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Factors affecting farmers' willingness to adopt salt-tolerant forage crops in south-eastern Tunisia

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Abstract

This paper analyzed the factors that affect farmers' willingness to adopt salt-tolerant forage for livestock, using a Tobit model. The data used for the empirical analysis was obtained from a survey of 97 farmers in southeastern Tunisia. The results of this study show that variables related to age, education level, the salinity level of water and membership in a farmers' association do not significantly influence the degree to which salt-tolerant forage production is adopted. It did, however, find a positive relationship between off-farm income availability and adoption. In addition, the flock size variable, expressed in Standard Livestock Units, has a significant and positive relationship with adoption. This indicates farmers' need to cover their forage deficit. Agricultural extension services should ensure that the requisite forage species are made available, and work with farmers to encourage them to adopt salt-tolerant forage species and pass on their knowledge to other farmers.

Keywords: Farmers' willingness to adopt; Salt-tolerant forage; Tobit model; Tunisia

Le présent travail vise à étudier les facteurs qui affectent la disposition de l'agriculteur à pratiquer les cultures fourragères tolérantes à la salinité au moyen de l'estimation d'un modèle Tobit. Les données utilisées pour l'analyse économétrique sont obtenues à partir d'une enquête réalisée auprès d'un échantillon de 97 agriculteurs de la région sud-est de la Tunisie. Les résultats empiriques montrent que les variables âge, niveau d'instruction, degré de salinité de l'eau, superficie agricole totale et l'appartenance à une association d'agriculteurs n'affectent pas d'une manière significative la superficie à cultiver en cultures fourragères tolérantes à la salinité par les exploitants. On a cependant détecté une relation positive et statistiquement significative entre la variable disponibilité d'un revenu hors exploitation et la superficie à cultiver. De plus, la variable taille du cheptel exprimée en Unité Gros Bétail affecte positivement cette superficie. Ce qui explique en grande partie la nécessité des agriculteurs de couvrir leurs besoins en matière de fourrages pour l'alimentation du cheptel. Les services de vulgarisation agricole doivent favoriser la disponibilité des semences de ces cultures fourragères et assister les exploitants pilotes pour qu'ils transmettent leur expérience à d'autres exploitants.

Mots clés : *Disposition à adopter ; Fourrages tolérants à la salinité ; Modèle Tobit ; Tunisie*

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1. Introduction

During the past few decades, salinity in the groundwater and soil has increased sharply in the arid areas of southeastern Tunisia and become a major constraint to crop and conventional forage production. In these conditions, the opportunity to use saline water to grow salt-tolerant forage is seen as essential to secure additional income for poorer sections of the rural population who depend on livestock. Without this there will be only marginal livestock.

Overuse of rangelands for livestock production has caused severe environmental degradation in the target areas. Salt-tolerant crops irrigated with saline water may contribute to the sustainability of agricultural systems in marginal lands. Farmers have become increasingly dependent on saline or slightly saline water irrigation. The use of saline water to produce non-conventional crops is of particular importance. Among crops and farming systems that are highly appropriate for salt-tolerant environments are the forage production systems.

During these decades, much effort has been made in Tunisia to evaluate and select new varieties of forage that will have better salt-tolerance, and to manage land and water so as to reduce salinity (Nasr, 2001; *CFPA*, 2006), but factors affecting the adoption of salt-tolerant forage production have not been sufficiently investigated. Several fodder crops that have the potential for economic production in salt-affected environments have been introduced at different levels of irrigation water salinity. Salt-tolerant barley, irrigated with 7.6 g/l (dry residue salt), yielded 55 t/ha based on the green vegetative component. Fodder sorghum (Sudanese sorghum) irrigated with 6.7 g/l (dry residue salt) yielded 60 t/ha/year based on green matter. Lucerne (Medicago sativa, variety Gabes), irrigated with 7.6 g/l (dry residue salt), yielded 60 t/ha/year based on green matter. Panicum turgidum and Cenchrus ciliaris, variety Bouhedma, irrigated with 7 g/l (dry residue salt), yielded 3.7 and 1.9 t/ha/year based on green matter, respectively. Kallar grass (Leptochloa festuca) irrigated with 6 g/l (dry residue salt) yielded 45 t/ha/year, whereas it yielded only 25 t/ ha/year when irrigated with 7.6 g/l (dry residue salt) (Nasr, 2007).

The main objective of this paper is to identify and analyze the factors that affect farmers' decisions to adopt salt-tolerant forages in southeastern Tunisia. The remainder of this paper is organized as follows. Section 2 describes the study area and the data collection, Section 3 specifies the model and the variables used in the analysis, Section 4 reports and discusses the obtained results, and Section 5 concludes.

2. Study area and data collection

The study involved three regions of southeastern Tunisia (the Gabes, Medenine and Tataouine governorates). This study area is arid, with an irregular rainfall of 100 to 200 mm per year, so no sustainable agricultural production system is possible without irrigation. Saline groundwater is the major source of water supply here. The total area is approximately 5,522,200 ha, 33% of the total area of Tunisia, with 3,031,300 ha being agricultural land (arable, rangeland and forest) and 2,490,900 ha non-agricultural. About 2,500,000 ha, 82% of the agricultural area, is rangeland. The arable land is 525,000 ha, covering 17% of the agricultural land. This means that only 9% of the total area contributes to agricultural production (excluding pastoral lands).

The total area of cultivated land increased to 428,810 ha in 2004, of which cereals occupy 21.3%, fruit trees 74%, vegetables 2.2%, legumes 1.3%, forage crops 1.2% and others 0.2% (MoA, 2006). Irrigated areas of forage crops are limited, since farmers prefer high return

vegetable crops rather than irrigated forage, if irrigation is possible. Part of the land (5,220 ha) is used for forage production but there is an ongoing shortage of animal feed. The main forage species used in the study areas are alfalfa, fodder sorghum and green barley.

The study area suffers severe land degradation, including desertification, salinization and poor agrobiodiversity. Livestock production is the main source of livelihood for the local population. On the basis of the latest Ministry of Agriculture surveys (2006), farm numbers in the three governorates (Gabes, Medenine and Tataouine) of Tunisia were estimated to be about 54,000. The farming structure is characterised by the predominance of small-size farms and land fragmentation. About 80% of the farms surveyed were less than 20 ha.

In 2006 a baseline survey of 30, 33 and 34 farmers was conducted in Tataouine, Medenine and Gabes governorates, respectively. The selected sample of farms was based on the two criteria: availability of saline water and ownership of livestock. Single visits were made to farmers to solicit answers to a standardized questionnaire covering qualitative and quantitative information about their farming systems, socioeconomic indicators, practices and attitudes to the use of saline irrigation water and feeding patterns of livestock. The survey was carried out as part of a project dealing with the use of freshwater resources with salt-tolerant forage production in marginal areas of the West and North Africa (WANA) region. We have used some socioeconomic and institutional variables to estimate the model in this paper. Unfortunately, we do not have detailed data about farmers' perceptions in the form of a Likert scale etc. to use in the empirical model.

3. Model specification and description of variables

The theory of the maximization of utility is generally used to explain farmers' responses to new technology (Adesina & Seidi, 1995; Adesina, 1996). According to this theory, a farmer will adopt a given technology if the utility obtained from the new technology exceeds that of the old one. Let U_{i1} represent the expected utility a particular farmer (i) could gain by adopting a new technology measure, while U_{i0} represents utility from the traditional farming practice. Although not directly observable, the utility function of a given farmer (*i*) from using a given measure (*j*) can be written as:

$$U_{ij} = X_i\alpha_j + \varepsilon_{ij}, \qquad j = 1, 0; \qquad i = 1,\ldots., n \tag{1}$$

where X_i is a farm-specific function, α_j is a parameter, ε_{ij} is a disturbance term with zero mean and constant variance, 1 represents adoption of a new technology measure and 0 represents non-adoption. The *i*th farmer adopts new technology, i.e. $j = 1$, if $U_{i1} > U_{i0}$.

Analytical models widely used to assess adoption of conservation technologies include Probit, Logit and Tobit models. To study the adoption behavior, a limited dependent variable provides a good framework where there is a cluster of farmers with zero adoption of the improved technology. The present study uses the Tobit model. This model measures not only the probability of salt-tolerant forage crops but also the degree of adoption.

The Tobit model supposes that there is a latent unobservable variable y_i^*. This variable depends linearly on x_i via a parameter vector β. In addition, there is a normally distributed error term u_i to capture random influence on this relationship. The observable variable y_i is defined as being equal to the latent variable whenever the latent variable is above zero and to be equal to zero otherwise.

$$y_i = \begin{cases} y_i^* & if \quad y_i^* > 0 \\ 0 & if \quad y_i^* \le 0 \end{cases} \tag{2}$$

where y_i^* is a latent variable:

$$y_i^* = \beta x_i + u_i, \quad u_i \; N(0, \sigma^2)$$

If the relationship parameter β is estimated by regressing the observed y_i on x_i, the resulting Ordinary Least Squares estimator is inconsistent. Maddala (1983) has proven that the likelihood estimator suggested by Tobin for this model is consistent.

The likelihood function of the model (2) is given by *L*, as follows:

$$L = \prod_0 F_i(y_{0i}) \prod_1 f_i(y_i)$$

$$L = \prod_0 [1 - F(x_i\beta / \sigma)] \prod_1 \sigma^{-1} f[(y_i - x_i\beta)/\sigma] \tag{3}$$

where f, F are the standard normal density and cumulative distribution functions, respectively. Then we can write the log-likelihood function as:

$$LogL = \sum_0 \log(1 - F(x_i\beta / \sigma) + \sum_1 \log(\frac{1}{(2\Pi\sigma^2)^{1/2}}) - \sum_1 \frac{1}{2\sigma^2}(y_i - \beta x_i)^2 \tag{4}$$

The parameters β and σ are estimated by maximizing the log-likelihood function

$$\begin{cases} \dfrac{\partial LogL}{\partial \beta} = -\sum_{0} \dfrac{x_i f(x_i\beta)/\sigma)}{1-F(x_i\beta/\sigma)} + \dfrac{1}{\sigma^2}\sum_{1}(y_i - \beta x_i)x_i = 0 \\ \dfrac{\partial LogL}{\partial \sigma^2} = \dfrac{1}{2\sigma^2}\sum_{0} \dfrac{\beta x_i f(x_i\beta/\sigma)}{1-F(x_i\beta/\sigma)} - \dfrac{n_1}{2\sigma^2} + \dfrac{1}{2\sigma^4}\sum_{1}(y_i - \beta x_i)^2 = 0 \end{cases} \quad (5)$$

Since the two equations (5) are non-linear, the maximum likelihood estimators must be obtained by an iterative process, such as the Newton-Raphson or Davidson-Flecher-Powell (DFP) or Berndt-Hall-Hall-Hausman (BHHH) algorithm (Greene, 2003).

To study the explanatory power of the model, a statistic based on likelihood ratio (LR) is appropriate. This ratio is defined as follows:

$$LR = -2(\log L_r - LogL_u)$$

where $LogL_u$ is the log-likelihood for the unrestricted model and $logL_r$ is the log-likelihood for the model with k parametric restrictions imposed. The likelihood ratio statistic follows a chi-square distribution (χ^2) with k degrees of freedom.

The variables used in the analysis are shown in Table 1. The dependent variable indicating the farmers' willingness to adopt salt-tolerant forage is measured by the area to be cultivated with the salt-tolerant forage. The average area farmers are willing to cultivate with salt-tolerant forage is about 1.31 ha. The area varies between 0 and 12 ha. The explanatory variables are the farmer's age, the farmer's educational level, the farm size, the salinity level of the irrigation water, the number of livestock, the farmer's main activity and the farmer's membership of a farmers' association.

It was hypothesized that AGE (continuous variable) is negatively related to adoption. Bagi (1983) found that younger farmers had a greater likelihood of adopting improved varieties. The farmers' education level (dummy variable) is measured as 1 for a farmer who has more than primary education level and 0 otherwise. The level of a farmer's education is hypothesized to be positively related to adoption of new crop varieties (Kebede et al., 1990; Adesina & Seidi, 1995). Farm size was expected to have a positive relationship with the adoption of improved varieties (Bagi, 1983; Kebede et al., 1990; Sarab & Vashid, 1994).

The salinity level of irrigation water (SAL) is a continuous variable. It was hypothesized that SAL is positively related to adoption. This is because when the level of water salinity is low, the farmers cultivate conventional crops. The flock size of livestock $(SLU)^2$ variable was expected to be positively related to adoption. Small ruminants (sheep and goats) are the most important species in the study areas. On average, the surveyed farmers have about three head of cattle, 59 sheep and 14 goats.

ACTIV is a dummy variable, which takes the value 1 if the farmer has only agricultural income and 0 with off-farm income. Several studies have shown that non-farm income positively influences the adoption of new technologies (Savadogo et al., 1994; Adesina, 1996). Off-farm income would reduce the perception of risk and increase the likelihood of adopting salt-tolerant forage production. Finally, FAS is a dummy variable that takes the value of 1 if the farmer belongs to a farmers' association and 0 otherwise. It is assumed that

[2] Standard Livestock Unit (SLU) = 1 head of cattle = 5 sheep = 6 goats = 1 camel

membership in a farmers' group is positively related to adoption of salt-tolerant forage. This may be explained by the numerous advantages of belonging to an association. For instance, members have easy access to training and information. Farmers can also benefit from the collective investments that can be made by such an association. The association can also be seen as the local entity that looks after local development and applies government policies locally. Farmers know this and try to benefit from various projects and investments.

Table 1: Description of variables used in the analysis of farm-level adoption of salt-tolerant forage crops

Variable acronym	Variable name	Variable definition	Expected sign	Mean
Dependent variable				
SURF	Willingness to adopt salt-tolerant forage	Number of hectares		1.310
Independent variables				
B_0	Constant	Unitary vector		
AGE	Farmer's age	Number of years	-	53.463
EDUC	Farmer's level of education	1 if farmer has more than primary education level, 0 otherwise	+	0.298
SIZE	Farm size	Number of hectares	+	23.365
SAL	Salinity level of irrigation water	Grams per liter	-	4.763
SLU	Standard Livestock Unit	Number of SLU	+	17.027
ACTIV	Activity	1 if farmer has only farm income, 0 otherwise	-	0.855
FAS	Membership of farmers' association	1 if the farmer is a member, 0 otherwise	+	0.092

4. Results and discussion

The iterative method of the Newthon-Raphson algorithm from the least squares solution was used to estimate the coefficients, using the data processing program E-views.[3] The solution was reached after six iterations**.** The maximum likelihood estimates for the Tobit model are shown in Table 2. It may be noted that the estimated model has explanatory power. In fact, the likelihood ratio (LR) of the Tobit model was significant at the 1% level. The effect of certain variables on the adoption decision shows additional information gained once the model was used.

The empirical results of the Tobit run indicate that five of the seven variables tested had the hypothesized signs. However, only two variables (SLU and ACTIV) significantly affect farmers' decision to adopt salt-tolerant forage production.

[3] www.eviews.com

The signs of the estimated coefficients of the AGE and EDUC variables are not consistent with our expectation. The coefficients sign of the SIZE, SAL and FAS variables are consistent with our expectation but not statistically significant. These variables have no significant influence on adoption.

The estimated coefficient of the ACTIV variable is negative and statistically significant at 5%. The negative sign of this variable, as expected, suggests that farmers with off-farm incomes are more likely to adopt salt-tolerant forage.

The estimated coefficient of the flock size variable (SLU) is positive and statistically significant at 1%, which indicates that this variable had a positive effect on the degree of adoption. It means that farmers with more livestock are more likely to adopt salt-tolerant forage. This variable had the greatest significant effect on the farmers' decision to adopt salt-tolerant forage because of its level of significance. This finding shows the pressure on farmers to meet their livestock needs.

Table 2: Estimation results of the Tobit model

Variables	Coefficients	t-statistic	Significance level
B_0	2.109	2.097	***
AGE	0.004	0.332	
EDUC	-0.081	-0.209	
SIZE	0.007	1.487	
SAL	-0.155	-1.290	
SLU	0.024	3.967	***
ACTIV	-1.082	-2.311	**
FAS	0.182	0.369	
$LogL_r$	-186.156		
$LogL_u$	-165.535		
LR	41.242		***
Degrees of freedom	7		

$LogL_u$: Log-likelihood function, $LogL_r$: Restricted log-likelihood, LR: Likelihood ratio test
* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

5. Conclusions

The fresh water resources in Tunisia are scarce and their quality is degrading. The southern region is the poorest in terms of available renewable fresh water resources. Salinity in the groundwater of the arid area of southeastern Tunisia is a major constraint to conventional crops. Among farming systems that are highly appropriate for saline environments are the salt-tolerant forage production systems. Saline water, which is relatively abundant in the study area, can be used to cultivate forage for livestock and help control rangeland degradation. Currently, forage production in the area is insufficient to meet the demands of an increasing livestock population.

In this paper we identified factors that influence farmers' willingness to adopt salt-tolerant forage. The Tobit model was used to analyze data from a sample of 97 farms in southeastern

Tunisia. The empirical results show that age, educational level, salinity level of water, farm size and membership in a farmers' association do not significantly influence willingness to adopt salt-tolerant forage production. Off-farm income availability and flock size variables were found to significantly affect farmers' willingness to adopt. These results also indicate that the most significant variable for the adoption of salt-tolerant forage is the size of the flock a farmer owns. This shows that the farmers need to meet the demands of an increasing livestock population. In fact, the majority of surveyed farmers would like to increase their head of livestock.

Since it is shown that the farmers who are more willing to adopt salt-tolerant forage crops are the larger livestock farmers, it is then essential that agricultural extension services should work closely, as a first step, with these farmers to educate them about the technology of biosaline agriculture. Farmers thus informed will become, as the next step, a source of technology diffusion to other farmers. In addition, the required salt-tolerant forage species need to be made available for the adoption process to be sustained.

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