Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

Deliverable D1.1

Status, needs and constraints of small-scale farms with regards to connected irrigation system features

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Contributors table

DOCUMENT SECTION	AUTHOR(S)	REVIEWER(S)
SECTION 1	Kechar B. & Baraka K.	P. Congduc
SECTION 2	Benkhelifa M. & Benabdelouahab T..	P. Congduc
SECTION 3	Kechar B., Benabdelouahab T. & Benkhelifa M.	P. Congduc
SECTION 4	Kechar B. & Baraka K.	P. Congduc

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Executive Summary

Deliverable D1.1 is entitled "Status, needs and constraints of small-scale farms with regards to Connected Irrigation System (CIS) features". The document starts by giving an introduction on the concept of connected irrigation (CI), then it reviews some statistical data on irrigation practices in Algeria and Morocco. After that, it presents successively the needs and constraints for CIS in small-scale agriculture; and the application of CIS in local technological context.

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1. Introduction

1.1. Introduction to Precision Agriculture

To meet the enormous need for food and achieve food security for humanity, with the increasing challenge of biotic and abiotic stresses on crops, the introduction and adoption of modern technologies in agriculture in the Maghreb is inevitable. Agriculture, like other industries, has entered the knowledge era, leaving its previous nature which was usually based on resources only. The agriculture of the future will be highly competitive, knowledge-based and market-driven. To face all these new challenges, increasing the productivity level of a pollution-free product is of vital importance. Precision agriculture (PA) is an emerging and very promising new technology that is rapidly spreading in developed countries. PA is conceptualized through a systems approach to reorganize the entire agricultural system for low-input, high-yield, sustainable agriculture. The integration of technological processes and human resources aims to improve cost and quality outcomes.

Precision agriculture presents a new concept of sustainable use of agricultural resources and is defined as a management concept that combines information and communication technologies to manage temporal and spatial changes on the farm. The fundamental objective of PA is to produce more and better while respecting the environment.

1.2. The Irrigation in Precision Agriculture

In order to feed humanity by 2050, irrigation will be paramount in order to guarantee the agricultural production of intensive crops that need water to grow and mature, and to compensate for the lack of water due to climate hazards. This increase in irrigation water needs may lead to conflicts with other uses (human, environmental, industrial needs). In the era of digital technology, scientists are developing innovative methods and techniques to irrigate, while preserving water reserves.

In Algeria, there is a crucial lack of water resources and agriculture consumes a large quantity of good quality water knowing that 70% of the water quantity is available only. Inadequate or poorly designed irrigation can be the source of many problems. In addition, a majority of currently deployed solutions are rudimentary.

In Morocco, competition for access to water resources continues to increase between sectors. In this context, agriculture is considered as the most water-consuming sector with more than 78% of water mobilized, according to the MEMEE (Ministry of Energy, Mines, Water and the Environment), risks facing the problems related to water management. Consequently, this sector is led to increase its productivity by practicing rotations that optimize the use of water efficiently. However, and since water is available to users at a heavily subsidized price, users have no incentive to conserve this resource and it is sometimes overexploited or wasted instead of treating it as a scarce resource (Lionboui et al. al., 2018).

Poor irrigation has many origins and weaknesses:

- lack of water, global warming,
- unbridled urbanization, evolution of irrigation water tariffs (In accordance with the water code (law n ° 83-17 of July 16, 1983), since the water pricing in Algeria is set by regulation.
- evolution and evaporation in dams,
- alarming degradation of infrastructure due to lack of maintenance,
- significant losses in the networks wastage facilitated by the low price of agricultural water,
- lack of use of TICS in the optimized management of irrigation,
- lack of reuse of purified wastewater,
- low irrigated area 8% of agricultural land has been irrigated yet it contributes 50% of the agricultural product,
- low quality of irrigation water,
- irrigation equipment are not renewed,
- inefficient, dilapidated and poorly maintained irrigation networks.

Indeed, drip irrigation has proven to be more efficient in terms of water saving than the conventional sprinkler method. Used in its buried or exposed form, drip irrigation consists of irrigating to bring water directly or indirectly to the roots of the plant, but not more than is necessary to avoid damaging the crops by supplying them with much more water than is needed. The degree of salinity of the water according to the type of crop (low resistance, medium resistance or high resistance) is an important parameter in addition to the soil moisture. It plays an important role in the irrigation process and therefore requires a rigorous control of the quality of the irrigated water.

1.3. The importance of water and irrigation in the Maghreb

Water resources in the Maghreb are limited and must be preserved. Particular attention must be paid to the silting up of dams and hillside reservoirs which sometimes reach worrying proportions. Soil quality is a factor to be closely monitored.

Often, irrigated land experiences problems related to salinization, which has worsened with the drought of the last two decades.

This salinity is measured with a conductivity meter, which is related to the content of mineral salts dissolved in water which varies according to the ionic concentration of water.

One third of the cultivated areas in Algeria have a slope greater than 12.5% which causes problems of erosion and soil conservation, as such, some lands are in the process of sterilization.

Algeria has implemented for over 40 years a vast program of rehabilitation and extension of existing perimeters, in order to increase the equipped and irrigated area of crops. The main crops concerned by total or partial irrigation are vegetable crops, fruit trees and palm trees.

In Morocco, the alarming depletion of groundwater, the drying up of sources, the deterioration of the quality of these waters, as well as the risk of a decrease in water resources under the effect of climate change, are all signs of the worsening of the situation. This led to a strong mobilization to establish institutional reforms and agricultural policies for a more efficient allocation of water resources between the different users. With the entry into force of the water laws, first Law 10-95 and subsequently Law 36-15, agricultural policies have been reoriented towards decentralized management of water resources according to the rules of good governance.

The necessary needs for agriculture vary according to the climate, the productions, the vegetative cycles and especially according to the modes of irrigation management.

Water consumption is evaluated from formulas involving climatic elements and is corrected according to factors related to the crops or according to economic objectives.

It is worth noting here the usefulness of a coherent methodology that is able to converge towards CI initiatives for smallholder farmers. This should highlight the status, needs and constraints of smallholder farmers to enable them successfully implement modern irrigation technologies.

2. SURVEYS OF EXISTING CONNECTED IRRIGATION INITIATIVES

In practice, different irrigation techniques can be considered: flooding irrigation, sprinkler irrigation and localized irrigation.

Flooding irrigation is the operation consisting of artificially bringing water to cultivated plants to increase their production, and allow their normal development in the event of a water deficit induced by a rainfall deficit, excessive drainage or drop in the water table, especially in arid areas, the flow of water is done according to the natural slope of the ground.

Surface irrigation has advantages such as : i) low investment cost per plot for the farmer, and no external energy supply; moreover, it has more disadvantages such as : i) Labor time for distribution and important monitoring, ii) significant water loss (50%), iii) Requires flat ground or leveling, iv) low efficiency, and v) possible pollution by spillage.

Sprinkler irrigation reproduces the natural phenomenon of rain, by controlling the intensity and height of precipitation, this technique requires medium to high pressure conditions (from 3 to 6 bars at the nozzle). At the level of the sprinkler, the centrepiece of the device, a nozzle creates a jet and directs it towards the spoon, the mobile arm is activated by the jet, the return spring causes the return of the mobile arm and thus ensures the rotation of the sprinkler.

Localized irrigation or micro-irrigation (known also as drip irrigation) consists of bringing water to a part of the soil only in small frequent doses. At the limit, the compensation of evapotranspiration takes place daily and water is supplied by distributors, which creates wet areas in the soil called "*watering or humidification bulbs*". Three main techniques are developed in this type of irrigation: localized irrigation by drippers (drip), localized irrigation by fixed perforated ramps, and localized irrigation by diffusion (micro jet, micro diffuser).

However, localized irrigation has more advantages than disadvantages. The advantages can be summarized as follows:

- water saving 50 to 70% compared to gravity and 30% compared to sprinkling,
- the reduction of pollution of the water table by fertilizers as well as a saving in fertilizers,
- facilitates the exploitation of very light soils filtering with strong percolation and heavy soils cracking in summer,
- possibility of exploiting land with irregular topography and configuration,
- easy access to the plots for carrying out the various farming operations,
- and, the increase in yield of around 20 to 40%, and an improvement in product quality.

While the main drawbacks of this irritation technique are the following:

- difficulty of managing localized irrigation, which requires high technicality,
- risk of rapid drying out of plants in the event of a spontaneous and prolonged stoppage of the supply of water,
- high cost of installing irrigation equipment and materials,
- and, finally the risk of clogging or clogging of the distributor which constitutes the major drawback of this technique.

2.1. What do we mean by connected irrigation?

Before introducing the concept of CI, we consider basic definitions given in [5].

Connected Devices: primarily refers to a product with a real-world function that is connected to the Internet in order to transmit data or be controlled remotely. For something to be classified as 'connected' it simply needs to be connected to the Internet or a network. This can be achieved by embedding energy efficient wireless technology modules into or attaching them onto something.

Smart Devices: they often have a much more complex hardware architecture, including things such as sensors, microcontrollers/microprocessors, data storage, controls, and embedded operating systems. Most smart devices are connected to the Internet or a network , but not all connected devices are smart..

Intelligent devices: for something to be classified as 'intelligent' then they must already be both connected and smart. What differentiates an intelligent device from an smart one are what actions are taken with data after capture. An intelligent device will produce insight, provide recommendations and help augment your decisions. An intelligent device is able to learn your preferences [5].

Thus, we can suggest the following meaning to CI:

CI consists of a combination of hardware and software that acts as a supervisor using networked CI-based sensors and actuators with the purpose of managing irrigation and other related practices such as maintenance. Generally, CIS are used to manage irrigation systems (e.g. localized irrigation systems) and can be divided into two categories: interactive systems and fully automatic systems.

Cyber-Physical Systems, Wireless Sensor Networks, Internet of Things (IoT) and Cloud/Fog/Edge computing, AI/ML Technologies are the main research paradigms used to enhance CI techniques by making them smarter. These paradigms have entered the agriculture industry as a means of creating an automated and integrated CIS. They rely on sensors that can record quantitative measurements of soil condition, crop growth, weather patterns, and other useful data. These sensors constitute a network of devices able to send and receive data, which streamlines data storage and processing [6].

2.2. Low-cost, do-it-yourself initiatives/solutions

Most farms in Algeria are private farms with an average area of 4 to 20 hectares. They are often family farms managed on their own funds. Financial resources are limited and sometimes catastrophic in case of disasters such as drought, floods, frost, locusts, etc.

So, to make smallholders aware of the use of IoT-based technology solutions, we need to think seriously about the capex cost. We need to provide them with a reliable, easy to use and more financially accessible solution. Also another problem consists of convincing them to use modern technology to enhance their production level as well as the quality of the products, so we need a training plan to support the solution. Therefore, when we propose our smart irrigation system to them, we need to seriously take into account the cost of the components and the necessary software that will be used in the IoT platform (the cost of sensors, actuators, internet access, etc....). The more we reduce the cost, the more we can raise interest from smallholders, as well as the major stakeholders.

2.3. Survey in Algeria

2.3.1. Context

It is important to remember that the scarcity of water resources and the water policy in Algeria are responsible for the agricultural sector absorbing nearly 70% of water resources, but remains in inadequacy with an agricultural production insufficient to mitigate the burden of imports in food needs of the country. Irrigation management can be approached on three scales: large, medium and small-scale hydraulics.

Large-scale hydraulics is made up of large irrigable areas officially structured into perimeters and dominated by large reservoir dams. Medium hydraulics concerns areas of less than 50 ha located outside the perimeters. They include either collective irrigation zones (irrigation zones downstream of hill dams), or groups of private operators grouped together in irrigation syndicates. Small-scale irrigation covers individual irrigation from wells, pumping in the wadis or flood spreading. Small and medium-scale irrigation (PMH) allows farmers to have more room to maneuver when using water.

2.3.2. Presentation of statistical data on agriculture in Algeria

General Data of Algerian Agriculture

The total area of Algeria is 2 381 741 km², the arid and semi-arid area occupy nearly 95% of this surface. The useful agricultural area represents only 3,6 percent of the total area of the country (20,5 percent of the agricultural area). The irrigated area is 1,3 million, equivalent to 15,3 percent of the agricultural land area (Table 1).

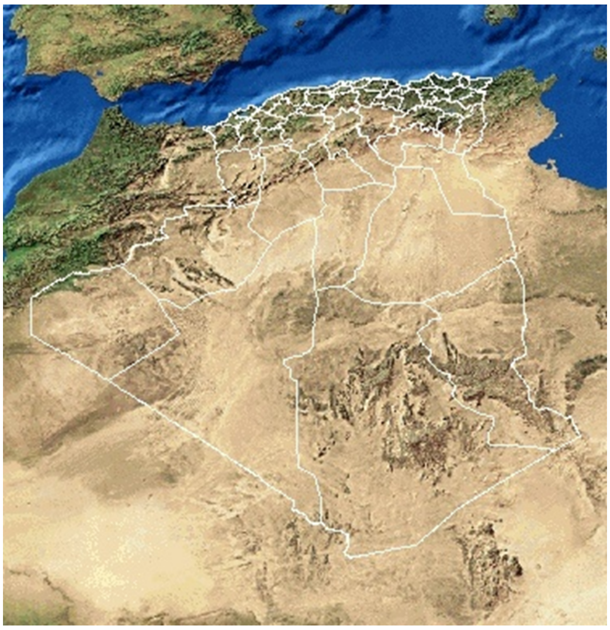

Figure 1 - Geo-climatic map of Algeria

Table 1 - Main Indicators of Agriculture in Algeria (FAO, 2018. Data Basis AquaStat)

Nature	**Area (Million ha)**	**% of TA**
Total Area (TA)	238,2	-
Agricultural land	41,4	17,4
Rangelands	32,9	13,8
Useful Agricultural Area (UAA)	8,5	3,6
Forests and scrubland	4,2	1,8
Irrigated Area	1,3	15,3 % of UAA area
Total	**79,8**	**33,6**
Agriculture part in GDP (%)		12,2
Renewable water resources per capita (m3/capita/year)		600

With 600 m3/capita/year of renewable water, Algeria is below the theoretical threshold of scarcity set at 1000 m3/capita/year by the World Bank. In Europe, this threshold reaches

30,000 m3/inhab/year. The country is therefore not only subject to climatic constraints but also to a limitation in water resources which have their impacts on the very diversified production and family type of agriculture (Figure 2).

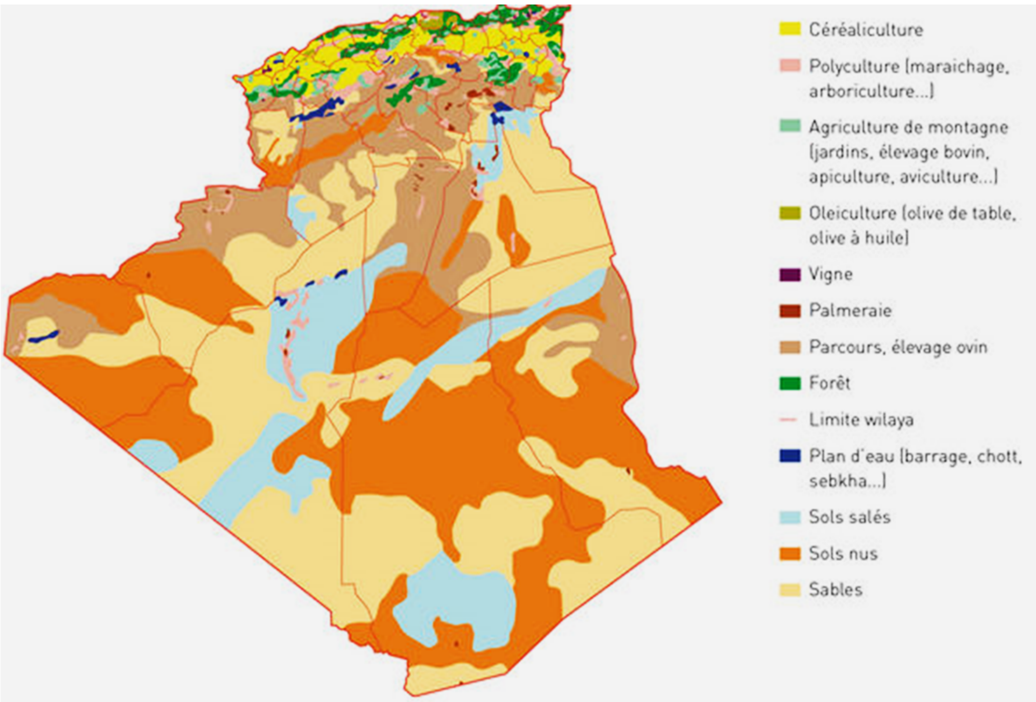

Figure 2 - Diversified Agriculture production in Algeria

Among the strategic sectors that Algeria produces (Figure 3), cereals (80% of the useful agricultural area) are the major challenge not only by the heavy import bill that they generate, but also by their strong dependence on rainfall (Table 2).

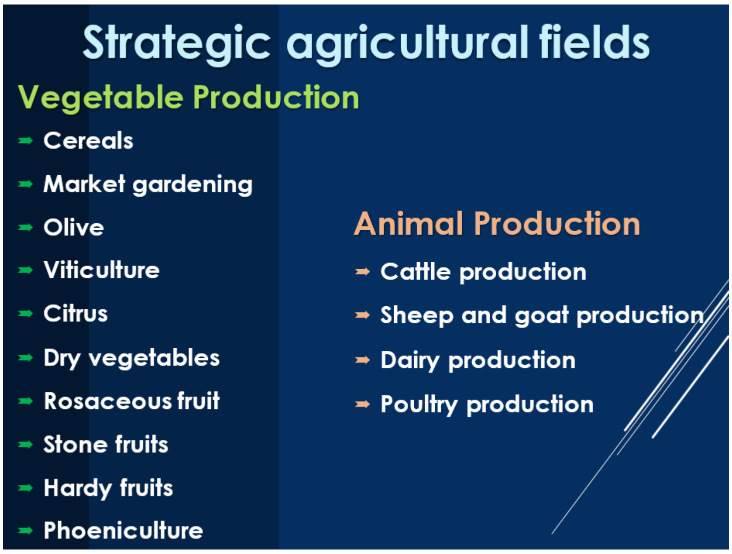

Figure 3 - Strategic agricultural fields

Table 2 - Evolution of cereal yield production between 2016 and 2018

Campaign	Production (Millions tons)	% Increase	Annual rainfall in Mostaganem (as a benchmark)
2015-2016	3,43	-	270,53 mm
2016-2017	6,10	77	325,38 mm
2017-2018	3,50	2	-

Global resources and irrigation situation

We focus here on water resources and the irrigation situation dedicated to agriculture in Algeria, especially in the cities of Oran, Mostaganem and Relizane, where the expected pilot farm sites for the INTEL-IRRIS project are located.

The example of the Macta watershed in the Oran hydrographic region (Chott-Chergui) is interesting as it is representative of the general situation of water resources in the country. Indeed, the Large Irrigated Perimeters (GPI) in this area allocate insufficient quotas for perennial irrigation. In 2017, the water quota claimed by irrigators was 85 million m3, while the allocated quotas were around 51 million m3, a satisfaction rate that does not exceed 60%, leading to an underutilization of equipped agricultural areas. In addition, farmers are increasingly using groundwater to irrigate their farms in the form of Small and Medium Hydraulics and this far from any control on actual withdrawals.

Figure 4 - Cheliff intake dam for transfer to Mostaganem, Arzew, Oran (MAO)

This situation has led to the mobilization of non-conventional resources through the construction in the region of the largest seawater desalination station in Africa with a capacity of 500,000 m3 per day and the import of water resources from other watersheds.

The example of Macta cannot be disconnected from the rest of the country's regions. Indeed, water scarcity has strongly affected irrigation practices throughout the country. The evolution of irrigation surfaces in Algeria from 2001 to 2018 (Figure 5), shows the increase of the irrigated area leads to the increase of three methods of irrigation (gravity, sprinkler, and drip) from 2001 to 2016. The year 2018 records a decrease in the area conducted under gravity irrigation compared to the previous trend. It stands out as the beginning of a trend of farmers to adopt sprinkler and drip irrigation, as we will confirm in the next step with the evolution of irrigation techniques in Mostaganem, Oran and Relizane during the last three years.

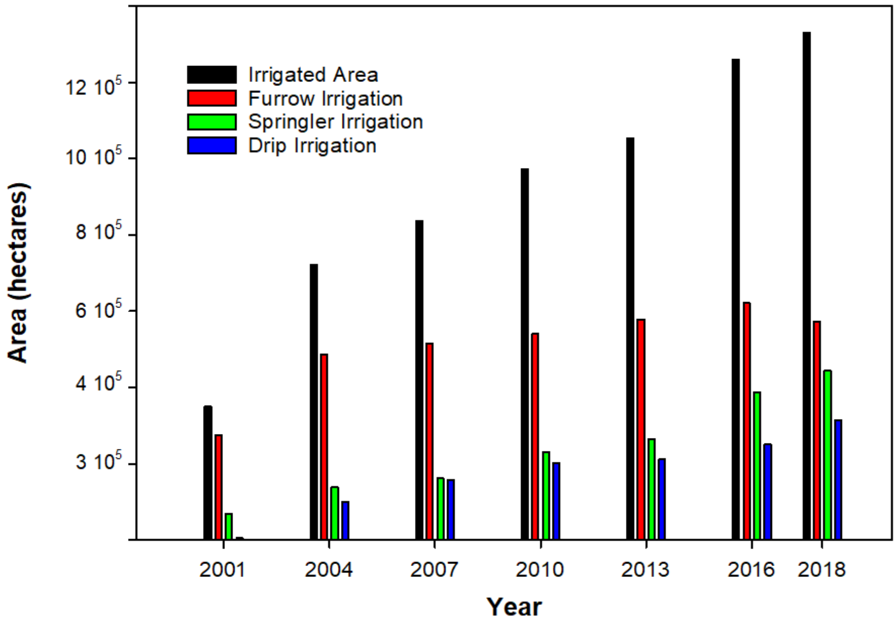

Figure 5 - Evolution of irrigated area by furrow, sprinkler and drip irrigation in Algeria (2001-2018)

Case of Oran City:

Oran city has potential in proven local resources, consisting of agricultural land of good quality, a coastal cordon, and a mountain area and foothills where mountain agriculture is practiced to preserve.

The total agricultural area of Oran city is 95 059.2 ha, representing 47.2% of the area of the city, including UAA, equal to 86 757.39 ha. Given the unfavorable climatic factors, the irrigated area remains insignificant (10,915 ha, or 12.58% of the UAA).

- *Juridical nature of the land*

Table 1 – Distribution of farm size by legal status

	Number	Area (ha)	Average Farm Size (ha)
Individual Farm (EAI)	3191	23766,40	7,45
Collective Farm (EAC)	590	46707,88	79,17
Pilot Farm	3	1971,13	657,04

- *Water Resources*

Table 2 – Situation of Water Resources of farm size by legal status

Water Resources	Unit (m^3)	Observations
Drilling	870000 m^3/year	
Wells	11786500 m^3/year	
Sources	456500 m^3/year	
Hillside reservoirs	120000 m^3/year	
Wastewater treatment station	12000 m^3/day	Steppe Cap Falcon
(purified and treated wastewater)	50000 m^3/day	Steppe El Kerma
Irrigated perimeters	72000 m^3/day	Perimeter of Mlata+ Perimeter of TARIK

- *Irrigation state according to the used method*

  The total irrigated area is 10915 ha. The distribution of this area according to the type of irrigation is shown in Figure 6.

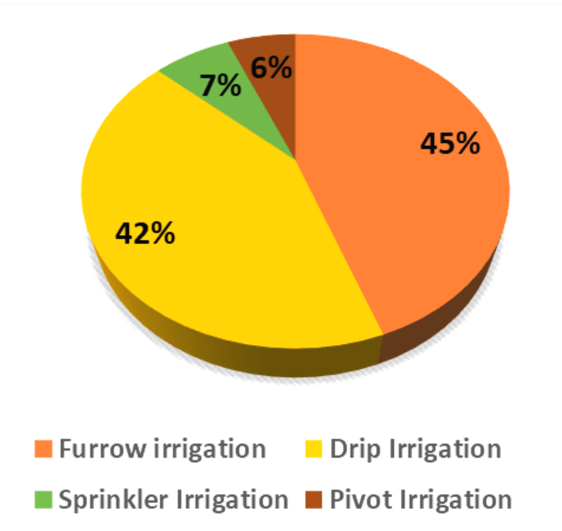

Figure 6 - Irrigated area according to the irrigation method

- *Irrigation methods used according to the nature of crop*

The distribution of irrigation methods used according to the nature of the crop is presented in Figure 7.

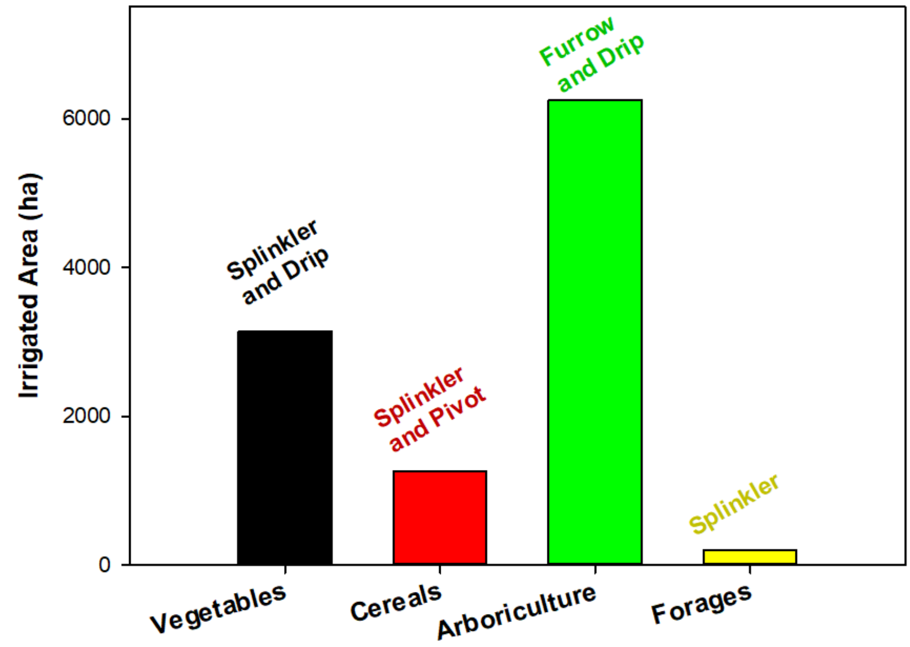

Figure 7 - Irrigation methods used according to the nature of crop

- *Crop yield by agricultural campaign (2018-2020)*

The different agricultural land uses in Oran city are shown in Figure 8. The levels of agricultural production yields are given in Table 3.

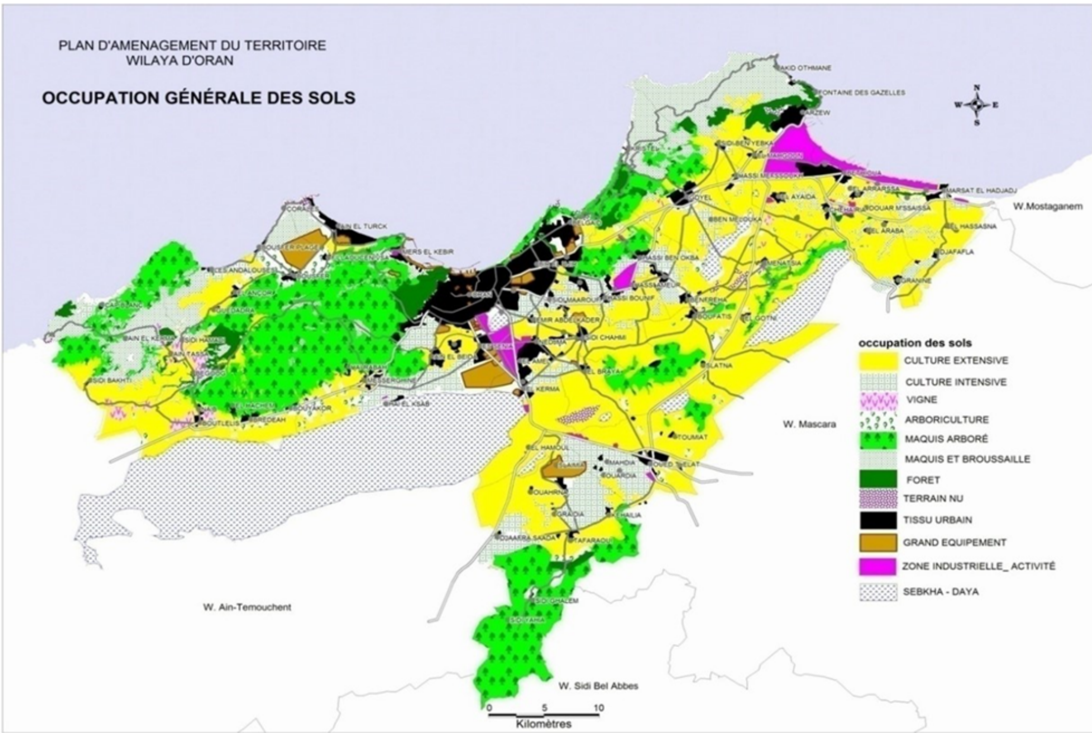

Figure 8 - Soil use map at Oran city

Table 3 – Situation of Water Resources of farm size by legal status

Campaign	2017/2018		2018/2019		2019/2020	
Areas and Productions	Area (ha)	Production (quintals)	Area (ha)	Production (quintals)	Area (ha)	Production (quintals)
Cereals						
Durum wheat	9 957	217 316	9 758	31 980	9 557	17 593
Soft Wheat	2 723	63 476	2 824	6 169	3 045	4 601
Barley	40 674	1 098 344	39 865	169 431	39 585	122 589
Oats	1 230	24 950	1 205	4 510	1 280	2 755
Dry vegetables						
Lens	-	-	80	80	37	10
Chickpeas	309,5	3 562,5	717	747	248	429
Forages	6 572	349 859	6 914	150 468	5 519	63 897
Vegetables						
Potato	165	52 220	193	45 872	173	43 415
Onion	50,25	7 920	39	5 750	61	6 675
Galtic	6,75	298	7,5	237	9	182
Grapes	645,5	40 210	612,5	43 500	570	23 866
Citrus	284	28 565	330	28 847	390	31 780
Pits and pips	2 783	71 061	-	-	2 547,65	69 618,86
Olive growing	8 463	169 075	8 470	128 618	8 541	146 866

Case of Mostaganem City:

- *Climatic Constraints*

In Mostaganem city (northwestern Algeria), although annual rainfall averages 370 mm, 70% of it is distributed over the four months of the year, from November to February.

The dry period according to the umbro thermal diagram of Emberger (https://fr.climate-data.org/) is spread over 9 months from March to November. This situation has led to an increase in irrigated areas in recent years (Table 4).

Table 4 - Distribution of agricultural land in Mostaganem city

Land distribution	**Area (ha)**	**Percentage of TA**
Total area of the city (TA)	226 900	
Total Agricole Area (TAA)	177 310	78 % of the TA
Useful Agricultural Area (UAA)	132 268	75 % of the TAA
Irrigated Useful Agricultural Area (IUAA)	39 650 in 2010	30 % of the UAA
	41 862 in 2014	32 % of the UAA
	46 392 in 2018	35 % of the UAA

- *Tendency of use drip irrigation*

The climatic constraints and those related to the limitation of water resources forced farmers to resort to drip irrigation. In 2021, the use of drip irrigation surpassed that of sprinkler and furrow irrigation (Figure 9).

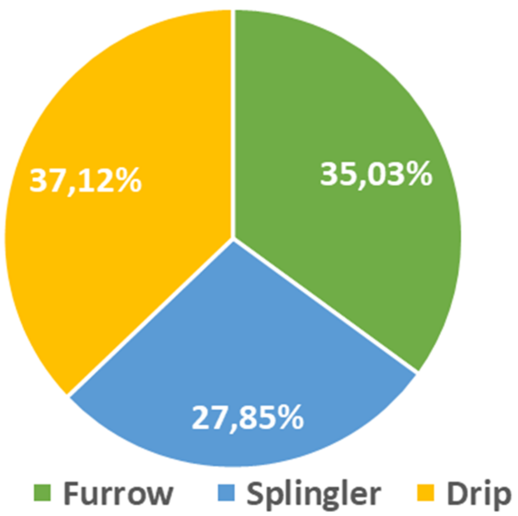

Figure 9 - Irrigated area distribution according to the used Irrigation method use (DAS[2], 2021)

Agriculture in Mostaganem is based on market gardening and arboriculture. For this reason, nearly 98% of irrigation use is directed to these two crops (Figure 10).

[2] Direction of Agricultural Services

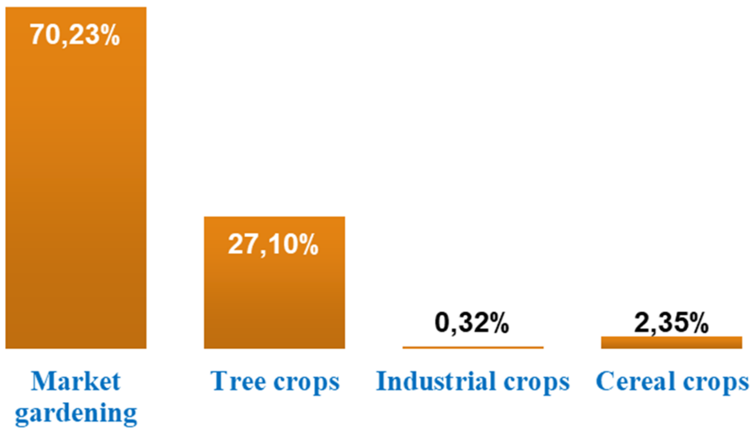

Figure 10 - Irrigated area according to agricultural speculation (DAS, 2021)

The use of localized irrigation is developing particularly for market garden crops considered as speculative (Figure 11). The percentage of use of this technique has increased from 70 to 75% between 2016 and 2021. However, the furrow irrigation technique has decreased from 17 to 9%. The sprinkler technique increased too from 13 to 16%.

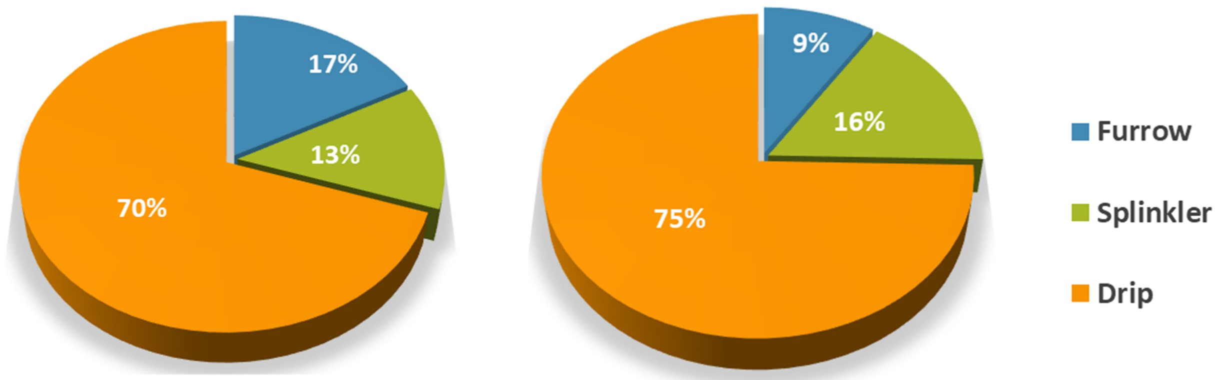

Figure 11 - Irrigated type distribution according to the irrigated area of Market gardening in 2016 and 2021 (DAS, 2021)

Although today the majority of smallholders are accustomed to the drip irrigation system, we realized through our visits made during the month of December accompanied by the Secretary General of the Chamber of Agriculture of Mostaganem (himself a member of the project). These smallholders rely solely on their experience with limited data on soil and climatic conditions to manage irrigation, which inevitably leads to an overexploitation of water resources with negative impacts not only on the economic yield of crops but also on the quality of soil and groundwater.

In these conditions, smallholders need technological tools that allow them to provide the right amount of water irrigation at the right time. In this sense, INTEL-IRRIS is the perfect solution to fill this technical gap.

Over the past few decades, several studies have examined specific aspects of monitoring indicators for precision irrigation control. These indicators can be based on soil, plant, remote sensing data and communication technologies.

Case of Relizane City:

In Relizane city, the situation is different, drip and gravity irrigation systems are used with close to 43% and 42% respectively. Sprinkler irrigation is used by 15% (Figure 12). Nevertheless, the distribution of these three irrigation systems among the different crops shows that drip irrigation is very much oriented towards cash crops (Figure 13).

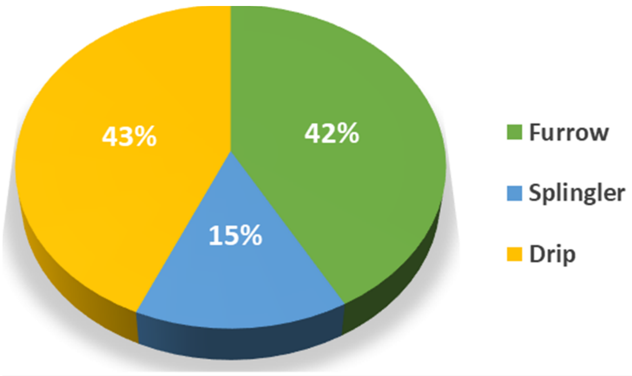

Figure 12 - Irrigation type distribution according to the irrigated area in 2021 (DAS, 2021)

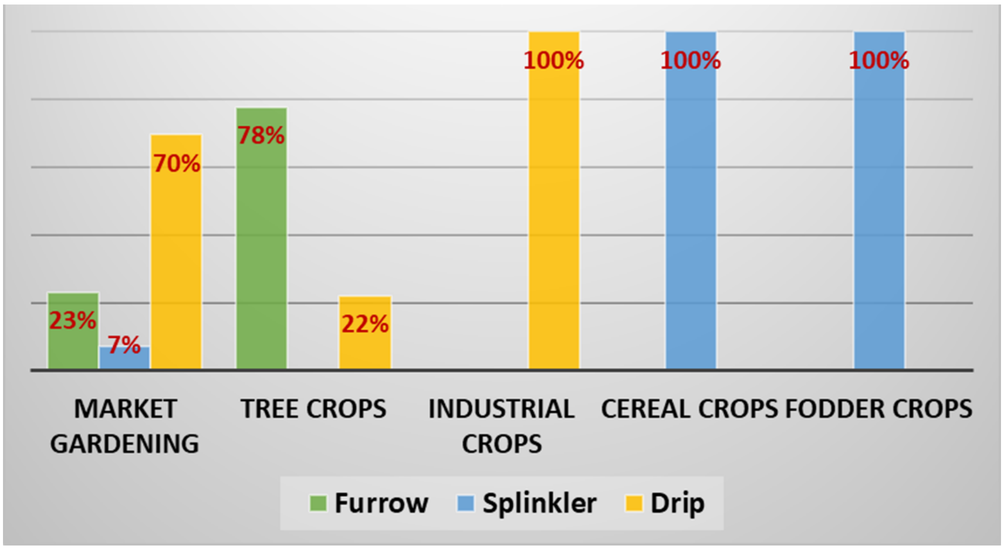

Figure 13 - Irrigation type distribution according to the agricultural speculation in 2021 (DAS, 2021)

2.4. Survey in Morocco

2.4.1. Context

Water availability in Morocco is one of the main limiting factors for obtaining good yields. Although irrigated agriculture occupies only 15% of Morocco's cultivated area (about 1.5 million hectares), it contributes about 45% to 75% of agricultural exports, depending on the season. This contribution is greater during dry seasons when production in rainfed areas is severely affected (MAPMDREF, 2021).

In this context, the global objectives expected by the actors and managers in the irrigated perimeters are centered on increasing production, water management control and irrigation rationalization which constitute a challenge of agricultural policy.

2.4.2. Presentation of statistical data on agriculture in Morocco

Agriculture is considered to be a strategic sector for the socio-economic development of Morocco given its weight in the GDP (Gross Domestic Product) (13.6%). Its role in terms of employment which alone represents 80% of rural employment and its participation in foreign trade. However, the sector remains very dependent on precipitation and therefore on climatic hazards. Thus, programs and plans have been launched to improve the resistance of the sector to this climatic insecurity. Covering an area of nearly 8.7 million ha, the UAA boasts a wealth of agro-climatic systems that enable it to produce a very wide range of agricultural products.

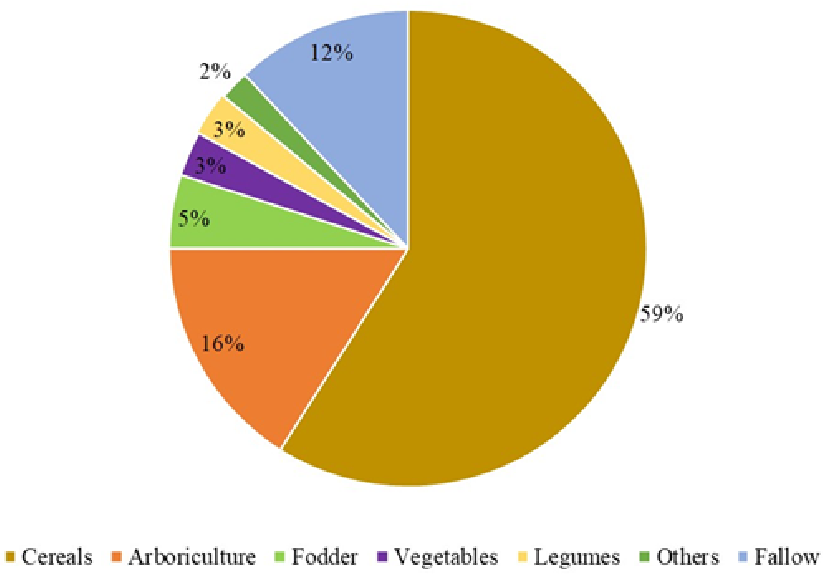

Figure 14 - Breakdown of Useful Agricultural Area according to the crop land

The importance of the area of cereals (59% of the UAA) as well as the fallow land (12% of the UAA), testify to the enormous possibilities of intensification and conversion. The extension of the cereal area has sometimes taken place on marginal land, making agricultural activity even more precarious in these extension areas. The dominance of the UAA by cereals makes agriculture poorly diversified and therefore more vulnerable to climatic hazards with all its consequences on the variability of production and growth in the sector.

Irrigation and water saving

Efforts made by the state and by farmers since the 1960s to develop irrigated agriculture have made it possible to reach one million irrigated hectares. In 2020, the irrigated area is 1,600,000 ha, or 18% of the total arable area and 21% of the cultivated area per year, or 38% of the total irrigated area at the national level. The irrigation programs cover 750,000 ha, 90% of which is intended for areas of less than 20 ha.

Morocco receives an annual average of about 29 billion m3 of rain, the hydraulic potential that can be mobilized, under current technical and economic conditions, is estimated at 68%, 55% of which comes from surface water and 14% from groundwater. Morocco currently has an important hydro-agricultural heritage and enjoys an important place internationally in terms of water management policy, particularly in agriculture.

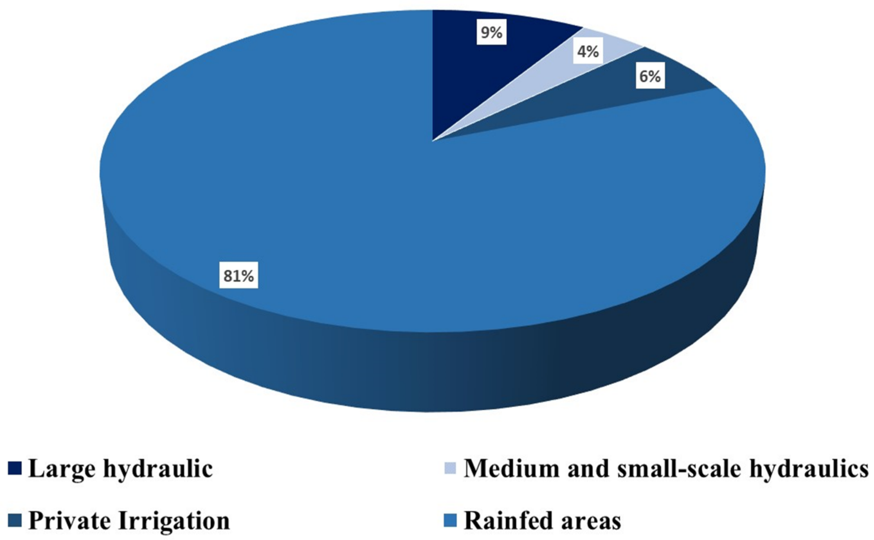

Figure 15 - Water distribution according to the type of irrigation

Faced with the context of climate change coupled with the relative scarcity of water resources, the government has implemented a policy aimed at rationalizing its use. Areas under localized irrigation have shown continuous growth for a decade, particularly since 2008 with the launch of the Green Morocco Plan. The incentive system plans to cover all the costs of micro-irrigation for farms of less than 5 ha or as part of the aggregation.

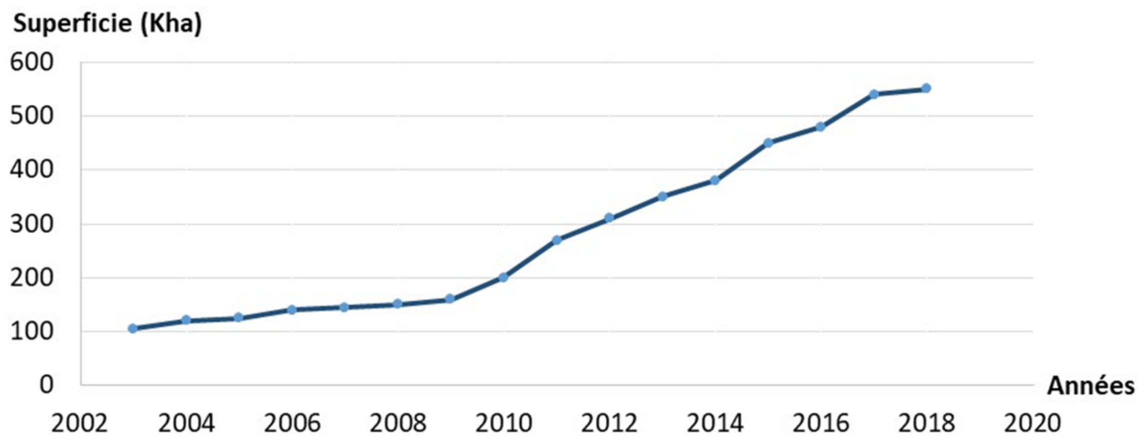

Figure 16 - Area irrigated with localized irrigation (Kha) ***(MAPMDREF Data)***

It should be noted that within the framework of the Green Morocco Plan, the objective of converting areas to localized irrigation is set at 550 000 ha.

Annual growth of GDP and agriculture

In Morocco, economic growth is closely linked to that of the agricultural sector: the strong variations in the added value of the agricultural sector which testify to the dependence of this sector on climatic conditions, and in particular on rainfall, have repercussions on GDP growth from the country.

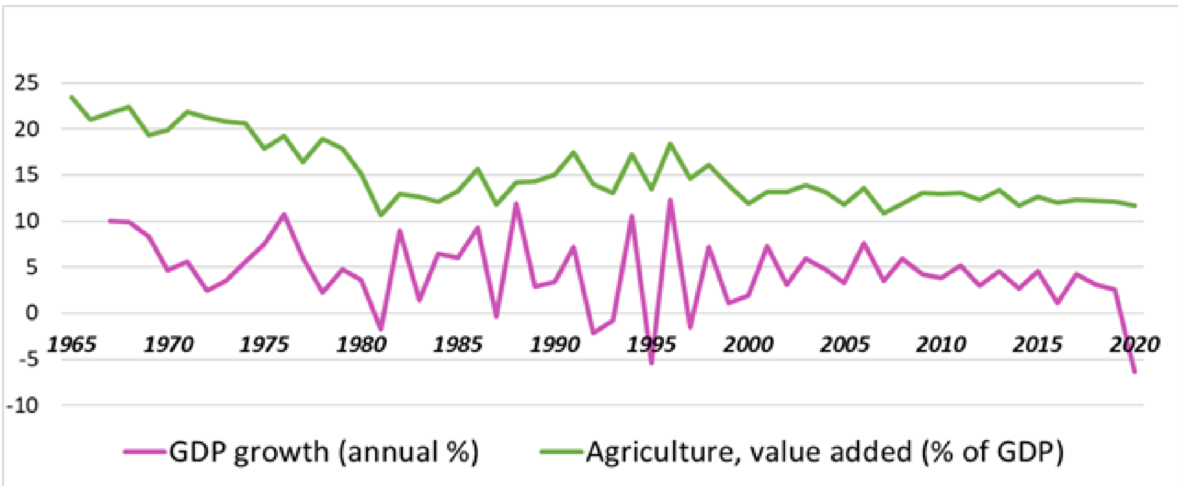

Figure 17 - Annual growth of GDP and agricultural added value in morocco (World Bank Data)

In the case of a drought, agricultural production, particularly cereals and arboriculture, experiences a decline which negatively impacts the agricultural value added and consequently the growth of GDP.

Case study: Chaouia region

Although irrigated is very limited in space, crop production can be divided into two main groups: rainfed or bour crop production and irrigated crop production.

a-Rainfed crops

The share of rainfed cultivated area per municipality varies between 75 and 100%, confirming the importance of rainfed agriculture in the region. This share dominates (more than 95.3%) in the countries of Béni Meskine, Boujâad, Haute Chaouia, Ouardigha, Haute Ouardigha and the country of Benslimane. For the Lower Chaouia East and West areas, this share varies from 78 to 97%.

Table 5 - Share of rainfed crops by agricultural area.

Areas	**Share of rainfed crops/common UAA (%)**
Oulad Hriz Sahel	78.6 à 91.6
Znata Sahel	78.6 à 95.3
Lower Chaouia West	78.6 à 99.3
Lower Chaouia East	78.6 à 97.6
Benslimane	91.6 à 99.3
Chaouia High Country	78.6 à 99.3
Ouardigha High Country	95.3 à 100
Ouardigha	95.3 à 100
Boujâad	98.5 à 100
Beni Meskine	78.6 à 100

Cereal production: rainfed agriculture is dominated by cereals which occupy around 696.405 ha with a total production of 7,460,305 quintals. The average production is 10.7qx/ha, all species and agricultural areas combined. From the point of view of land use, barley comes first with 36%, followed by soft wheat with 35% and durum wheat (27%). The rest is occupied by corn and oats.

Legumes production: the area of food legumes, consisting mainly of broad beans, horse beans, lentils, chickpeas and peas, is in continuous decline and currently occupies only 4.5% with a very low average yield of 5.5 quintals/ha.

Fodder production: despite the importance of livestock in the region, the fodder sole remains very limited and occupies only less than 7%. The main crops grown are barley, oats, maize and field peas. Yields vary between 23 and 41 t/ha.

Vegetable production: market gardening in rainfed mode primarily concerns the cultivation of onions in Tirs of High and Lower Chaouia West and a few garden peas in High Chaouia around Ben Ahmed.

Tree production: rainfed arboriculture occupies 10,337 ha, dominated by olive trees in the provinces of Settat and Khouribga and by vines in Benslimane. A remarkable extension of the cultivation of the olive tree is observed throughout the region and especially where the possibilities of irrigation exist.

b. Irrigated crop production:

Water resources for agricultural use: the water resources of the Chaouia-Ouardigha region are of two types: groundwater and surface water. They are both properties affected by droughts and non-rational exploitation. Two hydraulic basins cover the region, namely the Bouregreg hydraulic basin and the Oum Rabia hydraulic basin. The aquifers used for agricultural purposes are:

- the water table of Berrechid covers 1500 km with an average thickness of 20 m and has a water balance deficit of 100 Mm3/year.
- the Chaouia Côtière aquifer extends over 1260 km between Casablanca and Azemmour over a coastal strip width of approximately 25 km and presents a hydraulic balance deficit of 4.27 Mm3.
- the Khémissette de Chaouia aquifer: located 25 km south of Settat, this aquifer extends over approximately 800 km2 and is 5 to 15 m thick.
- the deep Turonian aquifer extends over 10,000 km. This tablecloth has a deficit of around 21 Mm3/year which has generated a piezometric drop of 1 to 1.6 m/year.
- pumping from the surface waters of Oum Rabia is very limited to a few farms along the river.

Water resources remain low compared to the irrigation potential of Chaouia; however, where groundwater exploitation is carried out, the use is very abusive.

Territorial distribution based on irrigated area: Irrigated agriculture is located mainly in the coastal area of Oulad Hriz Sahel and Znata, Lower Chaouia East, Lower Chaouia West with a share of the irrigated area on the total agricultural area varying between 1.33 to more than 16%. For the other areas, this share does not exceed 2.3% in most municipalities.

Table 6 - Share of irrigated crops by agricultural area

Areas	**Share of irrigated crops/common UAA (%)**
Oulad Hriz Sahel	4 à 16
Znata Sahel	4 à 16
Lower Chaouia West	0.56 à 16
Lower Chaouia East	2.36 à 16
Benslimane	0.56 à 7.3
Chaouia High Country	0.56 à 7.3
Ouardigha High Country	0.56 à 1.3
Ouardigha	0.56 à 1.3
Boujâad	0.56 à 7.3
Beni Meskine	0.56 à 16

Vegetable crops: market gardening occupies the first place in irrigated with 14,306 ha of which more than 98% is allocated to seasonal market gardening and the rest (approximately 1000 ha) is early market gardening. Vegetable crops in season are potatoes, field tomatoes and onions. Yields are generally good, but the presence of pests and diseases is a main constraint. The abuse of use of irrigation water is a priority management axis to preserve this limited resource in the region.

Cereal crops: about 262,250 ha of cereals are irrigated. Soft wheat comes first with 113,750 ha, followed by durum wheat (90,000 ha) and finally corn with 58,500 ha. The average yields achieved are encouraging with more than 40 quintals/ha. This area irrigated in cereals is intended for the production of seeds (common wheat and durum wheat) and the production of grain for animal feed (maize). Irrigated cereal crops are dominant in Lower Chaouia East and West and a little in the country of Benslimane.

Forage crops: the main irrigated fodder crops are maize, alfalfa and bersim. They are associated with dairy farming in the areas of Oulad Hriz Sahel, Znata, Low Chaouia East and West, Benslimane country and High Chaouia and Ouardigha. The yields obtained are high, but with non-rational use of water and management.

3. Needs and constraints for connected irrigation in small-scale agriculture

3.1. Smallholder's expectations

Small-scale farming, according to the FAO [1], makes a significant contribution to food security and the rural economy [2]. Smallholders' main concern all over the world, especially in Africa, is to increase sustainable agricultural production and food security, both of which are top-line priorities for governments and development agencies across the nation. The future of agriculture depends on agriculture human capital investment (AHCI) in order to encourage creativity, management decisions on the farm and small-scale farmers empowerment. Technological developments such as the internet of things (IoT), artificial intelligence (AI) and machine learning (ML), big data analysis, robotics, cloud/Edge/Fog computing have paved the way for the new era of an agricultural revolution [3]. These techniques have provided solutions to several problems that have been raised in what is now called smart farming where CI plays a major role. Among these problems we can mention the identification of plant diseases, the prediction of agricultural yields, drought as well as the efficient management of irrigation, which has a direct impact on agricultural production, especially if this water resource is scarce and in the case of insufficient rainfall [4]. Investing in farmers or agriculture human capital is critical for tackling difficulties in our food and agricultural systems. Smallholders' major goal is to foster long-term commercial relationships between small-scale farmers and bigger corporations while also improving their capacity to meet high-quality production and safety standards in accordance with market demands.

The main expectation of smallholder farmers is that the irrigation technology solution proposed to them through the INTEL-IRRIS project must be beneficial in terms of quality, quantity and profitability. It must also be developed, tested, and deployed with their close collaboration as the main actors exploiting the results of the innovation. This solution must preserve their usual practices and must adapt perfectly with their intellectual levels, their financial capacities, and their experience acquired over time. Even linguistic interfacing must be taken into account, especially in terms of communication and decision making (for example, automatic translation techniques using AI must be considered in the solution).

3.2. Needs and constraints in Algeria

It is important to remember that Algeria is characterized by limited water resources, a climate that is 95% arid and semi-arid, and by smallholder agriculture with more than 71% of farms smaller than 10 ha. With 70% of the water resource consumed by the agricultural sector, farmers are increasingly aware of the traditional irrigation systems. They used until recently, notably the Furrow and Sprinkler irrigation models, and consequently they lost considerable amounts of water without achieving the expected agricultural yields.

Under these conditions, the water needed for irrigation purposes can only be met through the use of optimized forms of irrigation that deliver just the right amount of water to the crops at the right time.

Precision irrigation is needed to cope with the scarcity of water resources and the aridity of the climate in order to ensure sustainable agri-food production. All the more so as in the north of the country, where there is a large demographic concentration, the Algerian state has invested in the desalination of seawater by reverse osmosis to meet the needs of the DWS (Drinking Water Supply) and to relieve the agricultural sector.

Consequently, the challenges for the future of the country are manifested in terms of food security through the generalization of precision irrigation in a hostile context characterized by smallholder farming, that is not only lacking in knowledge for precision irrigation but also unable to financially access to the technological irrigation installations, which are based on artificial intelligence and geomatics.

3.3. Needs and constraints in Morocco

In Morocco, irrigated areas have played a decisive role, both at the local level and at the national regional level. However, with the effects of climate change felt, the irrigated production system is faced with concern for the sustainability of water resources as Morocco is currently classified as a water stressed country. Therefore, managers of irrigation systems must ensure that irrigation is optimal in irrigated areas to cope with water shortages especially for small farmers. Hence the importance of developing intelligent irrigation techniques adapted to the needs of the Moroccan farmer.

However, there are some challenges that need to be considered and overcome:

• Improve capacity to finance smart irrigation installation at farm level, given the number of small farms (about 80% are < 5 ha).

• Find solutions for farms consisting of scattered fields of different sizes.

• Improve coordination between farmers, especially in a context where farmers may behave in an individualistic and competitive way.

• Convince farmers to adopt smart irrigation. Water scarcity and water prices are reasons that can push the farmer to adopt water-saving technologies. The fee for irrigation water, in large hydraulics, varies from 0.035 and 0.09 Euro/m3 and between 0.06 to 0.10 Euro/m3, for pumping water, depending on the region.

4. Adaptation to local technological context

New technologies such as IoT, AI/ML, Cloud/Edge/Fog computing are not easily found in the local hardware store. Recently, with the emergence of experimental work emanating mainly from research and innovation at universities and research centers, some suppliers have become interested in this promising new market and for which we are the potential customers.

4.1. Access to hardware

According to our investigations recently carried out on the possibility of purchasing specific equipment dedicated to our Inter-IrriS project to deploy, as a first step, a pilot prototype for data acquisition (starter-kit), it was found that all the material specified in the deliverable D1.2a could be acquired locally by contacting potential specialized suppliers. The main characteristic of this equipment is that it is as cheap as possible and affordable to smallholders in such a way that reliability and robustness are preserved in practice. This point is very relevant here, because it is not always so easy to ensure a compromise between low cost and robustness (reliability can be software-recovered by advanced calibration techniques planned in the project). Therefore, a great work of adaptation of the future innovative irrigation system, co-invention and co-design will be undertaken with the maximum number of actors to converge towards this compromise.

4.2. Cost of platform with regards to local economy

In the table below, we give comparative prices between starter-kit (as a first step of the project) components purchased by UPPA partner and those sold locally. By referring to the overall price of the starter kit (around 30$), it appears that this price is interesting and initially corresponds to our objectives. But, it obviously remains to be tested, adapted and evaluated into pilot farms with the involvement of different actors.

Table 5 : Comparative prices, related to Starter Kit components, between UPPA proposition and acquisition possibility by UORAN1

Equipements		UPPA	Cost	UORAN1	Cost
Gateway		RPI3B+ or RPI4	109.88$	RPI3B+ or RPI4	109.88$
		SD card 16GB or 32GB	15$	SD card 16GB or 32GB	15$
IoT device	Microcontroller	Arduino Pro Mini (3.3v, 8MHz)	2.5$	Arduino Pro Mini (3.3v, 8MHz)	8$
	Communications modules	LORA RADIO MODULES RFM95W (868MHz) RFM96W (433MHz) NiceRF SX1262 (868MHz),SX1268,SX1280	3.75$	NRF24L01 + PA+ LNA (2.4 GHZ)	2.6$

	Add-ons	FTDI breakout (to program arduino Pro mini that have not serial port)	One for all whole project 1.22$	LEDs + Jumpers	for all whole project 0,5$
		Displays (0.96" small OLED displays) for Raspberry pi	$2.09	LCD display nokia + LCD display I2C	$2.09
Antenna and related components		Simple whip (monopole) antenna for both devices and gateway	16.45$	We use NRF module with antenna	0$
Physical sensors		Soil humidity (SEN0308)	13.8$	Soil-Moisture YL-69 or moisture sensor V2.0 + DHT22 sensor	11$
Others				Water pump + relay switch	15$

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Acronyms List

Acronym	Explanation
CI	Connected Irrigation
CIS	Connected Irrigation System
IoT	Internet of Things
AI	Artificial Intelligence
ML	Machine Learning
FAO	Food and Agriculture Organization
DAS	Direction of Agricultural Services
UAA	Useful Agriculture Area

Project Co-ordinator Contact

Pr. Congduc Pham

University of Pau

Avenue de l'Université

64000 PAU

FRANCE

Email: Congduc.Pham@univ-pau.fr

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