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Irrigation Perimeters and Water Transfer in Setif: Towards Sustainable Water Resources Management in the Face of Climate Change

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Abstract
Climate change is manifesting globally, with North African nations, including Algeria, facing severe water scarcity. This scarcity is exacerbated by declining rainfall and rising temperatures, leading to increased evaporation and a significant deficit in water resources for both drinking and agricultural irrigation. Consequently, Algeria's agricultural productivity and food security are under threat. To address these challenges and ensure sustainable development, Algeria has adopted a strategic approach centered on the inter-basin transfer of dam water. This policy aims to mitigate the uneven distribution of rainfall and renewable surface and groundwater resources across the country, particularly between the northern, coastal, inland, eastern, and western regions. The primary objective is to balance water availability and alleviate the acute water shortages experienced by urban and semi-arid populations.

Keywords
Irrigation, Organization, Reform, Water Management, Setif, Sustainable Development

1. Introduction
Algeria faces significant challenges in ensuring consistent agricultural production due to its arid to semi-arid climate, characterized by low and unevenly distributed rainfall. Consequently, irrigation is vital for maintaining agricultural output. Since 1999, the Ministry of Water Resources has been responsible for the mobilization and optimal utilization of water resources for this purpose.

Algeria, with a land area of approximately 2.4 million square kilometers, is divided into two distinct climatic zones: the northern zone (14% of the territory) with a sub-humid to semi-arid climate, and the southern zone (86%) with a Saharan climate. The population has grown from 25 million in 1990 to over 46 million in 2024 (National Statistics Office). Despite 90% of the usable agricultural land (8.5 million hectares) being located in the northern zone, where over 80% of the population resides, only 5% of this land has been irrigated on average over the past two decades. Nevertheless, irrigated agriculture contributes nearly 50% of the total value of land-based products.

This situation puts increasing pressure on water resource mobilization and exploitation, further compounded by climate variability. Arable land is limited and increasingly encroached upon by urban and industrial development. Between 1967-1969 and 2020, the usable agricultural land per capita decreased from 0.52 to 0.21 hectares (General Agricultural Census, 2023), with over 250,000 hectares lost by 2000.

Studies by the National Water Resources Agency (ANRH, 2021) indicate a potential for over 1.5 million hectares of high-quality irrigable land. National development plans aim to irrigate one million hectares, with 40% of this through large-scale irrigation projects.

Algeria's total mobilizable water resources are estimated at 12.5 billion cubic meters, of which less than 50% is currently utilized. This includes surface and groundwater, notably the fossil aquifers of the northern Sahara (Continental Intercalaire/Albian and Terminal Complex). A study by the Sahara and Sahel Observatory (OSS) confirmed the potential to sustainably exploit over 5 billion cubic meters annually. These figures highlight the critical limitations of Algeria's soil and water resources.

To address these challenges, major water transfer projects, particularly in the Setif region, are crucial for meeting both drinking water and agricultural irrigation needs. These projects aim to revive the region's renowned "Mohamed El Bashir" durum wheat variety.

Specifically, two major water transfers, with a combined annual capacity of over 320 million cubic meters, will supply drinking water to 34 municipalities (80% of Setif's population) and irrigate 36,000 hectares (20,000 in El Eulma and 16,000 in the Upper Setif Plains). This integrated system, including dams, channels, tunnels, and pumping stations, is projected to increase Setif's agricultural output fivefold and contribute to a 20% increase in national agricultural production, while creating 100,000 jobs in the sector.

This water transfer strategy relies on large-capacity dams such as Beni Haroun (east), Koudiet Acerdoune and Taksebt (center), and Keddara and Cheliff (west), with the latter feeding the Mostaganem region. Overall, these projects aim to transfer approximately 3 billion cubic meters of water, ensuring both drinking water security and supporting economic activities, particularly agriculture, across the affected regions.

2. Material and Methods

2.1 Choice of Study Area

Setif province, located within the northeastern High Plateaus region of Algeria, holds significant strategic importance due to its geographical, economic, and demographic characteristics. Serving as a crucial link between the High Plateaus, the Tell regions, and coastal areas, Setif spans approximately 6,504 square kilometers, representing 0.27% of the national territory. With a population of 1,428,336 as of the 2008 census, it is a major demographic center, second only to the capital. The terrain is primarily flat or plain, with an average elevation of 950 meters, except for the mountainous southwest. The region experiences a semi-arid climate, characterized by cold winters and dry summers, with annual rainfall ranging from 400 to 600 mm.

Agriculturally, Setif is a dominant province, with approximately 360,000 hectares of arable land, primarily used for cereal production. Its rural character is evident in its 45 rural municipalities out of 60, and the fact that 66% of its population resides in rural areas. Furthermore, approximately 11% of the population relies on agriculture and livestock for their livelihood, solidifying Setif's status as a primarily agricultural region.

This study examines Algeria's water resource management strategy for sustainable agricultural development through a case study of the major water transfer projects in eastern Algeria, specifically the High Plateaus project in Setif province. This research aims to highlight the severity and significance of water resource challenges in the region. By focusing on Setif, the study seeks to extrapolate the issues faced by the High Plateaus to other similar inland Algerian provinces. This approach recognizes that water transfer projects, which move water from surplus (high rainfall) to deficit (low rainfall) areas for irrigation, drinking water, and industrial use, represent a national strategy. Therefore, this research transitions from a provincial case study to a broader national perspective.

This research employed quantitative descriptive statistical analysis to process data. The quantitative approach facilitated the use of various tests, statistical techniques, and econometric models to achieve the study's objectives. Data were primarily sourced from specialized entities, notably the National Office for Irrigation and Drainage (ONID). The study focused on evaluating the impact of water resource development on key indicators of sustainable agricultural development within Setif province, the defined spatial boundary of this research.

2.2 Natural Potentials of the Study Area

Slope is considered one of the most important physical factors that influence development works. To highlight its impact on surface features, slope gradients were classified as follows:

Gentle Slopes: Between (0 - 3%), representing the High Plateaus region, corresponding to elevations below 1100 meters.
***Moderate Slopes*:** Between (3 - 12%), occupying the northern areas and part of the southern region, which connects the plateaus to the foothills.
Steep Slopes: Between (12 - 25%), concentrated at the base of mountain slopes, considered pastoral areas.
Very Steep Slopes: (More than 25%), encompassing mountain slopes and high-altitude mountainous regions.
From the above, it is observed that gentle and moderate slope categories dominate the area. This factor has a direct impact on the agricultural sector, land use, and the distribution of population and settlements in the province.
Climate:The Setif province is characterized by a continental semi-arid climate, hot in summer and harshly cold in winter. Winter rains are heavy and damaging to the land, contributing to soil erosion and runoff. The amount of rainfall varies spatially and temporally across the province.

Setif province exhibits diverse terrain, resulting in varying average annual rainfall across its regions:
Mountainous Region: Located in the north, with mountain elevations ranging from 700 to 2000 meters, and an average annual rainfall not exceeding 700 mm. It is characterized by arboriculture (tree cultivation).
High Plateaus Region: Covering a significant area with arable land, characterized by an average annual rainfall of 300 to 400 mm. It is characterized by cereal cultivation.
***Southern Region*:** Semi-arid, with an average annual rainfall of less than 250 mm. It is characterized by pastoral activities and livestock rearing.

Mountainous Region: Predominantly covered by calcareous soil, while the Bou Sellam basin area exhibits sedimentary soil, as do the slopes of Mount Azdim and Mount Yousef.
High Plateaus Region: This region is covered by calcareous soil, except for the southern portion, which exhibits limestone-derived soil.
***Southern and Southeastern Strip Region*:** The low-lying lands of this region, characterized by numerous chotts (salt lakes), exhibit saline soils with low productivity.

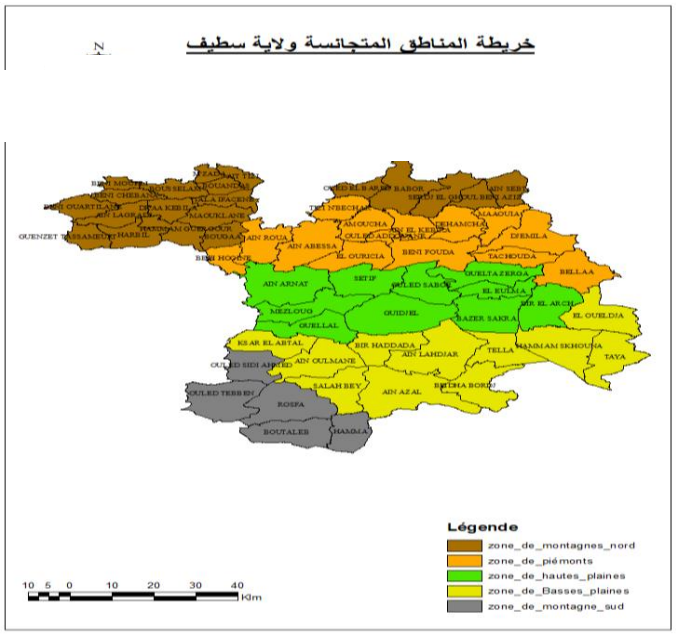

Fig. 1 Setif Province's Homogeneous Zones

3. Results and Discussion

Setif province is characterized by significant agricultural potential and capabilities. The utilized agricultural areas represent the dominant pattern in the Setif province region, with these areas estimated at 364,870 hectares, equivalent to 65.50% of the total agricultural area.

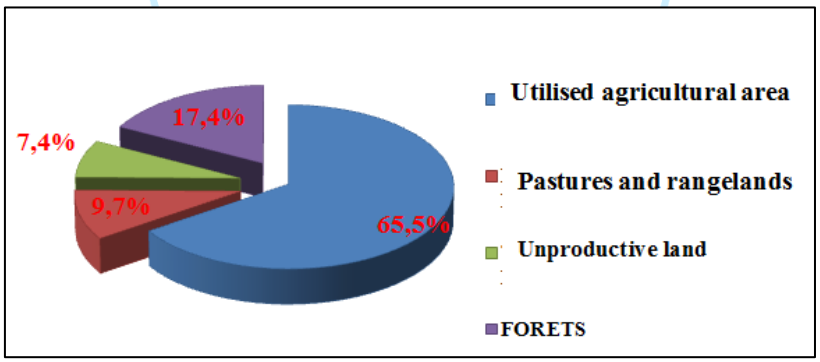

Fig. 2 Distribution of Total Agricultural Areas Cereal cultivation is the dominant and prevailing agricultural activity in the Setif province region. The area utilized for this type of activity amounts to 196,015 hectares, equivalent to 53.02% of the utilized agricultural area

3.1 Water Resources

The volume of mobilized water resources reached 13.75 hm³. This mobilization is sourced from 1.75 hm³ of groundwater and 12 hm³ of surface water. The mobilized water allows for a supply rate of 150 liters/capita.

Drinking water supply coverage reached 95% through various network connections.

The production capacity of the treatment plant at Mouane dam increased from 81,000 m³ to 115,000 m³, improving and securing drinking water supply for 56% of the population.

Groundwater is also exploited for irrigating agricultural crops in the region's agricultural perimeters to compensate for rainfall deficits. The irrigated area is estimated at 35,096 hectares, irrigated by both groundwater and surface water, with 297 boreholes and 119 springs. However, this groundwater exploitation has resulted in depletion within the area.

3.2 Major Water Infrastructure Projects and Transfer Schemes in the Province

The agricultural sector faces various climatic challenges that constrain crop production. Steppes comprise 8.2% of the province's area, while total arable land accounts for 79%, amounting to 365,286 hectares. The irrigated area represents

10% of the utilized arable land, totaling 35,096 hectares. This irrigation deficit stems from water scarcity and inadequate infrastructure for optimal dam water utilization. To expand irrigated land, projects are underway to meet the province's future needs through major water transfer schemes. Two dams within the province are planned for water transfers from external sources, as outlined in the table.

Operation	Irrigation	Drinking water
Ighil Emda mahoine transfer	88 million m³	34 million m³
Tablot Draa Eddis transfer	151 million m³	40 million m³
Total	239 million m³	74 million m³

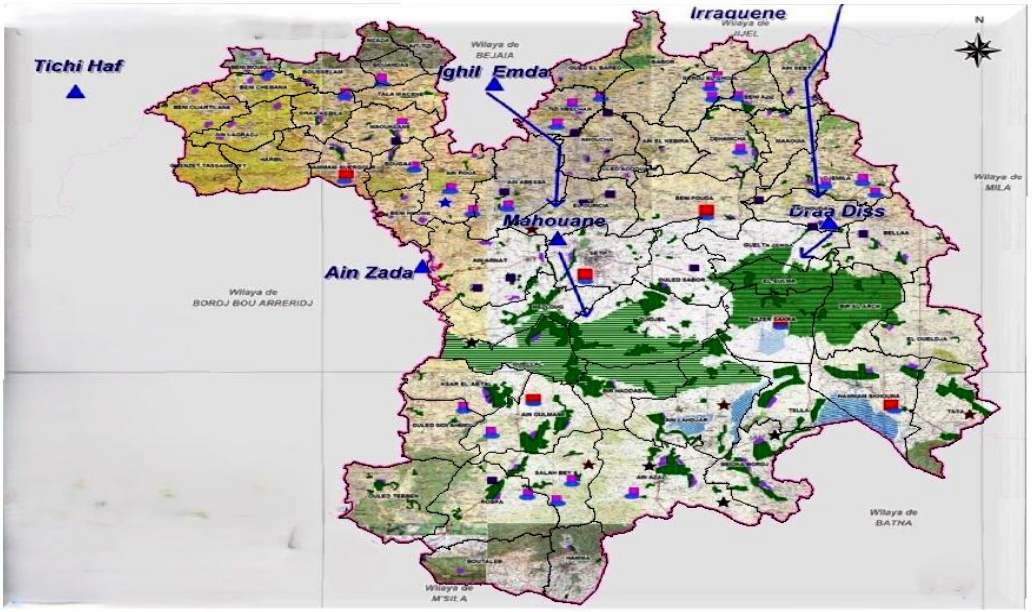

Fig. 3 Major water transfer projects in Setif Province

3.3 Iraguen-Tablot-Draa Eddis Transfer

This project is based on transferring water from the Jijel province, specifically the "Iraguen" area, with a capacity of 160 hm³, to the "Tablot" dam, which has a capacity of 214 hm³. This transfer occurs via gravity, utilizing the vertical difference in elevation between the two dams. The water is then transferred to the "Draa Eddis" dam, which has a capacity of 137 hm³, through steel pipes (diameter 1800-2000 mm) over a distance of 60 km, using five pumping stations (with a capacity of 115 megawatts). The elevation difference between the two dams is approximately 1000 meters.

While the construction of all dams and water transfer networks between them has been completed, the development of the perimeter with an irrigation water distribution network and various associated works has not yet commenced.

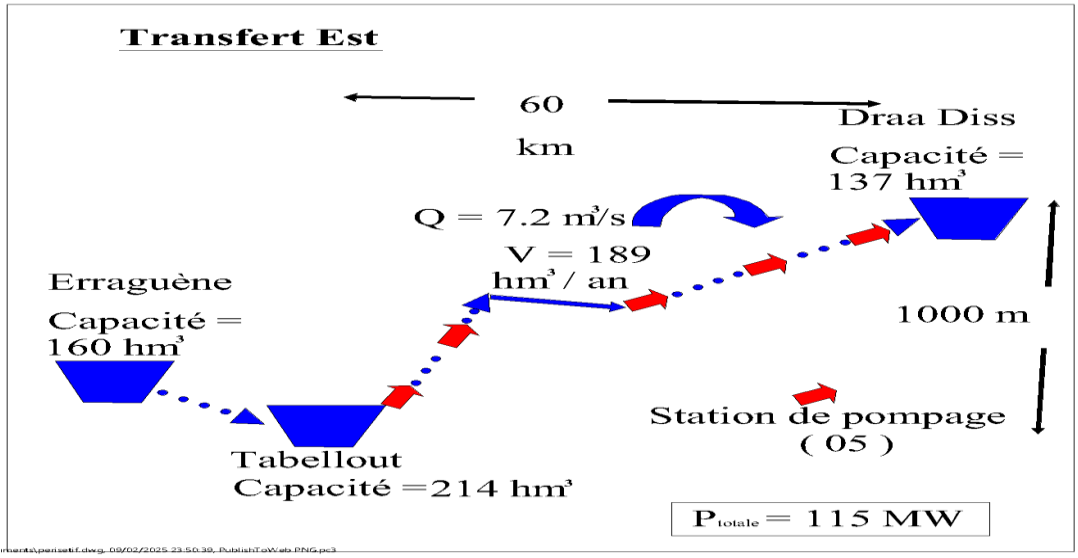

Fig. 4 Eastern Water Transfer (***Source:*** National Dams Agency2024)

3.4 Agricultural Potential of the Eastern Water Transfer Perimeter

The eastern region possesses considerable agricultural potential and valuable assets. The topographical feature of its flatness has significantly contributed to the abundance of arable land.

Table : Eastern Water Transfer

Irrigated Areable land	Total Utilized Agricultural Area (UAA)	Total Agricultural Area (TAA)	Municipality
510	10550,00	11700,00	bazersakhra
517	8000,00	8248,00	Ouled sabar
12552	10473.00	10995.00	birelarch
321	5324.00	5776.00	El eulma
562	7453,00	11707,00	Guelta zerga
828	8660,00	9697,00	eloualdja
15290h	**34663h**	**41352h**	**Total**

Based on the table, we observe that the municipalities within the El Eulma plains exhibit substantial agricultural potential. Specifically, these six municipalities have a total agricultural area of 41,352 hectares, with a utilized agricultural area of 34,663 hectares. Furthermore, the currently irrigated agricultural area amounts to 15,290 hectares.
Therefore, this project aims to:

- Irrigate 20,000 hectares of the El Eulma plains with an estimated volume of 151 hm³/year.
- Establish a system to transport 191 hm³/year to the El Eulma region.
- Improve the drinking water supply to 12 towns (Beni Aziz, Maaouia, El Eulma, Djemila, Dahamcha, Bir El Arch, Beni Fouda, Tachouda, Bella, Bazer Sakhra, Ain Sebt, and Ain Kebira), serving a combined population of 780,000, with a volume of 40 hm³/year."

3.5 The western system; Ighil Emda – Moan

Is directed towards the Setif region with a capacity of 122 million m³, to strengthen its water capacity by supplying the population centers, which are estimated at 13 population centers, as follows: (Setif, Ain Abassa, Qajjal, Qallal, Ain Arnat, Ain Oulmane, Mezloug, El Ourissia, Ksar El Abtal, Ouled Saber, Tizi Nbechar, Ouled Addoun, and Amoucha) with a quantity of 34 hm³/year, serving a total of 620,000 residents of the state - approximately one-third - in addition to irrigating the Setif High Plateaus basin with an estimated area of 15,800 hectares and a quantity of 88 hm³/year."

Table: Agricultural land distribution within the municipalities prior to the implementation of the irrigation scheme

Irrigated Areable Land	Total Utilized Agricultural Area (UAA)	Total Agricultural Area (TAA)	Municipality
725	12748,00	13764,38	Mezloug
1382	11024,90	14370,00	Kellal
2627	17220.00	18170.00	Guedjal
4734h	**23773**h	**28134,4**h	**Total**

From the table, we observe that the utilized agricultural area is estimated at 23,773 hectares, while the irrigable agricultural area is estimated at 4,734 hectares. This is a small area compared to the region's potential, attributed to a shortage of water resources. Therefore, the availability of this resource will lead to an increase in the irrigated area and create development in the region.

3.6 General Characteristics of the Water-Agricultural Development System in the Western Plains (Setif)

This project is based on transferring water from the Wilaya of Bejaia, specifically from the "Ighil Emda" dam, which has a capacity of 60 hm³, to the "Moan" dam, which has a capacity of 148 hm³. This transfer is achieved through 1800 mm diameter steel pipes over a distance of approximately 22 km, utilizing three pumping stations with a capacity of 119 hm³/year. The elevation difference between the two dams is approximately 750 meters, as illustrated in Figure 8."

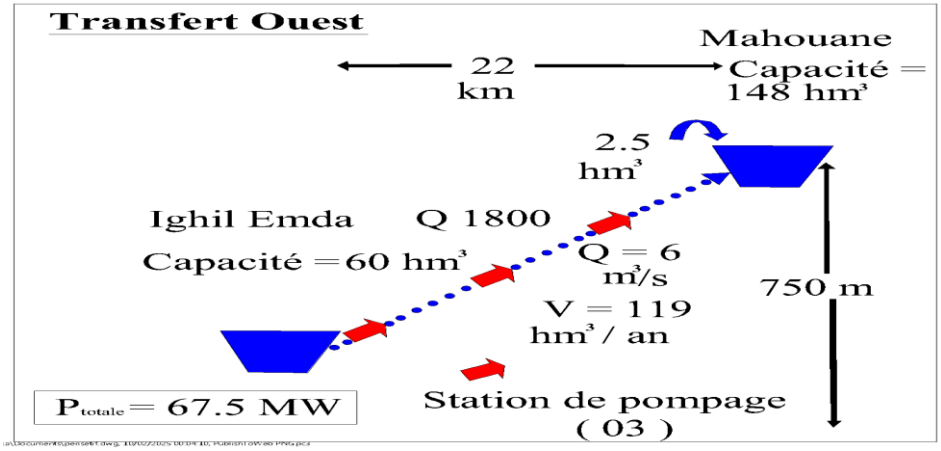

Fig. 5 Eastern Water Transfer (***Source:*** National Dams Agency2024)

3.7 Irrigation Perimeter Development Process

Water is transferred from the "Moan" dam to the irrigation perimeter through a distribution network within the perimeter (the network is 100% completed), using multiple pumping stations to deliver water according to the specific needs of each crop type.

3.8 Perimeter Division into Sectors

The irrigated perimeter has been divided into thirteen (13) sectors based on pedagogical and topographical data, as well as the sector's location relative to water sources. The following table illustrates the surface area of the various sectors. Furthermore, the sectors have been divided into blocks, with each block supplied by a single outlet not exceeding 100 hectares. Existing properties, roads, paths, infrastructure, and land topography were taken into account when defining the blocks. The perimeter has been divided into 292 blocks."

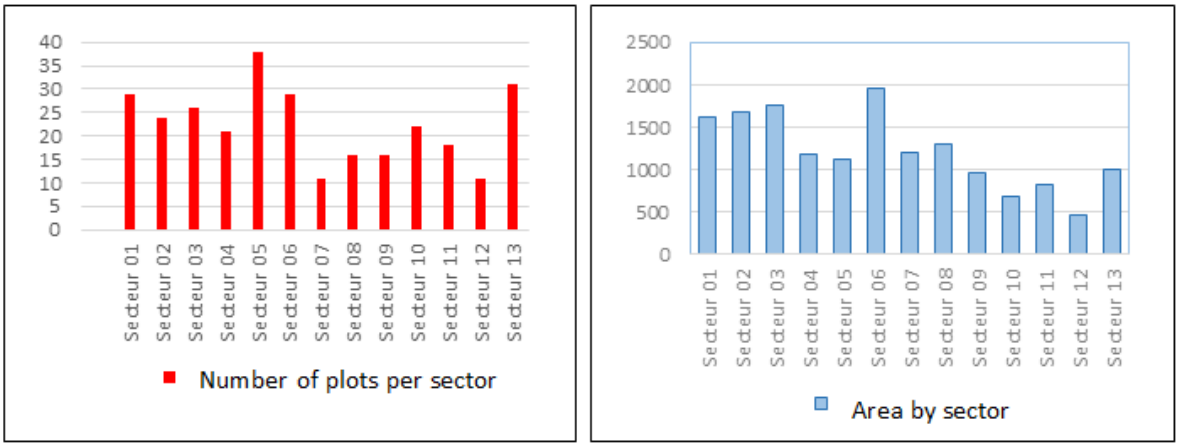

Fig. 6 Irrigation Perimeter Area and Divisions

3.9 Development of the Perimeter with Earth Roads

To enable farmers to carry out various agricultural activities within the region, such as transporting seeds, fertilizers, and crops, it was necessary to open roads to facilitate all operations for the farmers. Several main earth roads were opened with a length of approximately 17.08 km, and secondary roads with a length of approximately 59.02 km."

Fig. 7 Windbreaks and Terraces (Completed in the Western Irrigated Perimeter)

Most inland plains in the country are exposed to strong winds that cause soil erosion, increased evaporation, and the drying of leaves, flowers, and buds, leading to damage to crops and orchards.

Windbreaks act as barriers; they can reduce wind force by up to 40%, generating highly beneficial effects, such as cooler daytime temperatures and warmer nighttime temperatures.

Other benefits include increased air humidity, reduced evaporation and transpiration, and consequently, increased soil moisture. As a result, damage to trees and crops is minimized. This leads to a significant increase in production and yield.

Windbreaks have been installed in two perpendicular directions:

- Longitudinal (main) windbreaks, positioned perpendicular to the prevailing wind direction in the area.
- Transverse (secondary) windbreaks, positioned perpendicular to the longitudinal windbreaks and installed by operators.

Several factors determine the effectiveness of windbreaks:

- Direction.
- Length of the windbreaks.
- The need to prevent cold air accumulation.
- The selection, planting, and maintenance of trees.

The planting of these windbreaks within the western irrigated perimeter has been completed, with an estimated total of 108,782 units (representing a 100% completion rate) by the National Irrigation Office.

Fig. 8 Distribution of Water Requirements by Block Area

The net water requirements for all irrigation blocks within the studied perimeter are 88.84 million cubic meters per year.

Modèle	Classe (ha)	Superficie Exploitation (ha)	Surface (ha)	%	Besoins bruts annuels (m^3/ha)	Besoins bruts annuels (Hm^3)
1	0 - 3	1.8	482.61	3.05	10020.11	4.84
2	3 – 5	4.2	448.07	2.84	11739.86	5.26
3	5 – 10	7.2	1291.78	8.18	7805.36	10.08
4	10 – 20	15	1661.44	10.52	7075.56	11.76
5	20 – 50	33	3269.70	20.69	6480.89	21.19
6	50 – 200	107	5892.33	37.29	4419.94	26.04
7	> 200	480	2717.53	17.20	3558.95	9.67
Total			**15 763.45**	**100**		**88.84**

3.10 Water Requirements Determination and Agricultural Models

The water requirements within the perimeter have been determined based on the crops cultivated in the planned crop rotation, as part of the socio-economic agricultural file. Given that the total equipped area is 15,763.45 hectares, the overall irrigation standard is 5,636 m³/hectare.

3.11 Agricultural Models in the Projected Scenario

The agricultural models in the projected scenario are those proposed and studied in the socio-economic agricultural file, retained in the economic comparison conducted as part of the file for determining irrigable areas and water allocation for crop rotation selection.

Selection criteria relate to the following points:

- Surface area of the plot
- Type of treatment and crop
- Optimal use of the common network
- Standardization of starting elements for perimeter exploitation

3.12 Initiating Perimeter Exploitation

The perimeter was placed in an experimental phase during June 2024, where a quantity of water from the Mouane Dam, estimated at 3 million m³, was allocated to irrigate agricultural crops that suffered from drought due to rainfall shortage and groundwater level decline, over an area of 9,319 hectares (Sector 1) where development works related to the network and pumps were completed. This operation resulted in the recovery of the agricultural yield. The actual start of perimeter exploitation was given in late January 2025. The perimeter's needs are estimated at 50 million m³, according to the National Office of Irrigation and Drainage (ONID).

Fig. 9 Irrigation Operation in the Western Perimeter

4. Conclusion

Through our study of the subject, it has become clear to us that water transfer operations are of great importance in providing drinking water to the residents of municipalities, in addition to their very important role in irrigating agricultural lands. With the western irrigation perimeter entering service with an area of 9,319 hectares as an initial phase, awaiting the entry of the remaining area of this perimeter into service, and the start of developing the eastern perimeter with an area of 20,000 hectares, this will lead to an increase in the area of irrigated lands within the state's territory. It also contributes to reducing reliance on groundwater, which has suffered significant depletion in previous dry periods. In addition to raising production capacity and diversifying crops, this leads to the creation of jobs in the agricultural sector and increased investment, and undoubtedly aligns with the objectives of the National Spatial Planning and Development Scheme, which aims to reduce rural exodus and work on stabilizing residents in rural areas who practice agriculture and encourage them to settle.

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