Precision Irrigation with Cost-effective and Autonomic IoT Devices using Artificial Intelligence at the Edge

D1.2

Recommendations for the design of the irrigation system

Responsible: INRGREF

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1. Introduction

The drying of soil in a field can be attributed to various contributing factors. These factors can vary depending on the specific environmental conditions, geographical location, agricultural practices, and natural phenomena. Here are some common factors that can contribute to soil drying:

Climate and Weather Patterns: The climate of a region, including temperature, precipitation, and evaporation rates, plays a significant role in soil drying. Extended periods of high temperatures and low rainfall can accelerate soil moisture evaporation, leading to drying.

Rainfall Patterns: Insufficient or irregular rainfall can result in inadequate soil moisture replenishment, leading to drying. Factors such as drought, delayed or reduced rainfall, and inconsistent precipitation patterns can contribute to soil moisture deficit.

Soil Type and Structure: The physical properties of soil, including its texture, composition, and structure, influence its water-holding capacity. Soils with higher sand content tend to drain water more quickly, while clay soils have higher water retention capacity. Soil compaction and poor structure can impede water infiltration and availability, exacerbating soil drying.

- Crop Growth: The presence or absence of vegetation cover, such as natural grasses or crops, can impact soil moisture levels. Vegetation acts as a protective layer, reducing evaporation and promoting water retention in the soil. In the absence of adequate vegetation cover, soil drying can occur more rapidly.
- Land Management Practices: Agricultural practices and land management techniques can influence soil moisture levels. Factors such as over-irrigation, improper irrigation scheduling, inadequate drainage, and excessive tillage can contribute to soil drying. Improper water management practices may lead to inefficient water use, resulting in soil moisture depletion.
- Topography and Slope: The topography of a field, particularly its slope, affects water runoff and infiltration rates. Steep slopes can lead to increased water runoff, reducing soil moisture content. In contrast, flat or low-lying areas may experience poor drainage, which can contribute to prolonged soil moisture saturation followed by drying.
- Groundwater Level: The depth and availability of groundwater in a region can impact soil moisture content. If the groundwater level is too low or if there is limited access to groundwater for irrigation purposes, soil drying can occur, especially during dry seasons or periods of water scarcity.
- Human Factors: Human activities, such as deforestation, land clearing, and improper land use practices, can contribute to soil drying. These activities can disrupt natural ecosystems, alter water cycles, and reduce vegetation cover, leading to increased soil moisture loss.

It is important to note that these factors are interrelated, and their combined influence determines the extent of soil drying in a field. Understanding these contributing factors can assist in implementing appropriate soil moisture conservation strategies, efficient irrigation practices, and sustainable land management approaches to mitigate soil drying and maintain optimal soil moisture levels for healthy plant growth and ecosystem sustainability.

2. State of the Art

2.1. Preliminary

Understanding soil moisture is crucial for agriculture, as it directly impacts plant growth and crop productivity. Several key concepts play vital roles in comprehending the dynamics of soil moisture.

Saturation (S) : Saturated water content is the maximum amount of water a soil can store. It is closely related to the total soil porosity. That is, if a soil is 50 % solids (soil particles & organic matter) then the remaining 50% is porosity that can store water. In this case a soil, let say 10 cm deep can hold 5 cm of water as the maximum or saturated soil moisture content.

Field Capacity (FC) : is the amount of water in the soil held by sorption and capillary force (around 2.24 pF, 0.33 bars or 4.79 psi). In this water capacity all soil capillary pores (pores with 0.2-10 µm) are filled with water. In nature this happens after 24-48 hours after total soil saturation.

Permanent Wilting Point (PWP) : is the amount of water in soil held by force stronger than 15 bar, 4.2 pF or 225 psi, it represents the minimum point of plant available water.

Total available soil moisture (FC-PWP): is the water content between the field capacity and the wilting point expressed in (mm/m of soil).

Initial Soil moisture depletion (as % TAM): The initial available water is automatically calculated based on the % TAW depletion. This parameter makes it possible to start the simulation on water content different from the field capacity.

Understanding these concepts helps in managing irrigation, assessing soil fertility, and determining suitable crops for specific soil conditions. Farmers and agronomists use this knowledge to optimize water use and maximize crop yield.

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. The partitioning of evapotranspiration into evaporation and transpiration is plotted in correspondence to leaf area per unit surface of soil below it. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration.

Crop evapotranspiration under standard conditions (ETc) refers to the evaporating demand from crops that are grown in large fields under optimum soil water, excellent management and environmental conditions, and achieve full production under the given climatic conditions. We can identify it by the agroclimatic method. It is used to estimate the crop's needs and to monitor the irrigation.

Actual evapotranspiration (ETR) is the amount of water removed from a surface (by soil and plants) due to the process of evaporation and transpiration when water runs out. Plants are at a specific stage of physiological and health development. It is the real water consumed by a crop. We can calculate the ETR using the water balance method.

Reference crop evapotranspiration (ET_o)

The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o. The reference surface is a hypothetical grass reference crop with specific characteristics. The use of other denominations such as potential ET is strongly discouraged due to ambiguities in their definitions. The concept of the reference evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at the reference evapotranspiration surface, soil factors do not affect ET. Relating ET to a specific surface provides a reference to which ET from other surfaces can be related. It obviates the need to define a separate ET level for each crop and stage of growth. ET_o values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface.The only factors affecting ET_o are climatic parameters. Consequently, ET_o is a climatic parameter and can be computed from weather data. ET_o expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The FAO Penman-Monteith method is recommended as the sole method for determining ET_o. The method has been selected because it closely approximates grass ET_o at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters. Moreover, procedures have been developed for estimating missing climatic parameters.

Crop evapotranspiration under standard conditions (ET_c)

The crop evapotranspiration under standard conditions, denoted as ET_c, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions.

The amount of water required to compensate for the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application. Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors in the Penman-Monteith approach. As there is still a considerable lack of information for different crops, the Penman-Monteith method is used for the estimation of the standard reference crop to determine its evapotranspiration rate, i.e., ET_o. Experimentally determined ratios of ET_c/ET_o, called crop coefficients (K_c), are used to relate ET_c to ET_o or $ET_c = K_c\ ET_o$.

Differences in leaf anatomy, stomatal characteristics, aerodynamic properties and even albedo cause the crop evapotranspiration to differ from the reference crop evapotranspiration under the same climatic conditions. Due to variations in the crop characteristics throughout its growing season, K_c for a given crop changes from sowing till harvest.

Crop evapotranspiration under non-standard conditions ($ET_{c\ adj}$)

The crop evapotranspiration under non-standard conditions ($ET_{c\ adj}$) is the evapotranspiration from crops grown under management and environmental conditions that differ from the standard conditions. When cultivating crops in fields, the real crop evapotranspiration may deviate from ET_c due to non-optimal conditions such as the presence of pests and diseases, soil salinity, low soil fertility, water shortage or water logging. This may result in scanty plant growth, low plant density and may reduce the evapotranspiration rate below ET_c.

The crop evapotranspiration under non-standard conditions is calculated by using a water stress coefficient K_s and/or by adjusting K_c for all kinds of other stresses and environmental constraints on crop evapotranspiration.

Owing to the difficulty of obtaining accurate field measurements, ET is commonly computed from weather data. A large number of empirical or semi-empirical equations have been developed for assessing crop or reference crop evapotranspiration from meteorological data. Some of the methods are only valid under specific climatic and agronomic conditions and cannot be applied under conditions different from those under which they were originally developed.

Numerous researchers have analyzed the performance of the various calculation methods for different locations. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration, ET_o. The ET from crop surfaces under standard conditions is determined by crop coefficients (K_c) that relate ET_c to ET_o. The ET from crop surfaces under non-standard conditions is adjusted by a water stress coefficient (K_s) and/or by modifying the crop coefficient.

File Crop:

For the three experimental sites (S1, S2 and S3), we must enter the following crop parameters: For the first step (Campaign 1) we can use data from FAO (Irrigation and Drainage Paper No. 24). For the second step (Campaign 2), and the last step of validation (Campaign 3), we must use real data in a Tunisian regional context.

✓ **Crop coefficients (Kc):** Kc ini ; Kc mid and Kc end . Changes in vegetation and ground cover mean that the crop coefficient Kc varies during the growing period. The trends in Kc during the growing period are represented in the crop coefficient curve. Only three values for Kc are required to describe and construct the crop coefficient curve: those during the initial stage (Kc ini), the mid-season stage (Kc mid) and at the end of the late season stage (Kc end).

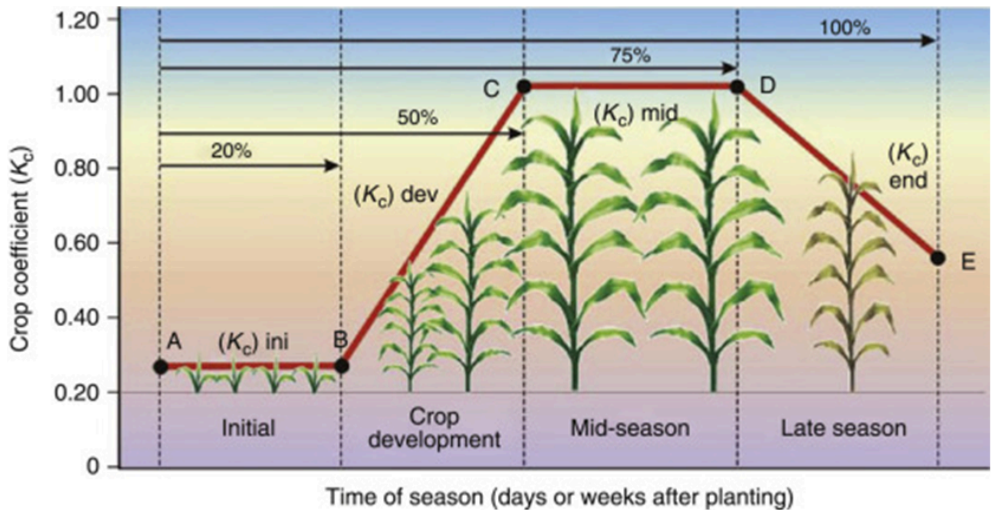


Figure 1: *Crop coefficient during cropping cycle*

✓ **Length of growth stages (days):**

NB/ Lengths of crop development stages provided in table FAO Irrigation and Drainage Paper No. 24 are indicative of general conditions, but may vary substantially from region to region, with climate and cropping conditions, and with crop variety. The user is strongly encouraged to obtain appropriate local information.

Stage	**Indicators**	**Crop Coefficient**
Initial	Planting date (or the start of new leaves for perennials) to 10% ground cover.	Kc ini
Development	10% ground cover to effective full cover, about 60-70% coverage for tree crops and 70-80% for field and row crops.	Kc ini – Kc mid
Mid season	Effective full cover to maturity, indicated by yellowing of leaves, leaf drop, browning of fruit. This stage is long for perennials but relatively short for vegetable crops that are harvested for their fresh fruit.	Kc mid
Late Season	Maturity to harvest: the Kc value could be high if the crop is irrigated frequently until fresh harvest or low if the crop is allowed to dry out in the field before harvest.	Kc mid –Kc end

The table 2 represents the mean Kc values reported for Citrus crop from differents authors according to A. Abu Ali et al. 2022.

Table 2 : Mean Kc values reported for Citrus orchard in published studies.

Month	Local Kc act values	(Rana et al., 2005)	(Er-Raki et al., 2009)	(Bouazzama et al., 2008)	(Heitz et al., 2011)	(Consoli and Papa, 2013	(Maestre-Valero et al., 2017)
1	0.62	0.90	0.50		0.75	0.70	1.80
2	0.49	0.90	0.60	0.54	0.60	0.88	0.80
3	0.56	1.10	0.70	0.50	0.65	0.57	0.60
4	0.62	1.10	0.75	0.55	0.65	0.52	0.40
5	0.63	1.10	0.75	0.80	0.65	0.58	0.54
6	0.64	1.10	0.75	0.88	0.70	0.60	0.49
7	0.61	1.00	0.75	0.88	0.70	0.61	0.49
8	0.63	0.95	0.60	0.88	0.70	0.68	0.58
9	0.65	0.90	0.50	0.54	0.70	0.84	0.74
10	0.72	0.90	0.40	0.54	0.70	0.86	1.06
11	0.63	0.90		0.54	0.65	0.95	1.15
12	0.76	0.90			0.65	0.61	1.12

Source: A. Abou Ali et al. (2022).

2.2. Rooting depth (m).

Critical depletion (fraction): p average fraction of Total Available Soil Water (TAW) that can be depleted from the root zone before moisture stress (reduction in ET) occurs.

NB/ The fraction p is a function of the evaporation power of the atmosphere. At low rates of ETc, the p values listed in Table FAO Irrigation and Drainage Paper No. 24 are higher than at high rates of ETc. For hot dry weather conditions, where ETc is high, p is 10-25% less than the values presented in Table 22, and the soil is still relatively wet when the stress starts to occur. When the crop evapotranspiration is low, p will be up to 20% more than the listed values. Often, a constant value is used for p for a specific growing period, rather than varying the value each day. A numerical approximation for adjusting p for ETc rate is p = p Table 22 + 0.04 (5 - ETc) where the adjusted p is limited to $0.1 \leq p \leq 0.8$ and ETc is mm/day.

The values for p apply for ETc » 5 mm/day. The value for p can be adjusted for different ETc according to p = p table 22 + 0.04 (5 - ETc) where p is expressed as a fraction and ETc as mm/day.

✓Yield response F: Factor that links the decline in yield to the deficit evapotranspiration (FAO Irrigation and drainage paper 33 and paper 66)

✓ Crop height (m): Adjusts Kc mid and Kc end to local conditions.

File soil:

For the three experimental sites (S1, S2 and S3), we must enter the following soil parameters:

✓ Total available soil moisture (FC-WP): i.e. the water content between the field capacity and the wilting point expressed in (mm/m of soil).

✓Maximum rain infiltration rate (mm/day).

✓Maximum Rooting depth (cm): The depth where there is an impermeable soil horizon. This parameter makes it possible to limit the root depth of the crop if the rooting depth is less than the root depth of the crop.

✓Initial Soil moisture depletion (as % TAM). The initial available water is automatically calculated based on the % TAW depletion. This parameter makes it possible to start the simulation on water content different from the field capacity.

✓ Initial available soil moisture (mm/meter).

2.3. Irrigation systems

Tunisia, located in North Africa, utilizes various irrigation techniques to support its agricultural sector. Here are some of the commonly used irrigation techniques in Tunisia:

Surface Irrigation: This technique involves distributing water over the soil surface and allowing it to infiltrate and move across the field by gravity. It can be implemented through methods such as furrow irrigation, border irrigation, or basin irrigation. Surface irrigation is commonly used for crops like cereals, vegetables, and fruit trees in Tunisia.

Sprinkler Irrigation: Sprinkler irrigation involves distributing water through a system of pipes and sprinklers that spray water over the crops. This technique is suitable for a wide range of crops and is used in Tunisia for irrigating fruits, vegetables, and some field crops. Sprinkler irrigation helps conserve water by reducing evaporation and can be effective in areas with varying topography.

Drip Irrigation: Drip irrigation, also known as micro-irrigation, involves delivering water directly to the plant root zone through a network of small tubes and emitters. This technique provides water in a controlled and precise manner, minimizing water loss through evaporation or runoff. Drip irrigation is widely used in Tunisia, especially for high-value crops like vineyards, olive orchards, and vegetables.

Subsurface Irrigation: Subsurface irrigation involves delivering water directly to the root zone of plants, below the soil surface. It can be achieved through methods such as buried clay pot irrigation or buried pipe irrigation. Subsurface irrigation helps reduce water loss and is suitable for crops with shallow roots. Although not as common as other techniques, it may be employed in specific areas of Tunisia.

Center Pivot Irrigation: Center pivot irrigation involves a circular or semi-circular system with a pivoting arm that rotates around a central point, irrigating the crops in a circular pattern. This technique is commonly used for large-scale agriculture, particularly for field crops such as cereals or forage crops in Tunisia. It allows for efficient water and nutrient distribution over large areas.

These irrigation techniques are used in different regions of Tunisia based on factors such as crop type, soil conditions, water availability, and farm size. The choice of technique depends on various factors, including the efficiency of water use, crop water requirements, and economic considerations.

Tunisia has been actively exploring and implementing various initiatives related to water management and agricultural practices, although specific notable experiences in smart irrigation may vary. However, there are some initiatives and projects that highlight efforts toward efficient water use in agriculture:

1. Tunisian Ministry of Agriculture's Initiatives: The Tunisian government has been promoting efficient water management in agriculture. Programs supported by the Ministry of Agriculture, such as the National Water Saving Program for Irrigation, focus on educating farmers about water-saving techniques and technologies.

2. Research and Innovation: Tunisian research institutions, in collaboration with international organizations and universities, have been involved in research and innovation related to smart irrigation. Projects aimed at developing improved irrigation systems suitable for the region's conditions have been underway.

3. Private Sector and NGO Initiatives: Several private sector companies and non-governmental organizations (NGOs) in Tunisia have also been involved in introducing modern irrigation technologies and practices to farmers. These initiatives often focus on introducing drip irrigation systems, soil moisture sensors, and training programs.

4. Pilot Projects and Demonstrations: There have been pilot projects and demonstrations of smart irrigation technologies in certain regions of Tunisia. These projects aim to showcase the benefits of efficient irrigation methods, encourage adoption among local farmers, and collect data for further improvements.

5. International Collaboration: Tunisia has collaborated with international organizations, such as the Food and Agriculture Organization (FAO) and the World Bank, to implement water management and agricultural projects. These collaborations often include aspects of smart irrigation and sustainable water use.

While there might not be a singular widely recognized initiative in smart irrigation, Tunisia has been gradually incorporating elements of efficient water management into its agricultural practices. The country continues to explore and adopt technologies and practices that promote sustainable and efficient use of water resources in agriculture.

2.4. Tensiometer usage

Tensiometers are devices used to measure soil water tension or suction, providing information about the soil's water availability to plants. In irrigation, tensiometers play a crucial role in determining when and how much to irrigate by directly measuring the soil moisture status. However, their usage in modern irrigation practices has somewhat evolved, and other technologies are also employed alongside or instead of tensiometers.

The choice of root depth for deploying soil moisture sensors, including tensiometers, depends on the crop type, the specific rooting patterns of the plants, and the soil characteristics. Different crops have varying root depths, and understanding these depths is crucial for effective sensor placement.

The goal is to place sensors at depths that correspond to the active root zone of the plants. This ensures that the measurements represent the moisture availability where the roots are actively extracting water. Collaboration with agronomists, considering the specific crop's root behavior, and monitoring soil profiles can aid in determining the appropriate depths for sensor deployment.

Water content and water potential are related as shown in Figure below for five soils of differing textures. In general, as clay content increases, the soil water content increases for a given soil moisture potential. The reason for this is that clayey soils have a higher porosity, and can hold on to more water at a given soil water potential Loamy soils have the largest plant available water content as well as relatively equally sized gravitational and unavailable water contents. For this reason, loam and silt loam soils are highly prized for agricultural production; they drain excess water quickly, have a large plant-available water content, and are not prone to drought conditions.

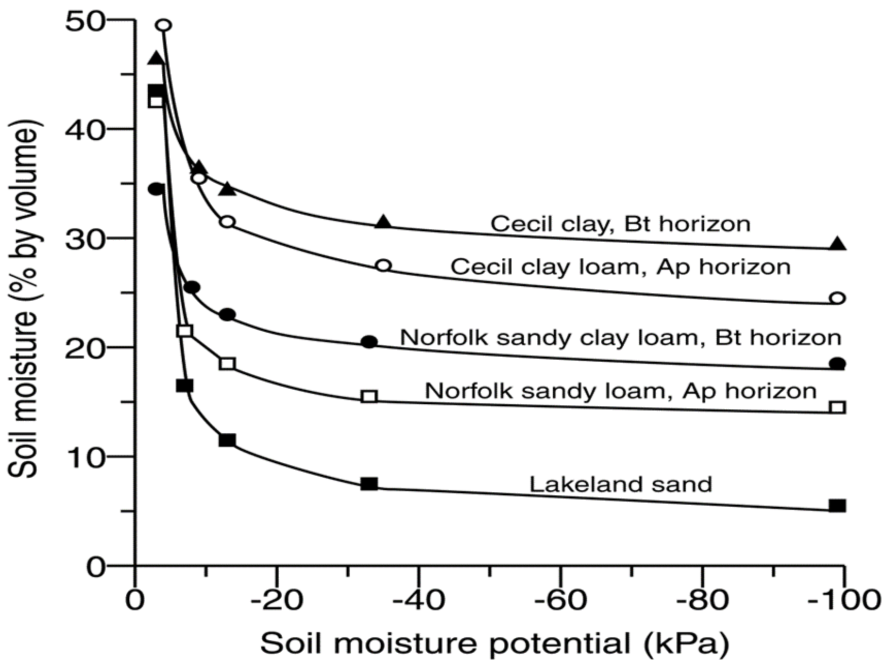


Figure. Relationship between moisture content and moisture potential for three soils down to -100 kPa.

Source: from King et al. (2003).

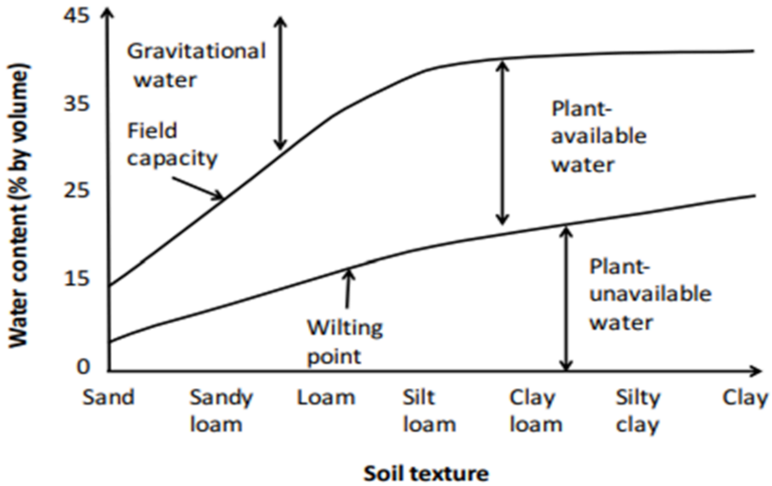


Table 4. Recommended SMP values at MAD for selected crops.

Type of Crop	SMP (kPa or cb)
Citrus	50 - 70
Small grain - Vegeta stage	40-50
Small grain - Ripening	70-80

Source: Hanson et al. (2000)

The 3 horizontal arrows noted "RU" in Figure below indicate the useful moisture range for each soil type. We see that for the coarse sandy soil it is between 0.07 and 0.1 or 3% of volume moisture. For sandy-loamy soil it is between 0.15 and 0.30 or 15%, and for loamy-clay soil between 0.23 and 0.43 or 20%. These figures only illustrate a very general well-known phenomenon: the finer the texture, the greater the soil's capacity to store water.

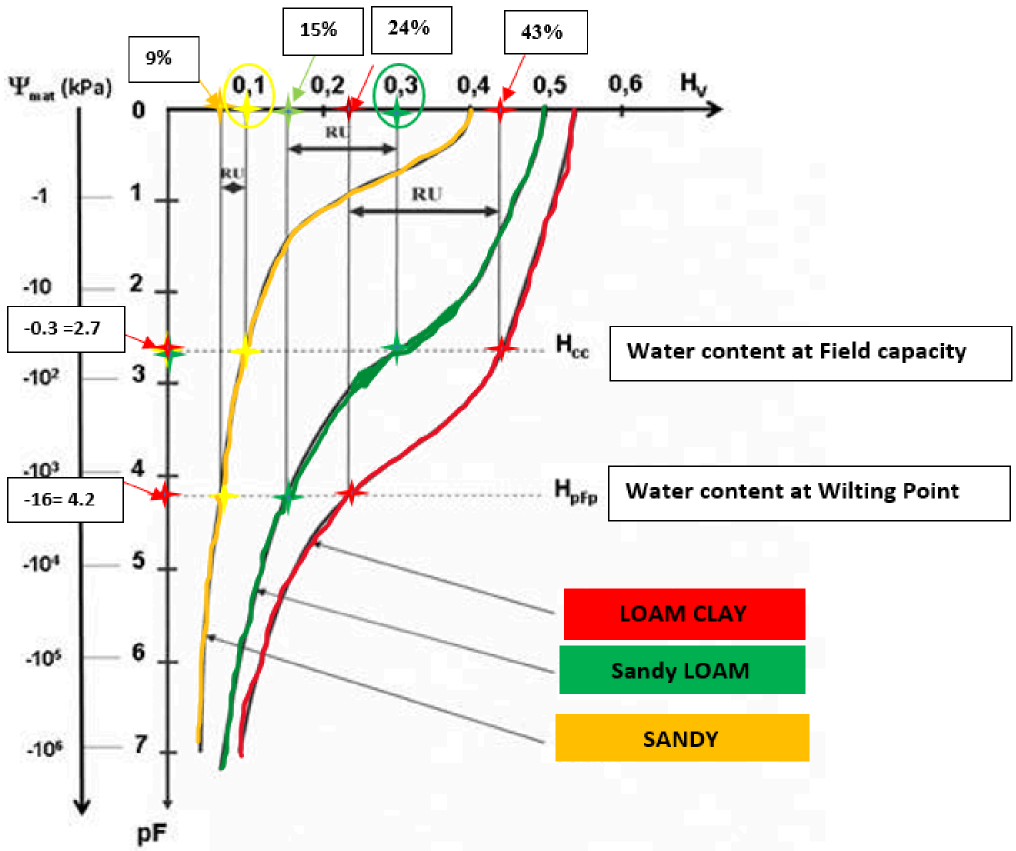
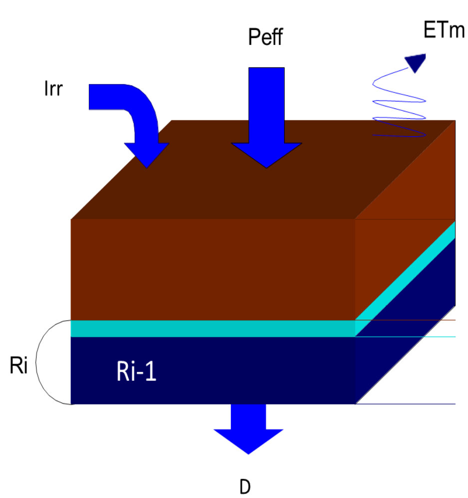


Figure. Example of experimental water potential – volume moisture curves for three soil types. Source: Tessier D. et al, Les relations potentiel hydrique - humidité dans un sol, les plantes et l'eau.



Irrigation scheduling platform will be developed based on the water balance applied at the root zone.

$$R\ i = R\ i\text{-}1 + Peff + Irr - D - ETm$$

R i Soil water reserve on day i (mm)

R i-1 Soil water reserve on day i-1(mm)

P eff Effective precipitation (mm)

Irr irrigation (mm)

D Drainage

ETm Maximum evapotranspiration

Drainage D will be estimated assuming that this phenomenon occurs when the water content at the root zone after rain or irrigation exceeds the water content at field capacity.

The model is:

$$QC < R\ i+1 = R\ i + ((Peff+Irr)\ I - (ETm)\ i) < QC$$

Roughly speaking, a tensiometer reads the following scale of SWT for a medium-texture soil (from C.C. Shock[1]):

- > 80 cb indicates dryness.
- 20 to 60 cb is the average field SWT prior to irrigation, varying with the crop, soil texture, weather pattern, and irrigation system.
- 10 to 20 cb indicates that the soil is near field capacity.
- 0 to 10 cb indicates that the soil is saturated with water.

Soil condition	Loamy sand	Sandy loam	Loam	Silt loam	Clay loam
	Soil water tension (kPa or cb)				
Field capacity	10	15	20	20	25
Typical irrigation threshold	25-30	30-40	35-50	40-60	60-80

Figure X: Typical irrigation thresholds for various soils

"Granular matrix sensors usually are installed in a group of six or seven per irrigation zone".

There is a complex relationship between the soil tension, as measured by the sensors, and the soil water content. It is different for every soil type and varies by region. Soil water content of soils varies by texture, soil organic matter and compaction. Therefore, field capacity and the soils ability to hold water vary and must be determined for each installation. In general, clayey soils contain smaller pores and have a greater ability to retain moisture in the matrix because it takes more energy to extract the water from the matrix. In sandy soils, the pore spaces are large and since water is easily extracted from

[1] https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8900.pdf

large pores, less water is available once the pores have been emptied. The following Figure shows a plot of the relation between soil tension and soil water content.

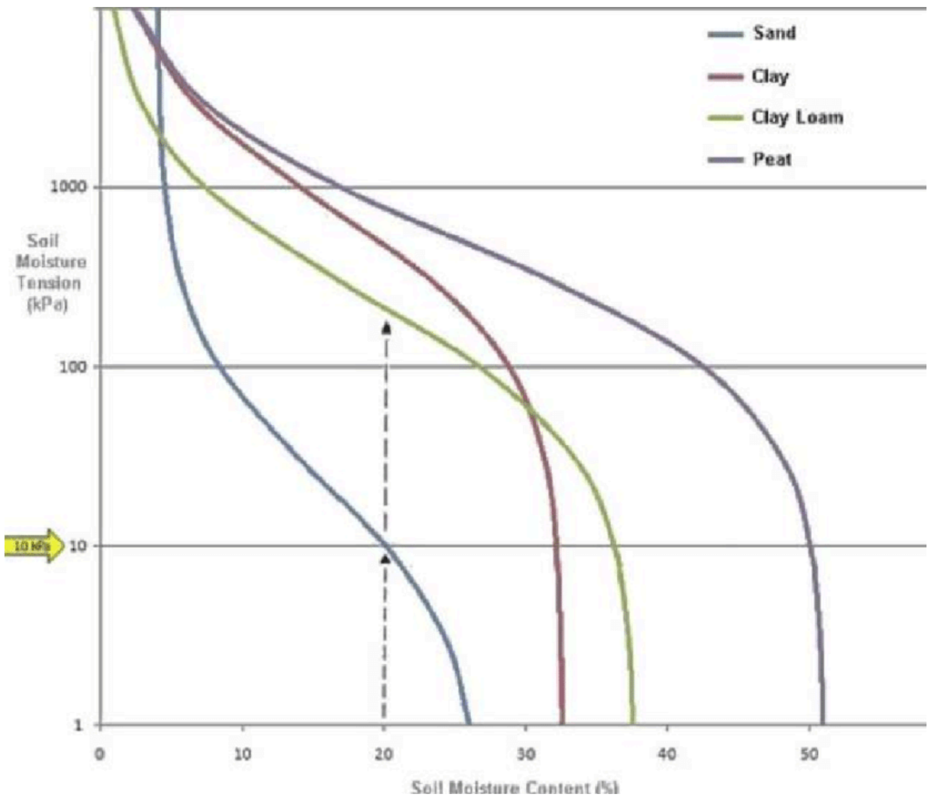
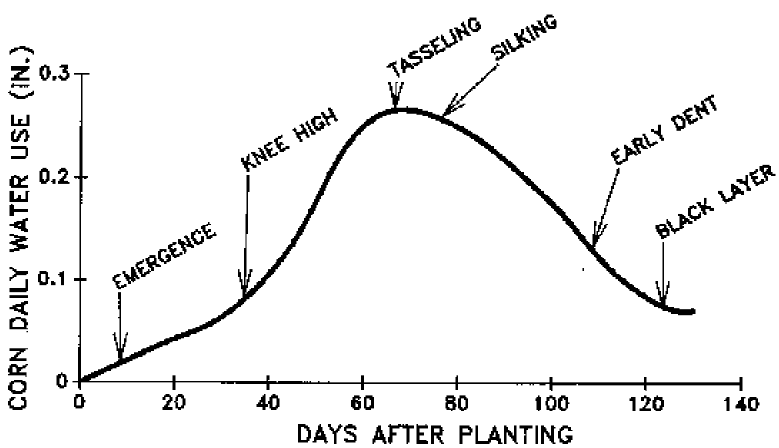


Figure : Courbe PF

As can be seen in the following Figure, the daily water usage is different depending on the crop growth stage.



Using this Figure, we can deduce the quantity of water needed by a particular crop every day. Using the soil water content calculated previously, it becomes easy to deduce the number of days before the soil is depleted.

According to Shock[2], the soil water tension can be closely related to the stress experienced by plant tissues. It thus makes sense to set up a threshold over which irrigation should take place. As mentioned in a paper from the University of Arkansas[3], a conservative over-dry threshold is 60 centibar average for silt loams and clays and 20-35 cb for sandy soils. Those values will be used for the first version of the system.

In our system, we will include a table to calculate the over-dry threshold based on:

- Crop type
- Crop growth stage

The following Table shows examples of threshold values for onion, for different locations and types of soil.

Soil water tension (SWT) as irrigation criteria for onion (*Allium cepa*) bulbs.

SWT (kPa)	Location	Soil type	Irrigation system	Soil moisture sensors, depth	Citation
8.5	Piauí, Brazil	Sandy	Microsprinkler	Tensiometer	Coelho et al., 1996
10	Pernambuco, Brazil		Flood	Tensiometer, gravimetric	Abreu et al., 1980
15	São Paulo, Brazil	Sandy and clay	Furrow	Gravimetric	Klar et al., 1976
10 to 15	Oregon	Silt loam	Drip	GMS 20 cm	Shock et al., 2009
17 to 21	Oregon	Silt loam	Drip	GMS 20 cm	Shock et al., 2000a
27	Oregon	Silt loam	Furrow	GMS 20 cm	Shock et al., 1998a
45	Karnataka, India	Sandy clay loam		Tensiometer, gravimetric	Hegde, 1986
30	Texas	Sandy clay loam	Drip	GMS 20 cm	Enciso et al., 2009

Figure : Soil water tension thresholds for onion (from Shock et al.)

2.5. Threshold based irrigation systems

These systems are measuring the soil water content, and triggers the irrigation when the value measured is below a threshold. They are not making any prediction, just reacting to the values read (like a thermostat).

[2] https://journals.ashs.org/hortsci/view/journals/hortsci/46/2/article-p178.xml
[3] https://www.uaex.uada.edu/publications/pdf/FSA58.pdf

2.6. Prediction based irrigation systems

In the paper "Time Series Forecasting to Support Irrigation Management", Braga et al[4] proposes to predict ET0 based on weather data, using a machine learning technique.

[4] https://periodicos.ufmg.br/index.php/jidm/article/view/12741

3. Recommendations

When considering smart irrigation systems for deployment in Tunisia, several factors need attention:

1. Drip Irrigation Systems: Drip irrigation is cost-effective and suitable for arid or semi-arid regions like Tunisia. It reduces water usage by delivering water directly to plant roots, minimizing evaporation and wastage. These systems vary in complexity and cost, offering options for different scales of agriculture.
2. Soil Moisture Sensors: Deploying soil moisture sensors helps in precise water management. Opt for sensors that are durable, accurate, and compatible with local soil types. Wireless or IoT-enabled sensors offer convenience and real-time data access.
3. Weather Forecast Integration: Choose systems that can integrate local weather forecasts. This feature aids in adjusting irrigation schedules based on predicted rainfall or temperature changes, optimizing water usage.
4. Ease of Installation and Maintenance: Prioritize systems that are easy to install and maintain. Simple setup and maintenance procedures reduce reliance on specialized technicians, making them more accessible to farmers.
5. Affordability and Cost-Effectiveness: Look for systems that offer a balance between cost and features. While initial investment might be higher for smart systems, long-term savings in water usage and improved crop yield should be considered.
6. User-Friendly Interface: Ensure the system has an intuitive interface. User-friendly dashboards or mobile apps for remote monitoring and control make it easier for farmers to manage irrigation schedules and access data.
7. Scalability and Adaptability: Systems that can scale according to farm sizes and are adaptable to different crops and soil types are advantageous. This ensures versatility and suitability for various agricultural practices in Tunisia.
8. Local Support and Training: Opt for systems supported by local agencies or companies that offer training and technical support. This helps farmers in utilizing the system effectively and troubleshooting issues.
9. Energy Efficiency: Consider systems that are energy-efficient, especially if relying on powered components. Solar-powered options can be beneficial in regions with abundant sunlight.
10. Compatibility with Existing Infrastructure: Check for compatibility with existing irrigation infrastructure to ease integration and minimize additional costs.

Tailoring a smart irrigation system to fit Tunisia's specific needs involves considering these factors to ensure it's cost-effective, easy to deploy, and sustainable for the local agricultural landscape. Collaboration with local stakeholders and pilot testing can help in selecting the most suitable system for widespread adoption.