الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي والبحث العلمي

NATIONAL HIGHER SCHOOL FOR HYDRAULICS
"The Mujahid Abdellah ARBAOUI"

المدرسة الوطنية العليا للري
"المجاهد عبد الله عرباوي"
ⴰⵖⴻⵔⴱⴰⵣ ⴰⵖⴻⵍⵏⴰⵡ ⵉⵎⵉⵏⴻⵣ ⵏ ⵜⵎⴻⵙⵡⵉⵜ

MEMOIRE DE FIN D'ETUDES

Pour l'obtention du diplôme d'Ingénieur d'Etat en Hydraulique

Option : **IRRIGATION ET DRAINAGE**

THEME :

ÉTUDE DU PERIMETRE D'IRRIGATION DE ZOUIA (200HA) A PARTIR DU BARRAGE DE ZOUIA BENI BOUSSAID (W. TLEMCEN)

Présenté par :

MEDDAH Fouad

Devant les membres du jury

Nom et Prénoms	**Grade**	**Qualité**
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AZIEZ Ouahiba	M.C.B	Examinateur
SAIL Nadhira	M.C.B	Examinateur
KERID Rachid	M.C.A	Examinateur
MEDDI Mohamed	Professeur	Promoteur

Session juillet 2024

الجمـهـوريـة الجزائـريـة الـديـمـقـراطـيـة الـشـعـبـيـة
وزارة الـتـعـلـيـم الـعـالـي والـبـحـث الـعـلـمـي

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END-OF-STUDIES THESIS

For the attainment of the State Engineer Diploma in Hydraulics

Option : **IRRIGATION AND DRAINAGE**

THEME :

STUDY OF THE (200 HA) IRRIGATION PERIMETER OF ZOUIA FROM THE ZOUIA BENI BOUSSAID DAM (W. TLEMCEN)

Presented by :

MEDDAH Fouad

Before the jury composed of:

Name and First Name	Quality
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AZIEZ Ouahiba	Examiner
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MEDDI Mohamed	Supervisor

July 2024 Session

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For their constant support, unwavering encouragement, invaluable presence, and unfailing love, I wish that the fruits of this work be the ultimate reward for their efforts. May Allah grant you good health and long life, Mom, and may Allah have mercy on you, Dad.

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For the love and bond that unite us.

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ملخص

تهدف هذه الدراسة إلى تصميم نظام سقي لمحيط زويا بني بوسعيد، الواقع في سهل بني بوسعيد، ولاية تلمسان، الذي يمتد على مساحة تزيد عن 200 هكتار ويضم مجموعة متنوعة من المزارع مثل زراعة الأشجار والخضروات والحبوب. يبدأ تصميم الشبكة بتحليل احتياجات المياه، تليها إنشاء نظام الضخ من سد زويا بني بوسعيد إلى شبكة التوزيع. بعد تقدير احتياجات المحاصيل وإجراء الحسابات الهيدروليكية، تم تحديد أقطار مختلفة لضمان ظروف تشغيل فنية مثالية من حيث الضغط والتدفق. وأخيرًا، تم تصميم شبكة سقي تشمل أنظمة الرش والتنقيط

كلمات مفتاحية: الري، الزراعات، شبكة السقي

Abstract

This study aims to design an irrigation system for the Zouia-Beni Boussaid perimeter, located in the plain of Beni Boussaid, Tlemcen province, covering over 200 hectares and hosting a variety of crops such as tree cultivation, vegetables, and cereals. The network design begins with an analysis of water needs, followed by the establishment of the pumping system from the Zouia-Beni Boussaid dam to the distribution network. After estimating crop requirements and conducting hydraulic calculations, various diameters were determined to ensure optimal technical operating conditions in terms of pressure and flow. Finally, an irrigation network comprising sprinkler and drip systems was designed.

Keywords: irrigation, crops, irrigation network.

Résumé

Cette étude vise à concevoir un système d'irrigation pour le périmètre de Zouia-Béni Boussaid, situé dans la plaine de Béni Boussaid, wilaya de Tlemcen, couvrant plus de 200 hectares et abritant diverses cultures telles que l'arboriculture, le maraîchage et les céréales. La conception du réseau commence par une analyse des besoins en eau, suivie par la mise en place du système de pompage à partir du barrage de Zouia-Béni Boussaid, jusqu'au réseau de distribution. Après avoir estimé les besoins des cultures et effectué les calculs hydrauliques, différents diamètres ont été déterminés pour garantir des conditions techniques optimales en termes de pression et de débit. Enfin, un réseau d'irrigation comprenant des systèmes d'aspersion et de goutte-à-goutte a été conçu.

Mots clés : irrigation, cultures, réseau d'irrigation.

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GENERAL INTRODUCTION

Irrigated area worldwide exceeds 280 million hectares, but its distribution varies greatly across continents. Interestingly, the most irrigated countries are not necessarily those with arid or semi-arid climates. Despite efforts to expand irrigated land in semi-arid countries, a significant portion of land remains under dry cultivation.

In this context, most irrigated areas in Algeria face water scarcity, a situation that varies depending on agricultural bioclimatic and pedological regions. Uncontrolled irrigation exacerbates this situation, leading to severe soil degradation, notably salinity issues, and a shortage of organic amendments. Precipitation also poses challenges by causing floods and, in winter, by replenishing reservoirs and groundwater to supply irrigation stations.

Currently, farmers fear that drought will harm their crops and the country's food security. This situation could lead to significant reductions in crop yields and increased agricultural dependence. In this context, managing irrigation water through a conveyance network becomes essential to optimize water resources and ensure a certain level of food security.

Our project focuses on hydro-agricultural development and irrigation in the Zouia perimeter, located in the Tlemcen province, covering an area of 200 hectares. The primary objective of this project is to establish a new conveyance network supplied by the Zouia dam.

After a general introduction, the study will proceed by examining natural conditions, then move on to calculating irrigation water needs, and conclude with a technical and economic assessment of the total project cost to ensure successful implementation.

Chapter I

Presentation of the Study Area

CHAPTER I: PRESENTATION OF THE STUDY AREA

Introduction

To develop an irrigation project, it is essential to understand the local environment and analyze the climatic conditions to assess water needs and design the hydraulic network. The purpose of this section is to conduct a diagnosis of the study area by examining various natural conditions, including geographical, geological, and climatological factors, to determine the most suitable crops for this specific area.

I.1 Geographical Location of the Site

I.1.1 The Presentation of the Wilaya of Tlemcen

The Wilaya of Tlemcen is located on the northwest coast of the country and has a coastline of 120 km. It is a border wilaya with Morocco, lying between 34°25' and 35°25' North latitude and 0°55' and 2°30' West longitude, covering an area of 9,017.69 square kilometers. It is geographically bounded as follows:

- To the North by the Mediterranean Sea
- To the Northeast by the Aïn Témouchent province
- To the East by the Sidi Bel-Abbès province
- To the West by the Algerian Moroccan border
- To the South by the Naâma province.

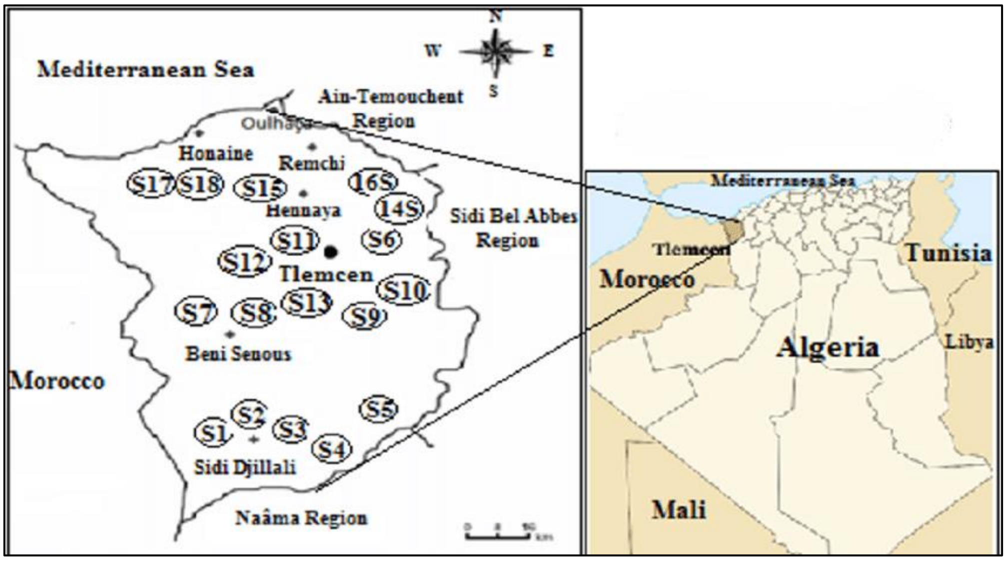

Figure I.1: Geographical location of the wilaya of Tlemcen (Source: https://bit.ly/441Qcew)

34°25' and 35°25' North latitude and 0°55' and 2°30' West longitude

I.1.2: Location of the Study Area

The studied area, located south of the Tlemcen province, encompasses the municipality of beni Boussaid. It is an integral part of the Ghar Roubane mountains, forming a natural region delimited by distinct geographical features. To the north, it is bordered by the Maghnia plain, to the east by the high Tafna, to the west by the Touissit-Boubeker depression, and to the south by the high plateaus.

Figure I.2: Localization of the Beni Boussaid area and its perimeter (Source: Google Earth 03/16/2024)

I.1.3 Topographic Characteristics of the Area

I.1.3.1 Relief

The region is composed of the Ghar Roubane mountains with altitude of 890m, which suggests a mountainous relief. Additionally, the mention of the Maghnia plain to the north, the high Tafna to the east, the Touissit-Boubeker depression to the west, and the high plateaus to the south provide an overview of the diversity of the surrounding relief.

I.1.3.2 Hydrography

Water supply for our study area will be provided from the Zouia Dam, located approximately 88 km south of the city of Tlemcen, along the Zouia River, at a minimum altitude of 850 meters.

I.1.3.3 Geology

These areas are primarily composed of carbonates, including limestone and dolomite, which are heavily fractured and karstified, reflecting their long geological history. Additionally, formations such as clays, sandstones, shales, and other types of limestone and dolomite dating back to the Paleozoic era (about 541 to 252 million years ago) are also present in the region. The area has been shaped by successive large-scale geological processes over time.

I.2 Climatological Characteristics of the Study Area

Meteorological and climatological data play a crucial role in irrigation planning. Climate analysis allows for the examination of key factors such as precipitation and temperature, which influence the hydrological balance and the water requirements of crops. Climate analysis is conducted based on data from the Maghnia weather station, which is near our study area. This data covers the period from 1992 to 2018, spanning over twenty years. They are acquired from the National Meteorological Organization (NMO) and the National Agency for Hydraulic Resources (NAHR).

I.2.1 Choosing the Meteorological Station

For our analysis, we relied on the weather station closest to the study area, namely the Maghnia station. The specific characteristics of this station are outlined in Table I.1.

Table I.1: Maghnia Meteorological Station

Meteorological Station	Longitude	Latitude	Altitude (m)	Observation Period	Observation Duration
Maghnia	1,78°	34,82°	426	1992-2018	26 years

I.2.2 Temperature

Temperature plays a crucial role in determining irrigation water requirements and selecting the appropriate type and system of irrigation. The temperature values of the studied region are listed in the table below.

Table I.2: Monthly Temperatures (°C).

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Max Temp	24.9	21.9	17.8	14.5	12.7	14.3	14.7	18.1	21.2	25.3	28.4	29.3
Min Temp	22.7	19.3	13.1	10.4	9.7	8.8	12.9	14.7	17.6	20.4	24.8	26.7
Avg Temp	23.9	20.6	15.5	12.2	11.3	11.7	13.9	16.6	19.5	22.9	26.5	27.5

(Source: NMO Alger, Series 1992-2018)

With:

- Min Temp: average of all observed minimums for each month in °C.
- Max Temp: average of all observed maximums for each month in °C.
- Avg Temp: Monthly average temperature in °C.

Thus, knowing the temperatures and their ranges is crucial for choosing irrigation methods and crops. The figure below shows the monthly temperatures for the area.

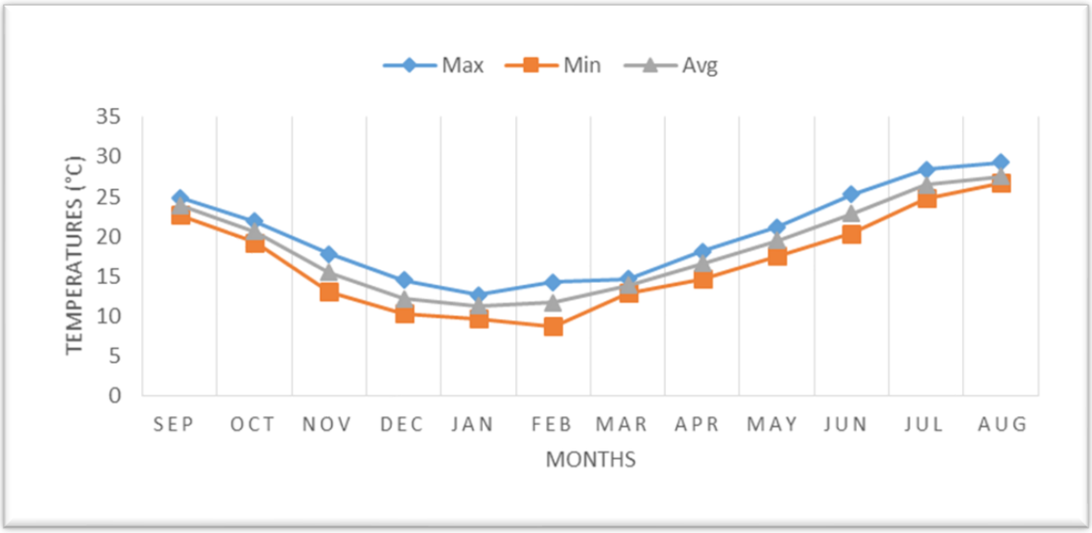

Figure I.3: Monthly Temperature Variations

Based on the chart, it's clear that July and August are the warmest months, averaging 27.5°C, while January and February are the coldest, averaging 11.3°C.

I.2.3 Precipitation

Annual precipitation is crucial in agriculture as it directly influences irrigation needs. With an estimated 344.89 mm, it stands as a determining factor for agricultural production.

Table I.3: Average Monthly Precipitation (mm)

Month	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Year**
P(mm)	21.4	32.78	53.25	44.24	47.24	39.69	33.25	24.60	20.42	8.62	8.71	10.64	344.89

(Source : NAHR Alger, Series 1992-2017)

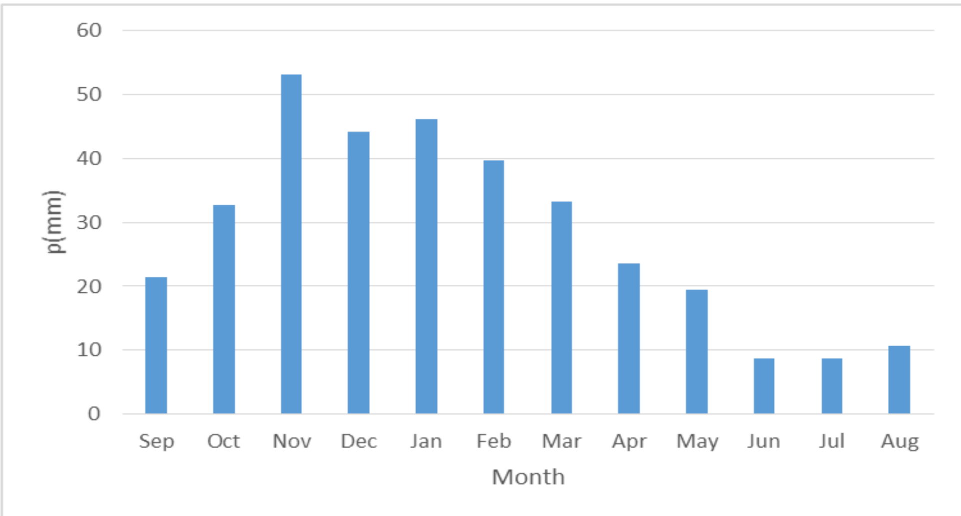

Figure I.4: Histogram of Average Monthly Precipitation (mm)

The annual distribution of precipitation varies across semi-arid climatic zones. Rainfall amounts fluctuate monthly, with the wettest months spanning from October to April, while the summer months are drier. Consequently, it is unlikely that precipitation alone can fully meet the water needs of crops, necessitating irrigation in the region.

I.2.4 Humidity

Air relative humidity is a crucial component of the hydrological cycle, as it plays a role in regulating soil evaporation and vegetation cover.

Table I.4: Air Relative Humidity (%)

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
H (%)	69.6	72.8	74.5	77.0	78.2	77.6	75.3	73.4	67.1	63.1	59.1	61.7

(Source : NMO Alger, Series 1992-2018)

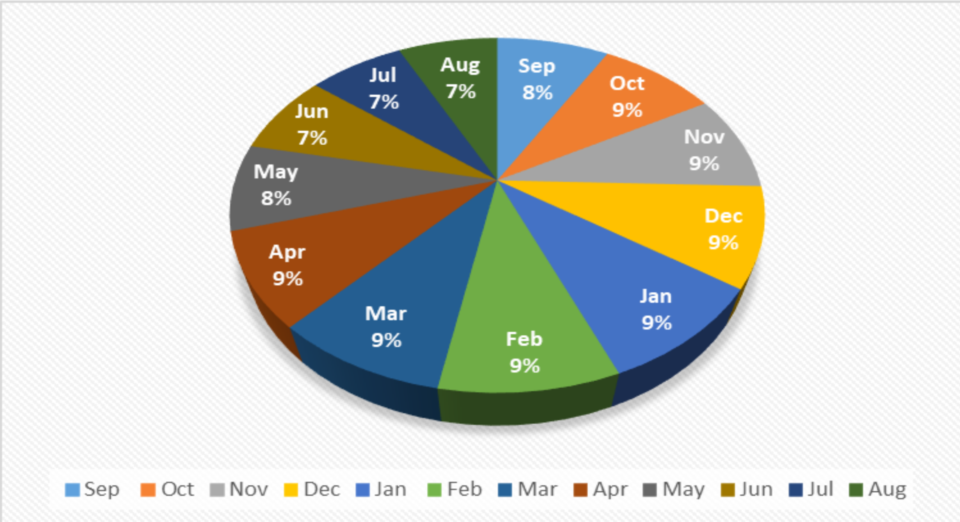

Figure I.5: Relative air humidity (%)

According to the data provided, December stands out as the wettest month, boasting a substantial humidity level of 78.2%, whereas July emerges as the driest, with humidity plummeting to a mere 59.1%.

I.2.5 Wind

Knowing the wind direction and frequency is vital for managing a perimeter to mitigate adverse winds. Additionally, it's a key factor in sprinkler irrigation. This data is presented in the following table

Table I.5: Average and Maximum Wind Speeds (m/s)

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Year
Max	2.94	3.28	2.81	3.21	3.19	3.50	3.86	3.06	3.17	3.22	3.22	3.22	3.11
Avg	2.47	2.47	2.25	2.57	2.39	2.64	2.61	2.67	2.69	2.64	2.72	2.69	2.61

(Source : NMO Alger, Series 1992-2018)

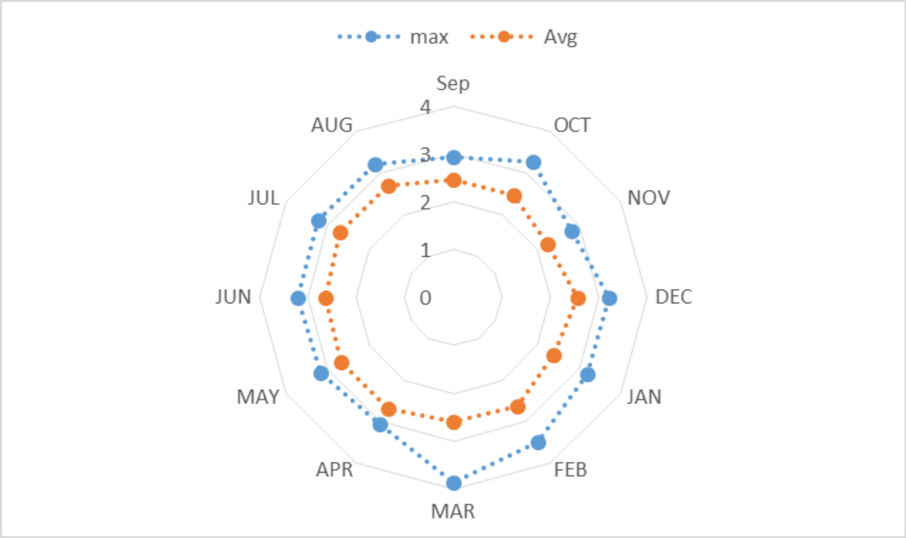

Figure I.6: Monthly Distribution of Average Speed (m/s)

The yearly average wind speed registers at 2.57 m/s, reaching its highest point in July. Notably, the speed fluctuations remain relatively stable throughout the year, offering a beneficial aspect for irrigation and planning purposes.

I.2.6 Evaporation

The transition from liquid to vapor state, known as evaporation, is a gradual process that contributes to the reduction of the surrounding temperature.

Table I.6: Average Monthly Evaporation in mm

Month	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Year**
Evaporation	186.2	118.8	78.8	63.3	58.2	56.4	88.9	104.8	146.6	201.1	276.0	266.4	1599

(Source : NMO Alger, Series 1992-2018)

July and August stand out as the most critical months for evaporation, primarily due to the rising temperatures.

I.2.7 Insolation

This factor plays a vital role in the evaporation and evapotranspiration processes.

Table I.7: Average Insolation

Month	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Hours/day	8.83	7.61	6.58	5.94	6.57	7.08	7.82	8.89	8.83	10.67	10.76	10.25

(Source : NMO Alger, Series 1992-2018)

The period of July and August is associated with the highest insolation values.

I.3 Agro-Meteorological Indices

Understanding climate and its effects on plants requires consideration of two fundamental indices: the Martonne index and Emberger's ombrothermic quotient. These indices are widely utilized for climate evaluation.

I.3.1 Martonne Aridity Index (1926)

This index offers insights into the region's dryness level, crucial for understanding its implications on irrigation practices. It serves as a valuable tool for agricultural production planning and water resource management.

$$IA = \frac{P}{T + 10} \qquad (I.1)$$

With:

- IA: Climatic Index
- P: Average Annual Precipitation (mm)
- T: Average Annual Temperature (°C)

Application:

Given: P = 344.89 mm/year and T = 18.5 °C

Therefore, IA = 12.10

The climate boundaries according to the Martonne climatic index are provided in the table below:

Table I.8: Climate Classification according to Martonne

Values of I	Climate Type	Irrigation
I<5	Desert	Essential
5<I<10	Very Dry	Essential
10<I<20	Dry	Often Essential
20<I<30	Relatively Humid	Occasionally Useful
I>30	Humid	Unnecessary

With 10 < IA < 20, it signifies a dry climate where irrigation is frequently necessary.

I.3.2 Bagnols and Gaussen Index

The ombrothermal diagram serves as a visual representation of climatic data, specifically showcasing precipitation and temperatures over a set period. It aids in identifying dry periods and determining the need for irrigation in each region. This method involves plotting months on the x-axis and average precipitation and temperatures on the same graph, while maintaining the P=2T scale.

Table I.9: Monthly Average Temperature and Rainfall Values

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug
P(mm)	21.4	32.7	53.2	44.2	47.2	39.6	33.2	24.6	20.2	8.62	8.71	10.64
T (°C)	23.9	20.6	15.5	12.2	11.3	11.7	13.9	16.6	19.5	22.9	26.5	27.5
2T	47.8	41.2	31	24.4	22.6	23.4	27.8	33.2	39	45.8	53	55

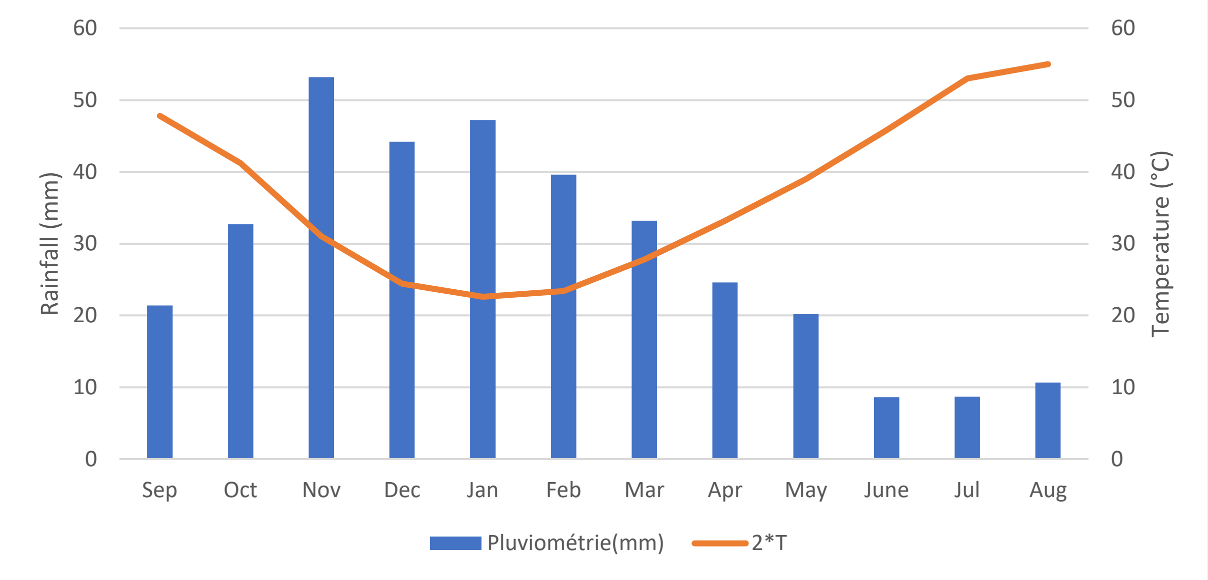

Figure I.7: Gaussen Climagram

Analysis of the Ombrothermic diagram reveals a distinct dry period spanning 7 months from April to October, as indicated by the space between the two curves. This period is marked by minimal precipitation, discernible by measuring the distance between the curves on the graph. Ultimately, our region's climate can be classified as a temperate winter zone.

I.3.3 Emberger Rainfall Quotient (1955)

Emberger's rainfall quotient aids in determining the bioclimatic zone and the rainfall coefficient value through the application of Emberger's bioclimatic formula and diagram. This is elucidated by the following formula:

$$Q = \frac{P}{M^2 - m^2} \times 2000$$

Given:

- Q: Emberger's rainfall quotient
- M: Average temperature of the warmest month in Kelvin
- m: Average temperature of the coldest month in Kelvin
- P: Annual precipitation in mm

Application:

- P = 344.89 mm
- M = 29.3°C + 273.15 = 302.45 K
- m = 8.8°C + 273.15 = 281.95 K

Therefore, Q = 57.57 mm

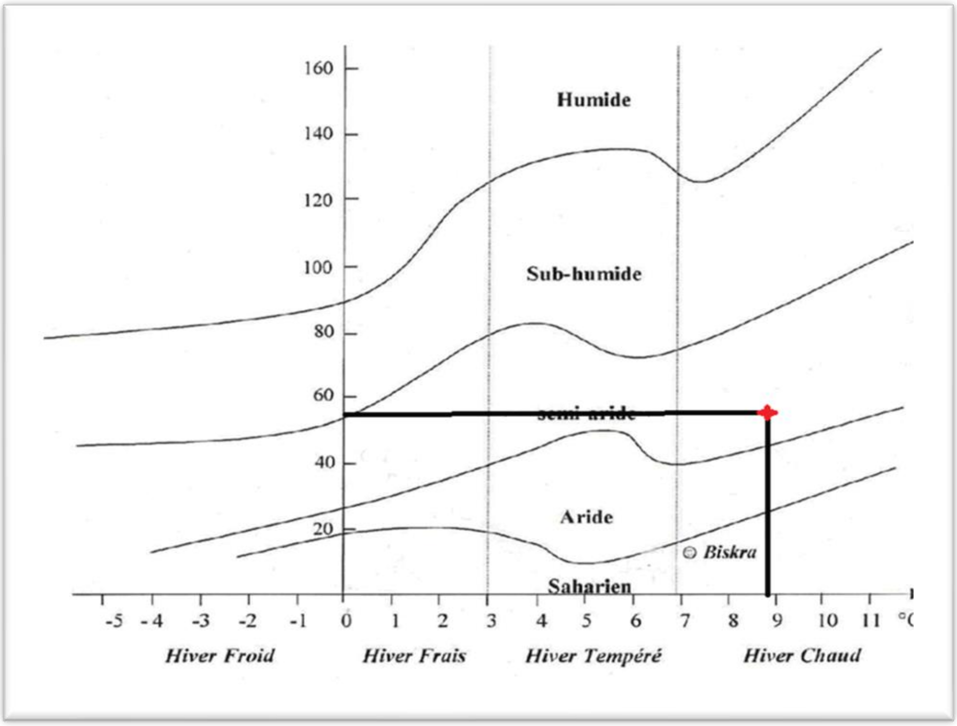

Figure I.8: Emberger Bioclimatic Diagram

Based on Emberger's bioclimatic diagram, it can be inferred that the climate of our region is semi-arid.

I.4 Comparison of Climatic Indices

Methods combining key climatic elements such as precipitation, temperature, and evaporation have categorized the climate of the study region as Semi-Aride, aligning with the bioclimatic zoning map developed by the National Agency for Territorial Planning **(NATP, 2004).**

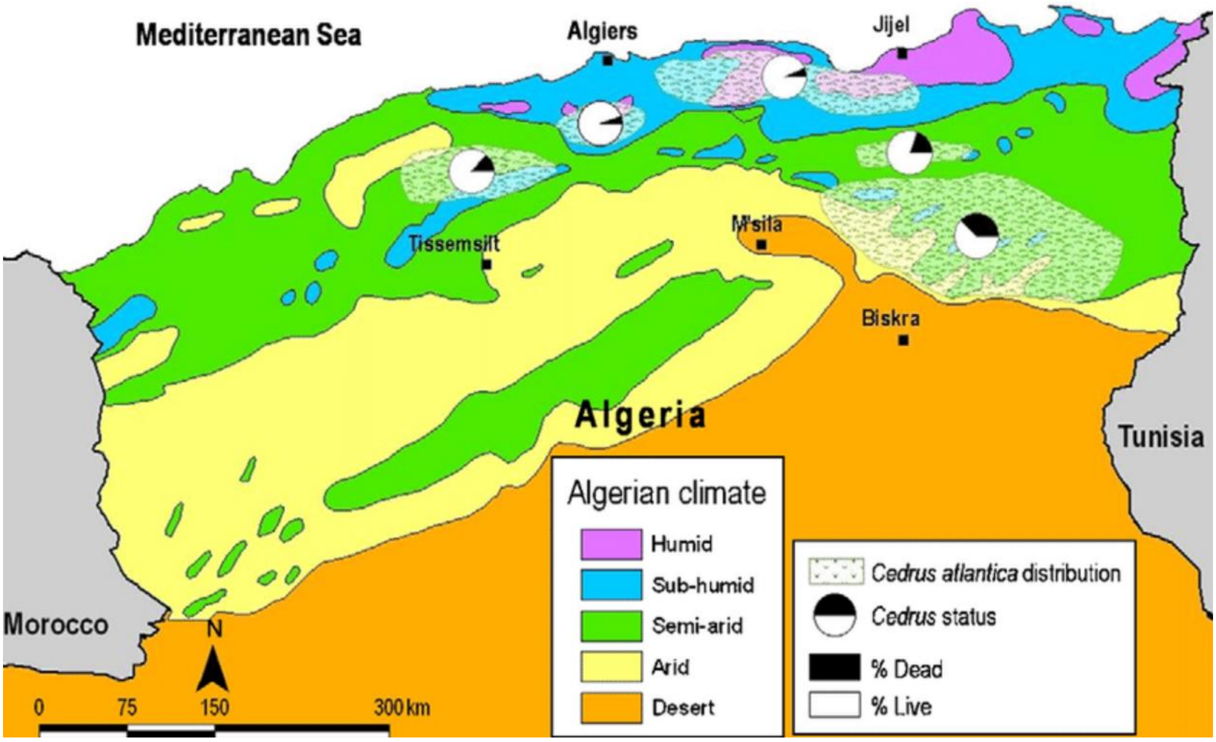

Figure I.8: Simplified map of bioclimatic zones in Algeria **(NATP, 2004)**

Conclusion

In this chapter, our analysis primarily revolves around the examination of pluviometric and climatic data within the study perimeter. From our investigation, the following conclusions have been drawn:

1. The climatic classification of the study area falls under the semi-arid category.
2. The average annual rainfall is approximately 344.89 mm.
3. The dry season spans from April to October.
4. The mean annual temperature registers at 18.5°C.

Given the semi-arid nature of our study zone and its agricultural prominence, irrigation stands as a pivotal tool for optimizing resource utilization, thereby fostering a more productive and sustainable agricultural landscape.

Chapter II

Soil And Water Resources

CHAPTER II: SOIL AND WATER RESOURCES

Introduction

Pedology is the scientific study Which focuses on the formation, classification, description, and mapping of soils. A thorough understanding of soil is vital for sustainable land and natural resource management. It allows for the assessment of soil's physical, chemical, and biological properties, such as texture, structure, pH, organic matter content, and nutrient levels.

II.2 Soil Resources

The study of soil resources aims to understand the nature and properties of soils to determine their potential and limitations for agriculture, forestry, or construction. In a development project, several characteristics must be considered, including:

- Soil depth, which determines the thickness of layers accessible to roots and the available water reserve.
- Soil texture, or particle size distribution and stone content, which influences water retention.
- Soil structure and the porosity of soil horizons, which dictate the permeability of the environment and the ease of irrigation.
- Chemical characteristics (pH, EC, SAR) that affect the agricultural viability of the irrigated area.

II.2.1 Soil Classification

The classification used in this study follows the framework established by the Soil Pedology and Cartography Commission of France (C.P.C.S, 1967). This system primarily focuses on determining the higher units (class, subclass, group, subgroup) as well as the lower units (family and series), providing users with a practical tool for assessing functional characteristics.

Our soil is primarily composed of Yellow Clay, which derives its bright color from the copper and zinc elements it contains. These soils often have good water and nutrient retention capacity, which can be beneficial for plant growth. However, they are also prone to compaction and slow drainage, which can negatively affect crops.

Additionally, the soil is rich in limestone, inherited from parent material predominantly composed of limestone. The limestone content varies with soil texture.

The two predominant factors influencing soil formation in the Zouia area are precipitation and limestone.

- Limestone: The soil in the area is rich in limestone, with several zones characterized by powdery limestone crusts.
- Precipitation: Precipitation plays a crucial role in soil formation by leaching limestone into deeper soil layers and contributing to soil erosion.

II.2.2 Morphological Characteristics

Several profiles were analyzed, the characteristics of profile 1 are detailed and summarized as follows:

1) Profile n°1 :

- **Class** : Calcimagnesian Soils
- **Subclass**: Carbonate Soils
- **Group** : Calcareous Brown Soils
- **Subgroup** : Modal
- **Family**: Calcareous Colluvium with a balanced texture
- **Series**: Deep
- **Type** : loam.

2) Depth :

The horizons are categorized based on their depth as follows:

- **0–15 cm:** Fresh, yellow soil with a balanced silty clay texture, massive to medium polyhedral structure, compact, low porosity, presence of roots and fine rootlets, detectable organic matter, reacts positively to HCl, clear transition.

- **15–37 cm:** Fresh to dry, light yellow, balanced texture, coarse polyhedral structure, compact, hard, low porosity, few roots and fine rootlets, detectable organic matter, low biological activity, presence of whitish limestone spots, a thin layer of gravel and limestone of various diameters, reacts positively to HCl, clear transition.

- **37–120 cm:** Fresh, light yellow, medium polyhedral structure, fairly developed, prismatic to massive structure, low porosity, few roots and fine rootlets, presence of whitish spots with some gravel, effervesces strongly with HCl.

II.2.3 Physico-Chemical Soil Analysis

Conducting a physico-chemical analysis in the laboratory has allowed us to gain a better understanding of the characteristics of our soil.

Tableau II.1: Laboratory Analysis of the Profiles

Depth (cm)	**0-15**	**15-37**	**37-120**
Clay (Argile)%	20	23	23
Fine Silt (Limon fin) %	28	24	24
Coarse Silt (Limon grossier) %	12	12	11
Fine Sand (Sable fin) %	16	16	16
Coarse Sand (Sable grossier) %	20	22	22
Real Density	2,61	2,47	2.48
Ph	7,24	7,21	7,22

C.E mmhos/cm		4	4.1	4.3
pF 4.2		14.29	13.5	13.62
pF 2.5		25.85	24.95	25.16
C ‰		19.1	14.6	15.0
N ‰		1.93	1.61	1.60
C/N		9.89	9.06	9.37
Total CaCO3		47.10	47.03	47.58
Activ CaCO3		15.25	15.25	15.5
P2 O5 total ‰		2.64	2.35	2.35
Absorptive Complex (meq/100 g)	**Ca++**	25.80	25.65	24.98
	Mg++	3.83	4.39	4.06
	Na^+	2.55	4.25	3.33
	K+	1.18	0.75	0.85
	T	14.47	17.50	13.74

(Source : ENHYD)

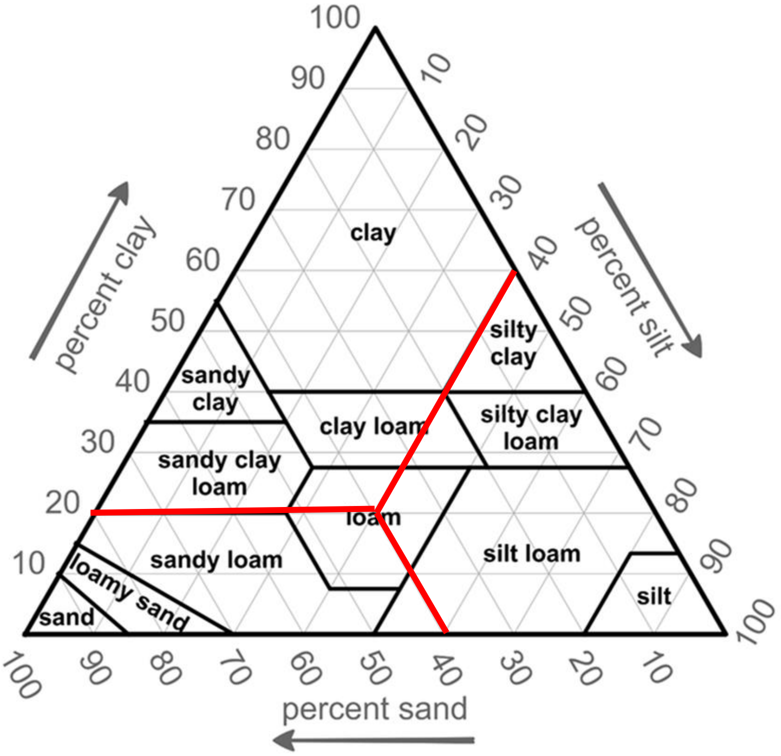

Figure II.1: Textural Analysis of the Studied Soils **(USDA texture triangle)**

Interpretation of the results

According to the USDA Texture Triangle illustrated above, our soil has a balanced Loamy texture.

The hydrodynamic properties are presented in the following table:

Table II.2: Hydrodynamic Properties of the Soil

Texture	**Loamy**
Field capacity moisture (Hcc)	23%
Wilting point moisture (HPF)	12%
Permeability	7 mm/h
Soil Density	1.3

II.3 Water Resources

The initially planned water resource, upon which the hydro-agricultural development study of the Zouia perimeter in the Tlemcen province was based, consists of water allocation from the Zouia dam. The analysis of water resources holds a crucial position, as the expansion of irrigation is closely linked to the availability of water resources.

II.3.1 The Surface Water Resources

II.3.1.1 presentation of the Zouia Dam

The zouia wadi, runs in a South-North direction. The zouia Dam, with a capacity of 2.3 hm3, is constructed on the Zouia Wedi, 3 kilometers south of the Beni Boussaid town. Its primary purpose is to supply irrigation water to the perimeters in the proximity.

II.3.1.1 Characteristics of the Zouia Dam

The Zouia Dam is a small dam capable of storing up to 2.4 million cubic meters of water. Its normal water level is maintained at an altitude of 840-850 m.

II.3.2.2 Irrigation water qualities

It is necessary to study the quality of irrigation water before any agricultural development project. To do this, it is essential to check certain key factors, which include:

- PH.
- Salinity risk.
- Sodium (Sodium Absorption Ratio or SAR).
- Carbonates and bicarbonates Ca, Mg.
- Toxic anions.

Table II.3: Irrigation water quality parameters

Characteristics	Symbol	Measured values	Measured values
PH	PH	7.9	-
Salinity			
Total dissolved solids	TDS	1568	-
Cations et Anions		**Measured values (mg/l)**	**Measured values (meq/l)**
Chloride	Cl-	311	8,7702
Sulfate	$SO4^{2-}$	550	11,44
Bicarbonate	HCO3	122	2,0008
Sodium	Na^{+}	95	4,1325
Magnesium	Mg++	43	3,5389
Calcium	Ca++	75	3,7425
Potassium	K+	14	0,3584
Nitrate	$NO3^{-}$	11	0,1771

(Source: NIDO)

II.3.2.4 Classification of water for irrigation

II.3.2.4.1 Electrical conductivity

Electrical conductivity is a characteristic related to the mobility of ions and thus allows for the assessment of water salinity. It is measured at a temperature of 25°C and expressed in mmoh per centimeter (dS/cm). Water salinity can be classified into four levels of danger based on its electrical conductivity:

Table II.4: Classification of water based on Electrical conductivity

Class	Electrical Conductivity EC (mmhos/cm)	Water quality	Suitability for crops
C1	EC≤ 0,25	Water of Low Salinity Risk	Suitable for all crops
C2	0,25 < EC ≤ 0,75	Water of Average Salinity risk	Suitable for moderately tolerant plants
C3	0,75 < EC ≤ 2,25	Water of high Salinity Risk	Suitable only for well-drained soils and tolerant plants.
C4	EC> 2,25	Water of very high Salinity risk	The water is difficult to use on well-drained soils.

The water from the Zouia Dam, intended for irrigation has an average electrical conductivity of **EC = 1.22 mmhos/cm**, which puts it in the C3 class, rendering it at high risk for use for irrigation purposes.

II.3.2.4.2 The Sodium Adsorption Ratio (SAR)

SAR is a measure used in assessing the suitability of water for irrigation. It helps determine the potential for soil degradation due to sodium accumulation when using irrigation water containing high sodium levels.

A high SAR can cause soil particle dispersion especially in clays, a phenomenon also known as deflocculation. which may reduce soil permeability and affect crop growth.

$$SAR = \frac{Na^+}{\sqrt{\frac{Mg^{2+}+Ca^{2+}}{2}}} \qquad (II.1)$$

With:

- Na^+: sodium in meq/l (1 meq/l = 0.0435 mg/l)
- Ca^{2+}: calcium in meq/l (1 meq/l = 0.0499 mg/l)
- Mg^{2+}: magnesium in meq/l (1 meq/l = 0.0823 mg/l)

$$SAR = \frac{4.1325}{\sqrt{\frac{3.54 + 3.74}{2}}} = 2.17$$

Table II.5: Classification of water based on SAR (for low EC)

Class	S.A. R	Alkalinization Risk
S_1	SAR ≤ 10	Low Risk
S_2	10 <SAR≤ 18	Medium Risk
S_3	18 <SAR≤ 26	High Risk
S_4	SAR > 26	Very High Risk

According to the table above, **SAR = 2.17** ≤ 10, Class S1, indicating a low risk of alkalinity.

I.3.2.4.3 Irrigation Water Classification

We use the following diagram to classify the irrigation waters from the Zouia Dam based on the results of the electrical conductivity calculation (EC = 1.22 mmhos/cm) and the sodium absorption ratio of the irrigation water (SAR = 2.17).

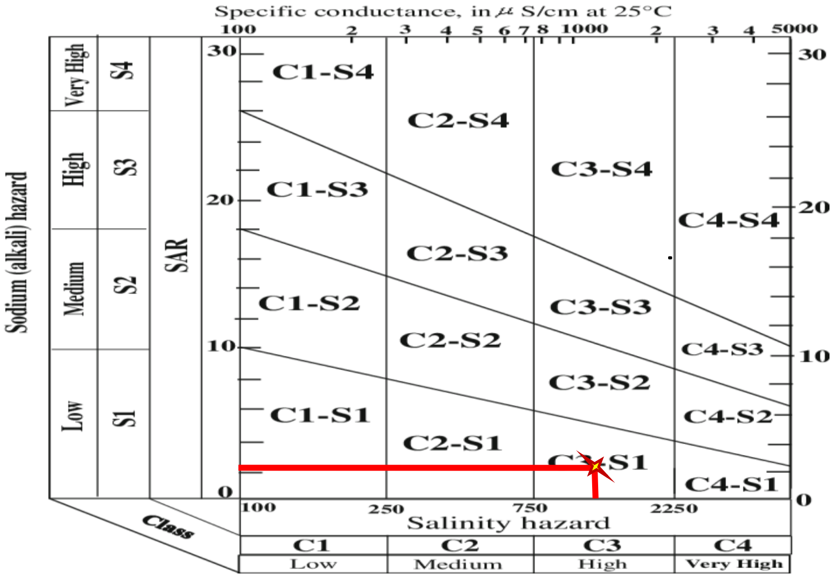

Figure II.2: Irrigation Water Classification Diagram **(USSL, 1954)**

Interpretation

The water from the Zouia Dam falls in the (S1-C3) category which presents a low alkaline risk (S1), indicating it can be used with minimal risk of harmful sodium accumulation for practically all soil types. However, it poses a high risk of salinity, requiring attention. High salt concentration may render this water unsuitable for certain soil and crop types, potentially necessitating special measures such as adequate drainage and the selection of tolerant plants. It's crucial to consider these characteristics when utilizing water from the Zouia Dam for irrigation, especially concerning the judicious choice of crops and the implementation of water management practices aimed at minimizing the negative effects of salinity.

II.4. Rainfall Frequency Analysis and Selection of Study Year

For our precipitation analysis, we relied on the rainfall data from the Maghnia station. This station offers a comprehensive dataset that accurately represents the study area.

Table II.6: Characteristics of the Pluviometric Station.

Meteorological Station	Longitude	Latitude	Altitude (m)	Observation Period	Observation Duration
Maghnia	1,78°	34,82°	426	1985-2015	30 Years

Table II.7: Series of Monthly Average Rainfall (mm)

Years	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
1985-1986	0,3	0	49,8	47,3	37,3	87,2	70,5	38	2,1	1,3	0	1,6	335,4
1986-1987	34,2	56,4	83,7	34,2	28,7	118,3	4,9	2	12,2	0	5,2	0	379,8
1987-1988	8,6	39,8	19,6	29,3	21,6	13,3	6,1	18,1	9,8	14,8	0	0	181
1988-1989	12,4	1,5	19,9	0	31,6	18,4	93,5	25,2	12,2	0,4	0	0	215,1
1989-1990	12,8	2,9	11,9	62,2	135,5	0	37,7	36,3	17,5	0,6	0	0	317,4
1990-1991	18,5	10,5	58,7	30,3	61	49,2	114,3	16,3	7,1	0	0	0	365,9
1991-1992	2,8	21,2	67	18,02	14,8	17	80,6	9,1	55,3	27,1	0	0	312,92
1992-1993	0,2	12,1	24,4	18,2	0	122,8	31,3	28,5	69,6	3,4	0	0	310,5
1993-1994	7	33,5	94,6	3,9	46,5	43,5	4,7	13,1	15,9	0	2	0	264,7
1994-1995	23,9	10,9	19,1	17,1	18,7	54,2	90,8	20	0,1	3,7	0	0,1	258,6
1995-1996	1,8	30,5	8,8	47	57,6	107,7	24,6	12,1	22,1	0	0	1,6	313,8
1996-1997	32,9	5,1	10	31,9	125,1	0	0,2	42,6	7,2	2,9	1,4	12,7	272
1997-1998	43,8	17,6	47,8	34,3	27,1	28,5	20	22,7	55,8	0	0,6	3,5	301,7
1998-1999	10,6	3,4	40,9	2,9	65,1	87,7	115,1	0	0,3	0	0	0	326
1999-2000	19,1	12,3	85,5	59	0,4	0	4	10,6	17,7	0	0	0	208,6
2000-2001	8,8	335,9	71,2	18,9	36,9	56	5,2	1,7	10,7	0	0	0	545,3
2001-2002	7,5	11,4	111,7	32,8	3,2	5,7	16,2	52,4	35,7	0	0	53,5	330,1
2002-2003	0	21,7	81,8	9,5	94,8	100,5	23,3	21,1	12,4	0,1	0,5	0	365,7
2003-2004	3,3	24,1	56,2	99,3	39,6	23,2	46,1	23,1	47,6	8,5	0	9,5	380,5
2004-2005	0	42,1	51,6	76,4	29,9	69,3	40,4	14,5	0	0	0	4	328,2
2005-2006	5,6	10,4	28,7	29,4	64,2	50,2	0	32,2	39,5	5	0,5	0	265,7
2006-2007	11,7	7,6	8,2	58,5	12,9	61,7	43,5	83,1	3,3	0	0	1,3	291,8
2007-2008	13,7	62,5	66,2	0	8	32,9	26,7	7	23,3	5	0,7	0	246
2008-2009	18,09	71	83,1	122,3	84,6	34,6	29,9	38	5,5	0	0	6	493,09
2009-2010	43	1	14,5	57,2	91,9	38,5	56,8	34,8	7	15,3	0	7,3	367,3
2010-2011	4,7	50,7	38,8	17	39,6	27,7	37,7	48,9	34,7	7,9	0	0,6	308,3
2011-2012	1,5	52,3	88,3	38	30,5	32,7	19,3	37,4	4,5	0	4,3	7,1	315,9
2012-2013	20,3	61,1	173,5	17,3	122,5	24,5	37,3	87,7	41	0	0	2,2	587,4
2013-2014	32,8	0	75	126,6	82,3	29,3	49,9	6,5	20,5	15	0	0	437,9
2014-2015	27	10,2	67,6	117,8	123,5	45,4	14,3	5,4	10,8	0	0	2,5	424,5
2015-2016	3,5	34,8	16,8	0	24,4	54,2	34,1	22,3	27,6	1	0	0	218,7
2016-2017	21,15	74,83	53,73	52,73	26,37	5,27	0	0	26,37	10,55	79,1	68,55	418,65
2017-2018	147,88	22,09	22,19	15,82	6,27	0	0	22,19	0	36,91	36,91	42,19	352,45
2018-2019	64,28	44,46	142,38	110,74	36,91	15,82	0	10,55	31,64	105,77	63,28	5,27	631,1
2019-2020	62,28	16,82	15,82	58,01	10,55	0	5,27	26,37	15,82	47,66	68,55	58,01	385,16
2020-2021	35,75	0	15,82	94,92	47,46	0	5,27	0	5,27	0	10,55	79,9	293,83
Average	22,25	33,87	55,12	45,88	49	41,17	34,48	25,51	21,17	8,93	9,02	11,03	343,08

(Source: NAHR Alger, Series 1985-2015 and NASA POWER 2016-2021)

III.2.1 Homogeneity of the Rainfall Series

To verify the homogeneity of the rainfall series, the Wilcoxon Test is employed. The method used to conduct this verification is outlined as follows:

1. Divide the complete series into two sub-series, denoted as X and Y, where N1 and N2 represent the respective sizes of these two sub-series, typically with N1 > N2.

2. Next, form the X union Y series by ranking the original rainfall series in descending order. At this stage, each value of the ranked rainfall series is assigned a rank, and it is specified to which sub-series it belongs.

Wilcoxon demonstrated that the series is homogeneous with a probability of 95% **(Touaibia, 2004)** if the following relationship is satisfied.

With:

$$W\text{min} < Wx < W\text{max} \qquad (III.4)$$

Where: Wx : Sum of ranks of sub-series

$$W\text{min} = \left(\frac{(N1 + N2 + 1) * N1 - 1}{2} - 1.96 * \left(\frac{N1 * N2 * (N1 + N2 + 1)}{12}\right)^{\frac{1}{2}}\right) \qquad (III.5)$$

$$\text{Wmax} = (N1 + N2 + 1) * N1 - \text{Wmin} \qquad (III.6)$$

The results of the Wilcoxon test are detailed as follows:

Table II.8: Homogeneity Test of the Rainfall Series

Rank	Original Series	Series Y (mm)	Series X (mm)	RANK (mm)	Y union X
1	335,4	335,4	545,3	631,1	X
2	379,8	379,8	330,1	587,4	X
3	181	181	365,7	545,3	X
4	215,1	215,1	380,5	493,09	X
5	317,4	317,4	328,2	437,9	X
6	365,9	365,9	265,7	424,5	X
7	312,92	312,92	291,8	418,65	X
8	310,5	310,5	246	385,16	X
9	264,7	264,7	493,09	380,5	X
10	258,6	258,6	367,3	379,8	Y
11	313,8	313,8	308,3	367,3	X
12	272	272	315,9	365,9	Y
13	301,7	301,7	587,4	365,7	X
14	326	326	437,9	352,45	X
15	208,6	208,6	424,5	335,4	Y
16	545,3		218,7	330,1	X
17	330,1		418,65	328,2	X
18	365,7		352,45	326	X
19	380,5		631,1	317,4	Y
20	328,2		385,16	315,9	X
21	265,7		293,83	313,8	Y

22	291,8			312,92	Y
23	246			310,5	Y
24	493,09			308,3	X
25	367,3			301,7	Y
26	308,3			293,83	X
27	315,9			291,8	X
28	587,4			272	Y
29	437,9			265,7	Y
30	424,5			264,7	X
31	218,7			258,6	Y
32	418,65			246	Y
33	352,45			218,7	X
34	631,1			215,1	Y
35	385,16			208,6	Y
36	293,83			181	Y

According to the table:

- N = 20
- M = 17
- Wmax = 444.31
- Wmin =315.69
- Wx = 336

Therefore:

315.69 < Wx < 444.31

Wilcoxon's condition is met, thus confirming the homogeneity of the annual average precipitation series from our station.

III.2.2 Study of the sample and choice of type of law

Precipitation data can be fitted to numerous statistical distributions, and for our project, we will choose the one that provides the best possible fit. The most used distributions for annual rainfall are:

- Gaussian distribution, also known as the normal distribution.
- Galton distribution, also referred to as the log-normal distribution.

III.2.2.1 Adjustment of Annual Rainfall to Gauss's Law

The calculation process involves the following steps:

1. Sorting the sample values in ascending order.
2. Assigning a rank number to each sorted value.
3. Calculating the experimental frequency (using, for example, the Hazen formula).

Gaussian reduced variable

$$U = \frac{X - \bar{X}}{\delta} \qquad (III.7)$$

Calculation of Empirical Characteristics of the Distribution (X), Cv, Cs)

$$\text{The coefficient of variation } \left(Cv = \frac{\delta}{\bar{X}}\right) \qquad (III.8)$$

The equation of the Henry line on Gaussian probability paper: $XP\% = \delta * Up\%$

Where :

- XP%: Precipitation at probability P%
- UP% : Reduced Gaussian variable.
- $\bar{X}$: Arithmetic mean.
- δ : Standard deviation.

For calculations, we used the HYFRAN software. The results obtained are presented below:

Table II.9: Adjustment to Gauss's law

Gauss's law				
T	***Q***	***XT***	***Standard deviation***	**Confidence interval (95%)**
100.0	0.9900	480	21.0	439 - 521
50.0	0.9800	460	19.2	422 - 498
20.0	0.9500	430	16.7	397 - 463
10.0	0.9000	403	14.7	374 - 432
5.0	0.8000	371	12.6	346 - 396
3.0	0.6667	341	11.3	318 - 363
2.0	0.5000	309	10.8	288 - 330
1.25	0.2000	247	12.6	222 - 272

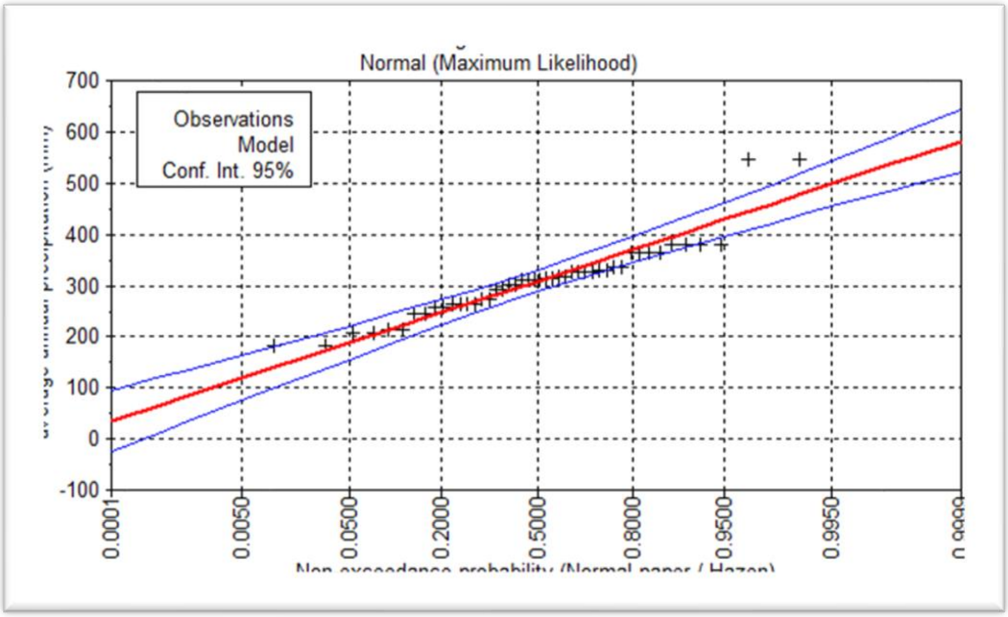

Figure III.1: Adjustment of annual rainfall to Gauss's law

Table II.10: Adjustment to log normal law

T	q	XT	Standard	Confidence interval
10000.0	0.9999	931	123	690 - 1170
2000.0	0.9995	827	98.5	633 - 1020
1000.0	0.9990	782	88.4	608 - 955
200.0	0.9950	677	66.1	548 - 807
100.0	0.9900	632	57.1	520 - 744
50.0	0.9800	585	48.5	490 - 680
20.0	0.9500	522	37.6	449 - 596
10.0	0.9000	472	29.8	414 - 530
5.0	0.8000	417	22.7	373 - 462
3.0	0.6667	372	18.1	337 - 408
2.0	0.5000	330	15.3	300 - 360
1.4286	0.3000	285	14.2	257 - 313

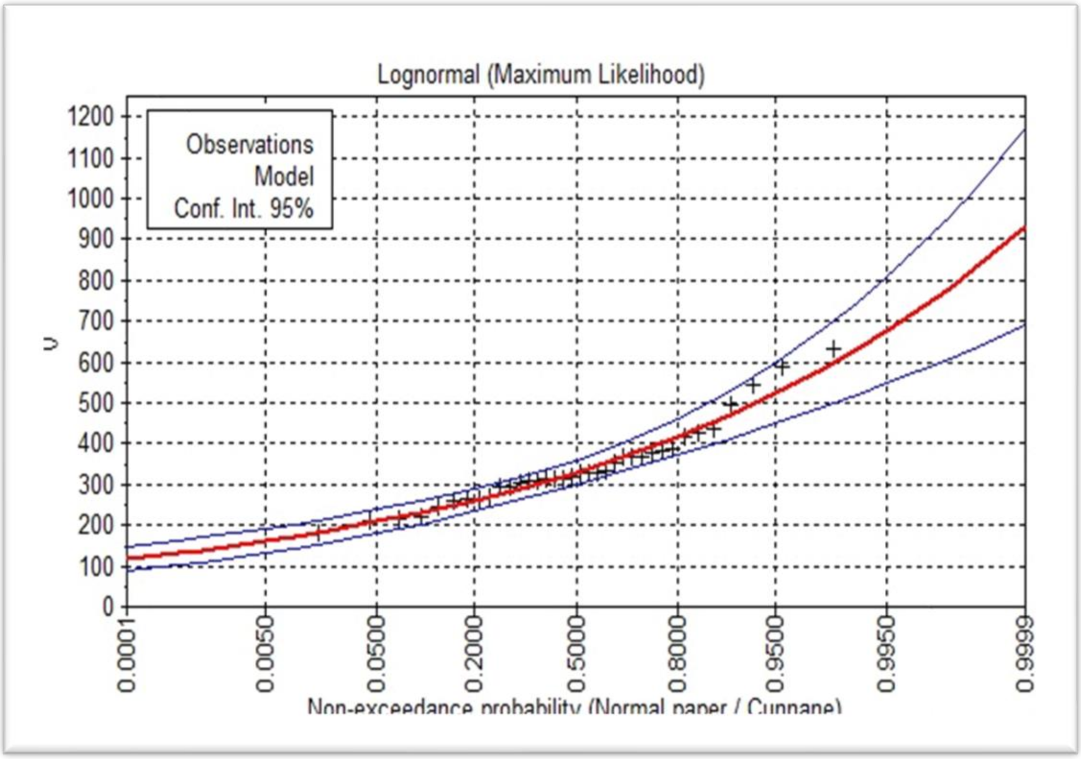

Figure II.2: Adjustment of annual rainfall to the Log-normal distribution

Test of validity of the adjustment to the chosen law

The chosen distribution to fit the statistical distribution of the sample represents only an approximation of the studied sample. The error incurred by adopting a specific distribution is a goodness-of-fit error. Therefore, it is necessary to compare the goodness of fit of different distributions to select the best match.

The most used test for this comparison is the chi-squared test (χ^2). Suppose we have a sample of N values, sorted either in ascending or descending order, for which a distribution function F(X) has been determined: We divide this sample into a certain number of classes K, where each class contains ni experimental values.

The number Vi represents the theoretical number of values in a sample of N values assigned to class i by the distribution function. This can be expressed by the following relationship:

$$Pi = N \int_{x}^{x+1} F(x)dx = N[f(x_i) - f(x_{i+1})] \qquad (III.9)$$

F(x) : The probability corresponding to the theoretical distribution. The random variable

$$X^2 = \sum_{i=1}^{k} \frac{(ni - ni')^2}{ni'} \qquad (III.10)$$

We calculate X^2, and then calculate the degrees of freedom:

$$\gamma = k - 1 - m \qquad (III.11)$$

We determine the theoretical χ^2 from Pearson's table.

With:

m: Number of parameters of the distribution law on which the distribution depends (m=2).

The distribution is adequate for a significance level $\alpha = 0.05$ if and only if:

χ^2 calculated < χ^2 theoretical.

- For the calculations, we used the HYFRAN software.

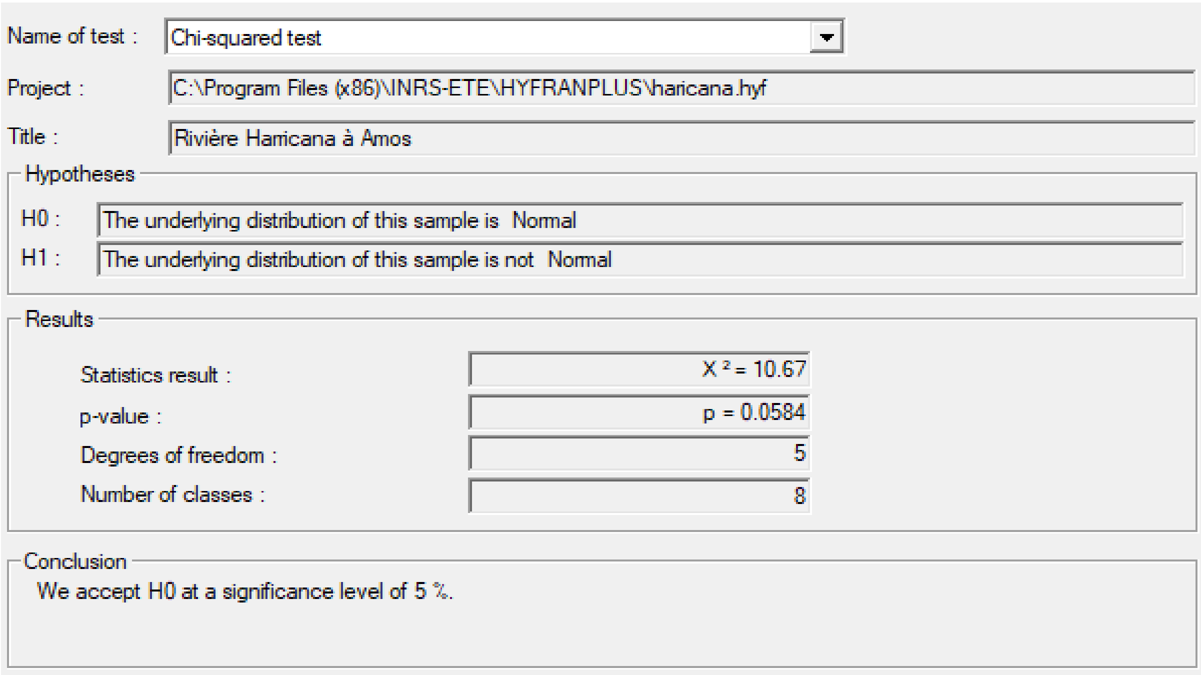

Figure II.3: Chi-squared test obtained using the HYFRAN software (guess's law)

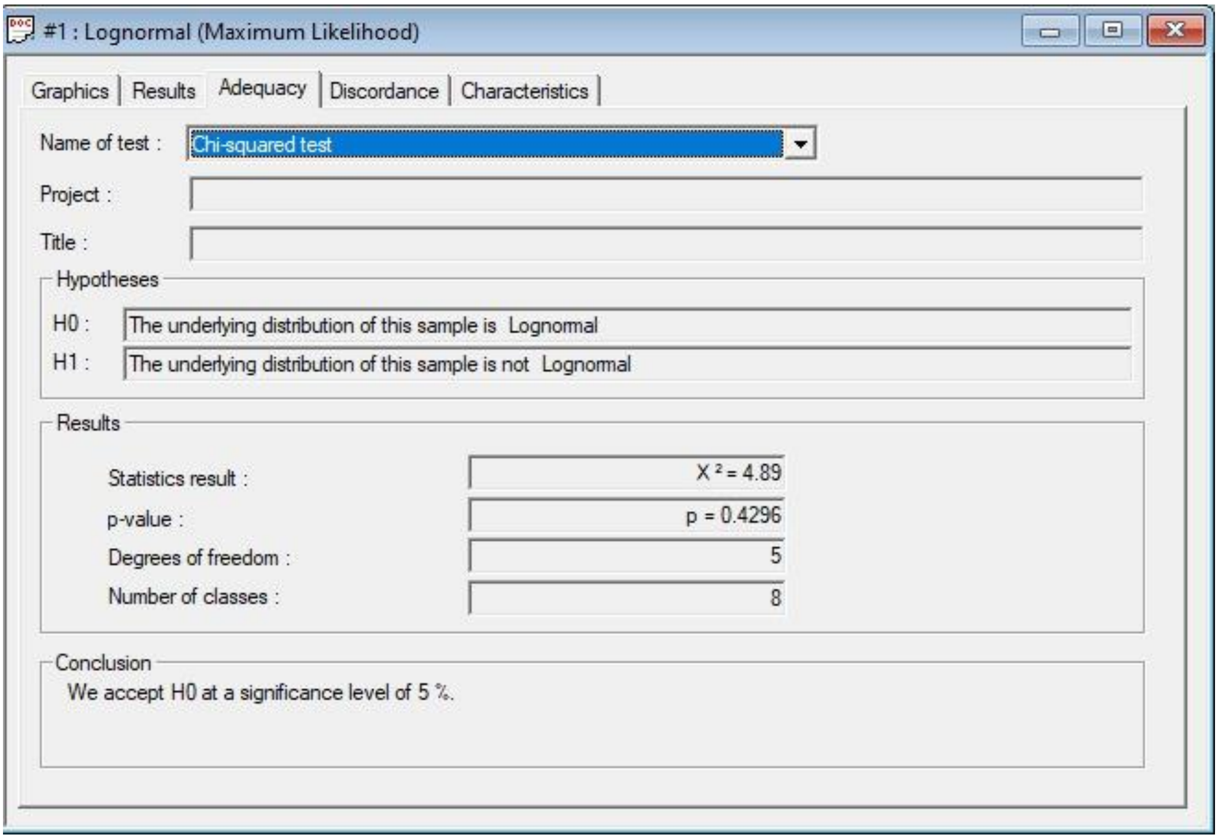

Figure II.4: Chi-squared test obtained using the HYFRAN software (log normal

Therefore, for our series, the Log-normal distribution proves to be the most appropriate.

Table II.11 Table of Chi squared

AŸ	0,9	0,5	0,3	0,2	0,1	0,05	0,02	0,01	0,001
1	0,016	0,455	1,074	1,642	2,705	3,841	5,412	6,635	10,827
7	0,211	1,386	2,408	3,219	4,605	5,991	7,824	9,210	13,815
3	0,584	2,366	3,665	4,642	6,251	7,815	9,837	11,345	16,266
4	1,064	3,357	4,878	5,989	7,779	9,488	11,668	13,277	18,467
5	1,610	4,351	6,064	7,289	9,236	11,070	13,388	15,086	20,515
6	2,204	5,348	7,231	8,558	10,645	12,592	15,033	16,812	22,457
7	2,833	6,346	8,383	9,83	12,017	14,067	16,622	18,475	24,322
8	3,490	7,344	9,524	11,030	13,362	15,507	18,168	20,090	26,125
9	4,168	8,343	10,656	12,242	14,684	16,919	19,679	21,666	27,877

According to the HYFRAN software, the following results were obtained:

- Calculated chi-square (χ^2) = 4.89

- Degrees of freedom (ϒ) = 5
- Referring to Pearson's chi-square table, we have:
- Theoretical chi-square (X^2) = 11.070
- Calculated chi-square (X^2) = 4.89 < Theoretical chi-square (X^2) = 11.07.

After examining the obtained fits, it appears that there is a good fit with the normal distribution for the annual rainfall series at the Maghnia station.

III.3 Determining the Calculation Year

Given that the normal distribution is the most appropriate for fitting the rainfall distribution, it is chosen to estimate the representative average annual rainfall for the region, with a frequency of 80%.

$$P_{\text{avg } 80\%} = P_{\text{monthly−avg}} \; * \frac{P_{\text{theo}}\,(80\%)}{P_{\text{theo}}\,(50\%)} \qquad (III.12)$$

- $P_{\text{theo}}\ 50\% = 417$ mm
- $P_{\text{theo}}\ 80\% = 330$ mm

$$P_{\text{avg } 80\%} = \frac{330}{417} \times P_{\text{monthly-avg}}$$

Table II.12 Calculation of Monthly Rainfalls for (frequency = 80%) (mm)

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Pavg	22.25	33.87	55.12	45.88	49	41.17	34.48	25.51	21.17	8.93	9.02	11.03
P80%	17.8	27.1	44.1	36.71	39.20	32.94	27.59	20.41	16.94	7.15	7.22	8.83

III.4 Calculation of Effective Rainfall

Effective rainfall is the amount of rain that is absorbed by the soil and is available for plants. It is therefore the difference between the total amount of rain that falls on an area and the amount of rain that is lost through runoff or evaporation. In our case, we referred to the percentage method, detailed as follows:

$$Peff = A \times P80\% \qquad (III.13)$$

Conclusion

In this section on water resource analysis, the waters from the Zouia dam, which supply our region, are classified as C3S1. These waters do not pose a risk of soil alkalinization and are suitable for coarse-textured or organic. Ensuring proper soil drainage is essential to prevent salinization issues.

Chapter III

Calculation of crop Water Needs

CHAPTER III: CALCULATION OF CROP WATER NEEDS

Introduction

The calculation of crop water needs is a vital process in determining the amount of water needed for crops to ensure optimal growth and yield, while also preventing water wastage and soil quality degradation. This typically involves utilizing mathematical models and meteorological data to ascertain the necessary water volume for a specific crop at a particular time. By comprehending crop water requirements, farmers and water managers can strategize and implement efficient irrigation techniques to secure optimal crop yields, all the while conserving water resources and reducing costs.

III.1 Water Needs of the Perimeter

Crop water requirements refer to the quantity of water needed to maintain optimal soil moisture levels for achieving maximum plant yield. Assessing the water needs of the perimeter involves identifying the specific requirements of each crop listed in the agronomic calendar.

III.1.1 Calculation of Water Needs

Determining water needs is a critical step for effective and sustainable crop irrigation. This calculation considers various factors, including cultivated area, crop type, precipitation, soil quality, and irrigation techniques. Tools and models are utilized to estimate the water quantity required for each crop. Calculating the volumes of water to be applied through irrigation involves conducting a water balance for each vegetative stage during specific periods.

$$Bi = ETMi - (Peff + RFUi - 1) \qquad (III.1)$$

With :

- ETMi: is the value of maximum evapotranspiration in mm, it is equal to:

$$ETM = ET0 \times K_c \qquad (III.2)$$

- Kc: The crop coefficient of the considered crop.
- Peff : Effective rainfall.
- RFU : Readily available water.

III.1.2. Calculation of Reference Evapotranspiration (ET0)

Reference evapotranspiration (ET0) is the quantity of water evaporated and transpired by a reference crop under standardized climatic conditions, considering temperature, air humidity, wind speed, and solar radiation. ET0 data serves to plan and fine-tune irrigation to meet crop water needs, aiming to maximize yield while minimizing water loss and irrigation expenses.

Various methods exist for calculating reference evapotranspiration, classified into two:

III.1.2.1 Direct Methods

Direct methods include the evapotranspiration or lysimeter approach. This method entails the construction of a lysimeter tank filled with soil and planted with an intercrop. Equipped with a drainage system, it collects water that drains through the soil. While highly accurate, this method is costly and demands regular monitoring.

III.1.2.2 Indirect Methods

These approaches enable the calculation of ET0 using formulas based on climatic parameters. Several calculation formulas are available, including:

- **Turc Formula (1960):** This method estimates ET0 using temperature and air humidity data.
- **Thornthwaite Formula (1955):** ET0 is estimated based on temperature data alone, if the evaporation rate depends primarily on available heat.
- **Blaney-Criddle Formula (1959):** This method estimates ET0 using temperature and relative humidity data, often used in areas with limited meteorological data.
- **Penman Formula or Energy Balance Formula (1948):** ET0 is calculated using temperature, air humidity, wind speed, and solar radiation data, considered the standard method for ET0 calculation.
- **Doorenbos and Pruitt Method (1977)** within the FAO framework: This method estimates ET0 using temperature, air humidity, wind speed, and solar radiation data, commonly applied in irrigated crop contexts.

In our context, we're employing the Modified Penman-Monteith formula.

Modified Penman-Monteith Formula

In 1948, **Penman and Monteith** collaborated to devise an energy balance equation utilizing a mass transfer approach. Drawing upon climatological data including sunlight, temperature, humidity, and wind speed, they formulated an equation for computing evapotranspiration from a free water surface. Subsequently, the Modified Penman-Monteith formula has emerged as the predominant method for estimating evapotranspiration and is strongly endorsed by the FAO. This formula is elaborated as follows:

$$ET_0 = \frac{0.408 \cdot \Delta(R_n - G) + \gamma \cdot \frac{900}{T + 273} \cdot u_2 \cdot (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0.34 \cdot u_2)} \qquad (III.3)$$

Where :

- (ET_0) represents reference evapotranspiration.
- (Δ) is the slope of the saturation vapor pressure curve.
- (R_n) is net radiation (in $\mathrm{MJ/m^2/}$ day).
- (G) is soil heat flux density (in $\mathrm{MJ/m^2/}$ day).
- (γ) is the psychrometric constant (in $\mathrm{kPa/\ ^\circ C}$).
- (T) is air temperature (in $^\circ\mathrm{C}$).
- (u_2) is wind speed at 2 meters above ground level (in $\mathrm{m/s}$).
- (e_s) and (e_a) are saturation vapor pressure and actual vapor pressure, respectively.

We employed the CROPWAT software (FAO, 2008) to calculate reference evapotranspiration using the Penman-Monteith method. Monthly data provided to the software included:

- Temperature: Monthly minimum and maximum temperatures.
- Air humidity: Relative air humidity expressed as a percentage (%).
- Daily sunshine duration: Measured in hours of sunlight.
- Wind speed: Wind speed, entered in meters per second (m/s).

The reference evapotranspiration data (ET0), derived from the CROPWAT software, are summarized in the table below:

Table III.1: Calculated Reference Evapotranspiration (ET0)

Country: Algeria | Station: Maghnia
Altitude: 426 m. | Latitude: 34.82 °N | Longitude: 1.78 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m²/day	mm/month
January	9.7	12.7	78	2.3	6.5	10.6	43.22
February	8.8	14.3	78	2.6	7.1	13.5	51.14
March	12.9	14.7	75	2.6	7.8	17.3	79.23
April	14.7	18.1	73	2.7	8.9	21.4	104.97
May	17.6	21.2	67	2.7	8.8	22.7	135.38
June	20.4	25.3	63	2.6	10.7	25.9	162.75
July	24.8	28.4	59	2.7	10.8	25.7	190.91
August	26.7	29.3	62	2.7	10.3	23.8	185.34
September	22.7	24.9	70	2.5	8.9	19.5	128.65
October	19.3	21.9	73	2.5	7.6	14.8	94.23
November	13.1	17.8	75	2.2	6.6	11.2	57.80
December	10.4	14.5	77	2.5	5.9	9.4	45.05
Average	**16.8**	**20.3**	**71**	**2.6**	**8.3**	**18.0**	**1278.68**

III.2 Soil water reserve calculation

It is the amount of water contained in the soil layer explored by the roots, between the point of drainage and the point of wilting. However, plants struggle more to extract water as moisture approaches the wilting point. The readily available water (RAW) is calculated by the following formula:

$$RFU = Y \times (Hcc - Hpf) \times Da \times Z \qquad (III.14)$$

In our case, the soil water reserve of the previous month (month i-1) can be calculated as follows, using the

- Hcc : Field capacity moisture (23%).
- Hpf : Wilting point moisture (12%).
- Z: Root depth (mm).

- Y: Degree of drying,
    - $Y = 2/3$ for general crops.
    - $Y = 1/3$ for sensitive crops (Watermelon).
    - $Y = 1/2$ For cereal crops.
- Da : Soil bulk density (1.3).

The soil water reserve of the previous month (month i-1) is given by the following formula:

$$RFU_{i-1} = k \times R_u \qquad (III.15)$$

Where:

- k: is a coefficient = 1, or 1/2, 1/3, or 0 depending on the water reserve.

III.3 Crop Choice

The choice of crops to cultivate depends on several factors, including:

- The natural location of the farm.
- The economic situation of the farm.
- Selecting crops while considering the economic situation.

III.3.1 The Proposed Crops

The objective of this project is to develop cereal production, primarily. For this purpose, the proposed crops are listed in Table III.2:

Table III.2: Land Occupation Based on Crops

The Crops	Occupied Surface (%)	Occupied Surface (ha)
Arboriculture: Olive trees Peaches Prunes	24.73	42.05
Cereals: Wheat Barley	51.14	86.95
Vegetables : Potatoes Carrots Peas Pepper	24.61	41.85
Total	100	170

Note: My perimeter is 200 hectares, but due to construction and the presence of a water basin, the irrigated area is 170 hectares.

III.3.2. The vegetative cycle

The vegetative cycle of the proposed crops is detailed in Table III.3.

Table III.3: Vegetative Cycle of Proposed Crops.

Crop Coefficient (Kc)												
Month	J	F	M	A	M	J	Jl	A	S	O	N	D
wheat	→	→	→	→	→	→					←	←
Barley	→	→	→	→	→	→					←	←
Olive trees	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
Peaches	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
Prunes	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
Potatoes								↔	↔	↔	↔	↔
Carrots									↔	↔	↔	↔
Peas	→	→	→									←
Pepper				↔	↔	↔	↔					

III.4 Estimation of Crop Water Requirements

Calculation of irrigation water requirements for crops:

$$Bi = ETM - \left(P_{eff} + RFU_{i-1}\right) \qquad (III.16)$$

With :

- Bi: Irrigation water needs (mm).
- ETM : Evapotranspiration (mm/month).
- Peff : Effective rainfall.
- RFU: This is the readily available water for crops. In this approach, it represents the soil moisture from the previous month accessible to crops.

III.4.1 Estimation of Water Requirements for Cereals

Table III.4: Calculation of Water Requirements for Wheat.

Wheat									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65		0		0	0	0
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8	0,2	11,56	0,3	27,3	27,3	0
Dec	36,71	29,37	45,05	0,4	18,02	0,5	45,5	22,75	0
Jan	39,2	31,36	43,22	0,4	17,29	0,5	45,5	22,75	0
Feb	32,94	26,35	51,14	0,6	30,68	0,6	54,6	0	0
Mars	27,59	22,07	79,23	0,8	63,38	0,6	54,6	0	41,31
April	20,41	16,33	104,97	1,15	120,72	0,6	54,6	0	104,39
May	16,94	13,55	135,38	1,15	155,69	0,6	54,6	0	142,14
Jun	7,15	5,72	162,75	0,4	65,1	0,6	54,6	0	59,38
Jul	7,22	5,78	190,91		0		0	0	0
Aug	8,83	7,06	185,34		0		0	0	0

Table III.5: Calculation of Water Requirements for Barley

Barley									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65		0		0	0	0
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8	0,2	11,56	0,3	27,3	27,3	0
Dec	36,71	29,37	45,05	0,4	18,02	0,5	45,5	22,75	0
Jan	39,2	31,36	43,22	0,4	17,29	0,5	45,5	22,75	0
Feb	32,94	26,35	51,14	0,6	30,68	0,6	54,6	0	0
Mars	27,59	22,07	79,23	0,8	63,38	0,6	54,6	0	41,31
April	20,41	16,33	104,97	1,15	120,72	0,6	54,6	0	104,39
May	16,94	13,55	135,38	1,15	155,69	0,6	54,6	0	142,14
Jun	7,15	5,72	162,75	0,4	65,1	0,6	54,6	0	59,38
Jul	7,22	5,78	190,91		0		0	0	0
Aug	8,83	7,06	185,34		0		0	0	0

III.4.2 Estimation of Water Requirements for vegetables

Table III.6: Calculation of Water Requirements for potatoes

Potatoes									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65	0,7	90,06	0,4	48,56	0	75,82
Oct	27,1	21,68	94,23	0,9	84,81	0,5	60,7	0	63,13
Nov	44,1	35,28	57,8	0,9	52,02	0,5	60,7	0	16,74
Dec	36,71	29,37	45,05	0,8	36,04	0,5	60,7	0	6,67
Jan	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97		0		0	0	0
May	16,94	13,55	135,38		0		0	0	0
Jun	7,15	5,72	162,75		0		0	0	0
Jul	7,22	5,78	190,91		0		0	0	0
Aug	8,83	7,06	185,34	0,5	92,67	0,2	24,28	0	85,61

Table III.7: Calculation of Water Requirements for Carrots

Carrots									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65	0,42	54,03	0,3	36,42	0	39,79
Oct	27,1	21,68	94,23	0,7	65,96	0,4	48,56	0	44,28
Nov	44,1	35,28	57,8	0,85	49,13	0,5	60,7	0	13,85
Dec	36,71	29,37	45,05	0,7	31,54	0,6	72,84	0	2,17
Janv	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97		0		0	0	0
May	16,94	13,55	135,38		0		0	0	0
Jan	7,15	5,72	162,75		0		0	0	0
Jul	7,22	5,78	190,91		0		0	0	0
Aug	8,83	7,06	185,34		0		0	0	0

Table III.8: Calculation of Water Requirements for Peas

Peas									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65		0		0	0	0
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8		0		0	0	0
Dec	36,71	29,37	45,05	0,5	22,53	0,4	48,56	24,28	0
Jan	39,2	31,36	43,22	0,8	34,58	0,7	84,98	0	0
Feb	32,94	26,35	51,14	1	51,14	0,7	84,98	0	24,79
Mars	27,59	22,07	79,23	0,95	75,27	0,7	84,98	0	53,2
April	20,41	16,33	104,97	0,5	52,49	0,7	84,98	0	36,16
May	16,94	13,55	135,38		0		0	0	0
Jan	7,15	5,72	162,75		0		0	0	0
Jul	7,22	5,78	190,91		0		0	0	0
Aug	8,83	7,06	185,34		0		0	0	0

Table III.9: Calculation of Water Requirements for Pepper

Pepper									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65		0		0	0	0
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8		0		0	0	0
Dec	36,71	29,37	45,05		0		0	0	0
Janv	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97	0,7	73,48	0,7	84,98	0	57,15
May	16,94	13,55	135,38	0,9	121,84	1,1	133,53	0	108,29
Jan	7,15	5,72	162,75	0,9	146,48	1,1	133,53	0	140,76
Jul	7,22	5,78	190,91	0,7	133,64	1,1	133,53	0	127,86
Aug	8,83	7,06	185,34		0		0	0	0

III.4.3 Estimation of Water Requirements for Arboriculture

Table III.10: Calculation of Water Requirements for Olive trees

Olive trees									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65	0,9	115,79	1,5	182,09	0	101,55
Oct	27,1	21,68	94,23	0,6	56,54	1,5	182,09	0	34,86
Nov	44,1	35,28	57,8		0		0	0	0
Dec	36,71	29,37	45,05		0		0	0	0
Jan	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97	0,6	62,98	1,5	182,09	0	46,65
May	16,94	13,55	135,38	0,6	81,23	1,5	182,09	0	67,68
Jun	7,15	5,72	162,75	0,6	97,65	1,5	182,09	0	91,93
Jul	7,22	5,78	190,91	0,8	152,73	1,5	182,09	0	146,95
Aug	8,83	7,06	185,34	0,8	148,27	1,5	182,09	0	141,21

Table III.11: Calculation of Water Requirements for peaches

Peaches									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65	0,65	83,62	1,5	182,09	0	69,38
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8		0		0	0	0
Dec	36,71	29,37	45,05		0		0	0	0
Jan	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97	0,5	52,49	1,5	182,09	0	36,16
May	16,94	13,55	135,38	0,9	121,84	1,5	182,09	0	108,29
Jun	7,15	5,72	162,75	0,9	146,48	1,5	182,09	0	140,76
Jul	7,22	5,78	190,91	0,65	124,09	1,5	182,09	0	118,32
Aug	8,83	7,06	185,34	0,65	120,47	1,5	182,09	0	113,41

Table III.12: Calculation of Water Requirements for prunes

Prunes									
Month	**P 80%**	**P_{eff} (mm)**	**ET_0 (mm/mois)**	**Kc**	**ETM (mm/mois)**	**Z(m)**	**RFU (mm)**	**RFU_{real} (mm)**	**Bi (mm)**
Sept	17,8	14,24	128,65	0,65	83,62	1,5	182,09	0	69,38
Oct	27,1	21,68	94,23		0		0	0	0
Nov	44,1	35,28	57,8		0		0	0	0
Dec	36,71	29,37	45,05		0		0	0	0
Janv	39,2	31,36	43,22		0		0	0	0
Feb	32,94	26,35	51,14		0		0	0	0
Mars	27,59	22,07	79,23		0		0	0	0
April	20,41	16,33	104,97	0,5	52,49	1,5	182,09	0	36,16
May	16,94	13,55	135,38	0,9	121,84	1,5	182,09	0	108,29
Jan	7,15	5,72	162,75	0,9	146,48	1,5	182,09	0	140,76
Jul	7,22	5,78	190,91	0,65	124,09	1,5	182,09	0	118,32
Aug	8,83	7,06	185,34	0,65	120,47	1,5	182,09	0	113,41

III.4.4 Calculation of Water needs

Table III.13: Net Requirements Results (mm)

Month	**Wheat**	**Barley**	**Potatoes**	**Carrots**	**Peas**	**Pepper**	**Olive Trees**	**Peaches**	**Prunes**	**Total**
Sept	0	0	75,82	39,79	0	0	101,55	69,38	69,38	355,9
Oct	0	0	63,13	44,28	0	0	34,86	0	0	142,2
Nov	0	0	16,74	13,85	0	0	0	0	0	30,59
Dec	0	0	6,67	2,17	0	0	0	0	0	8,84
Janv	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	24,7	0	0	0	0	24,79
Mars	41,31	41,31	0	0	53,2	0	0	0	0	135,82
April	104,39	104,39	0	0	36,1	57,15	46,65	36,16	36,16	421,06
May	142,14	142,14	0	0	0	108,29	67,68	108,29	108,29	676,83
Jan	59,38	59,38	0	0	0	140,76	91,93	140,76	140,76	632,97
Jul	0	0	0	0	0	127,86	146,95	118,32	118,32	511,45
Aug	0	0	85,61	0	0	0	141,21	113,41	113,41	453,64

III.4.5 Leaching

In irrigated agriculture, the leaching process is used to prevent primary salinization, assuming there are no drainage issues. In naturally saline soil, a semi-permanent equilibrium is reached (Hulin, 1982). The leaching fraction (LR), calculated by Rhoades (1976), represents the minimum amount of leaching necessary to combat salinity using common surface irrigation techniques. It is assumed that the leaching fraction LR is fully effective and percolates slowly through the soil.

Rhoades developed a model that requires less water, provided that the soil is maintained at an adequate moisture level through regular inputs or:

Rhoades devised a model that allows for the use of less water, provided that the soil is kept at an appropriate moisture level through regular inputs or:

$$LR = \frac{\text{CEiw}}{5\text{CEes} - \text{CEiw}} \qquad (III.17)$$

Using:

- CEiw: electrical conductivity of irrigation water.
- CEes: salinity of the saturated paste.

Numerical application yields:

$$LR = \frac{1.22}{(5 \times 4) - 1.22} = 6.5\%\ ET$$

The leaching volume is calculated using the formula below:

$$\text{V} = ETM \times \frac{1}{1 - \frac{LR}{Le}} \qquad (III.18)$$

With:

The leaching efficiency

- Le = 30% for cracked soils
- Le = 50% / 60% for medium-textured soils
- Le = 90% / 100% for sandy soils

The calculation results of the leaching volume for each crop are summarized in the following table:

Table III.14: The results of the leaching

Month	Wheat	Barley	Potatoes	Carrots	Peas	Pepper	Olive Trees	Peaches	Prunes	Total
Sept	0	0	84,16	44,16	0	0	112,72	77,01	77,01	395,06
Oct	0	0	70,07	49,15	0	0	38,69	0	0	157,91
Nov	0	0	18,58	15,37	0	0	0	0	0	33,95
Dec	0	0	7,4	2,4	0	0	0	0	0	9,8
Janv	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	27,51	0	0	0	0	27,51
Mars	45,85	45,85	0	0	59,05	0	0	0	0	150,75
April	115,87	115,87	0	0	40,13	63,43	51,78	40,13	40,13	467,34
May	157,77	157,77	0	0	0	120,2	75,12	120,2	120,2	**751,26**
Jan	65,91	65,91	0	0	0	156,24	102,04	156,24	156,24	702,58
Jul	0	0	0	0	0	141,92	**163,11**	131,33	131,33	567,69
Aug	0	0	95,02	0	0	0	156,74	125,88	125,88	503,52

III.5 Calculation of Specific Flow Rate

The specific flow rates are defined based on the water requirements of each crop assessed previously from the crop distribution. The irrigation dose of peak consumption is provided as a continuous flow rate supplied 24 hours a day to meet the monthly consumption needs.

$$Qs = \frac{\text{Bnet} \times 10 \times 1000}{Ni \times Nj \times 3600 \times Ef} \qquad (III.19)$$

Where :

- Bnet: Net peak month requirement in mm/ month.
- Ni: Number of irrigation hours = 22 h
- Nj : Number of days in the peak month = 30 days
- Ef : Irrigation efficiency = 75%

We calculate water needs for the most demanding crop rotation. Hence, the peak needs correspond to the month of May: **Bnet = 751.26 mm/month**.

qs=4.21 l/s/ha > 1.5 l/s/ha.

The specific flow rate obtained exceeds 1.5. Therefore, we consider the specific flow rate of the most demanding crop for the peak month, namely olive trees. Consequently, the specific flow rate considered for our area is:

Qs=1 (l/s/ha).

III.5.1 Evaluation of the characteristic flow rate

The calculation of the characteristic flow rate allows us to define the maximum flow rate that the distribution system will need to provide for the irrigation of each plot, determined by multiplying the peak flow rate by the usable agricultural area, as shown in the following formula:

$$\text{Qcar} = qs \times A \qquad (III.20)$$

Where:

- **qs:** equals the specific flow rate for the peak month (in l/s/ha)
- **A:** is the net irrigated area **= 170 ha**

$$\textbf{Qcar} = \boldsymbol{qs \times S = 1 \times 170 = 170\ l/s}$$

Table III.15: Total Water Requirements

Type of Crop	Area (ha)	Net Needs (mm)	Gross Needs (m3/ha)	Total Needs (m3)
Wheat	86.95	385.4	5138.7	446807.1
Potatoes	27.85	275.23	3669.7	102202.1
Carrots	14	111.08	1481.1	20734.9
Olive Trees	18.05	700.2	9336.0	168514.8
Peaches	14	650.8	8677.3	121482.7
Prunes	10	650.8	8677.3	86773.3
Total	**170**	**2773.51**	**36980.1**	**946,514.87**

Based on the previous table, it is evident that the total water requirement for the crops in our area amounts to **946,514.87** m3. The volume extracted from the dam, with a capacity of 2,428,680 m3, is more than adequate to fulfill the irrigation needs of our crops within the area.

Conclusion

In this chapter, we utilized the Penman method to estimate the water requirements of each crop. This method allowed us to quantify the amount of water evaporated from the soil and transpired by the plants, considering various climatic parameters.

After using the Penman method to assess the water needs of each crop. We calculated the water needs for each type of crop and proceeded to calculate the leaching volume, considering a salinity class of C3 in the water and exceeding 4 in the soil. This enabled us to determine the specific flow rate required to design the network for our irrigation zone

Chapter IV

Study of the Distribution System

CHAPTER IV: STUDY OF THE DISTRIBUTION SYSTEM

Introduction

Designing an irrigation perimeter primarily requires efficient and rational management of the irrigation system, along with its proper organization. An irrigation network comprises all structures, components, and devices that ensure the distribution and allocation of irrigation water to each agricultural plot.

IV.1 Irrigation Network

An irrigation network generally consists of three types of equipment:

- **Transport Structures:** These are the first type of equipment responsible for conveying irrigation water from the water intake point to the serviced perimeters. Designed to handle large volumes of water, ranging from a few cubic meters to several tens of cubic meters per second, these structures cover long distances. They include linear structures like canals and tunnels, as well as point structures such as aqueducts, siphons, and regulators.
- **Distribution Networks:** This network is in charge of distributing the water brought by the transport structures within the perimeter, delivering it to the individual irrigation intakes of each farmer. Typically, these networks have a branching structure to ensure efficient and equitable water distribution to various agricultural plots.
- **Parcel Irrigation:** This involves the application of irrigation water delivered to the network's intakes. Each irrigation plot is a unit of land with an individualized intake on the distribution network, distinct from cadastral or cultural plots. The equipment used varies based on the adopted irrigation technique: surface irrigation, sprinkler irrigation, or localized irrigation.

IV.2 Classification of Irrigation Networks

1. Gravity Networks

These networks feature a main canal with a very slight slope that roughly follows the terrain's contour lines. This design allows the water to flow naturally due to gravity.

2. Pressurized Networks

These networks are selected when the terrain has significant level variations. The primary goal of these systems is to deliver water at appropriate pressures. Pressurized networks are generally classified into two types: grid networks and branched networks.

3. Mixed Networks

These networks are used when certain areas of the gravity system are supplied by pumping. They combine the benefits of both gravity and pressurized systems to meet the specific irrigation needs of varied terrains.

IV.3 Organization and Structure of the Perimeter

The organization of a pressurized perimeter is a major initial constraint in its development. To design the pressurized network, the perimeter is divided into several groups of plots, known as irrigation plots.

IV.3.1 Irrigation Plots and Terminals

An "irrigation plot" refers to the hydro-agricultural unit supplied by an irrigation terminal. Organizing the perimeter into plots results from balancing several factors such as topography, technical and economic considerations, the size and number of parcel, etc. For small and medium-sized farms, it is generally accepted that the placement of terminals should meet the following criteria: one intake per plot, with a maximum of four intakes on a single terminal, and the terminals should be located at the plot boundaries or centrally for larger plots.

IV.3.2 Role and Function of the Irrigation Terminal

The irrigation terminal is a hydraulic device that delivers pressurized water to irrigators from a collective network. Each plot has an irrigation terminal with one or more outlets to allow simultaneous irrigation by multiple users. Each terminal and its outlets must perform all the functions of an irrigation intake, which include:

- Regulating the flow, precisely limiting it to the plot’s flow rate
- Controlling the water pressure
- Withstanding accidental shocks or disturbances
- Recording the volumes of water distributed through the intake for better management and monitoring.

IV.3.3 Hydraulic Calculation at Terminals

The flow rate for each terminal that can serve an irrigation plot is determined using the following formula:

$$Qb = qs \times S \qquad (IV.1)$$

Where :

- Qb is the flow rate for each plot ($1/s$).
- qs is the specific flow rate ($1/s/\text{ha}$).
- S is the area of the block (ha).

IV.3.4 Selecting the Diameter and Type of Terminals

The type of terminal is chosen based on the plot area and the number of parcel, following these general criteria:

- For plots with 4 to 10 parcels and an area less than 15 hectares, a terminal with four outlets (Type A4 terminal) is used.
- For plots with two parcels and an area less than 15 hectares, a terminal with two outlets (Type A2 terminal) is selected.

- For plots with two parcel and an area greater than 15 hectares, a terminal with two outlets (Type B terminal) is utilized.
- For large plot with an area greater than 50 hectares, Type C terminals are planned.

Table IV.1: Choice of terminal diameter

Flow provided	Terminal diameter
Q<40 m^3/h (11.11) l/s	D= 65mm
40 m^3/h (11.11l/s) <Q<80 m^3/h (22.22 ls)	D= 100mm
40 m^3/h (22.22 l/s) <Q<80 m^3/h (33.33 l/s)	D= 150mm

The diameters of the terminals depending on the flow rates are detailed as follows:

Table IV.2: Type and diameters of terminals depending on flow rate and parcels surface area

Plots	Area (Ha)	Parcel	Area (ha)	Qp (l/s)	Qb (l/s)	D(mm)	Type
1	2,65	P1	2,65	2,65	2,65	65	A2
2	2,72	P1	2,72	2,72	2,72	65	A2
3	3,97	P1	3,97	3,97	3,97	65	A2
4	6,83	P1	2,73	2,63	6,83	65	A2
		P2	4,10	4,20			
5	5,84	P1	3,2	3,2	5,84	65	A2
		P2	2,64	2,64			
6	6,75	P1	3,65	3,65	6,75	65	A2
		P2	3,1	3,1			
7	18	P1	9,3	9,3	18	100	A4
		P2	8,7	8,7			
8	3,17	P1	3,17	3,17	3,17	65	A2
9	11,44	P1	5,3	5,3	11,44	100	A4
		P2	6,14	6,14			
10	2	P1	2	2	2	65	A2
11	3	P1	3	3	3	65	A2
12	3,67	P1	3,67	3,67	3,67	65	A2
13	2,34	P1	2,34	2,34	2,34	65	A2
14	6,09	P1	4,2	4,2	6,09	65	A2
		P2	1,89	1,89			
15	10,74	P1	5,9	5,9	10,74	65	A2
		P2	4,84	4,84			
16	5,81	P1	4,2	4,2	5,81	65	A2
		P2	1,61	1,61			
17	9,91	P1	4,6	4,6	9,91	65	A2
		P2	5,31	5,31			
18	3,02	P1	3,02	3,02	3,02	65	A2
19	13,34	P1	5,8	5,8	13,34	100	A4

		P2	7,54	7,54			
20	5	P1	2,7	2,7	5	65	A2
		P2	2,3	2,3			
21	5,77	P1	2,8	2,8	5,77	65	A2
		P2	2,97	2,97			
22	19,70	P1	9,5	9,5	19,70	100	A4
		P2	10,2	10,2			
23	1,78	P1	1,78	1,78	1,78	65	A2
24	2,57	P1	2,57	2,57	2,57	65	A2
25	7,16	P1	5	5	7,16	65	A2
		P2	2,16	2,16			
26	6,47	P1	3	3	6,47	65	A2
		P2	3,47	3,47			

IV.4 Dimensioning of the Distribution Network

IV.4.1 Permissible Velocities

To ensure the integrity and efficiency of the irrigation network, permissible velocities are defined. Excessive velocities can lead to erosion, while too low velocities may result in solid deposits. Therefore, the permissible velocity range is typically set between 0.5 m/s and 2.5 m/s. For this network, a velocity of 1.5 m/s has been designated as appropriate.

IV.4.2 Pipe Diameter Calculation

The calculation of pipe diameters in the irrigation network is based on the flow rates carried by each section and the flow velocities. The "LABYE" formula is used to achieve a standardized approach to determine the economically optimal pipe diameter, balancing investment costs with pressure losses in the network.

$$D = \sqrt{\frac{4 * Q}{\pi * Vad}} \times 1000 \qquad (IV.2)$$

With:

- Q: Flow rate, expressed in m³/s
- D: Diameter, expressed in mm
- V: Economic velocity, around 1.5 m/s

IV.4.3 Estimation of Pressure Losses

The Hazen-Williams formula is used to estimate the pressure losses:

$$J = \left(\frac{3{,}592}{C_{HW}}\right)^{1{,}852} \frac{L}{D^{4{,}87}} Q^{1{,}852} \qquad (IV.3)$$

- J: Pressure loss in meters

- Q: Flow rate in the pipe in m^3/s
- CHW: Hazen-William's coefficient, taken as 120
- D: Diameter in meters

IV.4.4 Selection of Pipe Material

Choosing the appropriate pipe material requires considering soil aggressiveness, hydraulic conditions (such as flow rate and pressure), and market availability. Common materials used in irrigation networks include steel, cast iron, and PVC.

a) Cast Iron Pipes:

Cast iron pipes offer several advantages:

- Good resistance to internal forces
- Strong resistance to corrosion
- Very rigid and sturdy.

However, their drawback is their relatively high cost.

b) HDPE Pipes

HDPE pipes are widely used due to significant advantages:

- Good corrosion resistance
- Readily available in the market
- Easy pipeline installation
- Relatively low cost.

However, their drawback is the risk of rupture in the case of poor welding.

IV.4.5 Special Points of a Pipeline

- High points, where three-functional air release and venting valves will be installed to evacuate trapped air from the pipeline.
- Low points, where, in certain cases, branches will be installed to allow for exceptional draining of the pipeline if needed.
- Branch connections that enable the direction of water towards specific zones or extensions of the network.
- Intermediate cutoffs to divide the pipeline into sections and facilitate maintenance, repairs, or pressure adjustments in different parts of the network.

IV.4.6 Pressure Calculation at Terminals and Nodes

The pressure at point X is determined by the following relationship:

$$P = H - \Delta H - Z \qquad (IV.4)$$

With:

- H: Piezometric level (m)
- ΔH: Total Head Loss (m/m)

- Z: Downstream ground level (m) of point X.

The calculations are detailed in Table IV.3:

Table IV.3: Calculation Results

Section Number	Length (m)	Area (Ha)	Flow Rate Q (m³/s)	Calculated Diameter (mm)	Standard Diameter (mm)	Material	Actual Velocity (m/s)	Head Loss ΔH (m)	Total Head Loss ΔHt (m)	Downstream Ground Level Z (m)	Piezometric Head (m)	Pressure (bar)
ST-N1	84	170	0.1700	379.87	450.00	Iron	1.07	0.20	0.22	773.00	781.78	0.88
N1-B1	74	2.65	0.0027	47.43	50.00	HDPE PN10	1.35	3.52	3.87	767.00	777.91	1.09
N1-N2	74	167.35	0.1674	376.90	400.00	Iron	1.33	0.26	0.29	768.00	777.62	0.96
N2-B2	7	2.72	0.0027	48.05	50.00	HDPE PN10	1.39	0.30	0.34	768.00	777.28	1.02
N2-N3	170	164.63	0.1646	373.83	400.00	Iron	1.31	0.59	0.65	750.00	776.63	2.66
N3-B3	7	3.97	0.0040	58.05	63.00	HDPE PN10	1.27	0.20	0.22	748.00	776.41	2.84
N3-N4	217	160.66	0.1607	369.29	400.00	Iron	1.28	0.72	0.79	726.00	775.62	4.96
N4-B4	7	6.83	0.0068	76.14	90.00	HDPE PN10	1.07	0.10	0.11	725.00	775.51	5.05
N4-N5	20.1	153.83	0.1538	361.36	400.00	Iron	1.22	0.06	0.07	726.00	775.45	4.94
N5-B5	16.3	5.8	0.0058	70.4	75.0	HDPE PN10	1.3	0.4	0.4	728.0	775.00	4.70
N6-N7	185.1	148.0	0.1480	354.4	400.0	Iron	1.2	0.5	0.6	710.0	774.42	6.44
N7-B6	16.3	6.8	0.0068	75.7	90.0	HDPE PN10	1.1	0.2	0.2	710.0	774.18	6.42
N7-N8	351.8	141.3	0.1413	346.3	350.0	Iron	1.5	1.8	1.9	702.0	772.24	7.02
N8-B7	9.0	18.0	0.0180	123.6	125.0	HDPE PN10	1.5	0.1	0.2	702.0	772.07	7.01
N8-B8	11.0	3.2	0.0032	51.9	63.0	HDPE PN10	1.0	0.2	0.2	703.0	771.85	6.88
N8-N9	150.0	120.1	0.1201	319.3	315.0	HDPE	1.5	0.9	1.0	698.0	770.83	7.28
N9-B9	18.6	11.4	0.0114	98.5	110.0	HDPE PN10	1.2	0.2	0.3	699.0	770.55	7.16
N9-N10	88.3	108.6	0.1086	303.7	315.0	HDPE PN10	1.4	0.5	0.5	697.0	770.05	7.31

N10-B10	15.0	2.0	0.0020	41.2	50.0	HDPE PN10	1.0	0.4	0.4	697.0	769.64	7.26
N10-N11	15.0	106.6	0.1066	300.9	315.0	HDPE PN10	1.4	0.1	0.1	697.0	769.55	7.26
N11-B11	306.4	3.0	0.0030	50.5	63.0	HDPE PN10	1.0	6.0	6.5	688.0	763.00	7.50
N11-N12	145.0	103.6	0.1036	296.6	315.0	HDPE PN10	1.3	0.8	0.9	699.0	762.14	6.31
N12-B12	7.0	3.7	0.0037	55.8	63.0	HDPE PN10	1.2	0.2	0.2	698.0	761.92	6.39
N12-N13	164.0	100.0	0.1000	291.4	315.0	HDPE PN10	1.3	0.7	0.8	696.0	761.13	6.51
N13-N14	16.0	100.0	0.1000	291.4	315.0	HDPE PN10	1.3	0.1	0.1	687.0	761.05	7.40
N13-B13	7.0	2.3	0.0023	44.6	50.0	HDPE PN10	1.2	0.2	0.3	687.0	760.80	7.38
N14-N15	182.2	97.7	0.0977	287.9	315.0	HDPE PN10	1.3	0.8	0.8	687.0	759.95	7.29
N15-B14	7.0	6.1	0.0061	71.9	75.0	HDPE PN10	1.4	0.2	0.2	687.0	759.74	7.27
N13-N16	341.9	91.6	0.0916	278.8	280.0	HDPE PN10	1.5	2.6	2.9	673.0	756.87	8.39
N16-B15	7.0	10.7	0.0107	95.5	110.0	HDPE PN10	1.1	0.1	0.1	673.0	756.76	8.38
N16-N17	440.4	80.8	0.0808	261.9	280.0	HDPE PN10	1.3	2.7	2.9	670.0	753.83	8.38
N17-N18	179.2	80.8	0.0808	261.9	280.0	HDPE PN10	1.3	1.1	1.2	690.0	752.63	6.26
N18-B17	671.2	9.9	0.0099	91.7	110.0	HDPE PN10	1.0	7.9	8.7	705.0	743.95	3.89
N18-N19	100.0	70.9	0.0709	245.4	250.0	HDPE PN10	1.4	0.7	0.8	683.0	743.15	6.02

N19-B18	9.0	3.0	0.0030	50.6	63.0	HDPE PN10	1.0	0.2	0.2	683.0	742.98	6.00
N19-N20	195.4	67.9	0.0679	240.1	250.0	HDPE PN10	1.4	1.3	1.4	685.0	741.56	5.66
N20-B21	30.0	5.8	0.0058	70.0	75.0	HDPE PN10	1.3	0.7	0.8	687.0	740.75	5.38
N20-B22	131.8	19.7	0.0197	129.3	140.0	HDPE PN10	1.3	1.5	1.6	692.0	739.11	4.71
N17-N21	29.8	80.8	0.0808	261.9	280.0	HDPE PN10	1.3	0.2	0.2	664.0	738.94	7.49
N21-B20	13.9	5.0	0.0050	65.1	75.0	HDPE PN10	1.1	0.3	0.3	663.0	738.65	7.57
N21-N22	583.6	75.8	0.0758	253.7	280.0	HDPE PN10	1.2	2.7	3.0	663.0	735.64	7.26
N21-B23	8.0	1.8	0.0018	38.9	40.0	HDPE PN10	1.4	0.5	0.6	656.0	735.05	7.90
N22-N23	303.5	74.1	0.0741	250.7	280.0	HDPE PN10	1.2	1.4	1.5	657.0	733.55	7.65
N23-B24	86.5	2.6	0.0026	46.7	50.0	HDPE PN10	1.3	3.9	4.3	667.0	729.27	6.23
N23-N24	256.9	71.5	0.0715	246.3	250.0	HDPE PN10	1.5	2.2	2.4	673.0	726.90	5.39
N24-B25	7.0	7.2	0.0072	78.0	80.0	HDPE PN10	1.4	0.2	0.2	674.0	726.69	5.27
N24-B26	160.6	6.5	0.0065	74.3	80.0	HDPE PN10	1.3	3.6	3.9	678.0	722.78	4.48

Interpretation of results:

The examination of the hydraulic calculations table for our distribution network shows velocity and pressure data that confirm the design and performance are suitable for supplying our irrigation system.

1. Velocity (m/s)

The water velocities within the distribution network range from 1 to 1.5 m/s. These values are considered ideal for irrigation purposes.

2. Pressure (bar)

The pressure at the irrigation terminals ranges from 8.39 to 1.09 bars. These pressure levels are adequate for operating both sprinklers and drippers.

If the pressure exceeds 7 bars in an irrigation sprinkler or localized system, several steps can be taken to mitigate potential damage and ensure efficient operation:

1. **Install Pressure Regulators**: Use pressure regulators to reduce and stabilize the pressure to the desired level. These devices can be installed at the mainline or at individual sprinklers or emitters.
2. **Use Pressure-Reducing Valves**: Incorporate pressure-reducing valves (PRVs) into the system to maintain a consistent and safe pressure level throughout the irrigation network.
3. **Check and Adjust Pump Settings**: If the high pressure is due to the pump, adjust the pump settings or replace it with one that has a lower output pressure suitable for the system.
4. **Install Pressure Relief Valves**: Pressure relief valves can protect the system by releasing excess pressure when it exceeds the set threshold, thereby preventing damage.
5. **Use Appropriate Pipe Sizes**: Ensure that the pipe sizes are suitable for the flow rates and pressures in the system. Larger diameter pipes can help reduce pressure.
6. **Consider Multiple Zones**: Divide the irrigation system into multiple zones to spread out the pressure load and reduce the overall pressure in any single zone.
7. **Regular Maintenance**: Conduct regular maintenance and inspections to identify and address any issues that may cause pressure spikes, such as blockages or leaks.
8. **Consult Manufacturer Guidelines**: Follow the manufacturer's guidelines for maximum operating pressures for all components in the irrigation system to prevent damage and ensure proper operation.

- Sprinkler Irrigation: Effective sprinkler irrigation typically requires water pressure between 2,5 and 4 bars.
- Drip Irrigation: Drip irrigation usually operates at a pressure of around 1 bar.

A pressure range of 8.39 to 1.09 bars is generally sufficient to ensure the proper functioning of the network. However, pressure regulating valves will be specifically used for drip irrigation systems.

Conclusion

For this project, the 200-hectare area has been partitioned into 26 separate irrigation plots to ease terminal distribution, with each being supplied by its own irrigation point. Due to the terrain's elevation gap between the dam's water intake point and the perimeter, it was decided to adopt a gravity-based network, eliminating the need for water conveyance pumps.

After opting for this alternative, we conducted hydraulic parameter calculations for the pipelines across all sections of the distribution network. We suggested employing cast iron pipes for diameters of 400 and 450, and HDPE pipes for diameters smaller than or equal to 315 mm.

The pressures achieved across the entire distribution network are generally satisfactory, typically falling between 8.39 and 1.09 bars. This range will enable the incorporation of irrigation systems that demand high-pressure levels, such as sprinkler irrigation

Chapter V
Choice of Irrigation Technique

CHAPTER V: CHOICE OF IRRIGATION TECHNIQUE

Introduction

The choice of an irrigation system should be practical and economical, considering several factors: soil type (in terms of infiltration and retention capacity), terrain relief, type of crop, knowledge of the technique, and installation costs. Given these conditions, we have selected two techniques that suit our requirements: sprinkler irrigation for cereals and localized irrigation for other crops.

V.1 Choosing an Irrigation Technique

Selecting a suitable irrigation system requires considering numerous factors:

- **Soil Type**: Infiltration and retention capacities are crucial (soil hydrodynamic characteristics).
- **Relief**: Steeper terrains are less suited for traditional surface irrigation.
- **Crop Type**: Different irrigation methods are needed for different crops.
- **Technical Knowledge**: The chosen system should be familiar and, ideally, previously used by the farmer.
- **Installation Costs**: Costly systems are generally discouraged unless they are for highly productive crops.

V.2 Sprinkler Irrigation

Sprinkler irrigation delivers water to plants in the form of artificial rain using pressurized sprinklers. The arrangement of sprinklers determines the irrigation pattern, with square arrangements being most common.

V.2.1 Types of Sprinkler Systems

- **Fixed Sprinklers (Low and Medium Pressure):** Operating at 1.5 to 4 bars, these are the most common due to their robustness and affordability. They have a controlled jet that rotates to distribute water uniformly.
- **High-Pressure Fixed Sprinklers**: Used less frequently due to higher operational pressures.
- **Self-Propelled Sprinklers (Reel Sprinklers):** These mobile systems can cover larger areas and are suitable for irregular fields.
- **Giant Mobile Sprinklers (Pivots, Lateral Move Systems):** Used for large-scale irrigation with high efficiency.

Figure.V.1: Arroseurs to post fixe **(Source: ArchiExpo.fr)**

Figure.V.2: Pivot watering **(Source: Groundwater.org)**

V.2.2 Advantages

- Suitable for all soil types.
- Can include anti-frost measures.
- No water loss in transportation.
- Reduced labor requirements.
- Enhanced oxygenation of the sprayed water.
- No need for prior land leveling.
- Possibility of automation.
- Uniform distribution of liquid fertilizers.

V.2.3 Disadvantages

- High energy requirements if pumping is needed.
- More recent technology requires advanced skills.
- Promotes weed growth.
- Potential foliage damage when using saline water.
- Soil compaction due to crust formation.
- High installation costs.

V.3 Localized Irrigation

Localized irrigation targets only the root zones of plants, delivering water at low flow rates frequently. The drip system is the most widely used form.

V.3.1 Components of a Drip Irrigation System

- **Water Source:** Can be a pressurized communal network or a pumping station.
- **Head Unit:** Regulates flow and pressure and improves water quality via filtration and fertilization units.

Components include:

- Filtration unit (sand or gravel filters)
- Fertilizer injector
- Various valves, regulators, flow limiters, and meters
- Secondary and tertiary conduits.

Figure.V.3: Localized irrigation by drippers **(Source: Agronomie.info)**

V.3.2 Advantages

- Water savings of 50-70% compared to gravity irrigation, and 30% compared to sprinkler systems.
- Reduced weed growth.
- Optimal fertilizer is used with reduced evaporation.
- Labor savings with potential for automation.
- Suitable for uneven terrains and soils with low filtration rates or steep slopes.
- Yield increases of 20-40% with improved product quality.

V.3.3 Disadvantages

- Risk of emitter clogging.
- Higher installation costs.
- Best suited for row crops (tree crops and vegetables).
- Rapid plant desiccation if water supply is interrupted.

V.4 Surface Irrigation

Surface irrigation encompasses all techniques in which water available upstream of the plot is distributed over the irrigated land by gravitational surface flow, without requiring specific soil modifications.These surface irrigation techniques are generally classified into three main groups:

- Flood Irrigation: Water is directly poured onto the land, temporarily covering the surface of the crops. This method is often used for rice paddies.

- Runoff Irrigation: Water is channeled into shallow furrows or ditches and flows naturally over the land following the slopes.
- Furrow Irrigation: Water is conveyed into shallow furrows, where it gradually infiltrates the soil to reach the crop roots.

Figure.V.4 : Surface Irrigation **(Source : ecosources.org)**

V.4.1. Advantages

- Simple irrigation equipment.
- Low cost.
- No need for water pressurization equipment.
- Provides frost protection.

V.4.2. Disadvantages

- Soil compaction.
- Significant water losses.
- Requires water drainage systems.
- Soil erosion.
- Reduced soil permeability.

Conclusion

Choosing an appropriate irrigation technique is crucial for water conservation. Based on our conditions (soil type, terrain, crop type, and installation cost), we have chosen sprinkler irrigation for cereal crops and localized irrigation for nother crops.

Chapter VI

Dimensioning at the Parcel Level

CHAPTER VI: DIMENSIONING AT THE PARCEL LEVEL

Introduction

The determination of parcel size is a crucial step in the development of a layout plan, and this dimension is largely conditioned by the choice of the selected irrigation method. In this section, we will focus on the procedure for determining the optimal size of plots, considering the chosen irrigation technique, as well as the criteria and limitations specific to the geographical region examined within the study perimeter.

VI.1 Sizing of a Sprinkler Irrigation Network

- **Crop choice**: We have selected the practice of irrigation for the cultivation of Wheat, a cereal crop that offers notable benefits from both an agronomic and economic standpoint.

- **Choice of plots in the parcel**: The sprinkler irrigation network is set up on parcel P2 (plot 05), which has an area of 2.6 hectares. The plot is supplied by the B05 terminal, and the pressures calculated for this terminal are about 4.7 bars. These pressure values are largely adequate to ensure the water supply of the plot.

- **Length L**: 206 m
- **Width b**: 128 m
- **Texture**: Silty clay.
- **Irrigation efficiency E_{as}: 75%**
- **Working time**: 20 hours per day, and 26 days per month.
- **Peak needs**: 157.77 mm/month for the peak month (May).
- **Soil permeability**: The soil is of silty clay type with an estimated permeability of:
- **K** : 7 mm/h

VI.1.1 Practical Dose

The practical dose can be calculated using the following formula:

$$RFU = Y \cdot (H_{cc} - H_{pf}) \cdot D_a \cdot Z \qquad (VI.1)$$

where:

- Y : degree of desiccation $= 2/3$
- Da : bulk density $= 1.35$
- S : plot area $= 2.6$ ha
- Z : rooting depth mm (60 cm for Wheat)
- H_{cc}: moisture at field capacity (23%)
- H_{pf} : moisture at wilting point (12%)

$$RFU = \frac{2}{3} \cdot \left(\frac{23 - 12}{100}\right) \cdot 1.35 \cdot 0.6 \cdot 1000 = 59.4 \text{ mm}$$

VI.1.2 Theoretical Sizing

VI.1.2.1 Calculation of the nozzle diameter

Given the soil permeability $K = 7$ mm/h, we set $p \leq K$ such that p : precipitation of the nozzle.

$$P = 1.5 \cdot d^{1.04} \qquad (VI.2)$$

where:

- P : Precipitation of the nozzle in mm.
- d : Diameter of the nozzle in mm.

Thus:

$$d = \left(\frac{7 \cdot 1.04}{1.5}\right) = 4.85 \text{ mm}$$

Referring to the technical documentation for the PERROT sprinkler (as indicated in Appendix 4), it is noted that the closest standardized nozzle diameter is 4.8 mm.

VI.1.2.2 Calculation of the jet range

The jet range represents the distance between the emitting device and the point of impact of the jet, this parameter allows to delimit the circular area irrigated by the device, calculated by the following equation:

$$L = 3 \cdot d^{0.5} \cdot h^{0.25} \qquad (VI.3)$$

where:

- d : diameter of the nozzle (mm)
- h : pressure at the nozzle (m), in our case $P = 4.7$ bars, water height $= 47$ m.

$$L = 3 \cdot (4.8)^{0.5} \cdot (47)^{0.25} = 17.55 \text{ m}$$

For the nozzle diameter of 4.85 mm at a pressure of 4.7 bars, the range will be at least 17.55 m, according to the technical sheet of a Perrot type ZB sprinkler.

VI.1.2.3 Spacing between ramps and sprinklers

In accordance with the directives issued by American standards, the maximum spacing is recommended in correlation with the wind speed as follows:

- E_l between the irrigation lines: 1.25 L (low wind) to 1.02 L (strong wind).
- E_a between the sprinklers on the ramp: 0.8 L (low wind) to 0.5 L (strong wind).

The maximum values are associated with low wind intensity conditions, i.e., (< 10Km/h). The wind speeds in our case are relatively low and homogeneous throughout the year.

In our investigation area, the maximum wind speeds are about 3.9 $\mathrm{m/s}$, equivalent to 14.04 $\mathrm{km/h}$. Therefore, we use the following values.

- $E_l = 1.3 * 16.6 = 22.815$ m
- $E_a = 0.75 * 16.6 = 13.1625$ m

The standardized values of the spacings are as follows:

- $E_l = 18m$
- $E_a = 18m$
- Wetted surface $= 324m^2$

VI.1.2.4 Sprinkler flow rate

The calculation of a sprinkler's flow rate is carried out using the following relation:

$$q = \frac{0.95.\pi \cdot d^2}{4}\sqrt{2 \cdot g \cdot h} \ \ldots (VII - 4)$$

$$q = \frac{0.95.3.14.(4.8.10^{-3})^2}{4}\sqrt{2 \cdot 9.81 \cdot 40} = 0.000426 \ \mathrm{m^3/s}$$

$$q = 0.426 \mathrm{l/s}$$

Where q is the flow rate of the sprinkler $(\mathrm{m^3/s})$

VI.1.2.5 Verification of the Nozzle's Rainfall

Assuming that the spacing is proportional to the range, the hourly rainfall, denoted by P (in $\mathrm{mm/h}$), can be estimated using the following relation:

$$P = \frac{q}{E_l \cdot E_a} \qquad (VI.5)$$

Therefore:

$$P = \frac{0.000426}{18 \cdot 18} = 0.001315 \ \mathrm{m/h} = 1.315 \ \mathrm{mm/h}$$

Consequently, the selection of the nozzle diameter will ensure a rainfall $P \leq K = 7 \ \mathrm{mm/h}$.

VI.1.2.6 Calculation of the Water Cycle

The duration of the water cycle corresponds to the period required for the complete watering of all the plots.

$$T_{\mathrm{eau}} = \frac{\mathrm{Dose}_{RFU} \cdot N_j}{B_{mp}} \qquad (VI.6)$$

Where:

- Dose_{RFU} : Practical dose in mm (59.4 mm)
- N_j : Number of days per month (26 days)
- B_{mp} : Monthly peak need ($157.77 \ \mathrm{mm/month}$)

$$T_{\text{eau}} = \frac{59.4 \times 26}{157.77} \approx 9.78 \text{ days}$$

We take a water cycle for 10 days.

- We irrigate $\frac{30}{10} = 3$ times per month.

VI.1.2.7 The Actual Dose

The actual dose can be calculated as:

$$Dr = T_{\text{eau}} \cdot \text{ daily dose} \qquad (VI.7)$$

where:

- Daily dose $= \frac{157.77}{30} = 5.26$ mm/ day

Substituting the values :

$$D_r = 10 \times 5.26 = 52.6 \text{ mm}$$

VI.1.2.8 The Gross Dose

The gross dose can be calculated as:

$$D_b = \frac{\text{actual dose}}{E_{as}} \qquad (VI.8)$$

$$D_b = \frac{52.6}{0.75} = 70.13 \text{ mm}$$

VI.1.2.9 Irrigation Time

The time T required to apply a dose of water by a sprinkler without exceeding the infiltration capacity is determined using the following relation:

$$Ta = \frac{D_b}{\text{pluviometrie}} \qquad (VI.9)$$

$$Ta = \frac{70.13}{7} = 10.02 \text{ h}$$

Therefore, it will be possible to adjust two cycles per day for a sprinkler, which is equivalent to a total operating duration of 20 hours.

VI.1.2.10 Calculation of Equipment Flow Rate

$$Q_{eq} = \frac{S \cdot B_{mp} \cdot 10}{T \cdot n \cdot N_j} \qquad (VI.10)$$

$$Q_{eq} = \frac{2.6 * 157.22 * 10}{10 * 3 * 26 * 0.75} = 6.98 \; m^3/h$$

VI.1.2.11 Calculation of the Irrigation Unit

The area or surface irrigated per unit of measure:

$$SU = \frac{S}{T_{\text{eau}} \cdot n} \qquad (VI.11)$$

$$SU = \frac{2.6}{10 * 3} = 0.08\ ha$$

VI.1.2.12 Number of Required Sprinklers

$$N_{asp} = \frac{SU \cdot 10000}{E_l \cdot E_a} \qquad (VI.12)$$

$$N_{asp} = \frac{0.08 * 10000}{18 * 18} = 2\ asp$$

For our case, we will take into consideration the following elements:

- 2 Sprinklers for 0.08 ha.
- Such that: the real gross dose = real dose $/0.75$

VI.2 Hydraulic sizing of ramps

VI.2.1 Length of the ramp

This sizing phase varies from one plot to another depending on the dimensions of the plot and the way the sprinkler network projection is carried out. Two methods of installing the sprinkler devices on the ramp are envisaged.

The length of the ramp is therefore:

- For type 1 : $L = n \cdot E$
- For type 2 : $L = (n + 0.5) \cdot E$

Where:

$$L_r = \frac{width}{2} - \frac{E_a}{2} \qquad (VI.13)$$

$$L_r = \frac{128}{2} - \frac{18}{2} = 55\ \text{m}$$

The number of sprinklers per ramp can be calculated using the following formula:

$$N_{asp} = \frac{\text{width}}{E_a} = \frac{L_r}{E_a} \qquad (VI.14)$$

$$N_{asp} = \frac{55}{18} = 3\ \text{sprinklers}$$

VI.2.2 Sizing of the ramp

$$Q_r = \text{ flow rate of the sprinkler } \times \text{ number of sprinklers /ramp} \quad (VI.15)$$

$$Q_r = 1.315 \times 3 = 3.945 \text{ m}^3/\text{h} = 1.056 \times 10^{-3} \text{ m}^3/s$$

The number of ramps can be calculated as:

$$N_r = \frac{l_r}{E_l} \quad (VI.16)$$

$$N_r = \frac{206}{18} = 11.44 \approx 11 \text{ ramps}$$

VI.3 Sizing of the ramp

The diameter of the ramp can be calculated as:

$$D_R = \sqrt{\frac{4 \cdot Q_R}{\pi V}} \quad (VI.17)$$

Assuming that $V = 1.5$ m/s, we can calculate DR as:

$$D_R = \sqrt{\frac{4 \times 0.00136}{\pi \times 1}} = 0.04161 \text{ m} = 41.61 \text{ mm}$$

The standardized diameter is $DR = 50$ mm.

The speed can be calculated as:

$$V = \frac{4 \cdot Q}{\pi d^2} \quad (VI.18)$$

$$V = \frac{4 \times 0.00136}{\pi \times (50 \times 10^{-3})^2} = 0.7 \, m/s$$

VI.3.1 Calculation of pressure losses

The general expression for calculating linear pressure losses in pipes is based on the HAZEN WILLIAMS model:

$$J = \left(\frac{3.592}{CH}\right)^{1.852} \times \left(\frac{L}{D^{4.87}}\right) \times Q^{1.852} \quad (VI.19)$$

- J represents the linear pressure loss in m,
- CH is the HAZEN-WILLIAMS coefficient (130-140 for cast iron or PEHD pipes),
- D corresponds to the diameter of the pipe (m),
- L represents the length of the pipe (m),
- Q is the flow rate in 1 m^3/s.

The pressure loss is calculated as:

$$J = (3.592/140)^{1.852} \times (55/0.050^{4.87}) \times 0.00136^{1.852} = 1.32 \text{ m}$$

VI.4 Dimensioning of the ramp gate

VI.4.1 Length of the ramp gate

The length of the ramp gate is determined by:

$$L_{pr} = 206 - \frac{18}{2} = 197 \text{ m}$$

VI.4.2 Flow rate of the ramp gate

The diameter of the ramp is calculated by:

$$Q_{pr} = Q_r \times N_r \qquad (VI.20)$$

$$Q_{pr} = 4.92 \times 11 = 54.12 \text{ m}^3/\text{h} = 0.0150 \text{ m}^3/\text{s}$$

VI.4.3 Calculation of the ramp gate diameter

The diameter of the ramp gate is calculated by the following relation:

$$D_{pr} = \sqrt{\frac{4 \times Q_{pr}}{\pi \times V}} \qquad (VI.21)$$

With:

- Q_{pr} : the flow rate expressed in m^3/s,
- D_r : the diameter expressed in mm,
- V : the economic speed of 2 m/s.

For our case, we will take into consideration the following elements:

$$D_{pr} = \sqrt{\frac{4 \times 0.0150}{\pi \times 2}} = 97.7 \approx 110 \text{ mm}$$

We choose a standardized diameter of 110 mm for a PEHD pipe, to minimize pressure losses.

$$V = \frac{4 \times Q_{pr}}{\pi \times D_r^2} \qquad (VI.22)$$

$$V = \sqrt{\frac{4 \times 0.0150}{\pi \times 0.112}} = 1.57 \ m/s$$

VI.4.4 Calculation of the ramp gate head loss

The usual formula for calculating the general expression of linear head losses in pipes is based on the Hazan Williams model:

$$J = \left(\frac{3.592}{CH}\right)^{1.852} \times \left(\frac{L}{D^{4.87}}\right) \times Q^{1.852} \qquad (VI.23)$$

With:

- J : represents the linear head loss in m,
- CH: is the Hazen-Williams coefficient (130-140 for cast iron or HDPE pipes)
- D : corresponds to the pipe diameter (m)
- L : represents the measurement of the pipe length (m)
- Q : is the flow rate in 1 m^3/s.

Applying these data to the equation, we obtain:

$$J = \left(\frac{3.592}{140}\right)^{1.852} \times \left(\frac{197}{0.114^{4.87}}\right) \times 0.0150^{1.852} = 4.35 \text{ m}$$

The total head loss is $\Delta H_t = 4.35 + 1.32 = 5.67$ m, so the Christiansen rule is respected.

VI.4.5 Calculation of the network head pressure

This is the pressure required to ensure the optimal operation of the last sprinkler.

- $H = H1 + H2 + H3$
- H : pressure at the head of the plot
- H1: The pressure required to ensure the optimal operation of a sprinkler is (3 bars)
- H2: total head loss of the ramp.
- H3: the elevation difference (0 m. Relatively flat terrain)
- $H = 30 + 5.67 + 0 = 35.67$ m.

The pressure $P = 3.6$ bars, which is perfectly adequate given the pressure available at the terminal, which is 4.7 bars.

VI.5 Dimensioning of a Drip Irrigation Network

In this section, we will focus on the dimensioning of a localized irrigation system (the drip irrigation system). For this, it is essential to have fundamental data such as the area of the plot, the daily water requirements, and the maximum daily operating duration.

VI.5.1 General Data

The irrigation system will be installed on parcel P 2 of plot 4, supplied by terminal B04, with calculated pressures of approximately 4.7 bars. The total area of the farm spans 4.1 hectares and has a relatively rectangular configuration.

- Crop: Olive tree
- Peak water requirement: 146.95 mm
- Drip irrigation network arrangement: Spacing of 4 meters by 4 meters (4x4)
    - Area : 4.1 hectares
    - Length: 265 meters
    - Width: 158 meters

Dripper characteristics :

- Nominal flow rate: 4 liters per hour
- Nominal pressure: 10 meters of water column (10m.c.e)
- Number of drippers per tree: 2
- Dripper spacing: Approximately [1 – 2] meters

VI.5.2 Irrigation Needs for Crops in Localized Irrigation

a) Impact of Soil Coverage Rate

In a drip irrigation system, water is precisely applied to a small area of the soil surface, significantly reducing evaporation directly from the soil. To account for this, a reduction coefficient (Kr) is applied to the crop evapotranspiration (ETM). The Kr value depends on the percentage of soil surface covered by mature plants, which is typically around 60%. Various formulas can be used to calculate Kr, considering this coverage percentage.

Keller et Karmeli (1974)

$$Kr = \frac{Cs}{0{,}85} \qquad (VI.24)$$

The Freeman and Garzoli Formula

$$Kr = Cs + 0.5(1 - Cs) \qquad (VI.25)$$

We assume a 60% coverage rate is achieved for mature trees, which means:

- Kr $= 0.80$ according to Keller and Karmeli
- Kr $= 0.70$ according to Freeman and Garzoli

We will use a Kr factor of 0.80, therefore:

$$\text{Bnet} = Bj \times Kr \qquad (VI.26)$$

$$\text{Bnet} = \left(\frac{146.95}{30}\right) \times 0.8 = 3.91 \text{ mm/ day}$$

VI.5.3 Practical Net Dose

Once the daily water requirements are calculated, it is necessary to specify a fraction or percentage of moisture in the root zone. The dose (RFU) is determined based on the water depth P:

$$Dp = (Hcc - Hpf) \times Y \times Z \times da \times P\% = RFU \times P\% \qquad (VI.27)$$

Where :

- Hcc : Field capacity water depth (23%)
- Hpf: Permanent wilting point water depth (12%)

- da: Bulk density, valued at 1.5
- Y : Valued at $2/3$
- Z: Root depth of the plant, 1500 mm
- P : Soil water saturation rate

The value of P% is calculated using the following equation:

$$P\% = \frac{N \times Spd \times Sh}{Sa \times Sr} \qquad (VI.28)$$

With :

- P: the volume of moistened soil,
- N : the number of distribution points per tree,
- Spd: the distance between two neighboring distribution points of the same tree (m),
- Sh: the width of the moistened strip,
- Sr : being the spacing between rows of trees,
- Sa : the spacing of trees on the rows.

$$P\% = \frac{2 \times 2 \times 1}{4 \times 4} = 25\% \qquad (VI.29)$$

$$RFU = (0.27 - 0.16) \times 1500 \times \left(\frac{2}{3}\right) \times 1.5 = 165 \text{ mm}$$

$$\text{Dnette} = 165 \times 0.25 = 41.25 \text{ mm}$$

VI.5.4 Irrigation Frequency and Spacing (Fr)

The interval between two irrigations (watering cycle) is determined by the following formula:

$$\text{Fr} = \frac{\text{Dnette}}{\text{Bnet}} \qquad (VI.30)$$

$$Fr = \frac{41.25}{5.76} = 7.16 \text{ days}$$

Thus, we choose an irrigation cycle period of 8 days (Cycle $= 8$ days).

- 4 irrigations per month.

VI.5.5 Calculation of the Gross Dose

We reassess the actual dose:

$$Dr = \text{Bnet} \times Fr \qquad (VI.31)$$

$$Dr = 5.76 \times 8 = 46.08 \text{ mm}$$

VI.5.6 Actual Gross Dose

$$\text{Dbrute} = \frac{Dp'}{Eff \times Cu} \qquad (VI.32)$$

- Eff: Irrigation network efficiency Eff $= 90\%$
- Cu : Uniformity coefficient Cu $= 90\%$

$$\text{Dbrute} = \frac{46.08}{0.9 \times 0.9} = 56.88 \text{ mm}$$

VI.5.7 Duration of Operation per Irrigation Cycle (in hours)

$$h = \frac{\text{Dbrute} \times Sa \times Sr}{n \times Qg} \qquad (VI.33)$$

Where:

- Dbrute: the previously calculated gross requirement (56.88 mm),
- Sa and Sr : spacing between trees and rows,
- n : number of emitters (2),
- Qg : emitter flow rate (4 1/h).

$$h = \frac{56.88 \times 4 \times 4}{2 \times 4} = 113.76 \text{ h/month}$$

VI.5.8 Daily Irrigation Duration

$$Dj = \frac{\text{Duration of irrigation}}{Fr} \qquad (IV.34)$$

$$Dj = \frac{113.76}{8} = 14.22 \text{ h/day}$$

VI.5.9 Number of Trees per Hectare

The formula to calculate the number of trees per hectare is as follows:

$$\text{Narbr} = \frac{1\text{ha}}{Sa \times Sr} \qquad (IV.35)$$

$$\text{Narbr} = \frac{10000}{4 \times 4} = 625 \text{ trees}$$

VI.5.10 Number of Trees per Row

The formula to calculate the number of trees per row is as follows:

$$\text{Narmp} = \frac{\text{Lrg } p}{Sa} \qquad (VI.36)$$

$$\text{Narmp} = \frac{158}{4} = 40 \text{ trees}$$

VI.5.11 Number of Emitters per Row

The formula to calculate the number of emitters per row is as follows:

$$Ng = \left(\frac{\text{Lrg } p}{Sa}\right) \times 2 \qquad (VI.37)$$

$$Ng = 40 \times 2 = 80 \text{ emitters}$$

VI.5.12 Flow Rate of a Row

The method for determining the flow rate of a row is as follows:

$$\text{Qrmp} = Ng \times qg \qquad (VI.38)$$

$$Qrmp = 80 \times 4 = 320 \text{ l/h}$$

VI.5.13 Number of Rows:

The method for determining the number of rows is as follows:

$$\text{Nrmp} = \frac{\text{Lngp}}{Sr} \qquad (VI.39)$$

$$\text{Nrmp} = \frac{265}{4} = 66 \text{ rows}$$

VI.5.14 Flow Rate of the Main Pipe

The method for determining the flow rate of the main pipe is as follows:

$$Qprmp = Qrmp \times Nrmp \qquad (VI.40)$$

$$Qprmp = 320 \times 66 = 21120 \text{ l}/h$$

VI.6 Hydraulic Calculations of Drip Irrigation Network

Assessing hydraulic parameters like size, pressure, and head loss is crucial for accurately calculating the drip irrigation system's hydraulic performance to guarantee optimal network efficiency.

VI.6.1 Ramp Diameter

The formula for determining the ramp diameter is as follows:

$$D_{rmp} = \left(\frac{2.75 \times J_{th}}{0.478 \times Q_{rmp}^{1.75} \times L_{rgp}}\right)^{\frac{-1}{4.75}} \qquad (VI.41)$$

$$\text{Drmp} = \left(\frac{1.4 \times 2.75}{0.478 \times 320^{1.75} \times 158}\right)^{-\frac{1}{4.75}} = 15.67 \text{ mm}$$

We take DN $= 16$ mm.

Calculation of Ramp Head Losses

$$Jcal = \frac{0.478 \times \text{Lrgp} \times \text{Drmp}^{-4.75} \times \text{Qrmp}^{1.75}}{2.75} \qquad (VI.42)$$

Using these data in the equation, we obtain:

$$\text{Jcal} = \frac{0.478 \times 158 \times 16^{-4.75} \times 320^{1.75}}{2.75} = 1.26 \text{ m}$$

Head loss $= 1.2$ m $<$ 1.4 m, the condition is met.

Table VI.2: Ramp Characteristics

Crops: Olive trees
Lrgp(m) : 158
Ng: 80
Qrmp(l/h) : 320
Jth(m) : 1.4
Calculated Diameter (mm) : 15.46
DN (mm) : 16
Calculated Head Loss (m) : 1.26

VI.6.2 Manifold Pipe Diameter

The formula for determining the manifold pipe diameter is expressed as follows:

$$\text{Dprmp} = \left(\frac{Jth \times 2.75}{0.478 \times Qprmp^{1.75} \times \text{Lng } p}\right)^{-\frac{1}{4.75}} \quad (VI.43)$$

Using these data in the equation, the result is as follows:

$$\text{Dprmp} = \left(\frac{0.8 \times 2.75}{0.478 \times 21120^{1.75} \times 265}\right)^{-\frac{1}{4.75}} = 92 \text{ mm}$$

We take DN $= 110$ mm.

Calculation of Manifold Pipe Head Losses:

$$jcal = \frac{0.478 \times \text{Lngp} \times \text{ Dprmp } p^{-4.75} \times Qprmp^{1.75}}{2.75} \quad (VI.44)$$

Using these data in the formula, the result obtained is as follows:

$$jcal = \frac{0.478 \times 265 \times 110^{-4.75} \times 21120^{1.75}}{2.75} = 0.34 \text{ m}$$

Jcal $= 0.34$ m $<$ 0.8 m, the condition is met.

Table VI.3: Manifold Pipe Characteristics.

Crops: Olive trees
Lngp(m) : 265
Nr : 66
Qprmp(l/h) : 21120
Jth(m) : 0.8
Calculated Diameter (mm) : 92
DN (mm) : 110
Calculated Head Loss (m) : 0.34

VI.7 Calculation of Head Pressure in the Network

To determine the total pressure required for the operation of the drip irrigation system, we sum up the head losses across the entire network and include the specific pressure required for each emitter.

$$H = H1 + H2 \qquad (VI.45)$$

Where :

- H represents the head pressure of the parcel,
- H1 is the pressure required for the proper operation of a dripper (1 bar),
- H2 represents the total head loss,

Based on the provided values:

$$H1 = 1\text{bar},\ H2 = 0.34 + 1.26\ \text{m}$$

We obtain:

H = 10 + 1.94 = 11.6 m = 1.2 bar.

Therefore, a pressure of 4.6 bars is more than sufficient to supply the drippers and ensure their proper operation.

Conclusion

In conclusion, the pressure is more than adequate to supply the drippers and ensure their proper functioning. In this section, we have examined the methodology for sizing a sprinkler irrigation system dedicated to wheat cultivation, as well as a drip irrigation system suitable for olive cultivation. The dual objective inherent in the adoption of these systems is twofold: on one hand, the conservation of irrigation water resources, and on the other hand, the improvement of agricultural yield.

Chapter VII

Site Organization

CHAPTER VII: SITE ORGANIZATION

Introduction

After completing the various stages of the study, it is essential to conduct an analysis to estimate the project cost in all its components, including construction, preparation, and the expenses associated with the necessary facilities for project implementation.

VII.2 Execution of Pipeline Installation Works

VII.2.1 Excavation of Trenches

- This operation involves digging trenches in the ground to accommodate the pipelines. Typically, a mechanical excavator is used for this purpose.
- The dimensions of the trenches vary based on the diameter of the pipeline that will be installed in each section. It is crucial to excavate the trench with appropriate dimensions to accommodate the pipeline without compromising its stability.

VII.2.2 Sand Bed Installation:

- The sand bed is a layer of sand placed at the bottom of the trench before installing the pipeline.
- Its primary role is to evenly distribute the loads on the pipe's support area, which can help prevent potential damage.
- Before laying the pipeline, it is essential to prepare the trench by removing large stones, adhering to the longitudinal profile dimensions (ground levels), and carefully leveling the trench bottom to ensure a solid base for the pipeline.

VII.2.3 Backfilling of Trenches:

- Once the pipeline is correctly positioned in the trench on the sand bed, the previously excavated soil can be used as backfill.
- This operation involves filling the trench with the excavated backfill to bury the pipeline and hold it in place.

VII.2.4 Leveling and Compaction:

- After backfilling, leveling is necessary, meaning uniformly spreading the soil that was used as backfill, especially if it forms mounds.
- Subsequently, the soil must be compacted, mechanically compressing it to increase its density.
- **Soil Compaction**: Soil compaction is essential to prevent soil settlement over time, which could damage the pipeline or cause subsidence. These steps are crucial to ensure the stability and durability of the pipeline installation in the ground.

VII.2.5 Volume of Deep Irrigation Network Works and Trench Depth

- The trench depth must allow for the correct execution of specific connections and prevent contact with other pipelines.
- The trench depth (Htr) is calculated as follows:

VII.3 Excavation Volume

VII.3.1 Trench Dimensions

VII.3.1.1 Trench Bottom Width

The width of the trench will depend on the diameter of the pipe, applying the following formula:

The trench width (B) is calculated as follows:

$$B = D + 0.6 \qquad (VII.1)$$

Where:

- B: represents the trench width in meters.
- D: represents the pipe diameter in meters.

VII.3.1.2 Trench Depth

The depth of the pipe must be selected to allow proper installation of specific connections while avoiding any conflicts with other conduits. The trench depth is calculated using the following formula:

$$Htr = e + D + h \qquad (VII.2)$$

- Htr: represents the trench depth in meters.
- e: corresponds to the height of the bedding in meters.
- D : denotes the pipe diameter in meters.
- h : represents the height of the backfill above the pipe in meters.

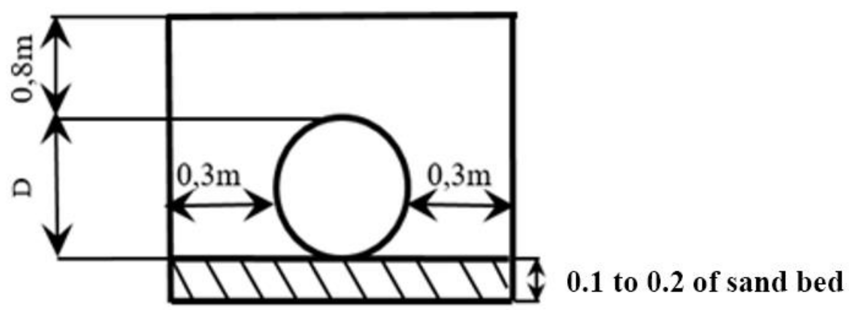

Figure VII.1: Trench Diagram

VII.3.1.3 Trench Cross-Section

The dimensions of the trenches are defined as follows:

$$Str = Htr \times B \qquad (VII.3)$$

With the following parameters :

- Htr: represents the total depth of the trench in meters.
- B: denotes the bottom width of the trench in meters.

VII.3.1.4 Trench Volume

The calculation of the trench volume is done using the following relation:

$$V\text{tr} = Str \times L \qquad (VII.4)$$

With :

- Vtr : represents the excavation volume in cubic meters.
- Str : is the cross-section of the trench in square meters.
- L : corresponds to the length of the trench in meters.

VII.3.2 Calculation of Excavation Volumes

VII.3.2.1 Excavation Volume

The excavation of a trench corresponds to the materials extracted from the ground to allow the installation of the pipes, and its calculation is done as follows:

$$\text{Vexcavation} = V\text{tr} = B \times H\text{tr} \times L \qquad (VII.5)$$

With:

- B: trench width (m).
- Htr: trench depth (m).
- L: trench length (m).

VII.3.2.2 Sand Bedding Volume

The sand bedding is a horizontal layer composed of sand that serves to establish a solid base, and its calculation is done using the following relation:

$$Vls = e \times B \times L \qquad (VII.6)$$

Using the following parameters :

- Vls : the volume of the sand bedding in cubic meters.
- e : the thickness of the sand bedding layer in meters.
- B : the width of the trench in meters.
- L : the length of the trench in meters.

VII.3.2.3 Volume Occupied by the Pipe

It is determined using the following formula:

$$\text{Vcon} = \text{Scon} \times L = \frac{\pi \times D^2 \times L}{4} \qquad (VII.7)$$

- Vcon : the volume occupied by the pipe (in cubic meters).
- Scon : the cross-section of the pipe (in square meters).
- L : the length of the trench (in meters).
- D : the outer diameter of the pipe (in meters).

VII.3.2.4 Backfill Volume

The backfill corresponds to the amount of soil required to fill a trench and return it to its original level. This volume is determined using the following formula:

$$\text{Vbac} = \text{Vexc} - (Vls + \text{Vcon}) \qquad (VII.8)$$

- Vbac : the backfill volume (in cubic meters).
- Vexc : the excavation volume (in cubic meters).
- Vls : the sand bedding volume (in cubic meters).
- Vcon : the volume occupied by the pipe (in cubic meters).

The calculation of excavation, sand, and backfill volumes for the distribution network is presented in Table:

Table VII.1: Calculation of Various Volumes

Tubes	**Length**	**Width**	**Height**	**Excavation volume**	**Sand volume**	**Conduits Volume**	**Backfill volume**
Buried	(m)	(m)	(m)	(m3)	(m3)	(m3)	(m3)
Distribution pipe							
50	190	0.65	0.95	117.33	12.35	0.37	104.98
63	341	0.663	0.963	217.72	22.61	1.06	195.11
75	68	0.675	0.975	44.75	4.59	0.30	40.16
80	168	0.68	0.98	111.96	11.42	0.84	100.53
90	24	0.69	0.99	16.39	1.66	0.15	14.73
110	697	0.71	1.01	499.82	49.49	6.62	450.32
125	10	0.725	1,025	7431.25	0.73	0.12	7430.51
250	553	0.85	1.15	540.56	47.01	27.13	493.50
280	188	0.88	1.18	195.22	16.54	11.57	178.61
315	761	0.91	1.2	831.01	69.25	59.28	761.68
355	352	0.95	1.25	418.00	33.44	34.82	384.46
400	667	1	1.3	867.10	66.70	83.78	800.27
450	90	1.5	1.35	182.25	13.50	14.31	168.59
			Sum	11,474.23	349	241	11,124.00

VII.4 Project Cost Calculation

- The cost per cubic meter of excavation is 450 Algerian Dinars (DA).
- The rate per cubic meter of backfill is 300 Algerian Dinars (DA).
- The price per cubic meter of sand is 1200 Algerian Dinars (DA).

Table VII.2: Estimation of Excavation Works Cost

Type of Work	Unit of Measurement	Quantities	Unit Price (DA)	Amount (DA)
Excavation	M3	11,474.23	450	5,163,403.50
Backfill	M3	11,124.00	300	3,337,200.00
Sand	M3	349	1200	419136
			Total Price (Excl. Tax)	**8,919,739.50**
			Total Price (Incl. Tax)	**10,614,490.01**

VII.4.1 Distribution Network Cost

This includes all HDPE pipes with diameters ranging from 50 mm to 315 mm, CAST IRON from 400 mm to 450, as well as irrigation water distribution terminals.

Table VII.3: Estimation of distribution network

Diameter (mm)	Unit of measurement	Quantity (m)	Unit price (DA/m)	Amount (DA)
50	ml	190	106	20186
63	ml	341	170	57851
75	ml	68	239	16230
80	ml	168	290	48794
90	ml	24	314	7540
110	ml	697	626	436322
125	ml	10	771	7710
250	ml	553	2960	1636880
280	ml	188	3262	613256
315	ml	761	4703	3578983
355	ml	352	4703	1655456
400	ml	667	14910.06	9945010
450	ml	90	17513.76	1576238
Sprinklers	U	3	600	1800

50mm Ramps	ML	605	80.77	48866
110mm Ramp Doors	ML	197	812.5	160063
Drippers	U	5300	45	238500
16mm Ramps	ML	10428	55.87	582612
110mm Ramp Doors	ML	265	812.5	215313
Valves	U	2	1400	2800
Irrigation terminals		26	100000	2600000
Special pieces		50	9500	475000
			Total	**23925409**
			Tax (19%)	**4545828**
			Amount including tax	**28471236**

VII.4.2 Total Project Cost

This is the sum of various prices calculated earlier.

Table VII.4: Project Total Cost Estimation

Works	Amount (DA)
Distribution network	28,471,236.00
Adduction: Pipes and Special pieces	10,614,490.00
Total Amount (including tax)	**39,085,726.00**

The project amount is thirty-nine million, eighty-five thousand, seven hundred twenty-six.

VII.5 The use of personal protective equipment is essential for ensuring better safety on a construction site

The use of personal protective equipment (PPE) is crucial to enhance safety on a construction site. These devices, such as helmets, gloves, safety shoes, protective glasses, and masks, are of utmost importance to prevent potential hazards. Here are some key points regarding these safety equipments:

- **Helmets**: They are now more comfortable, even in hot weather, which facilitates their mandatory use. It is crucial to ensure that helmets are in good condition, comply with current standards, and have not exceeded their recommended usage date. When working at heights, securing the helmet's chin strap is imperative to prevent it from falling.

- **Safety Shoes**: There is currently a wide range of safety shoes offering protection against impacts and aggressive agents such as fire or chemicals. It is recommended to choose shoes with non-slip soles and antibacterial treated interiors.
- **Gloves**: Hands are the body parts most exposed to injuries during work accidents. It is essential to choose gloves that fit the user's hand size and are suitable for the type of work and risks encountered (cuts, punctures, vibrations, allergies, chemicals). Gloves should comply with current standards and be properly maintained.
- **Protective Glasses**: Eye accidents represent 3% of work accidents and could easily be avoided by wearing appropriate protective glasses.
- **Protective Masks**: Solid particles, aerosols, liquids, vapors, and gases can be particularly harmful. Using appropriate respiratory protective equipment, such as cartridge masks, prevents the inhalation of these substances. For hot work, cartridge filter masks are recommended, while for cold work, disposable half-filter masks can be used.

It is imperative to use this personal protective equipment correctly and regularly to ensure the safety of workers on the construction site.

VII.6 Collective Protection on a Construction Site

Collective safety encompasses various aspects related to the protection of workers. Here are some crucial points to consider:

Earthworks

Earthworks involve specific risks such as the movement of machinery, collapses, the rupture of underground pipes, the use of explosives, and the fall of materials or people into excavations, which require preventive measures.

- The use of trench shoring is essential to prevent wall collapses during trench work.
- It is strictly forbidden to enter an unshored trench, whether to install shoring or to perform work.
- A proper safety distance must be maintained between the edge of the trench and the materials.

Machines and Tools

- Machines used for handling materials (wood, metal), cement mixers, welding or cutting devices, cranes, excavators, etc., must be operated and maintained by competent people trained for these operations.
- The instructions for use and maintenance must be strictly followed.
- Machines must be turned off for all cleaning and maintenance work.
- It is essential not to exceed the maximum load indicated on lifting equipment.
- Avoid being in the operating area of lifting and earthmoving equipment to prevent accidents due to collisions or falling materials.
- After a shock or fall, portable power tools must not be used until they have been checked by a competent person.
- Portable power tools should not be used outdoors in rainy weather

Electrical Installations

- Only qualified and designated electricians are authorized to install, modify, repair, and maintain electrical installations.
- When work is carried out near overhead lines or underground cables, it is imperative to maintain the recommended safety distances.
- These collective protection measures are essential to ensure the safety of workers on the construction site and to prevent accidents.

Conclusion

This chapter focused on evaluating the costs associated with each component used in our study. We began by estimating the costs for the volumes of sand, excavation, and backfill. Subsequently, we included the costs for all the pipes utilized, such as the supply pipes and network conduits.

We then moved on to assess the costs of the terminals, valves, and the drip and sprinkler irrigation systems. To demonstrate our approach, we provided an example for two plots that we sized, indicating that the same methodology will be applied to other plots.

By following this method, we were able to produce both quantitative and financial estimates. Consequently, we calculated the total project cost, which amounts to **39,085,726.00** **DA**.

GENERAL CONCLUSION

In this study, we examined the various components of the Zouia irrigation project and conducted detailed analyses of the irrigation system to develop 170 hectares of land using water from the Zouia dam. Our research on the regional climate reveals a semi-arid environment with a dry period lasting over seven months, highlighting the critical need for irrigation to maintain acceptable agricultural yields. The soil in the area is classified into three categories, enabling the selection of the most appropriate crops for cultivation.

The use of the Mann-Whitney U test is recommended for adjusting the annual precipitation averages at the Magnia station to ensure better accuracy

Studying the water needs of crops is crucial for designing an economical irrigation network, with an annual gross availability of approximately 2,428,680 m3 of irrigation water from the Zouia dam.

After calculating this flow rate, we were able to dimension the distribution network, which includes:

- 26 plots with 26 terminals.
- Pipes range in diameter from 50 mm to 400 mm.

Regarding the verification of flow velocity in the pipes and pressure at the outlets, the following results were defined:

- Flow velocity varies between 1 to 1.5 m/s
- Pressure ranges from 8.39 to 1.09 bars

These two results are acceptable and valid for all irrigation systems.

The choice of irrigation method depends on the crops, favoring drip irrigation for trees and vegetable crops, as well as sprinkler systems for cereal crops.

To meet the technical and budgetary criteria of our project, we conducted a comprehensive project management analysis. This analysis revealed that the implementation of our project will require estimated costs amounting to 39,085,726.00 Algerian Dinars (DA)

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APPENDIX I

Texture	Moisture at Field Capacity (HCC)	Moisture at Wilting Point (HPF)	Available Water Content (HCC - HPF)
Sandy	9% (6 to 12)	4% (2 to 6)	85% (70 to 100)
Silty Loam	14% (10 to 18)	8% (5 to 11)	6% (4 to 6)
Loam	22% (18 to 26)	10% (8 to 12)	12% (10 to 14)
Clay Loam	27% (25 to 31)	13% (11 to 15)	14% (12 to 16)
Silty clay	31% (27 to 35)	15% (13 to 17)	16% (14 to 18)
Clay	35% (31 to 39)	17% (15 to 19)	18% (16 to 20)

Source: FAO Irrigation and Drainage Bulletin Reference

APPENDIX II

SAR/conductivité	Indication
C1-S1	Water usable for most cultivated species and soils.
C1-S2	Water is usable for most cultivated species. Soil should be well-drained and leached.
C1S3	Soil must be well-prepared, well-drained, and leached, with the addition of organic matter. The relative Na content can be improved by adding gypsum.
C1-S4	Water is difficult to use in poorly permeable soils. Soil should be well-prepared, very well-drained, and leached, with the addition of organic matter. The relative Na content can be improved by adding gypsum.
C2-S1	Water suitable for plants with slight salt tolerance. Coarse or organic soil with good permeability.
C2-S2	Water suitable for plants with slight salt tolerance. Coarse or organic soil with good permeability.
C2-S3	Water suitable for plants with some salt tolerance. Coarse soil, well-prepared (good drainage, good leaching, addition of organic matter). Periodic addition of gypsum can be beneficial.
C2-S4	Water is generally not suitable for irrigation.
C3-S1	Water suitable for plants with good salt tolerance. Well-prepared soil (good drainage). Periodic monitoring of salinity evolution.
C3-S2	Water suitable for plants with good salt tolerance. Coarse or organic soil with good permeability, good drainage. Periodic monitoring of salinity evolution. Periodic addition of gypsum can be beneficial.
C3-S3	Species tolerant to salt. Very permeable and well-drained soil.
C3-S4	Water is not suitable for irrigation.
C4-S1	Water is not suitable for irrigation under normal conditions. Can be used if species have good salt tolerance and the soil is particularly well-drained.
C4-S2	Water is not suitable for irrigation under normal conditions. Can be used if species have very good salt tolerance and the soil is particularly well-drained.
C4-S3	Water is not suitable for irrigation.
C4-S4	Water is not suitable for irrigation.

Source: FAO Irrigation and Drainage Bulletin Reference