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Agriculture Adaptation Strategies of Tunisian Oasis Households to Climate Change

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Abstract

Climate change should have impacts on Tunisian arid regions oasis households are likely to bear the most significant negative impacts, the case of the oasis of "Metouia" in the governorate of "Gabes". This research is based on an econometric analysis through cross-sectional probit models involving 50 oasis households. The binary probit models showed that certain factors contribute significantly to the adaptation strategies identified, such as: the age of the agricultural household head, agriculture as a main activity, the agricultural production system adopted the mode of ownership of agricultural land, extension for farmers. All actions aimed at improving the resilience of Tunisian oasis agricultural households to climate change focus mainly on the strategies adopted by farmers in terms of water management, the technical choices and the production systems adopted combined with the experience and local know-how.

Keywords: Climate change, Adaptation, Agricultural, Households, Econometric analyses, Tunisia.

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Contents

Contribution of this paper to the literature
Research has shown that certain cultural practices can contribute to the resilience of agriculture in arid regions of Tunisia to climate change through adequate water management, technical choices and production systems adopted combined with the experience and local know-how of farmers.

1. Introduction

Agriculture lays a heavy burden on the environment in the process of providing humanity with food and fibers [1]. However, agriculture and food systems as well as the rural economies in the Maghreb and North Africa regions have been experiencing major drastically reduced agricultural production through extreme weather events, such as recurrent droughts and floods in these recent decades [2, 3].In these regions, the climate variability causes severe impacts on agriculture through long drought periods. Recurrent droughts often affect entire countries over multiyear periods and can result in serious social problems caused by water scarcity and the intensive demand of water for agriculture. Impacts anticipated under projected climate change such as increasing rainfall variability, increasing temperature, increasing evaporation rate and water deficit pose a significant challenge to the Maghreb region. Mean temperatures of Morocco, Algeria and Tunisia are expected to rise by between 2 and 4°C until 2100. Already by 2020, rainfall is expected to drop by between 5 and 20% [4]. Tunisia is one of the Maghreb countries and is very vulnerable to the water shortage. Most of the water resources have medium to poor quality, and the salinity is often high. Water deficits and droughts are ongoing risks for Tunisian agriculture. The agricultural sector that pro vides approximately 13% of the annual Gross Domestic Product to Tunisia is very vulnerable to climatic changes also due to poor soils, limited ground and surface water, low rainfall and recurrent droughts particularly in the arid regions of Tunisia In these regions, the consumption of irrigation water in irrigated areas and oases continues to increase to ensure the sustainability of the farming activity and guarantee the income of several households agricultural [5].

For example, in the arid regions of south-eastern Tunisia, the Gabes oases is known since antiquity for their vegetable crops that historically conserved the seeds, their greatest source of resilience facing difficult climate conditions (dry land). However, since the past few decades, the oases are getting very damaged (over-exploitation of resources, urbanisation…) as well as multiple factors have been behind this degradation [6]. The majority of young people and women are not interested in agriculture and the older populations that are, are turning to more profitable field crops. Producing local seeds is forsaken for the benefit of improved hybride seeds that are often combined with the use of chemical fertilizers (highly polluting the soil). The lack of valorisation of local indigenous seeds, the absence of a seed market or even laws restricting the commercialisation of local seeds. This all explains why farmers are discouraged and have difficulties guaranteeing their own production. The risk is that future generations that loses their capacity to adapt to climate change and no longer is able to guarantee food security for the population surrounding the oases [7]. Faced with climatic risks on agricultural activity in oases of irrigated perimeters, reviewing the concept of adaptation through a multidimensional vision touching different economic, social, agronomic, hydrological and political aspects is important to know and detect the main intervening factors in adaptation strategies. The adoption of a bottom-up approach that focuses on autonomous adaptation behavior seems to me more adequate to draw recommendations for adaptation strategies appropriate to oasis production systems in south-eastern Tunisia, case of the Metouia oasis in the governorate of Gabes.

Therefore, this article aims to study the perception and choice of appropriate measures among smallholders in the oases of south-eastern Tunisia for adaptation to climate change. The rest of the article is structured as follows: Section two describes the theoretical framework. Section three presents the methodology. Section Four discusses the results and Section Five provides conclusions and policy recommendations.

2. Theoretical and Methodological Framework

Farmers' behavior towards adaptation to climate change is shaped by socio-economic, physical and behavioral factors [8]. Institutional arrangements for the farmers and their working environment, development for access to markets and climatic factors are useful in shaping the behavior of smallholders [3, 9, 10]. The study of behavior adapting to climate change has many angles of analysis. There is both theoretical and empirical analysis. Some questions are positive, many others are prescriptive. There are microeconomic issues and more macroeconomic problems. Within this diversity, several approaches have been developed in particular: integrated assessment approaches, empirical (econometric) analysis, economy-wide simulation with models and decision support tools. Each of these approaches can help shed light on different aspects of the adaptation problem [11].

For the problem of adopting certain strategies or measures to adapt to climate change in agriculture, the behavioral study of the perception or the choice of strategies requires understanding the reaction of economic agents to current climate and weather events. Much of this evidence is provided by often interdisciplinary studies [12, 13]. However, more and more researchers are using large data sets at the household or farm level to explore how economic agents adapt fully and rationally. The evidence is particularly rich for the agricultural sector.

Such an economic approach in relation to adaptive behavior such as "the econometric approach to climate" has been reviewed by Dell, et al. [14] and Hsiang [15]. These two works mainly focus on assessing the impact and effect of climatic factors on economic variables such as labor productivity, production and growth, rather than on the benefits, costs or extent of the economy adaptation. However, many of the ideas of Hsiang and Dell et al also apply to the econometrics of adaptation.

Several researchers have sought to identify climatic effects both in transversely and chronologically, by comparing the impacts and / or adaptation behaviors across different climatic regimes by measuring the impact of particular meteorological events, such as floods, over time. Increasingly, they have access to panel data. Cross-sectional studies are closely associated with the "Ricardian approach" developed by Mendelsohn, et al. [16]; Kurukulasuriya, et al. [17]; Seo and Mendelsohn [18]; Wang, et al. [19]. Given the great diversity of climates around the world, these studies provide ample evidence of adaptive behavior. The approach of nominal and ordered econometric models can simultaneously model the influence of all the explanatory variables on each of the different adaptation practices, while allowing the potential correlation between the unobserved disturbances as well as the relationship between the adoptions of different adaptation practices [20]. Consequently, an agricultural household is confronted with the decision to adopt or not an adaptation strategy taking into account the parameters perceptions of climate change. Necessarily, this decision to adopt or not depend on the characteristics of agricultural households explained using an "ad-hoc" approach "through several factors: socio-economic, climatic, endowment of available resources (land, water and labor) and policies related to extension services as well as access to information at optimal time. Principal Component Analysis Method and the ordered and binary probit econometric model were mobilized in this work to study the behavior of small farmers in the Methaoui oasis in south-eastern Tunisia in the face of the challenges of climate change.

2.1. Ordered Econometric Models

Several studies have used various methodological approaches to analyze the determinants of adaptations to climate change and the choice of adaptation strategies. Most commonly used analytical approaches in the literature include discrete choice regression models like binary probit or logit [21, 22], multinomial probit or logit and multivariate probit [2, 3, 23-26]. Other empirical studies used principal component analysis and the Ricardian model [27]. Thus, the decisions of perception and adaptation to climate change are intrinsically multivariate and the attempt at univariate modeling excludes the useful economic information contained in the interdependent and simultaneous adoption decisions. On the basis of this argument, the study adopted the econometric technique of ordered and binary probit models to simultaneously model the perception and the influence of the set of explanatory variables on the main adaptation strategies [20, 28].

2.1.1. Ordered and Binary Probit Models

Ordered probit model is widely used approach to estimate models of ordered types. The ordered probit model is built around a latent regression in the same manner as the binomial probit model [29]:

$$y_i^* = \beta' x_i + \varepsilon_i \qquad (1)$$

Equation 1 presents the latent variable (farmers' perceptions) in this study exhibits itself in ordinal categories which were coded as 0, 1, 2…j. The response of category j is thus observed when the underlying continuous response falls in the j-th interval as:

$$y\,(farmers' perceptions) = \begin{cases} 0 & if\ y_i^* \le \delta_0 \ : low\ perception \\ 1 & if\ \delta_0 \le y_i^* \le \delta_1 \ : moderate\ perception \\ 2 & if\ \delta_1 \le y_i^* \le \delta_2 \ : high\ perception \end{cases} \qquad (2)$$

Where in Equation 2, the variable Y* (i = 0, 1, 2) is the unobservable threshold parameters that were estimated together with other parameters in the model. When an intercept coefficient is included in the model, Yo* is normalized to a zero value and hence only j-1 additional parameters are estimated with Xs. As binary data models adopt or not adopt (0/1) adaptation strategies, the probabilities for each of the observed ordinal response, that is, farmer's perception to climate change in this study had 3 responses which could be low, moderate and high with ordinal values of 0, 1, 2.

For adaptation of such a strategy j, the latent variable in this case is a binary dependent variable with yi = 1 to adopt strategies j or yi = 0 not adopt strategies j. Binary probit models can also be motivated by an underlying continuous latent variable yi * which depends on β'xi and an error term εi (for i = 1,…, n) as in the case of Equation 3. If the latent variables would be observable, this would lead to linear regression models. However, latent variables are not observable. But they can be related to the observed binary dependent variables yi:

$$y\,(Farmer's\ strategies) = \begin{cases} 1\ if\ \ y_i^* \ge 0\,, adopt\ strategies\ j \\ 0\ if\ \ y_i^* < 0\,, not\ adopt\ strategies\ j \end{cases} \qquad (3)$$

If follows for the probability $p(x_i, \beta)$ that y_i takes the value one in the following Equation 4:

$$p_i(x_i,\beta) = P(y_i = 1|x_i,\beta) = P(y_i^* \ge 0|x_i,\beta) = P(\beta' x_i + \varepsilon_i \ge 0) = P(\varepsilon_i \ge -\beta' x_i) \qquad (4)$$

Different binary response models can be derived by different distribution assumptions forε_i.If the error term ε_i has a standard normal distribution (with expected value of zero and variance one), this leads to binary probit models. In this case ε_i is symmetrically distributed around zero so that it follows in binary probit model Equation 5:

$$p_i(x_i,\beta) = P(y_i = 1|x_i,\beta) = \Phi_i(\beta' x_i) = 1 - \Phi_i(-\beta' x_i) \quad (5)$$

The assumption of a known variance of ε_i is not problematic since this variance is not identified in binary response models and thus cannot be estimated besides β so that it has to be normalized[29]. Interpretation of a parameter β_h in binary response models with respect to the (partial) effect of the corresponding explanatory variable x_{ih} $(h = 2, \dots, k)$ on the probability $p_i(x_i,\beta)$. The parameter β_h cannot be interpreted as simply as in the linear probability model, i.e. it cannot be interpreted as the change in$p_i(x_i,\beta)$. If x_{ih} increases by one unit (for a quantitative explanatory variable). Instead, the (partial) marginal probability effects of x_{ih} in binary response models are as follows (for i = 1… n) in the following Equation 6:

$$\frac{\partial p_i(x_i,\beta)}{\partial x_{ih}} = \frac{\partial F_i(\beta' x_i)}{\partial x_{ih}} = \frac{dF_i(\beta' x_i)}{d(\beta' x_i)} \frac{\partial(\beta' x_i)}{\partial x_{ih}} = f_i(\beta' x_i)\beta_h \qquad (6)$$

While $F_i(\beta' x_i)$ is the distribution function and $f_i(\beta' x_i)$ is the density function both of the standard normal distribution in binary probit models. Partial marginal probability effects of x_{ih} in binary probit models with $\varphi_i(\beta' x_i)$ as the density function of the standard normal distribution in the following Equation 7:

$$\frac{\partial p_i(x_i, \beta)}{\partial x_{ih}} = \frac{\partial \Phi_i(\beta' x_i)}{\partial x_{ih}} = \frac{d\Phi_i(\beta' x_i)}{d(\beta' x_i)} \frac{\partial(\beta' x_i)}{\partial x_{ih}} = \varphi_i(\beta' x_i)\beta_h \quad (7)$$

The discussion so far has implicitly assumed quantitative explanatory variables. However, if explanatory variables are discrete or even binary, to calculate of the (partial) effect of an infinitesimal change of an explanatory variable x_{ih} can be very inaccurate. Therefore, a discrete change of$p_i(x_i, \beta)$due to a discrete change Δx_{ih} is (for $i = 1\ldots, n$) for the following Equation 8:

$$\Delta p_i(x_i, \beta) = \Phi_i(\beta' x_i + \beta_h \Delta x_{ih}) - \Phi_i(\beta' x_i) \quad (8)$$

If x_{ih} is a dummy variable,$\Delta x_{ih} = 1$ implies the change from zero to one. Again it is possible to calculate (partial) average (discrete) effects and (discrete) effects at the mean $\bar{x} = \frac{1}{n}\sum_i^n x_i$ of the explanatory variables. Where, Φ is the normal density function, h the threshold parameter and x_{ih} the j the explanatory variables. The farmer's perceptions of climate change and the adoption of an adaptation strategy are specified as follows Equation 9:

$$Y * = \beta_0 + \beta_1 x_1 + + \beta_2 x_2 + \beta_3 x_3 + + \beta_3 x_3 + \beta_4 x_4 + + \beta_5 x_5 + + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 \quad (9)$$

Y*(farmer's perceptions) =1 (No perception), 2 (Average perception) or 3 (Good perception (Ordered probit model).
Y* (Farmer's strategies) = 1 (adopt strategies j), 0 (not adopt strategies j). (Binary probit models).
x_1= Ages of farmer (years), continuous (in number).
x_2 = Level of education (ordered), 1 (literate), 2 (primary), 3 (secondary), 4 (university).
x_3 = Main agricultural activity, binary (1 if agriculture, 0 other).
x_4 = Place of residence, binary (1 if on the farm, 0 outside).
x_5 = Farm size, continuous (in hectare).
x_6 = Type of agricultural production system, ordered (3-stage system, 2 classic system, 1 otherwise).
x_7 = Agricultural land owner, binary (1 if farm owner, 0 other).
x_8 = Membership of the Agricultural Development Group, binary (1 if yes, 0 no).

2.2. The Study Area

The Métouia oasis is one of the coastal oases of the governorate of Gabès. It is located 12 km north of the city of Gabès (south-eastern Tunisia) and covers an area of approximately 270 ha Figure 1. The Métouia oasis is characterized by low rainfall. The monthly distribution of precipitation is characterized by a period without rain (June, July and August) and a period with rainfall irregularly distributed over the other months and an annual water balance which is highly deficient. The oasis farms cover very small areas of around 1.5 ha on average. The crops are staged there in height, the palm trees are on the first floor, the pomegranate trees are on the second floor and alfalfa and market gardening are on the third floor. The drainage network is ineffective and moderately maintained. The Métouia oasis is characterized by the presence of a very shallow water table which closely conditions the evolution of the soil throughout the oasis [30, 31].

Figure 1. Location map of the Métouia oasis, South-Eastern Tunisia.

2.3. Data Type and Sources

Data used in this analysis were collected from a household survey conducted in Métouia oasis of the governorate of Gabes on south-eastern Tunisia. The zones have been chosen to take a representative sample of 50 farms for this case study. Data were gathered at the household level on socio-economic characteristics, agricultural production system characteristics, extension institutions and climate change perceptions Table 1.

Table 1. Summary of household characteristics.

Variable (type variable)	Description	Number (%)	Means
Perception (Ordered variable)	Climate change perceptions	50(100%)	
	No perception	*6(20%)*	
	Average perception	*5(17%)*	
	Good perception	*19(63%)*	
Age (discrete variable)	Ages of farmer	50(100%)	50
Education (Ordered variable)	Level of education	50(100%)	
	Literate =1	3(6%)	
	Primary =2	37(73%)	
	Secondary =3	0(0%)	
	University=4	10(20%)	
Main activity (Binary variable)	Main agricultural activity	50(100%)	
	if agriculture = 1	25(50%)	
	other = 0	25(50%)	
Residence (Binary variable)	Place of residence	50(100%)	
	if on the farm = 1	45(90%)	
	Outside = 0	5(10%)	
Farm size (Continuous variable)	Farm size	50(100%)	4.46
Agricultural system (Binary variable)	Type of agricultural production system	50(100%)	
	If stage system = 1	14(26%)	
	If other system = 0	36(74%)	
Land owner (Binary variable)	Agricultural land owner	50(100%)	
	if farm owner = 1	18(26%)	
	If other =0	32(74%)	
Membership (Binary variable)	Membership of (GDA)	50(100%)	
	If membership = 1	23(26%)	
	If no =0	37(74%)	

Source: Data survey.

3. Results and Discussions

3.1. Perception of Climate Change for Oasis Farming Households

The objective of this section is to identify the determining factors of perception of climate change for the oasis farming households. The ordered probit regression model was used to find out the contributing factors implicitly (ad-hoc) to the perception of the phenomenon of climate change and which can play in the development of adaptation strategies. The results of the ordered probit regression model are presented in Table 2.

Table 2. Results of ordered probit regression model for perception of climate change.

Perception of climate change via ordered probit regression model			
	Coef.	**Std. Err.**	**P>|z|**
X1: AGE	0.036	0.038	0.349
X2: EDUC	0.808 *	0.437	0.064*
X3: AGR	0.692	0.773	0.371
X4: RESID	3.364 ***	0.732	0.000***
X5: SIZE	0.611**	0.193	0.002**
X6: SYSTEM	0.467	0.544	0.391
X7: OWNER	1.512 *	0.788	0.055*
X7: MEMBERSHIP	1.991***	0.723	0.006***
	Number of obs. = 50 Wald chi2(8) = 504.42 Pseudo R2 = 0.353 Log pseudo likelihood = -17.636	Prob > chi2 = 0.000	

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%.
Source: Model results.

The results of the probit regression model ordered in Table 2 show an overall significance of the model at the 1% level (Prob> chi2). The positive contribution and the level of significance of the independent variables also determine the importance of these variables in the functioning of the oasis production system. Indeed, a significance level of 1% for the residence variable (RESID) clearly reflects that the farmer, who is installed in the oasis, felt the change of the environment and the deterioration of the oasis agricultural systems from day to day other than a farmer who is outside the oasis. The other variable that is significant at the 1% level is membership of an agricultural development group (MEMBERSHIP) which is responsible for the activity of agriculture in the oasis, among other things the distribution of irrigation hours. Being a member of this group means ease of access to information and extension and staffing of main irrigation hours or additional hours. Therefore, we can deduce that these two variables are of the first order from the point of view of perception of climate change among oasis farming households. Then, in second order, we find the variable area of the agricultural holding (SIZE) significance at the 5% level. This variable shows that the perception can be perceived at the level of large farms whose activities require a lot of production inputs such as water, labor, etc. In third order, at the level of positive significance of

10%, we find variables like the level of education (EDUC) as well as the property of the land (OWNER) which plays an important role in the understanding of the phenomenon of climate change and their impact on oasis systems when the farmer owns their agricultural land. The land ownership variable (OWNER) also reflects a socio-cultural aspect among some farmers, beyond that oasis activity is a source of agricultural income, but it is also a natural heritage characterizing the region which must be preserved for biodiversity, sustainable development and for future generations.

3.2. Adaptation Strategies on Oasis Farming Households

The results of the ordered probit regression model showed the positive and significant contribution of certain key variables that can be used firstly to understand the behaviors of oasis households with respect to the phenomenon of climate change and secondly, avenues for reflection to develop adequate strategies adaptation. in the Table 3, the Principal Component Analysis method (PCA) was used according to a set of classification criteria in relation to the variables of positive perception of climate change identified by the ordered probit model. Among these criteria are: CSD: change of sowing date; ADD_IRRIG: additional irrigation; PURCH_IRRIG: purchase of additional irrigation hours; SAL_AN: sale of animals to finance agricultural activity; ADOPT_CROP: adoption of other crops; POLITICAL_INSTR: State intervention through subsidies and encouragement; ACCES_CREDIT: Access to credit to invest and finance agricultural activity.

Table 3. Component matrix of principal component analysis (APC).

Classification Criteria	Components		
	1	2	3
CSD	-0.394	-0.244	0.729
ADD_IRRIG	0.799	0.404	0.254
SAL_AN	-0.593	0.542	-0.051
ADOPT_CROP	-0.630	-0.392	0.577
POLITICAL_INSTR	-0.206	0.628	0.534
ACCES_CREDIT	0.714	0.175	-0.315
PURCH_IRRIG	0.887	0.305	0.160

Note: Extraction method: Principal component analysis. a. 3 components extracted.

Component 1 characterized by the positive contribution of criteria (ADD_IRRIG, PURCH_IRRIG and ACCES_CREDIT) can be interpreted as Strategy 1: *Adaptation strategy in terms of water saving policy.* Component 2 characterized by the positive contribution of criteria (SAL_AN and POLITICAL_INSTR) can be interpreted as *Strategy 2: Autonomous adaptation incentive strategy* and component 3 characterized by the positive contribution of the criteria (CSD and ADOPT_CROP) can be interpreted as *Strategy 3: Technical strategy and production system.*

These three adaptation strategies reflecting the behaviors of oasis farming households which are deduced by the main component method on the data from the survey questionnaires are also confirmed by local actors, whether they are experts or agents of the service agricultural extension in the region.

3.3. Determinants factors of Adaptation Strategies of Oasis Farming Households to Climate Change

The results of ordered binary probit models in the Table 4 show that the overall significance of a level 5% (Prob> chi2) for the *Strategy 1* and *Strategy 2*; at level 1% (Prob> chi2) for the *Strategy 3* reflecting acceptance of the choice of adaptation variables to describe the strategies identified. The results also show the significant contribution of certain variables to express adaptive behavior among farmers in the oasis of Methouia.

Table 4. Binary probit models results.

Explanatory variables	Strategy 1		Strategy 2		Strategy 3	
	Coef.	P>|z|	Coef.	P>|z|	Coef.	P>|z|
X1: AGE	0.259***	0.003	0.065	0.250	0.155**	0.027
X2: EDUC	0.583	0.147	0.504	0.114	0.395	0.380
X3: AGR	1.863**	0.045	1.299**	0.047	1.747***	0.008
X4: RESID	1.828	0.191	-1.177	0.430	-2.879	0.060
X5: SIZE	0.050	0.795	0.044	0.854	0.075	0.755
X6: SYSTEM	-1.033	0.186	1.767***	0.003	1.731***	0.001
X7: OWNER	2.345***	0.001	1.366*	0.069	0.841	0.249
X7: MEMBERSHIP	2.472**	0.016	1.617*	0.079	2.051**	0.034
Constante	-19.642	0.002	-8.700	0.052	-13.740	0.015
	Number of obs. =	50	Number of obs. =	50	Number of obs. =	50
	Wald chi2(8) =	16.15	Wald chi2(8)=	23.02	Wald chi2(8)=	30.83
	Prob > chi2 =	0.040	Prob > chi2 =	0.003	Prob > chi2 =	0.000
	Pseudo R2 =	0.388	Pseudo R2 =	0.413	Pseudo R2 =	0.468

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%.

The positive and significant contribution at the 1% level for variables such as age (AGE) and land ownership (OWNER) and also other variables that are significant at the 5% level as the main activity variable which is agricultural activity (AGR) and the variable member of an agricultural development group (MEMBERSHIP). These variables explain and justify the adoption of strategy 1 (*Adaptation strategy in terms of water saving policy*) for some farmers in the oasis of Methouia. Indeed, an oasis household head who owns a farm, his main activity is agriculture and member of an agricultural development group where their access to water is possible, all these conditions allow him to access credit to invest in water saving for the purchase of drip irrigation or to build a water basin to store rainwater or additional irrigation water.

For strategy 2 (*Incentive strategy for autonomous adaptation*), the results of the binary probit models in Table 3 show the positive and significant contribution at the 1% level for the classification variable of the production system (SYSTEM), at the level of 5% for the variable (AGR) and at the level of 10% for the two variables (OWNER and MEMBERSHIP). This strategy explains that when agriculture is the main activity for the oasis household head who is also the owner of a farm and member of an agricultural development group for access to irrigation water, contribute to the choice of orientation of oasis agricultural production system. This orientation towards a new oasis production system can be interpreted as a kind of strategy of adaptation to climate change which is carried out for the benefit of the activity of the breeding in particular the cattle breeding which has known a significant deterioration due to of their significant cost. This autonomous adaptation strategy is achieved through the sale of heads of cattle to finance agricultural activity and also through the incentive procedure of public actors to encourage investment in profitable crops with high added value such as pomegranate trees. This strategy implicitly reflects the transformation and the dynamics of the functioning of oasis agricultural households in the south-eastern region, in particular in the oasis of Methouia.

For strategy 3 (*Technical strategy and production system*), the results of the binary probit models in Table 3 show the positive and significant contribution at the 1% level of the principal active variable (AGR) and the production system orientation (SYSTEM), and at the 5% level for age (AGE) and member of an agricultural development group (MEMBERSHIP) variables. In fact, in recent years, we have noticed a change in the classic oasis production system in three stages (palm, arboriculture, market garden and fodder crops) associated with the activity of cattle and goat breeding towards a new production system oasis in two stages (arboriculture, vegetable and fodder crops) associated only with goat farming. This strategy is imposed by the phenomenon of urbanization, the change in lifestyle of oasis households and also the degradation of natural resources due to climate change. This positive contribution explains that these variables together play an important role in the strategy of technical adaptation and orientation of the production system, whether through the change of the date for certain vegetable crops thanks to the experience of older farmers although the orientation towards less costly agricultural production systems that consume less water.

The perception of oasis households of climate change in the study area was consistent with the findings of other researchers around the world. Indeed, the regression analysis of the ordered probit model revealed that certain variables such as education, agricultural area, residence, owner of agricultural land and membership of an agricultural development group have influenced the perception of climate change by Farmers. The same interpretations for these variables are justified by the work developed in the central agricultural zone of the state of Delta, Nigeria [32]. For the different adaptation strategies and their determining factors which are identified by the binary probit regression model, for example, the variables: age, agriculture is the main activity, owner of agricultural land and membership of a development group agricultural, reflect the adaptive behavior of oasis households in Methouia. The motivation for this adaptive behavior is based almost on four key terms: experience for autonomous adaptation and orientation of production systems, the owner of agricultural land for access to credit and membership in a group of agricultural development for access to water and information and an extension service. These same key adaptation terms also summarize the adaptation of farmers' livelihoods to environmental changes in the case of the Minqin oasis, northwest China [33].

4. Conclusion and Recommendations

The study aimed to assess the perceptions and adaptation strategies of farmers to climate change in the oasis of Methouia in south-eastern Tunisia. It was found that the perception was raised among the majority of oasis farmers who were well aware that the climate was changing. The majority of farmers noted that there was an increase in temperature, decrease in rainfall, changes in the timing of rains and an increase in the frequency of droughts. The most common adaptation strategies among farm households were: crop diversification, change of production system, increase in water conservation practices, adjustment and management of livestock, the abundance of cattle breeding for the benefit of oasis agriculture and the increased use of irrigation technology through access to credit. The results of the study also show that certain variables such as level of education, residence on the farm, agricultural area, land owner and membership in the agricultural development group are crucial factors in influencing the probability oasis farmers to perceive climate change. Likewise, factors such as the age of the head of household, education, the system of the land owner and membership in the agricultural development group, facilitate access to credit and also to extension and information on change climate. These variables can be considered as factors to trace the most adequate adaptation strategies for oasis farmers of Methouia to climate change. Any policy aimed at strengthening the adaptive capacity of farmers in the study area should consider the use of the factors mentioned above in developing adaptation strategies. The importance of these socio-economic and technical factors of production in the perception and strategies of adaptation to climate change in the case of agriculture is justified by several studies in the world [24, 33-39]. Indeed, this study was an example to show that the bottom-up approach going from the individual scale for the case of the farmer to the global (community or society) to forecast the perception and ideas of the autonomous adaptation. This approach can be interpreted as the most effective methodological process in the design of adequate adaptation strategies which takes into account all the economic, social and ecological characteristics of a given region. Today, it is time to rethink the development of adaptation strategies to climate change by strengthening the adoption of the bottom-up approach on scientific and participatory bases with the actors concerned, first and foremost the farmer and their concerns for the internal and external environment of their activity.

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