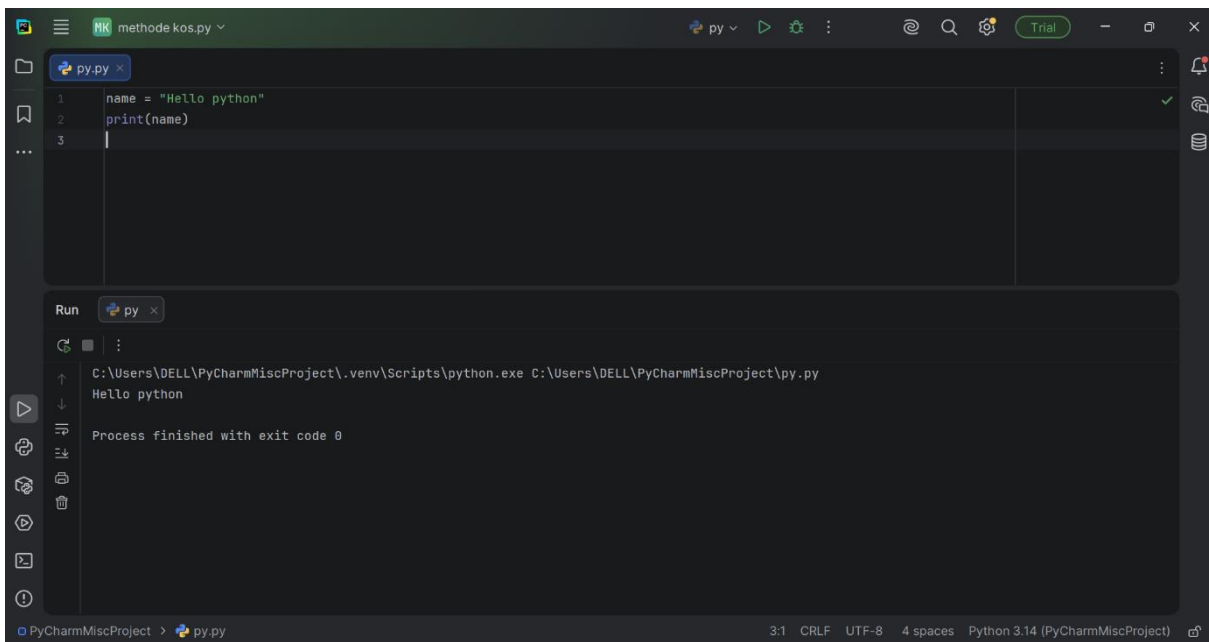


Photo IV.01: Python's main interface .

III. Programming Diagram (Structure) :

The diagram is a structure for the data input and calculation steps of the Kostiakov method, designed to facilitate its implementation as programming python code (**figure IV.01**) .

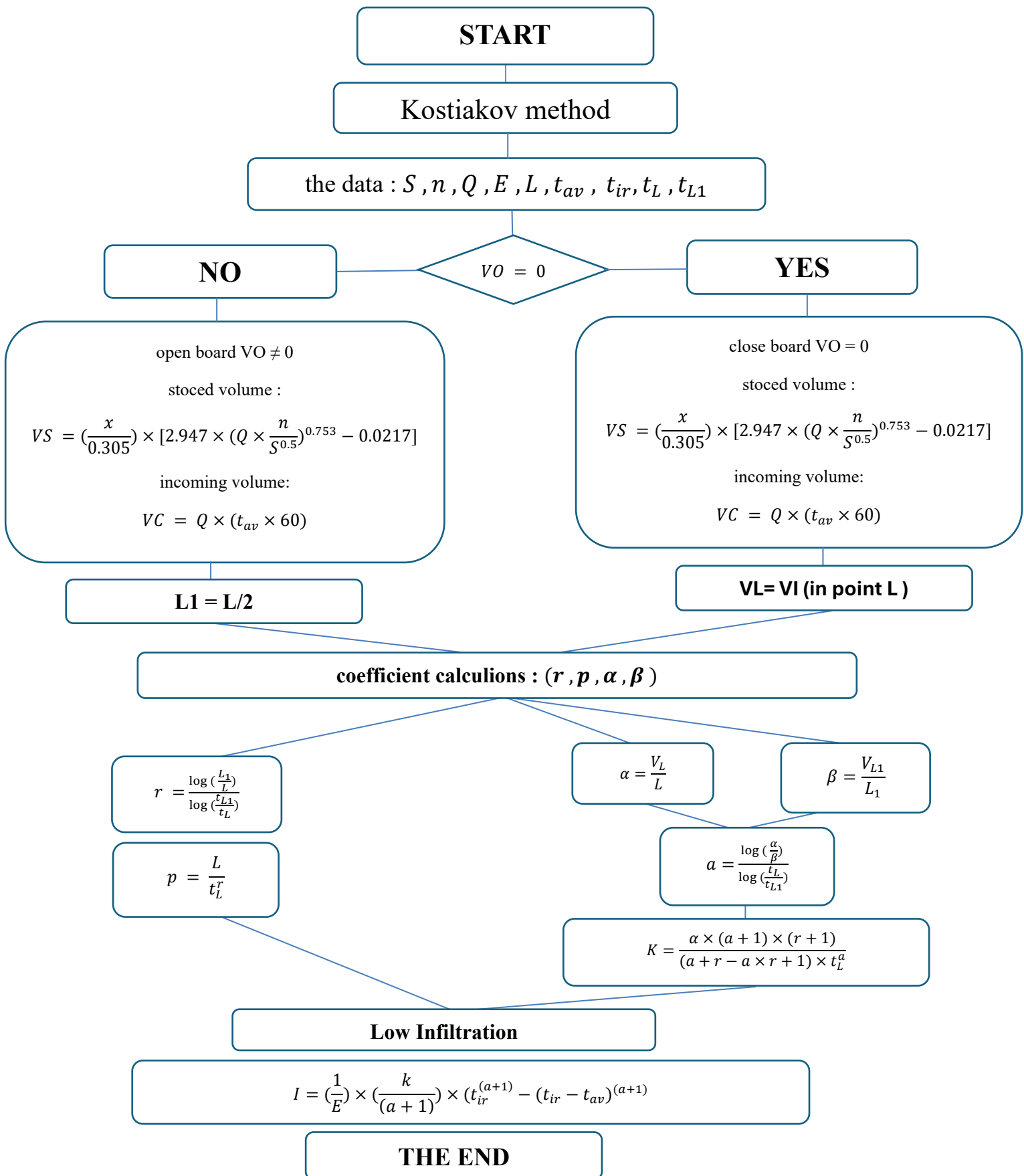


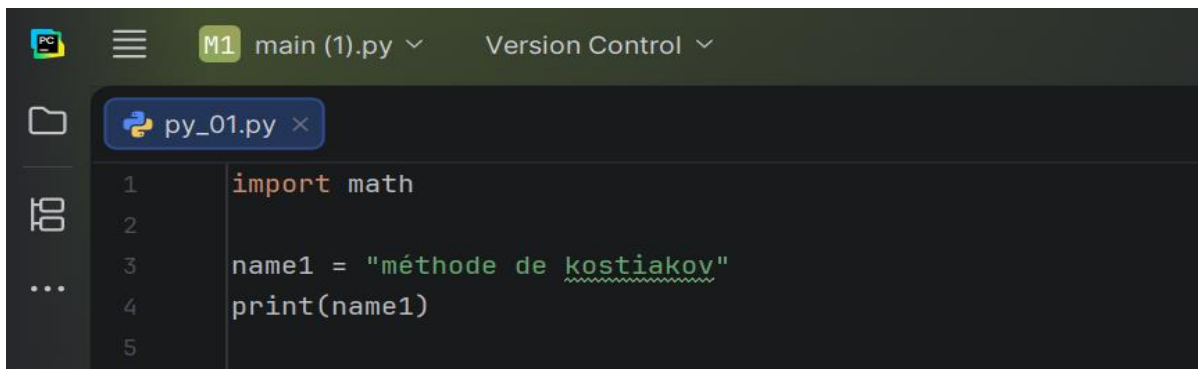
figure IV.01 :Diagrams of the method.

IV. Steps of programming :

1- Entry the information :

Call the “ import math ” command and begin entering the diagram’s content as described earlier (photo IV.02) :

- Enter the data (**photo IV.03**) .
- Enter the “ if “ statement to calculate the volume.
- Enter the distances and times as a list.
- Complete the remaining calculations in the same order as they appear in the diagram.

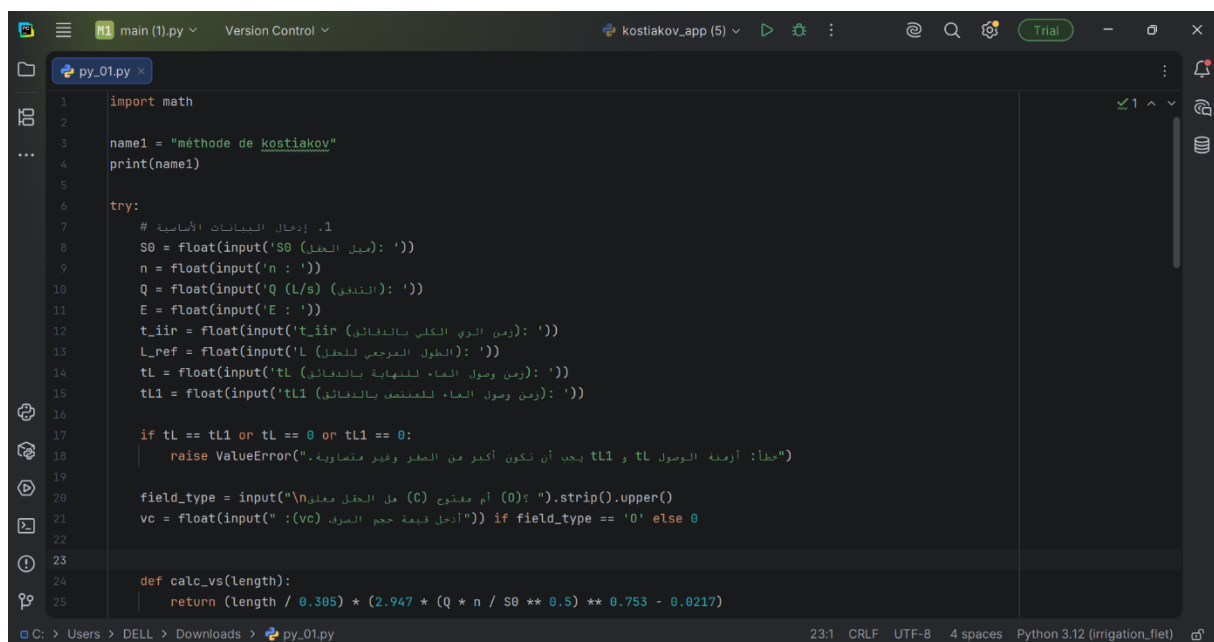


```

1  import math
2
3  name1 = "méthode de kostiakov"
4  print(name1)
5

```

Photo IV.02 : Call the command in python .



```

1  import math
2
3  name1 = "méthode de kostiakov"
4  print(name1)
5
6  try:
7      # إدخال البيانات الأساسية
8      S0 = float(input('S0 (معدل الخطأ): '))
9      n = float(input('n : '))
10     Q = float(input('Q (L/s) (المتدفق): '))
11     E = float(input('E : '))
12     t_iir = float(input('t_iir (زمن التوقف الكلي بالثواني): '))
13     L_ref = float(input('L (الطول الموزعي للخطأ): '))
14     tl = float(input('tl (زمن وصول الماء للنهاية بالثواني): '))
15     tl1 = float(input('tl1 (زمن وصول الماء للمنتصف بالثواني): '))
16
17     if tl == tl1 or tl == 0 or tl1 == 0:
18         raise ValueError("خطأ: الزمن الوصول tl و tl1 يجب أن تكون أكبر من الصفر وغير متساوية.")
19
20     field_type = input("\nمل الخطأ مغلق (C) أم مفتوح (0): ").strip().upper()
21     vc = float(input(":(vc) أدخل قيمة حجم الصرف) ") if field_type == '0' else 0
22
23
24     def calc_vs(length):
25         return (length / 0.365) * (2.947 * (Q * n / S0 ** 0.5) ** 0.753 - 0.0217)

```

Photo IV.03 : Insert the diagram content in python .

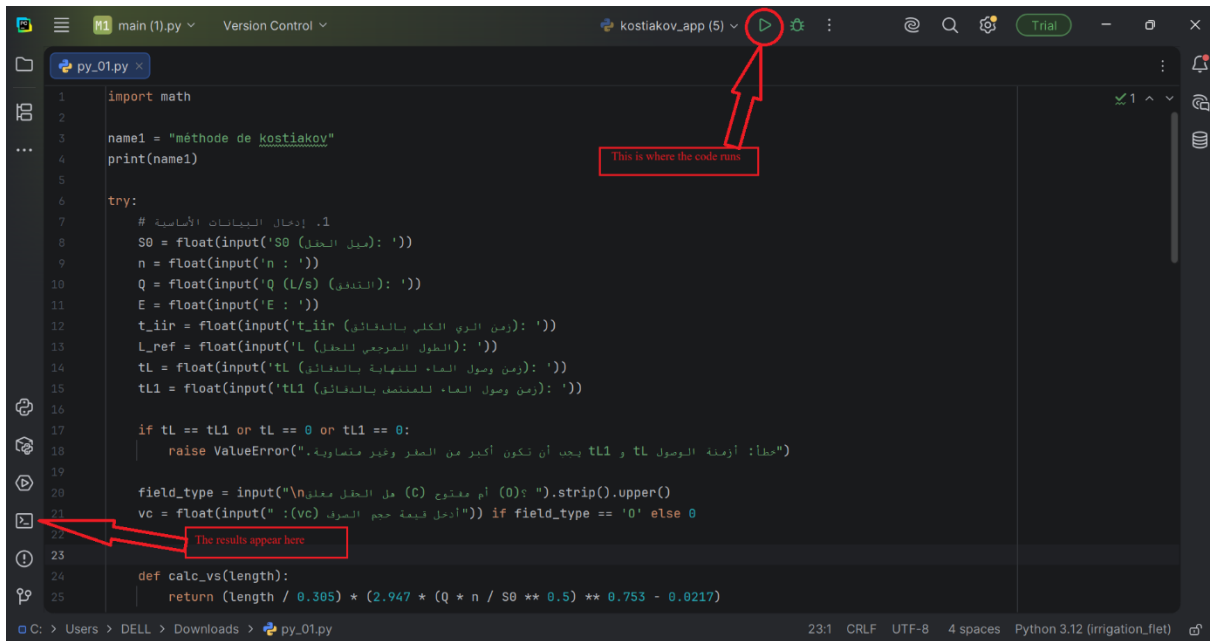


Photo IV.04 : How to run the program and view the results.

2- Development with the Flet Library:

We use the Flet library for development and optimization, to transform it from plain Python code into a visual application (**photo IV.05**) .

- Pagination : (page 01 , page 02 , page 03 , ...) .
- Building the interface :
 - Home : welcome title , title project , description of the project .
 - Login / accounts : sig in , log in , email , passwords , full name .
 - Entry the data : all the information (type of the boards , length , the irrigation times , the distance ...) .
 - Notes : Based on the infiltration results (high , low , acceptable , unacceptable) .
 - History : save all the entry data and the results .
- General adjustments : colors , field styles , button styles , the back grounds .
- Language support : Arabic , English .

```

import flet as ft
import math
import datetime

# -----
#  THEME CONSTANTS
#  -----
BLUE_DARK   = "#1565C0"
BLUE_MED    = "#1976D2"
BLUE_LIGHT  = "#80DEFB"
BLUE_XLIGHT = "#E3F2FD"
GREEN_DARK  = "#2E7D32"
GREEN_MED   = "#388E3C"
GREEN_XLIGHT = "#F1F8E9"
WHITE       = "#FFFFFF"
TEXT_DARK   = "#1A237E"
TEXT_MED    = "#37474F"
TEXT_LIGHT  = "#78909C"

# -----
#  TRANSLATIONS
#  -----
TR = {
    "ar": {

```

```

263 #
264 def run_calculation(params: dict) -> dict:
265     try:
266         S0 = float(params["S0"])
267         n = float(params["n"])
268         F = float(params["F"])
269         E = float(params["E"])
270         t_ir = float(params["t_ir"])
271         L_ref = float(params["L_ref"])
272         tL = float(params["tL"])
273         tL1 = float(params["tL1"])
274         vo = float(params.get("vo", 0))
275         points = params.get("points", [])
276
277         if tL == tL1 or tL == 0 or tL1 == 0:
278             raise ValueError(
279                 "tL و tL1 يجب أن تكونا أكبر من الصفر وغير متساويتين / "
280                 "tL & tL1 must be > 0 and different")
281
282         def calc_vs(length):
283             return (length / 0.305) * (2.947 * (F * n / S0 ** 0.5) ** 0.753 - 0.0217)
284
285         L1_ref = L_ref / 2
286         VS_L = calc_vs(L_ref)
287         VE_L = F * (tL * 60)
288         VT_ref = VE_L - VS_L - vo

```

Photo IV.05 : The Flet library in python for development code

V. The application :

After completing the previous steps , we will convert it in the final step into an Android mobile application (photo IV.06) (photo IV.07) (photo IV.08) (photo IV.09) (photo IV.10) (photo IV.11) .

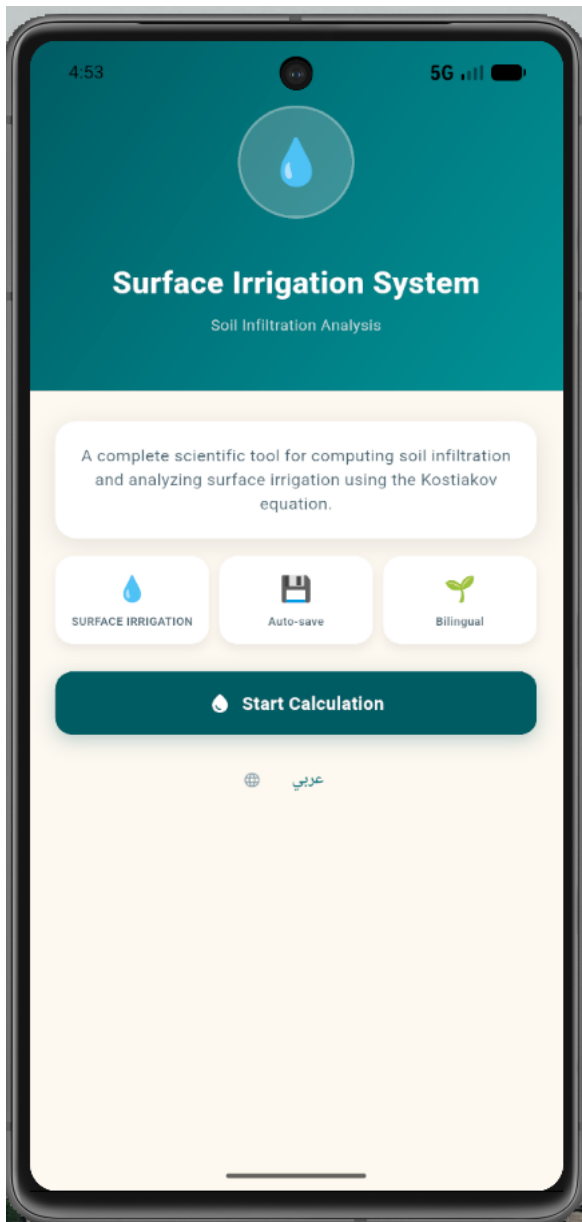


Photo IV.06 : Welcome page .

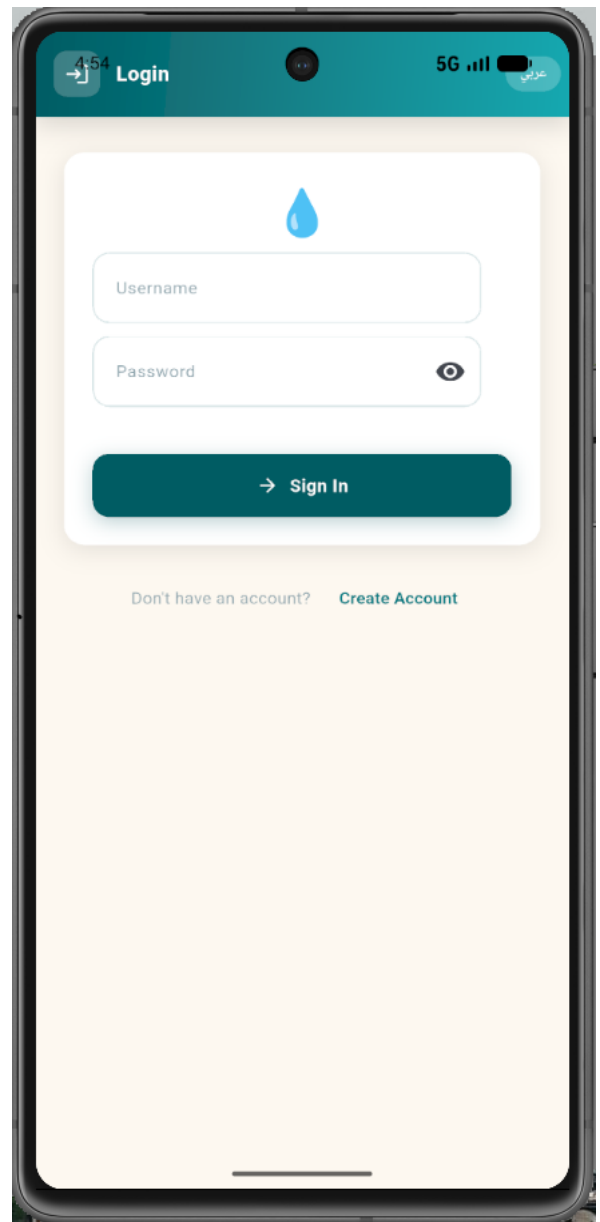


Photo IV.07 : Login page .

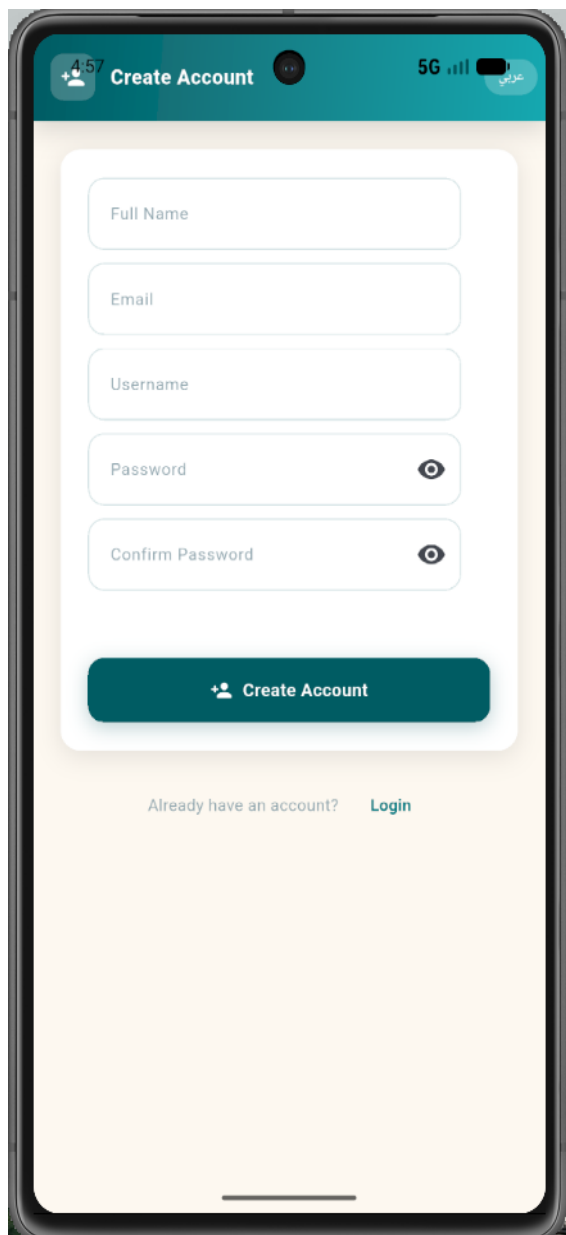


Photo IV.08 : Create account page .

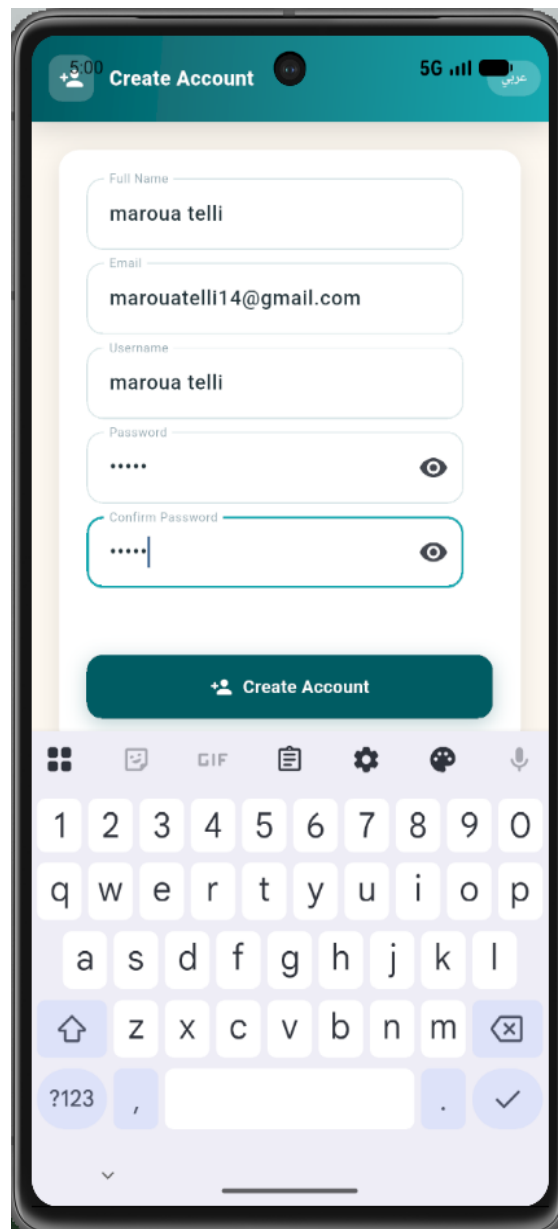


Photo IV.09 : Create account .

5:04 Calculation

M Hello, maroua telli 🌟

Field Parameters

S0 – Field Slope
0.001

n – Roughness Coeff.
0.0357

F (L/s) – Flow Rate
2

E – Board Spacing
8

t_{ir} (min) – Total Irrigation Time
45

L (m) – Reference Length
65

tL (min) – End Advance
35

tL1 (min) – Mid Advance
12

Field Type ☒ Closed (C) ☐ Open (O)

Measurement Points + Add Point

Calculate Now

5:01 Calculation

M Hello, maroua telli 🌟

Field Parameters

S0 – Field Slope

n – Roughness Coeff.

F (L/s) – Flow Rate

E – Board Spacing

t_{ir} (min) – Total Irrigation Time

L (m) – Reference Length

tL (min) – End Advance

tL1 (min) – Mid Advance

Field Type ☒ Closed (C) ☐ Open (O)

Measurement Points + Add Point

Calculate Now

Photo IV.10 : Entry data page .

35
5:06 5G

TL1 (min) — Mid Advance

12

Field Type ☒ Closed (C) ☐ Open (O)

Measurement Points + Add Point

#1 Distance 1: 0 Advance Time (min) 1: 0

#2 Distance 2: 10 Advance Time (min) 2: 4

#3 Distance 3: 20 Advance Time (min) 3: 7

#4 Distance 4: 30 Advance Time (min) 4: 12

Calculate Now

5:08 5G

#7 Distance 7: 60 Advance Time (min) 7: 33

#8 Distance 8: 65 Advance Time (min) 8: 35

Calculate Now

✓ Results

k: 9.753720 a: 0.5309 r: 0.6475

Distance (m)	t _{ad}	VS	VI	Infiltration I
0.0	0.00	0.00		270.4057
10.0	177.70	302.30		234.4900
20.0	355.39	484.61		208.7395
30.0	533.09	906.91		168.1930
40.0	710.79	1209.21		138.0069
50.0	888.48	1991.52		84.1983
60.0	1066.18	2893.82		35.7470
65.0	1155.03	3044.97		27.0410

Auto-saved to disk

Photo IV.11 : The results .

VI. The results of infiltration in the application :

The same information applies to (Table III.17) from Chapter [III] of Board 01 , And it appears in the application as in (photo IV.11) .

Table IV.25 : The results of infiltration in the application in the board 01 .

L (m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	4	7	12	16	24	33	35
I (mm)	264.02	230.01	205.3	169.04	140.3	87.13	37.28	28.01
$t_{ad\ 2}$ (mn)	0	4	6	14	16	23	33	34
I (mm)	258.01	224.02	209.11	145.04	142.4	97.5	41.5	29.5
$t_{ad\ 3}$ (mn)	0	3	5	12	15	22	32	34
I (mm)	262.09	235.15	218.44	159.4	138.5	90.0	36.09	28.09
$t_{ad\ 4}$ (mn)	0	2	5	9	15	22	31	34
I (mm)	267.3	243.05	222.01	185.81	138.2	90.4	40	27.08
$t_{ad\ 5}$ (mn)	0	2	5	9	15	22	31	33
I (mm)	255.07	236.16	210	176.13	129.9	83.1	35.9	27.09
$t_{ad\ 6}$ (mn)	0	2	5	9	14	22	30	33
I (mm)	255.03	236.3	208.9	176.8	137.04	82.08	41.10	28.2
$t_{ad\ 7}$ (mn)	0	2	5	9	14	21	30	31
I (mm)	227.9	210.42	186.01	155.49	119.02	76	31.9	28.5
$t_{ad\ 8}$ (mn)	0	2	5	9	13	21	30	32
I (mm)	241.72	222.77	197.5	165.07	135.2	82.8	35.09	27.9
$t_{ad\ 9}$ (mn)	0	2	5	9	13	20	29	31
I (mm)	227.9	210.42	186.42	155.08	126.46	81.8	36.1	28.5
$t_{ad\ 10}$ (mn)	0	2	4	9	13	19	28	30
I (mm)	213.81	197.54	182.9	145.06	118.92	81.82	36.4	28.9
$t_{ad\ 11}$ (mn)	0	2	4	8	12	18	27	29
I (mm)	207.14	189.99	174.06	144.02	116.05	79.50	35.9	27.7
$t_{ad\ 12}$ (mn)	0	2	4	8	12	18	27	29
I (mm)	207.14	189.99	174.06	144.02	116.05	79.50	35.9	27.7

The same information applies to Table III.18 from Chapter III of Board 02.

Table IV.26 : The results of infiltration in the application in the board **02** .

L (m)	0	10	20	30	40	50
$t_{ad\ 1}$ (mn)	0	2	5	7	10	15
I (mm)	207.03	178.2	136.8	113.4	79.04	33.05
$t_{ad\ 2}$ (mn)	0	2	5	7	10	15
I (mm)	207.03	178.2	136.8	113.4	79.04	33.05
$t_{ad\ 3}$ (mn)	0	2	5	7	10	15
I (mm)	207.03	178.2	136.8	113.4	79.04	33.05
$t_{ad\ 4}$ (mn)	0	2	4	6	9	14
I (mm)	196.2	165.12	136	111.5	77.09	32.22
$t_{ad\ 5}$ (mn)	0	2	4	6	9	14
I (mm)	196.2	165.12	136	111.5	77.09	32.22
$t_{ad\ 6}$ (mn)	0	2	3	6	8	13
I (mm)	182	154.4	142.67	107.03	85.1	40.4
$t_{ad\ 7}$ (mn)	0	2	3	6	8	13
I (mm)	182	154.4	142.67	107.03	85.1	40.4
$t_{ad\ 8}$ (mn)	0	2	3	6	9	14
I (mm)	196.2	165.12	154.8	111.5	77.09	32.22
$t_{ad\ 9}$ (mn)	0	2	3	6	8	13
I (mm)	182	154.4	142.67	107.03	85.1	40.4
$t_{ad\ 10}$ (mn)	0	2	3	6	7	12
I (mm)	161	139.40	128.76	98.71	89.3	47.7
$t_{ad\ 11}$ (mn)	0	2	3	5	7	12
I (mm)	181.34	149.51	135.3	108.7	83.3	37.1
$t_{ad\ 12}$ (mn)	0	2	3	5	7	12
I (mm)	181.34	149.51	135.3	108.7	83.3	37.1

The same information applies to Table III.19 from Chapter III of Board 03.

Table IV.27 : The results of infiltration in the application in the board **03** .

L(m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	2	5	7	11	16	23	27
I (mm)	456.46	412.00	348.8	309.68	235.9	156.07	68.63	31.6
$t_{ad\ 2}$ (mn)	0	2	4	7	10	16	22	27
I (mm)	456.46	412.00	348.8	309.68	235.9	156.07	68.63	31.6

$t_{ad\ 3}$ (mn)	0	2	4	7	10	15	21	25
I (mm)	395	355.55	318.3	263.6	214.12	140.1	68.8	32
$t_{ad\ 4}$ (mn)	0	2	4	5	9	15	21	24
I (mm)	390.2	345.4	300.9	281.5	206.87	116.5	51.2	29.39
$t_{ad\ 5}$ (mn)	0	2	4	6	9	11	16	22
I (mm)	322.01	285.28	251.61	218.31	173.35	145.06	85.1	32.3
$t_{ad\ 6}$ (mn)	0	2	4	5	8	10	14	20
I (mm)	283.2	246.9	213.08	195.98	152.1	125.6	79.4	29.6
$t_{ad\ 7}$ (mn)	0	2	4	5	7	10	13	17
I (mm)	208.2	178.8	153.4	140.7	117.1	85.56	57.8	29.7
$t_{ad\ 8}$ (mn)	0	2	3	5	7	9	12	17
I (mm)	208.2	178.8	153.4	140.7	117.1	95.6	65.5	29.7
$t_{ad\ 9}$ (mn)	0	2	3	5	7	9	12	16
I (mm)	183.3	156.9	145.4	123.2	102.05	82	57.4	29.6
$t_{ad\ 10}$ (mn)	0	2	3	5	7	8	11	16
I (mm)	183.3	156.9	145.4	123.2	102.05	92	66.01	29.6
$t_{ad\ 11}$ (mn)	0	2	3	5	8	9	11	15
I (mm)	158.03	135.7	125.7	104.01	78.8	70.1	55.5	29.5
$t_{ad\ 12}$ (mn)	0	2	3	5	8	9	10	14
I (mm)	142.23	122.8	114.4	97.2	73.5	66.4	59.6	34.3

The same information applies to Table III.20 from Chapter III of Board 04.

Table IV.28 : The results of infiltration in the application in the board 04 .

L (m)	0	10	20	30	40	50	60	65
$t_{ad\ 1}$ (mn)	0	3	6	9	13	18	24	28
I (mm)	400.14	349.02	299.89	254.89	196.9	131.17	65.83	30.8
$t_{ad\ 2}$ (mn)	0	2	5	9	13	18	23	27
I (mm)	373.13	340.42	294.77	235.04	179.77	119.76	66.13	31.51
$t_{ad\ 3}$ (mn)	0	2	4	9	12	16	22	25
I (mm)	318.85	291.45	262.5	199.1	162.85	117.43	58.50	32.7
$t_{ad\ 4}$ (mn)	0	2	4	8	12	16	22	24
I (mm)	304.36	274.89	248.09	195.02	146.8	104.87	48.92	33.04
$t_{ad\ 5}$ (mn)	0	2	4	8	10	14	20	23
I (mm)	278.78	251.98	226.77	178.50	155.6	111.9	57.24	33.99

$t_{ad\ 6}$ (mn)	0	2	3	6	9	12	18	20
I (mm)	239.87	212.82	199.52	161.34	128.1	96.41	45.98	32.61
$t_{ad\ 7}$ (mn)	0	2	3	5	9	12	17	19
I (mm)	226.33	196.40	182.7	156.20	109	80.01	40.55	28.29
$t_{ad\ 8}$ (mn)	0	2	3	5	8	12	17	19
I (mm)	226.33	196.40	182.7	156.20	108	80.01	40.55	28.29
$t_{ad\ 9}$ (mn)	0	2	3	6	8	12	16	18
I (mm)	178.19	157.47	147.18	119.59	100.9	69.06	42.33	30.63
$t_{ad\ 10}$ (mn)	0	2	3	6	8	12	16	18
I (mm)	178.19	157.47	147.18	119.59	101	69.06	42.33	31
$t_{ad\ 11}$ (mn)	0	2	4	5	7	11	15	17
I (mm)	195.2	169.25	145.14	133.8	113.08	75.8	45.1	33.35
$t_{ad\ 12}$ (mn)	0	2	3	5	7	11	13	15
I (mm)	195.2	169.25	118	133.8	113.08	75.8	42.9	31.4

1. Analysis of results :

Initially, calculations were performed using Kostakiav mathematical equations at various stages until the infiltration rate was calculated, as shown in the tables (Table III.17) (Table III.18) (Table III.19) (Table III.20) . After the application was created in its final form (photo IV.06) (photo IV.07) (photo IV.08) (photo IV.09) (photo IV.10) (photo IV.11) ., as described, the same calculations were repeated using the same data within the application to ensure accuracy, compare the results, and determine the application's effectiveness. The results were consistent in some cases, with variations only occurring in the decimal places.

VII. Conclusion :

In this chapter [IV] , the Kostakov computational method was developed into a mobile application (Android system) in order to develop and improve surface irrigation systems and reduce existing problems, thus conserving water resources from waste .

General conclusion

General conclusion

The world is experiencing a water scarcity crisis. To rationalize water consumption, protect the environment, and mitigate the negative impacts of water mismanagement, particularly in desert regions and specially in Ouargla Basin, this study examines surface irrigation. Since the agricultural sector consumes over **70%** of available water resources, this study provides an overview of irrigation methods and the most commonly used methods in desert areas (specifically the Ouargla Basin).

To improve surface irrigation and reduce its negative impacts, the first phase of this work involves a comprehensive study of irrigation methods, especially surface irrigation. This method was chosen because it is the most widely used by farmers and investors in the agricultural sector in the Ouargla Basin.

However, they do not use modern methods for determining flow rates and irrigation times to calculate the necessary infiltration doses, which vary depending on the crop. The targeted crop in this study is date palms.

Therefore, this study aims to determine the water infiltration process into the soil when irrigated in basins. The U-Sing model, based on the Kostiakov equation and the standard power adjustment equation, was selected to determine infiltration during the storage phase. This model requires estimating the two Kostiakov permeability coefficients, a and K , using the two-point method. Water progress along four basins (board 1 = 65 m / flow rate = 2 L/s), (board 2 = 50 m / flow rate = 6 L/s), (board 3 = 65 m / flow rate = 6 L/s), and (board 4 = 65 m / flow rate = 6 L/s) was determined for 12 irrigation cycles : **35** minutes for the first board , **18** minutes for the second , **27** minutes for the third , and **28** minutes for the fourth . The progress time decreases due to increased soil permeability after each irrigation cycle. This progress time was also determined using the two-point method to test the accuracy of the chosen model.

Studying the water flow along the bottom of the basin allowed us to determine the Kostiakov infiltration equation. The infiltration was calculated and plotted graphically, showing that it decreases towards the end of the field. The irrigation times were as follows : **45** minutes for the first irrigation , **25** minutes for the second , **27** minutes for the third , and **34** minutes for the fourth.

General conclusion

To move away from the old method, we sought to develop a simpler and faster approach. We programmed the method using Python , the easiest and most widely used programming language in the world . For code development , we used the Flet library to create icons , backgrounds , colors , and the overall appearance of the application . We then developed a mobile application that we use to calculate and determine the appropriate flow and irrigation time. It displays feedback based on the infiltration rate.

This research contributes to the development of a mobile application that helps determine the flow and irrigation time to control the infiltration rate. By determining the flow and irrigation time and controlling the infiltration rate, we can conserve water resources, reduce the rise in groundwater levels, and protect the environment.

Recommendations

In light of this work, and in order to improve and develop surface irrigation, which is still in its early stages, the following recommendations are proposed:

- Abandoning reliance solely on personal experience in determining irrigation timing and quantities, and keeping pace with advancements in scientific research.
- Investing in the development of smart irrigation systems and real-time water control, and contributing to their dissemination.
- Striving to develop the agricultural sector and find solutions to the existing problems.
- Integrating programming and scientific methods in the field of irrigation to conserve water resources, especially in desert regions, given their scarcity.
- Properly leveling agricultural land, as slope is a crucial factor.
- Controlling and reducing irrigation time is essential, because the shorter the irrigation period, and the more precisely the crop receives the required amount of water, the more efficient the use of available water resources becomes.

Bibliographical references

Bibliographical references

-A-

- Abdul Salam, M. and Al-Mazrooei, S. (2007) 'Crop water requirements of date palm (*Phoenix dactylifera* L.) in arid regions', *Acta Horticulturae*, 736, pp. 215–222.
- Al-Karadsheh, E. et al. (2015) 'Water management in date palm orchards: Surface irrigation techniques', *Agricultural Water Management*, 157, pp. 123–132.
- Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998) *Crop evapotranspiration: Guidelines for computing crop water requirements*. Rome: FAO.
- Alzba, A.A. and Fangmeier, D.D. (1995) 'Hydrograph shape and border irrigation efficiency', *Journal of Irrigation and Drainage Engineering*, 121(6), pp. 452–457.
- Alzba, A.A. and Strelkoff, T. (1994) 'Correct form of Hall technique for border irrigation advance', *Journal of Irrigation and Drainage Engineering*, 120(2), pp. 292–307.

-B-

- Bengezi, F. et al. (2017) 'Date Palm (*Phoenix dactylifera* L.) as a Microclimate Modifier in Oasis Agriculture', *Journal of Arid Environments*, 140, pp. 29–38.
- Blair, A.W. and Smerdon, E.T. (1988a) 'Infiltration from irrigation advance data. I: Theory', *Journal of Irrigation and Drainage Engineering*, 114(1), pp. 4–17.
- Blair, A.W. and Smerdon, E.T. (1988b) 'Infiltration from irrigation advance data. II: Experimental', *Journal of Irrigation and Drainage Engineering*, 114(1), pp. 18–29.

-C-

- Choukr-Allah, R. (2014) *Date Palm Irrigation and Soil Salinity in Arid Regions*. Rome: FAO.
- Christiansen, J.E. (1966) *Estimating Evaporation and Evapotranspiration from Climatic Data*. Logan, Utah: Utah State University.

Bibliographical references

-E-

- Elliott, R.L. (1980) *Furrow irrigation evaluation data*. Fort Collins: Colorado State University (unpublished report).
- Elliott, R.L. and Walker, W.R. (1982) 'Field evaluation of furrow infiltration and advance functions', *Transactions of the ASAE*, 25(2), pp. 396–400.

-F-

- FAO (2021) *Water scarcity in the Near East and North Africa*. Rome: FAO. Available at: <https://www.fao.org/neareast/action-areas/wsi/en>
- Fok, Y.-S. (1986) 'Derivation of Lewis-Kostiakov intake equation', *Journal of Irrigation and Drainage Engineering*, 112(2), pp. 164–171.
- Food and Agriculture Organization (1997) *Irrigation Technology Transfer in Support of Food Security*. Rome: FAO.
- Food and Agriculture Organization (2002a) *Irrigation in arid regions: principles and practices*. Rome: FAO.
- Food and Agriculture Organization (2002b) *Irrigation Manual: Planning, Development, Monitoring and Evaluation of Irrigated Agriculture* (Vol. 2). Rome: FAO.
- Food and Agriculture Organization (2011a) *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)*. Rome: FAO.
- Food and Agriculture Organization (2011b) *The state of land and water resources for food and agriculture in the world: Managing systems in danger*. Rome: FAO.

-G-

- Gebreselassie, M., Alemayehu, T. and Tsegaye, D. (2023) 'Effect of furrow irrigation systems and irrigation levels on maize agronomy and water use efficiency', *Heliyon*, 9, e17833. Available at: <https://doi.org/10.1016/j.heliyon.2023.e17833>

Bibliographical references

- Gray, D.M. (1972) *Manuel des principes d'hydrologie*. Ottawa: Comité canadien de la décennie hydrologique internationale.

-H-

- Haghiabi, A.H., Jahangir, A.K., Manouchehr, H. and Jahanshir, M.H. (2011) 'A new method for estimating the parameters of Kostiakov and modified Kostiakov infiltration equations', *World Applied Sciences Journal*, 15(1), pp. 129–135.
- Hart, W.E. and Reynolds, W.N. (1965) 'Analysis of Border Irrigation', *Transactions of the ASAE*, 8(1), pp. 58–61.
- Hartley, D.M. (1992) 'Interpretation of Kostiakov infiltration parameters', *Journal of Irrigation and Drainage Engineering*, 118(1), pp. 156–165.
- Hati, A. and Baoua, M.L. (2022) *Analyse et Diagnostic de l'irrigation par ruissellement à l'aide des eaux épurées de la Step de Ouargla*. Mémoire de Master. Université Kasdi Merbah, Ouargla.

-I-

- Idda, S. et al. (2021) 'Revealing the foggara as a living irrigation system', *International Journal of the Commons*, 15, pp. 199–214.
- Israelsen, O.W. and Hansen, V.E. (1962) *Irrigation Principles and Practices*. 3rd edn. New York: John Wiley & Sons.

-K-

- Kang, S.Z. et al. (2000) 'Soil water distribution and efficiency under alternate furrow irrigation', *Irrigation Science*, 19, pp. 181–190.
- Karim, K. and Karim, K. (2020) 'Enhancing furrow irrigation performance', *Iraqi Journal of Agricultural Sciences*, 51(5), pp. 1276–1289.

Bibliographical references

- Keller, A. and Keller, J. (2003) *Affordable Drip Irrigation for Small Farmers*. Colombo: IWMI.
- Kendy, E. and Pala, M. (2005) 'Improving efficiency of furrow irrigation', *Agricultural Water Management*, 74(1), pp. 1–19.
- Kostiakov, A.N. (1932) 'On the dynamics of the coefficient of water-percolation in soils and on the necessity for studying it from a dynamic point of view for purposes of amelioration', *Transactions of the Sixth Commission of the International Society of Soil Science*, Part A, pp. 17–21.
- Kuper, M. et al. (2009) 'Supporting the shift from state water to community water', *Irrigation and Drainage*, 58, pp. 279–291.

-L-

- Ley, T.W. and Clyma, W. (1980) *Evaluation of furrow irrigation systems*. Staff Paper No. 39.
- Lutz, M. (2013) *Learning Python: Powerful Object-Oriented Programming*. 5th edn. Beijing: O'Reilly Media.

-M-

- Maas, E.V. and Hoffman, G.J. (1977) 'Crop salt tolerance', *Journal of the Irrigation and Drainage Division*, 103(2), pp. 115–134.
- Marzouk, Y. (1989) 'Sociétés rurales et techniques hydrauliques en Afrique', *Études Rurales*, 115–116, pp. 9–36.
- Merriam, J.L. and Keller, J. (1978) *Farm Irrigation System Evaluation*. Logan: Utah State University.
- Mohamed, Z.E. et al. (2026) 'IoT-driven smart irrigation system', *Scientific Reports*, 16, Article 2609.

Bibliographical references

-O-

- Ollier, C. and Poirée, M. (1983) *Irrigation: théorie et technique*. Paris: Eyrolles.
- Oulhaci, D. (2003) *Evaluation de l'infiltration dans l'irrigation par planches dans la région de Ouargla*. Thèse de Magistère. Université Mohamed Khider, Biskra.

-P-

- Pallas, J. (2004) 'Surface irrigation methods', in *Irrigation of Agricultural Crops*. ASA, pp. 173–222.
- Plauchu, V. (2013) *Socio-économie de l'environnement*. Paris: Éditions Campus Ouvert.

-R-

- Rosegrant, M.W., Cai, X. and Cline, S.A. (2002) *World Water and Food to 2025*. Washington: IFPRI.

-S-

- Seckler, D., Molden, D. and Barker, R. (1999) 'Water scarcity in the 21st century', *International Journal of Water Resources Development*.
- Snyder, R.L. and Haman, D.Z. (2017) *Irrigation principles and practices*. University of California.

-T-

- Tixier, P. (2010) *Les oasis*. IRD Editions.

-U-

- UN-Water (2020) *Water scarcity*. United Nations.

Available at: <https://www.unwater.org/water-facts/water-scarcity>

Bibliographical references

-Y-

- YitaYadeta, B. et al. (2022) 'Performance evaluation of furrow irrigation', *Journal of Engineering and Applied Science*.
- Yu, F. and Singh, V.P. (1989) 'Analytical model for border irrigation', *Journal of Irrigation and Drainage Engineering*, 115(6), pp. 982–999.

-Z-

- Zegait, R. et al. (2025) 'AI-based prediction of TDS in desalination', *Desalination and Water Treatment*, 323, 101411.
- Zhang, Y. et al. (2023) 'Effects of ridge–furrow irrigation on wheat yield', *Agricultural Water Management*, 289, 108537.

Available at: <https://doi.org/10.1016/j.agwat.2023.108537>

Annex

