Economic impact of water irrigation management for durum wheat

H. Maaroufi[1], R. Nciri[1], A. Bouselmi[1], T. Jarrahi[1], F. Ghedifi[1],
[1] National Institute of Fields Crops
[2] Campus Universitario Albacete

Abstract

Under the climate change context and the scarcity of natural resources, the adoption of new technologies and good farming practices for the management of soil and water in Tunisia is becoming an emergency to improve agricultural production, farmer's income and strengthen the pillars of economic, social and environmental growth.

This work aims to analyze the economic profitability through indicators such as gross margin and the benefit/cost ratio of durum wheat across demonstration plots crop in relation to irrigation management methods used by average farmer and those recommended by SUPROMED using **MOPECO or IREY** models. The study was conducted over two cropping season (2019-2020 and 2020-2021) in the central of Tunisia where the SUPROMED project is implemented.

The economic results showed that the **SUPROMED plots** has obtained the highest value of **Gross Margin** (GM €/ha). The rate of increase was about **65%** compared to the **average plots**

and it is related mainly to the higher Yield (Kg/ha) of the SUPROMED plots recorded by applying the best irrigation schedule and full technical package especially in the application of right quantities of DAP fertilizer, seeds, nitrogen fertilizer and herbicide.

The analysis of the **agronomic productivity of irrigation water** (**APW)** (kg/m^3) under the two management of irrigation indicated an increase of **49 %** under SUPROMED plots compared to average plots management justified by innovation in water management using decision-making tools (IREY and MOPECO)

In fact, the **indicator of benefit/cost ratio** obtained with each management irrigation is more than 1, which means that durum wheat crop under these conditions is economically profitable. and we recorded an increase of **36 %** for SUPROMED plots.

The dissemination of resource-efficient farming methods for farmers and support its adoption would enable them to efficient use of water, fertilizer which lead to increase the level of production and income to contributes to enhancing food security.

Key words: Gross Margin, Agronomic Productivity of irrigation Water, Benefit/Cost ratio, SUPROMED plots, Average plots, MOPECO & IREY

1. Introduction

In Tunisia, irrigated cereal areas are facing many constraints and the yields are still lower than the potential, water resources represent an essential element for the sustainable development of economic and social sectors, the national water policy aims to ensure water security for present and future generations and maintain water balance between supply and demand especially in climate change context and successive periods of drought (Ministry of agriculture, Tunisia).

The potential of the varieties currently used for irrigation is higher than the average recorded. The gap of potential water use efficiency (WUE=1.6 kg/m3) and the current one (WUE=0.9 kg/m3) explains the excess of water used for cereal irrigation (Bhouri Khila et *al*., 2016). Irrigation under limited water requires particular attention as to decrease water demand and to increase water use efficiency.

It's important to highlight that the agricultural sector alone consumes 70% of water resources in Tunisia, which poses a huge problem for the management of this increasingly rare resource (FAO, 2017).

However, the frequent irrigation in large quantities in order to raise the output can lead to low use efficiency of this factor.

The use of improved technology packages is essential to ensure food security, reducing poverty and improving livelihood of rural farmers (Maria Andrade, 2016). Hence a low interest, and therefore adoption of this technology, has been observed especially at the level of small farmers.

The lack of knowledge on the best water management practices is among the major constraints to improve wheat production in Tunisia. Hence, a better management of production factors, particularly water and nitrogen, is likely to improve the production potential of cereal varieties (ICARDA, 2014)-.

The evolution of the cereals production is largely related to the climatic conditions, in particular rainfall area. However, research results and national statistics show that the potential of cereals varieties is underexploited. Cereal yields depend on controllable factors (varieties, fertilizers, irrigation water, pesticides, mechanization, etc.) and uncontrollable factors such as rainfall and temperature (INGC).

To provide effective advice for more efficient crop management, SUPROMED is combining different models and tools: water, energy and fertilization management models, meteorological and climatic tools in order to develop, implement and validate an end user's IT Platform (SUPROMED, 2019).

This study aims to analyse the economic profitability through indicators such as gross margin and the benefit/cost ratio of demonstration plots of durum wheat crop in relation to irrigation management methods used by average farmer and those recommended by SUPROMED using MOPECO or IREY models

2. Materials and Methods

2.1 Study Area

The study was conducted in Sidi Bouzid, the area concerned by SUPROMED project in Tunisia, over two cropping season 2019-2020 and 2020-2021. This site is located in the center with a great diversity of irrigated crops. It has a potential for cereal intensification under irrigated and supplemental irrigated conditions. It is also characterized by an over exploitation of groundwater causing an alarming situation (Average annual decrease of groundwater is about 0.5 m).

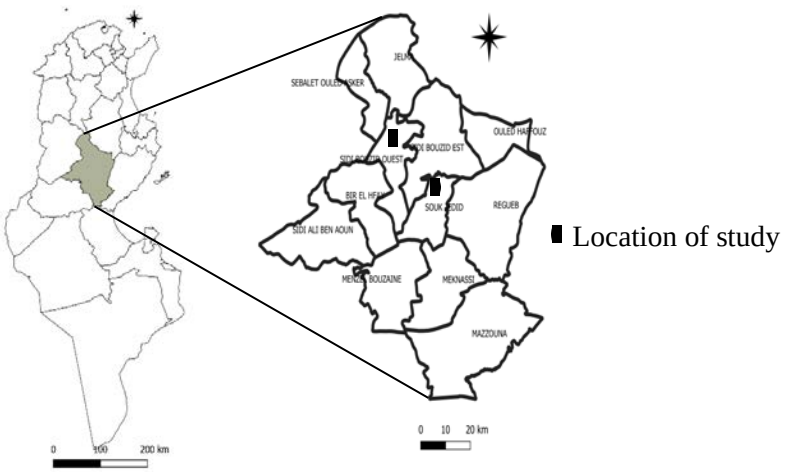

Figure 1. Geographic location of the study area

2.2 demonstration-site description

The demonstration plots have been established in on-farm project site. The approach adopted in Tunisia was based on the selection of two types of farmers the leader farmer and the average farmer. At the leader farmer level, the plot of the monitored crop was subdivided into two subplots: a plot managed according to SUPROMED research team recommendations by using MOPECO or IREY models integrated in SUPROMED (mainly water management) and a plot managed by farmer as he usually does. At the average farmer level, the plot is managed by farmer applying traditional methods.

2.3 Crop monitoring at plot level.

The monitoring of the plots included:

- Acquisition of daily climatic data for the determination of reference potential evapotranspiration (ETo) and Growing Degree-Days (GDDs);
- Weekly evolution of the crop phenology using the BBCH phenological scale.
- Volume and timing of the different water supplies based on water metering and irrigation duration. Real amount of irrigation water applied at each subplot is made possible with the installation of a pressure transductor and data logger to monitor the duration of each irrigation and water applied according to the evolution of the pressure during the irrigation event.
- Irrigation scheduling used by the farmer and those proposed by MOPECO or IREY models in the SUPROMED subplot, based on the 7-day weather forecasting offered by the ARW tool. This information will be very useful for determining the best irrigation schedule one week in advance, which coincides with the normal management of irrigation systems in farms included in Irrigator's Communities.
- Harvest: The harvest samples (at least four samples per subplot) have been used to determine the total yield, the efficiency in the use of water (agronomic and economic irrigation water productivity) and the profitability of the crop, while the rest of data has been used to reach the technical itinerary of both strategies (traditional and SUPROMED).

At the end of the crop monitoring period, a comparison was made between the results obtained by the farmer on the basis of his traditional and conventional approach, and the scientific and innovative method proposed by SUPROMED. The comparison focuses on off-season soil management practices

2.4 Methodology:

In this study, the methodology used to analyze profitability of durum wheat across the demonstration plots is based on comparing economic indicators relative to the production, the irrigation volume and efficiencies under the two management of irrigation such as:

a) Gross Income related to demonstration plots: Revenues from crop sales (Principal and secondary product) has been calculated using the information facilitated by the producer related to the sale price and the yield obtained from the harvest.
b) Production costs: have been calculated using the labor, fertilizer, and other raw material inputs as well as the costs associated with irrigation that have been furnished by the farmer, the costs can be classified as: a) external costs associated with the costs of seed, fertilizer, pesticides and water; b) calculated costs related to labor and machinery; and c) estimated costs of crop insurance and machinery rental.
c) Gross Margin of production: The difference between the annual gross income and the total of costs associated with the demonstration plots which is tool or measure for the relative profitability of the crop, calculated as:

$$GM = Vp - Ct$$

Where Vp is the total value of the commodity, including subsidies (€/ ha) and Ct is the total costs (variable plus fixed costs). The production cost and the gross margin depend on several factors such as the technical package adopted in the plot.

d) The Benefit/Cost ratio calculated from dividing Gross margin by Variable Costs, considered as a decision support tool that allow better management, calculated as:

$$BC_R = GM/Ct$$

e) Agronomic productivity of irrigation water (APW) (FAO, 2003) relates the yield of the crop (Y_a) (kg/ha) to the volume of gross irrigation water applied (I_G) (m^3)

$$APW = Ya/I_G$$

f) Water productivity (WP) relates the yield of the crop (Y_a) (kg/ha) to the actual evapotranspiration (ETa) (m^3)

$$WP = Ya/Eta$$

3. Results and discussion

3.1 Crop data

Table 1. Crop data

CROP: **Durum Wheat**				**Cropping season** 2019-2020		
Sowing or sprouting date • SUPROMED:**03/12/2019** • Leader:**06/12/2019** • Average:**28/11/2019**				Harvest date: • SUPROMED:**08/06/2020** • Leader:**08/06/2020** • Average:**08/06/2020**		
- Number of days per stage (initial/development/mid-season/late-season) • SUPROMED: 32/69/55/31 • Leader: 26/69/55/31 • Average: 38/69/55/31						
Total rain during the crop season (initial/development/mid-season/late-season) mm: • SUPROMED: **127.2** (6.1/20.6/100/0.6) • Leader: **127.2** (6.1/20.6/100/0.6) • Average: **127.2** (6.1/20.6/100/0.6)				- Et_0 Total (initial/development/mid-season/late-season) mm • SUPROMED: 78.5/195.4/252.6/161.1 • Leader: 79.1/204.8/266.2/159.4 • Average: 91.1/184.9/236.8/164.5		
KC value (initial/development/mid-season/late-season): (0.7/0.7-1.15/1.15/1.15-0.25)						
Water content in the soil at the beginning of the soil water balance (as **%** of total available soil water within the root zone (***TAW***))**45% for all treatments**						
Type of Farmer	Gross irrigation water applied (I_G) (mm)	Total rain during the crop season (mm)	Labor description	Applied fertilization description(kg/ha) N/P2O5/K2O	Other raw material description	Crop yield by sampling (kg/ha)
SUPROMED	462.6	127.2	a/2xb/c	110/55.5/0	Herbicide (d)	3664
Leader	526.6	127.2	a/3xb/c	83/0/0	Herbicide (e)	3332
Average	430	127.2	2xb/c	104.4/36.8/0	Herbicide (e)	3150

a: Tillage, b: disc harrowing plough, c: preparing sowing bed, d: herbicide Amilcar OD, e: herbicide Corida

Comments on the analysis of results

The leader plot consumed more water than SUPROMED plot and the average plot consumed less water. we have not recorded any significant difference between the yields of the three plots, but with a few dominances of SUPROMED plot 3664 kg/ha.

Table 2. Crop data

CROP: **Durum Wheat**	**Cropping season** 2020-2021
Sowing or sprouting date • SUPROMED: **27/11/2020** • Leader: **20/11/2020** • Average 1: **15/12/2020** • Average 2: **08/11/2020**	Harvest date: • SUPROMED: **14/06/2021** • Leader: **14/06/2021** • Average 1: **10/06/2021** • Average 2: **12/06/2021**
- Number of days per stage (initial/development/mid-season/late-season) • SUPROMED: **36/72/41/29** • Leader: **34/73/51/25** • Average 1: **32/84/51/28** • Average 2: **33/63/40/25**	
Total rain during the crop season (initial/development/mid-season/late-season) mm: • SUPROMED: (12.6/6.8/47.7/6) • Leader: (37.6/2.8/53.7/6) • Average 1: (30.4/2.8/53.7/6) • Average 2: (5/6.8/47.7/6.2/65.7)	- Et_0 Total (initial/development/mid-season/late-season) mm • SUPROMED: (60.4/162.6/154.7/ 152.3) • Leader: (53.1/160.8/184.4/ 130.2) • Average 1: (55.8/173.7/181.7/ 145.8) • Average 2: (60.4/131.5/164/ 153.3)
KC value (initial/development/mid-season/late-season): (0.7/0.7-1.15/1.15/1.15-0.25)	
Water content in the soil at the beginning of the soil water balance (as **%** of total available soil water within the root zone (***TAW***)) **46% for all treatments**	

Type of Farmer	Gross irrigation water applied (I_G) (mm)	Total rain during the crop season (mm)	Labor description	Applied fertilization description(kg/ha) N/P2O5/K2O	Other raw material description	Crop yield by sampling (kg/ha)
SUPROMED	412	73.1	a/2xb/c	135/46/25	Herbicide (d)	8068.25
Leader	450	100.1	a/3xb/c	134/0/0	Herbicide (e)	6059.05
Average1	430	92.9	2xb/c	99/115/0	Herbicide (e)	5023.75
Average 2	480	65.7	a/2xb/c	127/69/0	None	4185

a: Tillage, b: disc harrowing plough, c: preparing sowing bed, d: herbicide Amilcar OD, e: herbicide Amilcar WG

Comments on the analysis of results

The sowing dates of the different plots of durum wheat: SUPROMED, Leader, Average 1 and Average 2, were different. But the harvest dates were getting closer. The quantities of water applied were also different from 412 mm (SUPROMED plot scheduled by MOPECO model) to 480 mm (Average 2). We also observe a variation in rainfall between the different plots. During the crop cycle, the average 2 plot received the lowest amount of rain (65.7 mm) while the leader plot received the highest amount (100 mm). The highest yield was recorded by SUPROMED plot (8068.25 kg / ha: a best result for this campaign) and the lowest yield was recorded by Average 2 (4185 kg / ha). As a result, (SUPROMED plot recorded an increase in yield of 24%, 37% and 48% respectively compared to leader, average 1 and average 2. this increase in yield can be justified by the good management of the irrigation water. in (SUPROMED plot using the MOPECO model, and also by the traditional irrigation system (flood irrigation) with wicked irrigation scheduling, which can damage the crops which affected the final yield.

3.2 Irrigation system

Tabla3. Results of the irrigation system evaluation

CROP: **Durum Wheat**					**Cropping season**
Irrigation efficiency considered (Ea) (%) • SUPROMED:**60%** • Leader:**60%** • Average:**60%**					2019-2020
Type of Farmer	Irrigation system and emitter spacing (m x m)	Average working pressure (m)	Average discharge (m^3 h^{-1}))	Application rate (mm h^{-1})	EU[(1)] or DU (%)
SUPROMED	Flood irrigation	-	11	61.11	Emision Uniformity was not measured for flood irrigation
Leader	Flood irrigation	-	11	61.11	
Average	Flood irrigation	-	10	55.55	

[(1)] EU: Emision Uniformity (Drip irrigation) or Distribution Uniformity (DU) (sprinkler irrigation)

Comments on the analysis of results

An evaluation of the irrigation systems has been carried out. The pressure and emission uniformity are difficult to measure for Wheat plot under flood irrigation.

Tabla 4. Sensors used in the crop monitoring

CROP: **Durum Wheat**		**Cropping season** 2019-2020			
Is there Local Weather station		NO		**UTM coordinates**	
Type of Farmer	Drill¬Drop or similar	Pressure transducer	Datalogger ECO.D3 or similar	Date of installation	Others
SUPROMED	No	No	No	-	Flow meters
Leader	No	No	No	-	Flow meters
Average	No	No	No	-	Flow meters

Comments on the analysis of results

Equipment not yet acquired. The COVID-19 pandemic prevented us from having the sensors in time. The equipment acquisition process is almost finished. We will most likely receive the material in September 2020.

Table5. Results of the irrigation system evaluation

CROP: **Durum Wheat**					**Cropping season**
Irrigation efficiency considered (Ea) (%) • SUPROMED (Drip irrigation):**80%** • Leader (flood irrigation):**50%** • Average 1 (flood irrigation):**50%** • Average 2 (Drip irrigation)**: 80%**					2020-2021
Type of Farmer	Irrigation system and emitter spacing (m x m)	Average working pressure (Bar)	Average discharge (m^3 h^{-1}))	Application rate (mm h^{-1})	EU (1) or DU (%)
SUPROMED	0.1×0.6	2.3	0.48	8	93.77
Leader	Flood irrigation	0.06	1.3	7.22	-
Average 1	Flood irrigation	0.06	1.2	6.66	-
Average 2	0.1×0.6	2.3	0.5	8.33	80

(1) EU: Emision Uniformity (Drip irrigation) or Distribution Uniformity (DU) (sprinkler irrigation)

Comments on the analysis of results

The results of the irrigation system evaluation show low Irrigation efficiency of the flood irrigation systems (50%) used by leader and average 1. Since the drip irrigation system at SUPROMED plot was controlled by the team of l 'INGC, we observe a good Distribution Uniformity (DU) compared to average 2 plot which uses the same irrigation system. However, it was not possible to calculate this parameter for the flood irrigation system. The Application rate between the two drip irrigation systems is almost the same view as the Irrigation system and emitter spacing were the same.

Table 6. Sensors used in the crop monitoring

CROP: **Durum Wheat**		**Cropping season** 2020-2021			
Is there Local Weather station		No		SUPROMED:10.62Km (Sidi bouzid) Leader: 10.6Km (Sidi bouzid) Average 1: 14.18 Km (Sidi Bouzid) Average 2: 12.92 Km (Sidi Bouzid)	
Type of Farmer	Drill¬Drop or similar	Pressure transducer	Datalogger ECO.D3 or similar	Date of installation	Others
SUPROMED	**YES**	**YES**	**YES**	22/01/2021	Flow meters
Leader	**YES**	**YES**	**YES**	22/01/2021	Flow meters
Average 1	**YES**	**YES**	**YES**	22/01/2021	Flow meters
Average 2	**No**	**No**	**No**	-	-

Comments on the analysis of results

We have installed the sensors (Drill & drop, and water pressure) on the same date (01/22/2021) at SUPROMED, leader and average1. Due to the limited budget allocated for this equipment, we did not install these sensors in average 2.

3.3 Gross Margin (GM), **Benefit/Cost Ratio** (BC_R) *and Agronomic productivity of irritation Water (APW)*

Tabla 7. Determination of the Gross Margin (GM), Benefit/Cost Ratio (BC_R) **and Agronomic productivity of irritation Water (APW)**

CROP: **Durum Wheat**	**Cropping season** 2019-2020
Gross Margin (GM) €/ha • SUPROMED:778 • Leader:702 • Average:589	**Benefit/Cost Ratio** (BC_R) • SUPROMED:1.2 • Leader:1.18 • Average:1.13
Agronomic productivity of irrigation water (***APW***) (kg/m^3) • SUPROMED: 0.80 • Leader: 0.63 • Average: 0.73	Production/Eta (kg/mm) • SUPROMED: 6.96 • Leader: 6.04 • Average:6.21

Type of Farmer	External costs (€ ha^{-1})	Calculated costs (€ ha^{-1})	Estimated costs (€ ha^{-1})	Total costs (C_t) (€ ha^{-1})	Total value of the commodity (V_p) (€ ha^{-1})
SUPROMED	391	53	207	651	1430
Leader:	342	50	204	596	1299
Average:	312	56	152	520	1109

Comments on the analysis of results

The economic result showed that the SUPROMED plot has obtained the highest value of Gross Margin (MG €/ha). The rate of increase was 9.7% compared to the leader plot and 24.3% compared to average plot. the origin of this difference related mainly in the higher Yield of the SUPROMED plot and the differences in the doses of water and inputs applied between plots, especially in the application of DAP fertilizer, quantity of seeds, nitrogen fertilizer and herbicide.

Table 8. Determination of the Gross Margin (GM), Benefit/Cost Ratio (BC_R) **and Agronomic productivity of irritation Water (APW)**

CROP: **Durum Wheat**	**Cropping season** 2020-2021
Gross Margin (GM) €/ha • SUPROMED:1584.8 • Leader: 1079 • Average 1: 966.05 • Average 2 : 718.93	**Benefit/Cost Ratio** (BC_R) • SUPROMED:1.73 • Leader: 1.3 • Average 1: 1.3 • Average 2: 0.88
Agronomic productivity of irrigation water (***APW***) (kg/m^3) • SUPROMED: 2.24 • Leader: 1.34 • Average 1: 1.17 • Average 2: 0.87	Production/Eta (kg/mm) • SUPROMED: 1.78 • Leader: 1.38 • Average 1: 1.25 • Average 2: 1.01

Type of Farmer	External costs (€ ha^{-1})	Calculated costs (€ ha^{-1})	Estimated costs (€ ha^{-1})	Total costs (C_t) (€ ha^{-1})	Total value of the commodity (V_p) (€ ha^{-1})
SUPROMED	460.88	367.23	86.9	918	2502.8
Leader	488.72	236.84	89.9	815.46	1894.4
Average 1	341.31	316.67	66.65	724.63	1690.7
Average 2	399.75	354.49	57.35	811.58	1530.5

Comments on the analysis of results

The economic result showed that the SUPROMED plot has obtained the highest value of Gross Margin (1584.8 €/ha). The rate of increase was 32% compared to the leader plot, 39% compared to average 1 plot

and 54.6% compared to average 2 plot. the origin of this difference related mainly in the higher Yield of the SUPROMED plot and the differences in the doses of water and inputs applied between plots, especially in the application of DAP fertilizer, quantity of seeds, nitrogen fertilizer and herbicide.

3.4 Key Performance Indicators (KPI)

Table 9. Definition of Key Performance Indicators (KPI) for durum wheat crop (Cropping season 2019-2020)

KPI	UNIT	SUPROMED	Leader	Average
Yield	Kg/ha	3664	3332	3150
Annual irrigation water by irrigated area	m^3/ha	4626	5266	4300
APW	Kg/m^3	0.8	0.63	0.73
Total percolation	m^3/ha	1280	1640	1130
Percolation due to irrigation events	m^3/ha	440	600	490
Rain Percolation	m^3/ha	830	1040	640
GM	€/ha	778	702	589
GM/Water required by crop	€/ha	0.12	0.03	0.1
GM/irrigation water	€/m^3	0.168	0.133	0.136
N/Irrigated area	UN/ha	165.5	83	141.2
APN	Kg/UN	22.2	40.1	22.3
N/Water supply	UN/m^3	0.035	0.015	0.032
WF_{Green}	m^3/kg/ha	1.285	1.413	1.494
WF_{Blue}	m^3/kg/ha	0.369	0.214	0.533
WF_{grey}	m^3/kg	0.155	0.162	0.185
WF_{Total}	m^3/kg	1.809	1.789	2.212

Table 10. Definition of Key Performance Indicators (KPI) for durum wheat crop (Cropping season 2020-2021)

KPI	UNIT	SUPROMED	Leader	Average 1	Average 2
Yield	Kg/ha	8068.25	6059.05	5023.75	4185
Annual irrigation water by irrigated area	m^3/ha	4120	4500	4300	4800
APW	Kg/m^3	1.95	1.34	1.16	0.87
Total percolation	m^3/ha	430	350	730	670
Percolation due to irrigation events	m^3/ha	345.8	267	644	588
Rain Percolation	m^3/ha	84.2	83.1	86.2	82
GM	€/ha	1584.8	1079	966.05	718.93
GM/Water required by crop	€/m^3	0.32	0.22	0.20	0.15
GM/irrigation water	€/m^3	0.38	0.23	0.22	0.15
N/Irrigated area	UN/ha	135	134	99	127
APN	Kg/UN	59.76	45.21	50.74	32.95
N/Water supply	UN/m^3	0.032	0.029	0.023	0.026

WF_{Green}	m^3/kg/ha	0.47	0.56	0.61	0.82
WF_{Blue}	m^3/kg/ha	0.12	0.13	0.03	0.16
WF_{grey}	m^3/kg/ha	0.16	0.14	0.27	0.3
WF_{Total}	m^3/kg/ha	0.75	0.83	0.91	1.28

Comments on the analysis of results

The table of KPI for the durum wheat crop show good water productivity for SUPROMED and leader plots (1.95 and 1.34 kg / m3). Regarding percolation, the values were higher than average1 and average2 (730 and 670 m3 / ha during the whole durum wheat cycle). these two plots were managed by farmers who gave high doses to keep soil moisture close to field capacity. for the other indicators, the SUPROMED plot showed good economic and environmental performance. The applied technical package made it possible to obtain the low value of the total Water footprint (0.75 m^3/kg/ ha).

4. Conclusion

The platform implemented to test the Mopeco and Irey model to manage the water irrigation of wheat in Tunisia, were reliable in this study in one region namely Sidi Bouzid (under supplemental irrigation). However, from the preliminary results in the reliable region, the use of Mopeco and Irey model improved the management of water irrigation through enhancing wheat yield and farmer income in this region.
In Tunisia, enhancing the economic and environmental sustainability of farming systems through a more efficient management of water, energy and fertilizers is an exigence in a context of scarcity, fragility of natural resources and climate change.

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6. References

Bhouri Khila S., Douh B., Mguidiche A., Boujelben A. 2016. Efficience d'utilisation de l'eau de la culture de blé dur en conditions pluviales et irriguées en Tunisie.
FAO, 2017. FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.
ICARDA, 2014. Enhancing Food Security in Arab Countries.
INGC, Annual report of applied researches and technologies transfer
Ministry of agriculture, Strategic development plan.
SUPROMED, 2019. Sustainable production in water limited environments of Mediterranean agro-ecosystem.
MariaAndrade, World Food Prize, 2016. The Role of Technology in Achieving Global Food Security