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**DETERMINANTS AND STRATEGIES OF FARMERS'
ADAPTATION TO CLIMATE CHANGE: THE CASE OF
MEDENINE GOVERNORATE, TUNISIA**

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ABSTRACT

Climate change is a worldwide environmental issue to all economic sectors, mainly the agricultural sector. Tunisia is one of the countries adversely affected by climate change because of its low adaptive capacity. Adapting to climate threat is the main goal of farmers, who are the primary stakeholders in agriculture, to increase the resilience of their farming systems. Based on a survey between March and May 2018 with 100 agricultural households from the governorate of Medenine, which belongs to Southeast Tunisia, this paper examined the main adaptive measures to climate change used by farmers, the factors influencing their choice of measures and the constraints to adaptation. To explore the factors affecting the choice of adaptive measures, this study employed a multinomial logit regression. Results showed that irrigation, crop diversification, integration of crop with livestock and shifting from farm to non-farm activities were the main adaptive measures implemented by farmers in the study area. Further, the multinomial logit model indicated that the factors influencing the choice of adaptive measures included household head age, access to extension services, household income, number of years of experience of the household head in agriculture, and the distance to the market. The results demonstrated also that adaptation to climate change was hindered by many factors such as constrained resources, lack of money, and water shortage. The findings of this research suggest the need for improving the access to extension services, to water, and to means of production to enhance the resilience of vulnerable agricultural households and to improve their wellbeing.

Keywords: *Climate change, adaptive measures, agricultural households, multinomial logit regression, governorate of Medenine.*

INTRODUCTION

Currently, climate change is at the center of concerns of both scientific actors and political decision-makers. Climate change poses an increasingly discernible threat to the viability of in developing countries. It has a direct impact on agricultural

production, since farming systems are climate dependent (Belay et al., 2017). In fact, the conditions of agricultural production have become more and more difficult (Brunette et al., 2018). This impact is particularly significant in developing countries where agriculture constitutes the main source of employment and income for the majority of the population. Furthermore, the social construct and the economic constraints that underlie inequalities in access to productive resources are reinforced by climate change (Hisali et al., 2011).

Agriculture is an important sector of the Tunisian economy. It contributes about 10 % of the GDP and employs about 18 % of the active population. Despite its significant contribution to the entire economy, this sector is challenged by the negative effects of climate change. Its influences are manifested by droughts and lack of rainfall, heat waves and low productivity. In such context, and to ensure the viability of farming systems and income stability of farm households, adaptation measures are today the only alternatives to reduce the effects of climatic uncertainties. Adaptation to climate change refers to "*strategies, initiatives, and measures aimed at reducing the vulnerability of natural and human systems to the current and expected effects of climate change, which mitigates damage or values the benefits*" (IPCC, 2001). Understanding the adaptive measures choices improves policies focused toward tackling the issues that climate change is imposing to farmers. Moreover, for any adaptive measure several socio-economic, environmental, and institutional factors may drive its employment. The examination of these factors is crucial for policy makers to improve the farmers' adaptive capacity.

Although internationally extensive studies on agricultural households adaptation to climate change, limited researches have been performed so far in Tunisia. In fact, a considerable number of researches have investigated farm-level adaptation in different countries and have attempted to explore farmer's adaptive measures choices as well as their determinants (Belay et al., 2017; Deressa et al., 2009; Hassan and Nhemachena, 2008; Hisali et al., 2011; Shikuku et al., 2017). Up to date researches on climate change and agriculture in Tunisia have been limited to impacts of climate change on agricultural production. A very few number of studies have considered farmers' climate change adaptation. Therefore, the aim of this study is to fill this research gap with regard to adaptation to climate change in the agricultural sector. This paper seeks to answer the three following research questions: What are the major adaptive measures employed by farm households? What are the factors influencing these adaptive measures? What are the main barriers to adaptation?

MATERIAL AND METHODS

The study was carried out in Medenine governorate, which belongs to Southeast Tunisia (Figure 1). Medenine governorate, characterized by an arid climate, is considered one of the most vulnerable governorates to the impacts of climate change due to high temperatures and low rainfall (Sghaier and Ouessar, 2013).

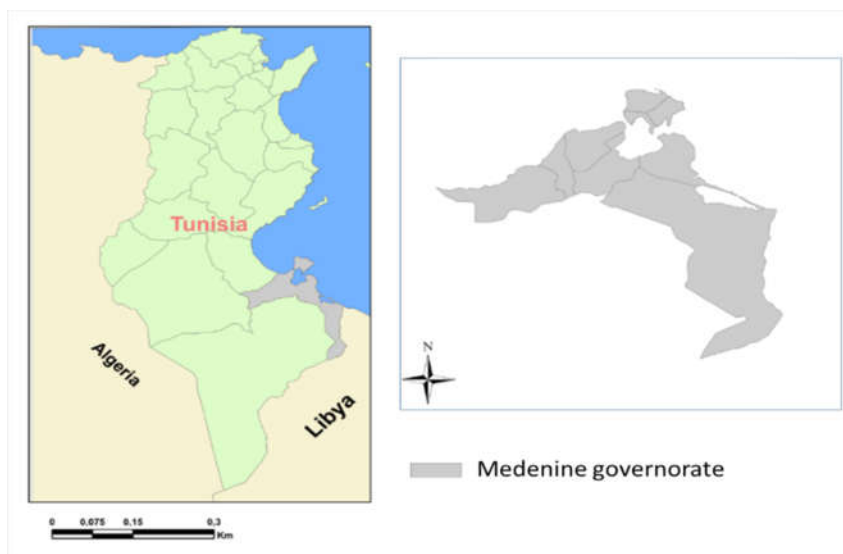


Figure 1. Geographical location of Medenine governorate

*Source: Own elaboration

The data was collected through a questionnaire survey during the period March-May 2018 from 100 agricultural households that represent the main production systems in the governorate of Medenine. A structured questionnaire was designed to collect information on socio-demographic characteristics of farmers, their farming systems, their incomes, their relation with institutions, and their main adaptive options. To answer our research questions, our analyses were performed using three steps, following a progressive approach: In a first step, we carried out a descriptive statistics to explore the main adaptive measures employed by the surveyed farmers. In a second step, to analyze the determinants of farmers' adaptation choices, we used a multinomial logit model (MNL). This model is widely used in adoption decision researches involving multiple choices (Alam et al., 2016; Deressa et al., 2009; Hisali et al., 2011). It has two main advantages: firstly, it allows the analysis of decisions for more than two options (Hassan and Nhemachena, 2008); secondly, its estimation and interpretation are simple. An important condition that must be satisfied in MNL regression is the assumption of Independence of Irrelevant Alternatives (IIA); it indicates that the probability of adopting a specific adaptation strategy by a given farmer requires independence from the probability of selecting another adaptation strategy (Alam et al., 2016). To resolve this problem we have considered the most preferred adaptation measure for each farmer. For our study, the adaptation measures are five: diversifying income sources, integrating crop with livestock, crop diversification, irrigation and non adaptation. In the MNL, a baseline alternative must be chosen because the option should always be in the interviewees' choice (Sadiq et al., 2019). The option "no adaptation" was considered as the baseline and was compared with other

adaptation strategies. The form of the MNL model is specified in the following equation:

$$\text{Prob}(A_i = j) = e^{\beta_j X_i} / \sum_{k=0}^{k=j} e^{\beta_k X_i} \quad (1)$$

Where A_i is the probability of farm household i to choose option j , j indicates the adaptation strategies (Table 1), β is a vector of coefficients for each of the independent variables X_i , k represents the “no adaptation” choice that was used as the base option, and X_i represents the independent variables. The independent variables were chosen based on a literature review (Deressa et al., 2009; Sadiq et al., 2019; Shikuku et al., 2017) and our previous experience in the field.

In a third step, this study investigates the declared constraints that prevent farmers to successfully employ their adaptive strategies.

RESULTS AND DISCUSSION

The results of our study revealed that agricultural households are adopting different adaptive measures to face climate change. Farmers were asked about their preferred adaptive measure. The results reported by the surveyed farmers are shown in figure 2. Our findings revealed that the most important adaptive measure employed by farmers in the study area is crop diversification followed by the integration of crops with livestock, the diversification of income sources, and irrigation. The MNL regression was used to explore farm households’ choices of adaptive options to reduce the effects of climate change. In our analysis, we employed “no adaptation” option as a baseline category and estimated the other options as its alternatives. The likelihood ratio specified by the Chi-square test is significant as shown in Table 1. Our findings showed that the IIA assumption was respected. Therefore, the use of MNL model is appropriate to examine the determinants of adaptation options employed by farmers.

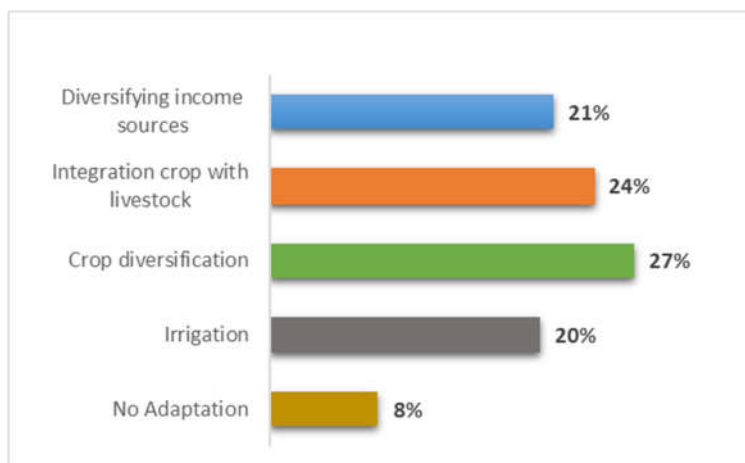


Figure 2. Main adaptation options to climate change and the proportion of respondents that practiced them.

The coefficient of MNL model gives only the direction of the effect of the independent variables on the dependent variable: estimations do not assess the magnitude of change. Therefore, in our analysis, we used odds-ratio for a simple and intuitive interpretation of coefficients. The following analysis presents and discusses the results of explanatory variables (Table 1).

The age of household head represents the experience, which may affect the adaptation to climate change. The household heads' age was a significant positive factor to crop diversification and to the integration of crop with livestock. It may be because skilled farmers have a better understanding of climate uncertainties. In those cases, the odds ratio of age variable are greater than one, this indicates that an increase of one year in the household head age will lead to 6 % increase in the odds of using crop diversification and 4 % in the integration of crops with livestock. Moreover, the access to extension services has a positively significant relationship with crop diversification; however, its relationship with the diversification of income sources is negative. This result is expected because extension advice is used to encourage farmers to diversify their crops. Therefore, this choice hinders the ability of household members to undertake off-farm work, as more labor is required at the farm-level. As for odds ratio, an additional intervention from extension services will increase the practice of crop diversification by 33%, and decrease the probability of undertaking off-farm work (by 33%) as its odds ratio is less than one. Besides, the study revealed a significantly positive relationship of the experience of household head in agriculture with crop diversification and irrigation. This result supports previous evidence showing that farmers with high experience level were more likely to adapt to climate change (Deressa et al., 2009). A household head with an additional year of experience in agriculture is more likely to engage in crop diversification and irrigation, 12% and 14% respectively. In addition, the household income has a positively significant relation with the use of irrigation, the crop diversification and the integration of crops with livestock. Thereby, financial resources are required to adapt to climate change effects especially when it comes to expensive choices like irrigation and crop diversification. This result confirms previous studies, which found a positive relationship between household income and adaptation (Alam et al., 2016). With regard to odds ratio, increasing one unit in household income leads to an increase of the probability of employing irrigation and crop diversification by 2% and 3%, respectively. The distance to the market was found to be significant to explain farmers' adaptive choices (crop diversification and integration of crop with livestock). This factor acts as a proxy for the availability of input and the marketing of agricultural products. Increasing the distance to the market by one unit, leads to the decrease of probability of employing crop diversification and the integration of crop with livestock by 4% and 2% respectively.

Table 1. Predictability of the Multinomial Logit model

Explanatory Variable	Adaptation choices (dependent variable)								
	Irrigation		Crop diversification		Integrating crop with livestock		Diversifying income sources		
	Coef.	Odds-ratio	Coef.	Odds-ratio	Coef.	Odds-ratio	Coef.	Odds-ratio	
Intercept	1.760		0.459		4.138		-0.11		
Age [Years]	0.95	1.38	1.06*	1.330	2.04**	1.113	3.93	1.020	
Household size [Number]	1.649	5.202	5.249	190.440	4.615	100.963	0.497	1.644	
Number of years of education of HH [Years]	0.48	1.12	1.01	1.14	-1.329	0.265	-0.58	0.555	
Trainings [Number]	2.313	10.105	-0.422	0.656	1.082	2.950	2.511	12.319	
Years of experience of HH [Years]	1.31**	3.709	1.386*	3.997	3.198	24.487	4.833	125.526	
Herd size [Livestock Unit]	-2.290	0.101	-2.476	0.084	-4.307	0.013	-2.38	0.092	
Agricultural area [ha]	0.579	1.784	0.292	1.339	-0.917	0.400	1.010	2.745	
Irrigated area [ha]	-1.385	0.250	3.964	52.665	0.328	1.388	-4.47	0.011	
Access to extension services	-6.688	0.001	1.83**	1.33	-3.499	0.030	-0.2*	0.779	
Crop diversity index [Index]	-3.091	0.045	-2.334	0.097	-3.987	0.019	-2.23	0.107	
Membership in any organization	-0.956	0.384	1.424	4.152	-0.888	0.411	-1.09	0.334	
Household income [Local currency]	2.012*	1.02	2.060**	1.27	1.03*	1.54	8.4	0.428	
Subsidies [Local currency]	1.778	5.920	-5.534	0.004	-1.369	0.254	4.705	110.482	
Distance to the market [Km]	3.58	36.161	-4.20**	0.96	-0.1**	0.98	3.054	21.193	
Agricultural equipment [Local currency]	2.750	15.640	-0.936	0.392	-0.285	0.752	3.779	43.769	
Base category : No adaptation				* p < 0.1 ; ** p < 0.05 ; *** p < 0.001					
Number of observations : 100									
LR chi ² : 90.8 **									
Log likelihood : - 218.66 **									
Pseudo R ² : 0.29									

HH: Household

Turning now to the analysis of constraints that hurdle farmers to employ adaptive measures to mitigate climate change effects, despite the fact that farmers are trying to adapt their farming systems to climate change, they mentioned that there are many constraints that hurdle their adaptive choices. The main constraints declared by farmers include the lack of money, resource constraints, lack of information, shortage of water, and others... Lack of money hindered agricultural households from obtaining crucial inputs (purchasing seeds, irrigation facilities and fertilizers) they may need to adapt their practices to suit the climate change conditions. Although irrigation is used by some farmers, its extent is still limited. This deals with the failure of agricultural households to use groundwater because of the shortage of financial and technological capacity. The lack of information is associated with limited access by farmers to extension services in order to modify their agricultural practices in case of high temperature and prolonged drought. Moreover, farmers cited that the unavailability of resources at the farm level hurdle their capacity to adapt to climate change. Resources may include agricultural equipment, irrigation facilities, wells, means of transport, etc.

CONCLUSION

This study analyzed the adaptive choices made by farmers of Medenine governorate (Tunisian Southeast). The results showed that farmers are using different adaptive options to counter the adverse effects of climate change. The main practices and measures are grouped into five adaptation options: diversifying income sources, integrating crop with livestock, crop diversification, irrigation and non adaptation. A Multinomial Logit Model was used to examine factors affecting farmers' climate change adaptive choices. The logit model indicated that the factors influencing the choice of adaptive measures included household head age, access to extension services, household income, number of years of experience of the household head in agriculture, and the distance to the market. However, the farmers' capacity to adapt was hindered by several constraints: the lack of money, resource constraints, lack of information, shortage of water.

Our findings have several policy implication. The findings imply that improving the access to extension services, to water, to climate information and to means of production might enhance the resilience of vulnerable farm households. This involves the need to support the farmers' adaptive choices with a wide range of policy, technology, and institutional support.

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