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A bio-economic model to improve irrigated durum wheat performance and regional profit in Mediterranean conditions

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1. Introduction

In Tunisia, Durum wheat (DW) holds the most important place among irrigated cereals in terms of production and cultivated area. It is grown on an average annual area of 48 700 ha, which represents two-thirds of the irrigated cereal area. This area allows producing an average of 180 000tons representing around 20% of national durum wheat production. However, the achieved yield of the durum wheat, reached 360kg/ha against an expected yield of 700 kg/ha (El Faleh and Gharbi, 2014). This result showed also very low water productivity and economic performance. Focusing on the irrigation practices, researches have shown that poor management in terms of applied dose and irrigation timing are major factors limiting the agronomic performance of the DW. Other researches have focused on the cropping system and have pointed out the negative impacts of pricing policy on the economic performance of DW and profit at regional level. In order to improve the durum wheat production and the economic performance, there is an urgent need for approaches that integrate both economic and agronomic criteria. As pointed out by many studies that bio economic modelling approach is the most widely recommended approach for studying the effect of different management practices on farm performance (Blanco and Flichman, 2002). Several bio-economic models have been developed for production at the field level and farm level (Reckling et al., 2016). However, they fail to identify impacts at higher levels (e.g., region, country) that may be useful to policy makers. Hybrid models address this issue by aggregating results from the farm level to higher levels (Britz et al., 2012). These models usually consider the diversity of farm types (e.g., crop, livestock) and technologies, but none of them focuses on cereal production.
This work aims to highlight the main levers for improving the agronomic and economic performance of DW crop and the regional profit. In order to do this issue, we develop the economic model MORBIT coupled to the biophysical model CROPSYST.

Materials and Methods

The study was carried out in the governorate of Kairouan, Jendouba and Siliana, which are the main zone where the irrigated DW has been grown.
In order to identify the main technical and economic levers offering a better profitability of the activity and a better valorisation of water resources a bio-economic model coupling the biophysical model CropSyst (*Cropping System Model*) and the economic regional model *MORBIT (regional model of irrigated durum wheat in Tunisia)* has been developed. Cropsyst is used to assess the impact of management irrigation alternatives on DW yield taking into account climatic factors, and soil characteristics. MORBIT is an optimization regional model, which has been developed by adapting the SARAS model for Tunisian conditions (Olubode -Awosola et al ., 2008). MORBIT maximizes a regional profit subject to set of resource constraints. The general mathematical formulation of MORBIT is presented below (Eq.1):

Figure1: Location of the study

$$\text{Maximize} \prod = \sum_f \sum_t \sum_c \left(\left(PB_{f\,t\,c} - (\alpha_{f\,t\,c} + 0.5\beta_{f\,t\,c}) \right) sup_{f\,t\,c} \right) - \sum_f \left(\theta_f \left(\sum_t sup_{f\,t\,c} \right)' covPB_c \left(\sum_t sup_{f\,t\,c} \right) \right) \quad \text{(Eq.1)}$$

Subject to: $$Nf \sum_f \sum_t \sum_c sup_{f\,t\,c} \leq Disp_{Rterre} \quad \text{(Eq .2)}$$

$$\sum_t \sum_c sup_{\,f\,t\,c} \leq Disp_{fterre} \quad \text{(Eq .3)}$$

$$Nf \sum_f \sum_t \sum_c (Beseau_{\,f\,t\,c}\; sup_{f\,t\,c}) \leq Disp_{Reau} \quad \text{(Eq .4)}$$

$$\sum t \sum c\; Beseau_{f\,t\,c}\; sup_{f\,t\,c} \leq Disp_{feau} \quad \text{(Eq .5)}$$

The principal technical and socio-economic constraints are irrigable land and water constraints. Eq. (2) and (Eq. 3) represent the land constraint respectively at the regional and farm level. The regional irrigation water capacity was also modelled as constraints at both farm type and regional levels (Eq.4 and Eq.5)

To apply the CROPSYST- MORBIT model chain, three types of data are required: (i) the bio-physical characteristics of the agri-environmental zones used as input for the biophysical model CROPSYST, (ii) the farm type characteristics used in MORBIT to define the resources availability and (iii) the input output data/coefficients of the current activities which include technical and economic information such as yield, input, prices and costs.

To collect data on farm operations during the cropping year (2014-2015), we carried out face to face a targeted survey with 698 farms. We have focused mainly on the characterization of the farms' structure (SAU, access to water) and on the farming system (land use, irrigated activity, etc.). It allows to gather detail data regarding the technical management (tillage, fertilization, irrigation, treatment, harvesting) of the DW crop as well as all the input and product prices. The data collected made it possible to develop a typology of farming systems and to analyse the performance of the durum wheat cultivation activity. Three types of farming systems were identified: A monocultural system based on durum wheat cropping, a diversified cereal-oriented system and a diversified horticulture-oriented system. Performance analysis revealed a clear disparity between two distinct performance levels for each farming system (Mazhoud et al., 2020). Ten farm types were considered in the region. Each farm type identified represents a virtual farm obtained by averaging data from farm that are grouped in the same type.

3. Results and discussion

The results showed that the surveyed land reached 4327 ha. The area of the irrigated Durum reached 2095 ha representing around 48% of the irrigated area. In terms of irrigation practice, results showed that the consumption of the DW reached 1609 m^3/ha. The practice of the complementary irrigation allowed the surveyed farmers to achieve an average yield of DW of 360 kg/ha. Given this result, the total production of DW reached 9367 tons and the water productivity reached only 7.6 kg/ha /mm/ which is the half of the potential level that should be reached following agronomical studies (Lasram et al., 2015). Economic results showed that Gross margin of DW reached only 509 TND/ha and the regional profit account for 201480TND.

The analysis of farmers' practices in terms of irrigation revealed that the low performance of the irrigated DW crop is due to the practice of low irrigation dose, the inadequation of the irrigation schedule and the cereal pricing. Given these results and by using the bio economic model, two types of scenarios were simulated, including: (S_1) implementing of adequate irrigation to meet the needs of the plant taking into account the rainfalls and (S_2) increasing cereal price by 20%.

The simulation of scenarios showed that the yield of the durum wheat may increase by 20% compared to the baseline scenario (S_0) (Table1). This improved the water productivity by 25% reaching an average of 9.5 kg/ha/mm and allowed farmer to earn 1170 TND/ha as Gross margin. These results showed an improvement of total production of DW to reach 11419 tons and allowed to achieve a better regional profits (219910 TND) representing an increase of 9 % compared to (S_0)

Table 1. Simulation results of scenarios

Scenarios	Definition	Yield (kg/ha)	Water productivity (kg/ha/mm)	Gross Margin (TND/ha)	Production of durum wheat (Tons)	Profit (TND)
S_0	Baseline	400	7.6	509	9367	201480
S_1	Adopting adequate irrigation	480	9.5	1170	11419	219910
S_2	increasing cereal price	400	7.6	1012	9676	216700

4. Conclusion

This work aims to highlight the main levers for improving the performance of DW crop and the regional profit. This was done using the bio-economic modelling approach coupling the biophysical model CROPSYST and the economic regional model MORBIT**.** This model allowed to identify main levers relate to (i) the control of irrigation and (ii) the increase of cereal price. The concretization of these paths requires a concerted reflection between the actors to put forward suitable strategies according to the studied context.

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