

# Farmers' willingness to adapt to climate change for sustainable water resources management: a case study of Tunisia

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## ABSTRACT

Shrinking water resources as a potential result of climate change (CC) creates a challenging tradeoff situation in the north of Tunisia. This study provides valuable insights into the conditions that can promote farmers' acceptance of regulated deficit irrigation and a new water pricing policy to address CC impacts on the semi-arid irrigated region which will allow for a sustainable irrigation regime and the conservation of water resources at regional scale. Binary logistic regression was used to analyze data collected from 100 farmers in the citrus regions of Beni Khaled and Menzel Bouzelfa, to identify determining factors for farmers' willingness to accept the proposed water management strategies. Empirical findings reveal that the significant explanatory variables are essentially linked to farmer satisfaction about the current irrigation management in relation to water supply reliability, rather than the social criteria and farmers' awareness of water scarcity. More efforts are needed to improve the transparency of water allocation systems to motivate the willingness of water users to adopt new technologies or policies. The different stakeholders should agree to take action now about strategic extension and communication plans to enhance awareness on ensuing environmental problems, to take advantage of long-term profitability of the water restriction.

**Key words** | citrus, farmer willingness, sustainable water resource management

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## INTRODUCTION

Due to aridity, water resources in Tunisia are subject to high demand pressure especially in the irrigated areas where chronic water shortages have reached critical levels, causing important environmental degradations and serious social tensions among users, as in the case of the Governorate of Nabeul in north-eastern Tunisia, also known as the Cap-Bon peninsula, which is specially characterized by orange production. This area represents an important economic

activity (Chouchane *et al.* 2015) and provides 85% of the total citrus production in the country (Regional Agricultural Development Commissariat of Nabeul 2014) and substantial income to about 25,000 rural households (Zekri & Laajimi 2001). It is why this region with regards to citrus production occupies an important place in the local and national economy by contributing to the creation of employment, improving livelihoods, and enhancing the balance of

payments through exports, in addition to its role in securing the food security for the local and national population. In this region, decrease in groundwater level of the main aquifers and water quality degradation are damage resulting from overexploitation, citrus surface extension, and non-controlled increase of wells. This situation implies important losses of soil fertility due to salt accumulation (Sarraf *et al.* 2004).

To mitigate the large hydrological deficits, additional water was brought to Cap-Bon through a canal from the north-western regions of the country, which is better endowed with water resources. By fixing an annual transfer quota of 80 Mm<sup>3</sup> (National Center of Agricultural Studies 2007), the canal was supposed to solve the problem of water imbalance. However, the plan failed because it did not account for the needs of new expansion in cultivated areas. Other measures taken to mitigate water shortages in the irrigated areas include up to 60% subsidies extended to farmers who adopt drip irrigation. However, despite the intentions of the modernization efforts to promote water saving and conserve quality resources, on-farm water use was not significantly reduced (Al Atiri *et al.* 2004), surface irrigated areas have been extended (Regional Agricultural Development Center of Nabeul 2014), groundwater resources continue to be degraded (National Center of Agricultural Studies 2007) and hence the government has not managed to curb the demand for more irrigation water.

With the increase in groundwater salinity in the Cap-Bon region and as citrus trees have been classified as a salt-sensitive crop (Syvertsen & Garcia-Sanchez 2014), farmers are becoming more dependent on canal water, which is strongly and simultaneously solicited by other economic sectors such as tourism and industry. The availability of canal water during the summer season is then exposed to large fluctuations, making unplanned water cuts a serious threat to the entire region. This challenging tradeoff situation is making water allocation for agricultural purposes a real dilemma for local water managers. The paradox is that farmers who are complaining of water shortages are, at the same time, blamed for wasting too much water. Indeed, Dhehibi *et al.* (2007) found, on the basis of a survey, that the technical efficiency of citrus growers was too low in Cap-Bon and that farmers could have the same yields with reduction of the water supply by 47%.

The prospects of increasing temperature and decreasing precipitation in the region, due to CC (Ludwig *et al.* 2013; Dakhlaoui *et al.* 2017), are expected to constrain more water availability for agricultural uses and lower the supply reliability (Nunes *et al.* 2017), exposing the sustainability of the entire production system to imminent risk. For the winter–spring period, the increase trend of maximum temperatures is about 0.43 °C/10 year during 1973 to 2013 (Lasram *et al.* 2017) and the decrease of cumulative precipitation, not yet significant, is expected to be at least 16% during 2050–2090 (Bargaoui *et al.* 2014). Since the citrus sector is one of the most important economic sectors in the region (Chouchane *et al.* 2015) and since this region is the most edaphic-climate suitable in Tunisia for the production of special tasting citrus fruits (Ben Abdelaali *et al.* 2018), solutions based on cropping pattern optimization such as substituting citrus with other crops, as proposed by many authors in similar climate conditions (Bozorg-Haddad *et al.* 2016; Rai *et al.* 2017; Stein & Steinmann 2018) are not suitable in this particular ecosystem. However, for sustainable development, adaptation measures have to be mobilized and created to deal with the water scarcity problem in order to avoid an irreversible depletion of the aquifer and to protect the water resources. Innovative water management options and the use of technology such as desalination are among the important adaptive pathways (Adger *et al.* 2007) and could be embedded within policy changes.

Quantitative and price control policies are the two most commonly used mechanisms for water demand management, as underlined by many authors (Wietzman 1974; Feike & Henseler 2017), and could enhance the adaptive capacity of communities. For quantitative control, it was proved through many studies that the application of regulated deficit irrigation (RDI) is appropriate for managing water scarcity in citrus-planted areas and could save between 25 and 30% of water resources in Mediterranean-like climates and others, with an improvement of the fruit quality and no significant reduction of the yield (Ballester *et al.* 2014; Panigrahi *et al.* 2014; Panigrahi & Srivastava 2016). The planned restrictions of irrigation water are applied in order to avoid random water cuts, imposed by reduced supplies. RDI is considered to be a promising technology for ensuring the distribution of canal water among

farmers with more equity, avoiding over-irrigation, and increasing water productivity. Likewise, with less irrigation water, inputs of dissolved salts into the soil are expected to be reduced.

For pricing control, and in order to improve the adaptive capacity of both stakeholders and policymakers to cope with climate impacts on water resources, a new water pricing policy (WPP) could be also used as an incentive mechanism for farmers to enhance the sustainability of water use (Turner *et al.* 2004; Iglesias *et al.* 2011; Ziolkowska 2015). In Tunisia, water prices (the equivalent of €0.045/m<sup>3</sup> according to Tunisian exchange rate on 15/09/2015) were subsidized and not related to the marginal values of crops grown by irrigation and were set too low to affect farmers' irrigation behavior significantly or act as an incentive to limit water demand (Chebil *et al.* 2010). Higher prices could be applied for water amount beyond the crop requirements to reduce overirrigation and enhance rational use of this valuable natural resource.

However, current water irrigation price inelasticity (Varela-Ortega *et al.* 1998; Chebil *et al.* 2010) and long-term benefits from RDI practices are counter-intuitive to farmers who are more interested in short-term and tangible gains. Additionally, farmers' attitudes may be classified as risk averse and cautious about changing their traditional practices, especially in a non-stable economic context as experienced by Tunisia after the civil uprisings of 2011 (Trabelsi Mnif 2017). Moreover, it has been asserted that the acceptance and involvement of the local community is important to succeed in achieving the impact of sustainability (Chevrillon *et al.* 2017; Degol Fissahaye *et al.* 2017; Dolinska 2017) and farmers' environmental behaviors are significantly decided by their awareness about the resource situation and intention about adaptation strategies (Bamberg & Moser 2007; Li *et al.* 2017). For all these reasons, an investigation of these variables is required in order to devise appropriate measures for rehabilitating the failing schemes and guaranteeing the expected results for sustainable water management. Several works at different sites regarding willingness to pay for water (Alcon *et al.* 2014; Bozorg-Haddad *et al.* 2016; Knapp *et al.* 2018) or for water restriction (Tembata & Takeuchi 2018) have presented different results according to the site-specific plot attributing different weights to the socio-economics variables, agricultural

practices, and institutional governance and making it difficult to extrapolate these results to our specific context.

The main objective of this study was the assessment of farmers' awareness regarding CC threats on water resources, their likelihood of adopting new strategies such as RDI, and their perception about new WPP for the sustainability of water resources and citrus production in the Cap-Bon region of Tunisia. Both farmers' willingness and perception are analyzed with respect to their current practices and the agricultural technologies used in water irrigation management held by the communities of two neighboring principal citrus growing regions. Identification of the determining factors of the farmers' predisposition could be helpful in filling the gap that exists concerning the drivers of adoption within the region, drawing conclusions about the strategies that should be undertaken by policy designers, and the profile of farmers who must be more targeted by institutional extension to foster optimal water allocation and efficient productivity.

The paper is structured as follows: the next section presents the methodological framework. This is followed by the results and discussion on the farmer water delivery, qualitative analysis of the survey, and the econometric model results. Finally, conclusions and policy recommendations are presented.

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## METHODOLOGICAL FRAMEWORK

### Study area and data collection

The study area is located in the peninsula of Cap-Bon, corresponding administratively to the Nabeul Governorate, in the north-eastern part of Tunisia. The region is characterized by a semi-arid Mediterranean climate with a long-term annual reference evapotranspiration of 1,100 mm and rainfall average of about 450 mm (Masmoudi *et al.* 2010). Late spring, and especially summer, are characterized by dry and hot conditions. The surveyed farmers belong to two neighboring delegations: (i) Beni Kalled (36°39'N; 10°35'E) and (ii) Menzel Bouzelfa (36°41'N; 10°35'E), which both provide most of the citrus production of the Nabeul Governorate. The two Agricultural Development Groups (GDA), or Water User Associations, which distribute water among

farmers, each have about 1,200 member farmers. The water from the canal in relation to the selected delegations is pumped from the stations of Belli and Soliman to supply Menzel Bouzelfa, whereas it is only pumped from Belli to supply the Beni Khalled area. GDAs keep records on payments of irrigation water use by farmers and, therefore, can provide precise figures on canal water deliveries for individual members.

Before conducting an extensive survey targeting a representative sample of farmers, figures on canal water use in the selected sites were estimated from records on invoice payments to GDAs. Data on delivered canal water were analyzed in terms of probability distribution of users according to the amounts of water used. The analysis covered three consecutive years, 2011–2013, in order to determine recent trends of irrigation water use in the main citrus growing areas of Cap-Bon.

Farmers' attitudes with respect to their acceptance for the new water management strategies to cope with CC threats on the water resources were assessed based on the result of a survey carried out on 100 farmers, randomly selected from the delegations of Beni Khalled and Menzel Bouzelfa during the 2014–2015 cropping year.

### Empirical model

The dependent variables, farmer attitudes regarding RDI and WPP adoptions are binary in nature taking the value of 1 and 0 for the choice of accepting and rejecting, respectively, the project of the new water management strategy. The RDI technology was explained to farmers as reducing the amount of the supplied water with a regulated irrigation schedule and the WPP was explained as progressively increasing price beyond the crop-water requirement threshold. Water pricing is an institutional consideration that is imposed on farmers by both the agricultural ministry and the GDAs. However, farmer acceptance of increasing the irrigation water price beyond the amount of the crop requirement was presented as an efficient way to reduce overirrigation practices inducing the mismanagement of the limited water resources.

In our case, the benefit of the new proposed water management strategies are not immediately attainable, so the farmer attitude is then related to his awareness and

appreciation of the severity of the decrease of the long-term availability and the short-term variability of water if no actions for improving water resource management were undertaken. The explanatory variables cover therefore a subset of socio-economic conditions of the farmers, their agricultural practices, their knowledge through training (relating to any topic on citrus agricultural practices) and contact with extension institutions, and their perception of the water resources situation and current water governance (Table 1). These variables were selected based on extensive review of the literature on factors that generally affect farmers' willingness to adopt agricultural technologies (He *et al.* 2007; Hall *et al.* 2009; Keelan *et al.* 2009) and citrus production technical efficiency measurements (Dhehibi *et al.* 2007). A total of 17 potential explanatory variables are expected to impact the farmers' acceptance decision. For instance, Dhehibi *et al.* (2007) found that farmer's age, education level, agricultural training, farm size, and the availability of water affected positively both technical and irrigation water efficiency in Cap-Bon citrus farms. Variables related to agricultural technologies adopted by farmers to increase water productivity, such as drip irrigation system use, tree rejuvenation, and organic manure use, were also expected to influence positively the willingness of farmers to accept adopting such technology. The use of manure improves the total available soil moisture, which is low for the frequent sandy soil of the region. Farmers' behavior depending on the water salinity is not well defined, and 1.5 g/L presents the threshold of water salinity above which citrus productivity is affected if irrigation is applied without provision of drainage (Nagaz *et al.* 2015). Access to information through relationship with the stakeholder institution (Local Extension unit or CTV) is another variable expected to accelerate the adoption process of new water management strategies. Farmers are considered to over-irrigate if the irrigation water supply exceeds the theoretical irrigation requirement of the crop in the Cap-Bon area estimated by water balance method – 4,200 m<sup>3</sup>/ha as formulated by Steduto *et al.* (2012). This value is also consistent with the proposals of Carr (2012) in like Mediterranean sites.

Binary logistic regression, used in this paper, is a widely used method to measure the relationship between the dichotomous choice variable (Y) and both categorical and

**Table 1** | Description of the variables used in the analysis study

Variable	Description of the variable and their specific codes
ADOP	Adoption of new WPP or DRI (no = 0; yes = 1)
Socio-economic characteristics	
DELEGATION	Menzel Bouzelfa = 0; Beni Khalled = 1
AGE	Old >45 years = 0; young ≤45 years = 1
EDUC	Level of education (illiterate = 0; primary or secondary = 1; high = 2)
OFFA	Principal activity (off farmer = 0; farmer = 1)
SIZE	Area of the exploitation (ha)
RESOUR	Resource of water (only canal = 0; canal + well or borehole = 1)
SAL	Salinity of the water irrigation (canal water or ≤1.5 g/L = 0; >1.5 g/L = 1)
YIELD	Yield (t/ha)
APPRt	Farmer appreciation of the current water price (high = 0; acceptable = 1)
Agricultural practices	
SYST	Irrigation system (drip = 0; surface = 1)
SUPL	Total water supply (≤4,200 m <sup>3</sup> ha <sup>-1</sup> year <sup>-1</sup> = 0; >4,200 m <sup>3</sup> ha <sup>-1</sup> year <sup>-1</sup> = 1)
MANU	Manure use (rare application = 0; frequent application = 1)
REJV	Tree rejuvenation plantation (no = 0; yes = 1)
Contact with extension institutions	
TRAI	Training (no = 0; rare = 1 (if their number <3); frequent = 2)
CTV	Contact with the technical extension center (no = 0; yes = 1)
Awareness about the environmental situation	
APPRi	Farmer opinion about their irrigation amount (deficit = 0; equal to requirement = 1; excess = 2)
APPRr	Farmer opinion about the regional water resource (insufficient = 0; sufficient = 1)

Source: Own elaboration from survey (2017).

metric explanatory variables by estimating probabilities using logistic function (He *et al.* 2007; Hall *et al.* 2009; Keelan *et al.* 2009):

$$Y = \begin{cases} 0 & \text{if farmer disagrees} \\ 1 & \text{if the farmer agrees} \end{cases} \quad (1)$$

According to this method, the farmers were more likely to adapt their water management strategy by accepting the new one if the logit (Z), derived from the agreeable respondents, exceeds that obtained from the disagreeable respondents. Z<sub>i</sub> of the i<sup>th</sup> farmer is a linear function of n explanatory variables X = (X<sub>1</sub>, ..., X<sub>n</sub>):

$$Z_i = \ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \sum_{k=1}^n \beta_k x_{ik} \quad (2)$$

where  $x_i$  is the observed value of the explanatory variables for observation i and

$$P_i = \text{Probability}(Y_i = 1 | X_i = x_i) \quad (3)$$

where  $\beta_0$  is the intercept term, and  $\beta_k$  are the coefficients associated with each explanatory variable X<sub>k</sub>. They are estimated by maximum likelihood estimation (MLE) method.

## RESULTS AND DISCUSSION

### Canal water supplies

Making reference to the Beni Khalled and Menzel Bouzelfa GDA records, the average irrigation water supply over the three cropping years 2011–2013 for those using regularly

water from the canal was about 3,600 and 4,800 m<sup>3</sup>/ha, respectively. These values compared to crop irrigation requirement reflect more deficit irrigation behavior in Beni Khaled and a greater over-irrigation trend in Menzel Bouzelfa. The coefficients of variation of the yearly irrigation water amounts (0.86 and 0.83, respectively) presented high values reflecting important irregularity in water supplies. It is assumed that some farmers consider access to canal water as an ‘opportunity’ for taking as much water as possible. Therefore, practices of over-irrigation contrasting with situations of under-irrigation and the large disparity in water productivity among farmers in the same production areas, are normal consequences of the existing management methods and the low price of water. This finding is consistent with that of Muchara *et al.* (2016), who concluded that unequal distribution and inefficient use of water are common when water irrigation is provided free.

The GDA gathered data showed that farmers exceeding 5,000 m<sup>3</sup>/ha of irrigation water uptake (the upper limit of the citrus water requirement in like Mediterranean sites according to Carr (2012)) increased throughout the three years by about an average of 12–15% in Beni Khaled and 20–30% in Menzel Bouzelfa (Figure 1). However, 75% and 60% of the farmers did not exceed 3,600 m<sup>3</sup>/ha of canal water (the lower average of the citrus water supply of the two GDAs), respectively, and almost 40% and 30% of them did not use any canal water in Beni Khaled and Menzel Bouzelfa, respectively (Figure 1), most likely because they also use well water. These percentages are especially higher in Beni Khaled, probably because farmers excavated more boreholes. However, the trend is decreasing

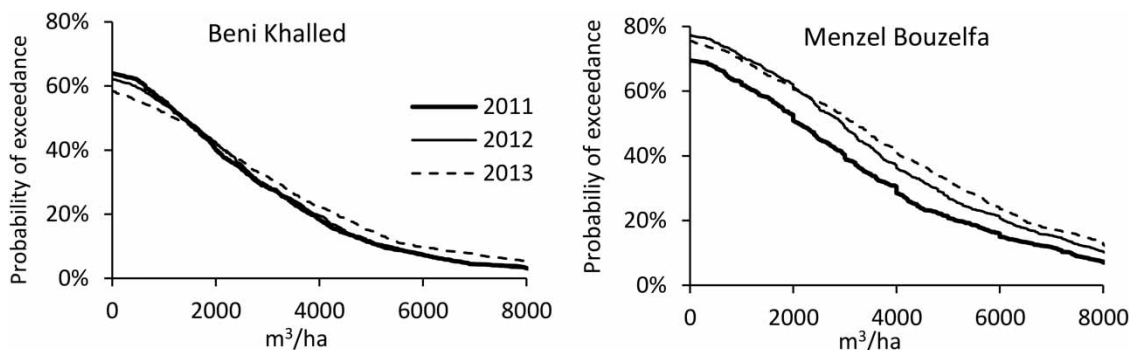
in Menzel Bouzelfa as more farmers are obliged to use canal water as a consequence of the increasing salinity level in their wells.

### Quantitative analysis of the survey data

The descriptive statistics analysis of the categorical and metric variables used in the logistic model and collected from the survey are presented in Tables 2 and 3, respectively.

Basically, irrigation water delivered to farmers exceeded 3,600 and 5,000 m<sup>3</sup>/ha for 77% and 50% of the surveyed farmers, respectively, although 71% of them were equipped with drip irrigation systems. In addition, around 45% of these farmers have a well or boreholes and 73% of this category presented a salinity exceeding 1.5 g/L. The water irrigation productivity of the farmers (yield divided by water supply) varies widely with a coefficient of variation about 0.90 and presented a mean value of about 4.3 kg/m<sup>3</sup>. The lower value of productivity was related to young tree age. However, the average productivity is considered low if it is compared to the obtained values in other researches and conducted in similar climate and agro-systems conditions, which fluctuated between 6 and 11 kg/m<sup>3</sup> (Carr 2012). The cost of water irrigation represents an average of 3.3% compared to the selling price of the citrus production (calculated from data surveys and using the market price estimated by the Ministry of Agriculture (National Observatory of Agriculture 2013)).

The farmers were quasi-unanimous (86%) on the inefficiency of the current water governance structure, which reflects the lack of trust in public institutions. However,



**Figure 1** | Probability of exceedance of a given amount of irrigation water obtained for the different farmers in Beni Khaled and Menzel Bouzelfa using water through GDAs. Source: Authors' presentation based on GDA records of Menzel Bouzelfa and Beni Khaled (2016).

**Table 2** | Descriptive statistics of metric variables used in the econometric model and the water supply of the farmers surveyed

	Minimum	Maximum	Mean	Std. deviation
SIZE (ha)	0.25	10	2.3	1.9
YIELD (t/ha)	0.5	60	21.2	14.8
Supply (m <sup>3</sup> /ha)	2,400	13,600	6,000	2,700

Source: Authors' calculation based on the survey data.

**Table 3** | Modality frequencies of the categorical variables used in the econometric model

Modality	0	1	2
ADOP RDI	45	55	
ADOP WPP	48	52	
DELEGATION	45	55	
Age	77	23	
EDUC	18	70	12
OFFA	29	71	
RESOUR	55	45	
SAL	70	30	
APPRt	65	35	
SYST	71	29	
SUPL	29	71	
MANU	20	80	
REJV	61	39	
TRAI	71	20	9
CTV	47	53	
APPRi	55	38	7
APPRr	48	52	

Source: Authors' calculation based on the survey data (2017).

their awareness about the importance of water scarcity and environmental problems remains insufficient and reflects a poor commitment of the extension system. Surveyed farmers claim an average water supply of 6,000 m<sup>3</sup>/ha and only about half of them had a skeptical perception about the availability of the water resources (Table 3). Farmers' knowledge about citrus water requirements also seems insufficient as the current supply status (over-irrigation, equal to requirement, deficit irrigation) and the farmer's appreciation (APPRi) were not significantly dependent ( $p$ -value of Chi square Pearson test = 0.08). Indeed, around 33% of the surveyed farmers have a good appreciation about their water

supply but 46% of this farmer category over-irrigates while thinking that their supply was deficient or equal to the requirement. Empirical findings also indicate that no significant dependence between the farmer acceptances of RDI and new WPP was found ( $p$ -value of Chi square Pearson test = 0.6).

The farmers can be grouped according to their response choices. The first group of farmers perceived a high risk regarding the reliability of water supply and accepted the adoption of both water management strategies and represented only 30% of the total surveyed farmers. The farmers of the least environmentally aware group, representing 23% of the respondents, were skeptical about the CC risk on water resources and refused the adoption of both suggested options. The remaining respondents, who have chosen only one strategy among the two proposed, reflected a prudent attitude; their choices depended on what they believe to be the least restrictive for their benefit margins.

The new average water price proposed by farmers who have accepted the adoption of the new WPP is about 0.0675 Euro/m<sup>3</sup> which is 50% higher compared to the current price, but still low enough to generate an elastic response.

### Willingness analysis

Table 4 presents the empirical findings of the two logistic models' estimation (RDI and WPP). The statistical results confirm the validity of the two models and the binary regression estimates fit well with the data used at an acceptable level, as the  $p$ -values of the Hosmer and Lemeshow goodness-of-fit were superior to 0.05.

Nine out of the 17 variables used in the regression explained significantly the agreement of the farmers for adopting RDI. The farmers' attitude is more likely to be positively influenced when they thought they were over-irrigating, their groundwater resources depended on both the canal water and the wells or were affected by salinity, they frequently applied organic manure, they were older, they thought that regional water resources are sufficient, they rejuvenated their citrus trees, they are from Beni Khalled delegation and have no off-farm income. These significant explanatory variables are enumerated in a decreasing positive influential weight according to exponential B values (Table 4). Exponential B indicates how many times would

**Table 4** | Binary regression results

	RDI				WPP			
	B	S.E.	Sig.	Exp(B)	B	S.E.	Sig.	Exp(B)
DELEGATION	1.32	0.72	0.06*	3.75	1.66	0.62	0.01***	5.27
AGE	1.79	0.86	0.03**	6.01	0.44	0.68	0.51	1.55
EDUC	-1.10	0.74	0.13	0.33	0.54	0.57	0.34	1.71
OFFA	-1.26	0.67	0.06*	0.28	-0.70	0.59	0.23	0.49
SIZE (ha)	0.16	0.18	0.38	1.17	-0.34	0.18	0.05**	0.70
RESOUR	3.01	1.18	0.01***	20.29	0.74	0.77	0.34	2.09
SALT	2.79	1.18	0.01***	16.35	0.45	0.82	0.58	1.58
YIELD (t/ha)	0.03	0.02	0.12	1.03	0.01	0.01	0.53	1.01
APPRt	-1.05	0.68	0.122	0.34	0.79	0.59	0.18	2.21
SYST	0.52	0.66	0.42	1.69	0.22	0.59	0.70	1.25
SUPL	0.52	0.66	0.42	1.69	-0.57	0.63	0.36	0.56
MANU	2.15	0.84	0.01***	8.61	0.20	0.66	0.75	1.22
REJV	1.47	0.62	0.02**	4.35	-0.41	0.53	0.43	0.66
TRAI	-0.51	0.58	0.37	0.59	0.10	0.47	0.82	1.10
CTV	-0.19	0.68	0.77	0.82	0.70	0.55	0.19	2.02
APPRi	3.04	0.79	0.00***	20.96	-1.43	0.50	0.01***	0.23
APPRr	1.75	0.76	0.02**	5.78	-0.78	0.56	0.16	0.45
Constant	-7.53	2.41	0.01	0.00	-0.37	1.79	0.83	0.68
Hosmer and Lemeshow	0.74				0.14			
Nagelkerke R <sup>2</sup>	0.53				0.38			
Correct predictions (%)	79				0.70			

Note: \*\*\*, \*\*, \* Significance level at  $P \leq 0.01$ , 0.05, and 0.10, respectively. Source: Authors' calculation based on model result (2017).

the probability increase of farmer acceptance of the RDI for every one unit increase of each explanatory variable, keeping all others variables unchanged.

Some socio-economic variables such as the level of education, the size of the exploitation, and the yield did not present an obvious impact on farmer attitude, as shown in several recent technology willingness studies (He *et al.* 2007; Hall *et al.* 2009; Keelan *et al.* 2009; Zongo *et al.* 2015). Their effects may be secondary and hidden by the dominant effect of the rest of the environmental and technical variables. For the level of education, the incentives for farmers to attain a capital of knowledge can be more dynamic than the level of schooling as was suggested by Wozniak (1984). When the size of the farm is relatively large (>2 ha), it does not reflect necessarily that the owner is wealthier so he may be more able to assume risk and

adopt the technology. Big and small farmers in this case are equally concerned with the insecurity of resources.

Water resources in Beni Khaled pumped only from one hydraulic station were limited compared to Menzel Bouzelfa where the water was pumped from two hydraulic stations. Nevertheless, Beni Khaled farmers were more likely to adopt the RDI. The statistical significance of the empirical model reflected the technical efficiency level of both farmer community and GDA staff. In fact, the management staff of the GDA elected by farmer communities do not undergo training to be sufficiently qualified for the job. The canal water governance of supplies seems to be more efficient in Beni Khaled than in Menzel Bouzelfa. Older farmers seem more flexible than younger ones because the majority of the younger farmers' water resource depends only on canal water (RESOUR and AGE are significantly



dependent, Chi square Pearson test  $p = 0.02$ ) and hence they were more affected by water supply reliability. Digging wells is an expensive investment for the junior farmers who need more time to accumulate enough money for the task. Farmers living on other incomes, apart from farm incomes, are more unwilling to adopt RDI because they are economically more affected by water supply reliability as they are not always available for agricultural work and irrigation management. The significance of the water resource variable reflected also greater willingness to accept practicing RDI by farmers whose water resource depended on both water canal and wells. Pumping water from wells secures a comfortable water delivery for the users when canal water is exposed to intermittent cuts. The farmers are more likely to adopt a positive position if their water resources are affected by salinity because they are already suffering from the potential risk of CC on water resources quality, so they have become totally dependent on canal water.

The perception of farmers about their water irrigation supply and the regional water resources availability influenced strongly their position. They were more cooperative when they thought that the water situation is more reliable and water supply is equitable.

As the environment profitability and the well-being of farm communities when adopting these new strategies is not immediate, farmers adhering to agricultural practices for improved water productivity (frequency of manure application, tree rejuvenation) are better prepared and ready for adoption. In this context, the role of extension has to be highlighted to improve water productivity and farmer resilience. However, the logistic models revealed also that the significant variables linked essentially to farmer willingness to accept new water management strategies reflected their level of satisfaction about the way the water supply is managed (source of water, delegation) and their perception about its reliability (APPRr). These findings consolidate the serious impact of social capital, particularly the trust in local governance, on farmer intentions and behaviors as underlined by Hunecke et al. (2017). The lack of trust in a reliable water supply is among the reasons for the increase of illicit wells in the region that have accelerated groundwater depletion and water quality degradation.

Empirical findings from the WPP model indicate that only three explanatory variables are statistically significant

(Table 4). Farmers' attitude is more likely to be negatively influenced when farmers have relatively big farms and think that they are over-irrigating. Their attitude seems to be more related to the economic impact of increasing the water price on their profit margin. Their reluctance can be explained by both a lack of awareness about the water situation, and the emergence of a growing sense of insecurity within the farming community facing the weakness of the citrus price guarantee mechanism and decreasing exportation amounts (Inter-professional Group of Fruits 2014), which generally regulate the price in the local market. On the opposite side, the smallholder farmers, probably more affected by the unequal distribution of water supply, presented a positive attitude. These findings are consistent with scientific ones presented by Alcon et al. (2014) in southern Spain, where farmers were also concerned by the uncertainty of water allocations and were willing to pay twice as much as their current irrigation water price to ensure regularity in water supply. In fact, farmers from this region preferred a guaranteed water amount of about  $4,000 \text{ m}^3/\text{ha}$  for the citrus crop (Alcon et al. 2014) which is close to the average farm delivery of the two Tunisian GDAs.

The farmers were more likely to accept WPP when they are from Beni Khalled delegation, for the same reasons mentioned previously, i.e., linked to the inconvenience of local water management that impacts water supply reliability.

The results of the two models emphasize the great concern of farmers of semi-arid regions such as the Cap-Bon where there is irregularity in the equity of water allocation. However, willingness to adopt RDI, whose results presented more statistically significant indicators, appears more propitious for minimizing farm income loss, as the farmers have already experienced the shortage of water and its poor reliability has been constraining the efficiency of irrigation schedule. For the WPP, the biggest consumers are reluctant to accept this strategy, and even when farmers presented a positive response, their proposed new price is too low to enhance the reduction of agricultural water use. The significant indicators of farmers' responses to RDI reflected more the environmental concern. On the other hand, the farmers' responses to WPP are more related to economic concern.

The mismanagement of water resources induces a negative perception of local water resource reliability and then a

lack of trust in local governing institution, and the lack of support for adhering to new water resource management policies.

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## LIMITATIONS OF THE STUDY

Although the research has reached its aims, there were some unavoidable limitations. First, since the questionnaire is designed and the model is applied with the finality of understanding the main factors influencing the adoption of RDI and the factors affecting the adoption of the option of new WPP, it seems not to provide enough evidence of the farmers' actual behavior to these two most commonly used adaptation mechanisms for water demand management.

Second, we recognize that we did not address fully the issue of adaptation to CC; in general, rather we focused on a special agro-ecosystem (citrus) which is vital to the economy in the Cap-Bon region (study area). In addition, our methodological framework mainly addressed the assessment of the RDI technology, ruling out, knowingly, adaptation options relating to crop patterns. At the same time, we need to stress the relevance of our approach in trying to figure out how citrus growers would adapt to water scarcity imposed by CC.

Finally, we consider the assessment of the proposed RDI technology, as a measure for citrus growers to remain in the orange production business, is more than needed. Otherwise, if they continue doing what they have always done, they will find themselves soon forced to reduce the size of their cropped area and/or to switch to much less profitable crops, such as olive cultivation, or winter vegetables, knowing in advance these less profitable crops could increase farmers giving way to land speculation for urbanization. Thus, this scenario was not considered in our research paper, because we hypothesized from the beginning that there is a consensus about citrus conservation in the studied area, at least for the foreseeable future.

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## CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Water scarcity is a major threat to sustaining semi-arid irrigated regions such as citrus growing areas in Tunisia.

Irregularities in water supply, frequent social tensions among users, and hazardous environmental degradations are some of the critical challenges for a sustainable citrus-growing system in the studied area.

A review of the literature indicates that adaptation to CC by the adoption of agricultural technologies and new policies depends on farmers' intentions. This study examined the perception and willingness of farmers in Cap-Bon to accept the adoption of RDI and WPP as strategies to increase water productivity, to promote equitable distribution and use of scarce water resource, and to prevent further degradation of natural resources. The empirical results are sourced from 100 surveyed farmers and binary regression model. According to the empirical findings, the proposed intervention is more likely to be adopted by farmers who were more satisfied about the regularity of the water supply compared to those suffering from current irregular supply. The impression of security when the water resources came from both wells and canal water enhances a positive attitude. It also clearly showed that farmers with large farm size and those who over-irrigate their trees stand opposed to the WPP option due to the potential increase in their costs of production. Strong challenges to adopting both RDI and WPP technologies include low pricing of water, lack of strict regulation of water use, and farmers' lack of awareness of the scarcity of water.

This analysis points out also the effect of the local water governance on farmer behavior. The adoption of new water management coping strategies depends essentially on farmers' awareness about the water resource situation and their perception about the damage endured by water supply irregularity, which is considered as the main constraint to adopting technologies and management policies. Well-defined water supply rules and reliable allocations will clearly accelerate farmer adoption.

Comparison of the results of farmers' intentions allows advancing the view that a quantitative water control measure is more effective at reducing water use than pricing. However, governmental institutions are required to show more commendable efforts in improving the transparency of water allocation systems and the distributional equity of the resource in order to help water operators in the development of alternative strategies for water restrictions and ensure the feasibility of a future adaptation plan. These

efforts can be realized by strengthening the role of GDAs and enhancing the feedback between them and the formal agricultural institutions. The role of the GDAs have to be well anchored in the planning of adaptive strategies, must be modernized, and not only restricted to the conventional management of resources and sale of water at the will of farmers. The elected GDA staff have also to be strengthened by employing an agricultural engineer. This will ensure availability of technical advice in order to avoid overpassing the threshold of citrus water requirement and convince farmers that wide adoption of RDI is important to guarantee, at the same time, equity, social justice, and water resource sustainability. The government should also strengthen the role of extension in building collective awareness and resilience. The extension efforts have to consolidate the trust between formal and informal local institutions and operate to build a reactive social network.

This research highlighted the need for strategic extension and modernized GDAs to increase awareness about the ensuing environmental problems and institutional and structure reorganization to significantly influence the behavior of farmers.

## ACKNOWLEDGEMENTS

The authors are grateful to GDA and CTV agents who assisted with the primary data collection process. We acknowledge the Middle East and North Africa Water Livelihoods Initiative (WLI-USAID), Modernizing Extension and Agricultural Systems (MEAS), and the Office for Global Research Engagement (University of Florida) for supporting this research. The reviewers are acknowledged for their pertinent and constructive comments.

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First received 10 October 2017; accepted in revised form 10 March 2018. Available online 29 March 2018