Biophysical and Econometric analysis of adoption of soil and water conservation techniques in the semiarid region of Sidi Bouzid (Central Tunisia)

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Abstract - Land degradation, within an era of rapid depletion in the natural resource base, is of both historical and contemporary concern for Tunisia. Notwithstanding significant concerns related to well-being and stability within rural communities, soil and water conservation technologies (SWCT) have received much attention from both the research community and policy makers given that declining soil health, erosion, and moisture stress have implications for agricultural livelihoods; and thereby national food security. Yet, despite early adoption in Tunisia, broad uptake of SWCT has been less than desired. This study aims to identify and analyze those factors which have affected the adoption within the Sidi Bouzid governorate of Central Tunisia; a region which we feel is generally representative of resource-poor environments within the republic. Employing a binary logistic regression model, with data obtained through a survey of 250 farmers, our results suggest that socio-economic and institutional factors have played an important role in the adoption of SWCT, with membership in a cooperative found to have been a particularly significant and positive contributor. Somewhat surprisingly, however, farmers' participation in trainings were found to be negatively correlated with adoption. Equally important was a finding that farmers with livestock holdings are less likely to adopt SWCT. Taken together, this would suggest that linear processes of knowledge generation and dissemination, through training and extension, will likely need to be augmented with more dynamic systems of multi-stakeholder engagement, inclusive of rural institutions, and within a contemporary movement for greater efficacy in innovation systems.

Key words: Adoption, Soil and water conservation, Physical conservation, Biological conservation, Logistic regression, Tunisia.

Introduction

Land degradation and depletion of natural resources in Tunisia are major challenges to the development and sustainability of the agricultural sector. Indeed, annual soil losses are estimated at 23 000 hectares, of which 13 000 hectares cannot be recovered (Souissi, 2001). Soil and water conservation technologies (SWCT) have are of continued and pressing interest to researchers and policy makers given that agricultural productivity, and thereby food security, are seriously threatened by a steady decline in soil health and with increasing soil moisture stress. Tunisian institutions have promoted soil and water conservation techniques since the 1990s (Ministry of Agriculture, 2014), in order to reduce surface runoff, enhance groundwater recharge, reduce rain water losses, and towards mitigating soil erosion. Despite notable (environmental) success, obtained through large scale initiatives undertaken nationally, broad (farmer) uptake has been less than desired. Relatively poor adoption rates can be ascribed to a number of reasons, but for SWCT, causality is not well identified. Notwithstanding social and cultural considerations in the decision to adopt, the need to economically examine incentives to adopt SWCT is of immediate importance, in so far as evaluating the impact of adoption within environmentally sensitive areas of Tunisia.

Objectives of the study

We provide a set of explanations for why farmers within the study area appear hesitated to the use of SWCT, through identification and analysis of those specific factors which appear to influence the decision to adopt, and in order to flesh out policy relevant lessons aimed at fostering greater adoption.

Geographical boundary

This study was undertaken within two rural communities (Zoghmar and Selta) belonging to the Governorate of Sidi Bouzid in central Tunisia. The governorate is of national importance to agricultural production, specifically in terms of area under production, as well as in relation to the existence of strong crop-livestock interactions. Soil salinization within the plains, in addition to water erosion on the Western Mountain and hills are characteristic of the study area.

Methodological framework

Data types and Data Sources

In employing a mixed methods design, data were collected through semi structured household interviews with analysis augmented through the collection and use of secondary sources of data.

Sampling Technique and Procedures

For data collection, a multistage sampling technique was employed, with two regions (Zoghmar and Selta) selected in the first phase. In the second stage, eleven districts were randomly selected. Data were collected for the 2014-2015 cropping year from 250 producers (97 adopters and 153 non-adopters) located within the chosen regions.

Data was compiled using SPSS (V.20) and analyzed using descriptive statistics, with econometric analyses undertaken for the purpose of comparing adoption rates (and factors for adoption) between adopters and non-adopters.

Model Specification

Understanding the main determinants of SWCT adoption is a complicated process, similar to any other research on agricultural technology adoption (Adesina and Chianu, 2002), given the influence of a set of interrelated biophysical, socioeconomic, and institutional factors. According to Adesina and Zinnah

(1992), the theory of the maximization of utility has been used to explain farmer response to new technology. According to this theory, maximization of utility in relation to the adoption of a new technology by an individual farmer takes into consideration both new and existing technology. A new technology will be adopted by the farmer if the utility obtained through adoption exceeds that of the existing use. In our hypothesis, and consistent with a host of other studies, we also assume that farmer response to new technology is consistent with the objective of utility maximization (Rahman and Huffman, 1984; Adesina and Zinnah, 1993; Bekele and Drake, 2003 and Asfawa and Admassie, 2004).

Given that conventional regression analysis (Ordinary Least Squares or OLS) cannot accommodate missing observations for the dependent variable, Logistic Regression is utilized in order to predict a categorical (usually dichotomous) variable from a set of predictor variables. In our specific case, the objective of modelling is to predict an event that has two possible outcomes, adoption vs. non adoption, thereby rendering the dependent variable as non-continuous, with only two possible values, 1 or 0. This case violates the assumption of normal distribution (single peak), since a 1/0 variable by definition is binomially distributed (double peak). The Binary Logistic Regression model addresses this problem by setting the predicted dependent variable as a function of the probability that a particular subject will be within one of the categories, i.e., by determining the odds of 1 or 0. If the odds of 1 are higher than the odds of 0, then a 1 would be expected. This is accomplished by estimating the Log Odds Ratio, which is the log of the odds of 1 divided by the odds of 0. Given that probabilities cannot take on negative values, the log of a positive number can have a value between negative infinity and positive infinity, thereby removing upper and lower bounds on the dependent variable, and allowing for estimation through a standard regression model.

Based on the approach described above, Binary Logistic Regression was utilized in order to regress the dependent variable (Y), which represents the choice of farmer adoption, against the factors affecting household head's adoption decision (He *et al.,* 2007; Hall *et al.*, 2009; Keelan *et al.,* 2009) with:.

$$Y = 1\text{: adopted SWCT; } 0\text{: otherwise} \qquad (1)$$

Let X_i represent the set of factors influencing the adoption decision of the i^{th} farmer. For the farmer, Y_i is indirect utility derived from the adoption decision, a linear function of k explanatory variables (X), and expressed by the following prediction equation:

$$Y_i = \ln\{\text{odds (event)}\} = \ln\{(\text{prob(event)}/\text{prob(nonevent)}\} = \ln\{(\text{prob(event)}/1-\text{prob(event)}\}$$

$$= Ln\left(\frac{P_i}{1-P_i}\right) = Ln\ odds = \beta_0 + \sum_{i=1}^{n} \beta_i X_{ki} = Z_i$$

$$= \beta_0 + \beta_1 X_1 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots.. + \beta_k X_k \qquad (2)$$

where $\tilde{Y}$ is the predicted probability of the event coded with 1 (adopt), $(1 - \tilde{Y})$ is the predicted probability of the alternate decision (not to adopt), α is the intercept, and X_k represents the following predictor variables (Table 1): AGE, EDUC, FSIZ, FEXP, LABE, TENUR, OFFA, CRED, CBOS, VLIVST, CONT, CapBui, LFRA, and FSR. β_1, β_2, β_3, ..., β_i are the coefficients associated with each explanatory variable X_1 to X_{ki}.

The model can therefore be expressed as follows:

$$Y = \alpha + \beta_1 AGE + \beta_2 EDUC + \beta_3 FSIZ + \beta_4 FEXP + \beta_5 LABE + \beta_6 TENUR + \beta_7 OFFA + \beta_8 CRED + \beta_9 CBOS + \beta_{10} VLIVST + \beta_{11} CONT + \beta_{12} CapBui + \beta_{13} LFRA + \beta_{14} FSR + \xi \qquad (3)$$

The above econometric model was estimated using an interactive maximum likelihood estimation procedure (Sidibe´, 2005). This estimation procedure yields unbiased, efficient and constant parameter estimates.

Table 1: Description of the variables specified in the empirical binary logistic model (N=250).

Acronym	Description	Type of measure	Expected Sign
Dependent variables			
ADOP	Whether a farmer has adopted (or not) SWC technology	Dummy (1 if yes, 0 if no)	
Explanatory variables			
#1 – AGE	Household head's age	Years	-
#2 – EDUC	Educational background of the household head	Dummy (1 if the farmer accumulate more than 6 years in education, 0 if less than 6 years)	+
#3 – FSIZ	Number of people within the household	Numbers (#)	+
#4 – FEXP	Household head's farming experience	Years (#)	+
#5 – LABE	Family labor force	Active labor force numbers (#)	+
#6 - TENUR	Status of land ownership	Dummy 1 (1 if fully owned; 0 otherwise)	+
#7 - OFFA	Farmer has an off-farm income generating activity	Dummy (1 if yes, 0 if no)	?
#8 - CRED	Obtained credit / funding	Dummy (1 if yes, 0 if no)	+
#9 - CBOS	Member of a community based organization (CBO)/cooperative	Dummy (1 if yes, 0 if no)	+
#10 - VLIVST	Importance of livestock in the farming system	% of livestock-related income in total farm income	?
# 11 - CONT	Contact with extension	Estimated yearly number of visits of extension agents to the farm (#)	+
# 12 - CapBui	Farmer attendance at training meetings	Dummy (1 if yes, 0 if no)	+

# 13 - LFRA	Land fragmentation	Number of plots owned divided by total land area owned by the farmer (#)	-
# 14 - FSR	Stocking rate	Flock size divided by total land area owned by farmer	-

Source: Own elaboration from survey (2015).

Results and discussion

Soil and water conservation practices within the study area

Within the study area, improved soil and water conservation measures have been historically introduced through a range of national and international initiatives. Survey results indicate that the adoption of SWCT within the study area has been occurring since the 1980's. The most widely and intensively used techniques are generally physical and agronomic/biological practices (Table 2), with 16% and 26% of farm households practicing physical and biological conservation respectively.

Table 2: Soil and water conservation practices in study area (N=250)

Soil and Water Conservation Practices	Adopters - of at least 1 practice (N=97)*		Non Adopters (N=153)	
	N	%	N	%
Agronomic practices				
Manuring	16	6	234	94
Crop rotation	47	19	203	81
Minimum tillage	3	1	247	99
No tillage	1	0	249	100
Physical structures				
Terraces	35	14	215	86
Soil bunds	3	1	247	99
Stone bunds	3	1	247	99

*Source: Own elaboration from survey (2015). * 10 farmers adopt two different practices in at least one of their plots, and one farmer adopts three practices.*

Factors affecting adoption of SWCT within the study area

A binary logistic regression model was fitted to estimate the effect of expected explanatory variables on the probability of a farmer being an adopter (or not) of SWCT. Fourteen explanatory variables (seven continuous and seven dummy) were included within the model. The summary data for the fourteen variables expected to affect adoption are presented in Table 3.

Table 3: Summary of explanatory variables included in the logistic regression model (N=250)

Variables	N	Minimum	Maximum	Mean	Std. Deviation
ADOP	250	0.00	1.00	0.3880	0.48827
AGE	250	24.00	90.00	54.9880	15.19260
EDUC	250	0.00	1.00	0.4440	0.49785
FSIZ	250	1.00	30.00	6.4040	2.98066

FEXP	250	2.00	75.00	31.1240	15.61808
LABE	250	0.00	9.00	2.7240	1.65977
TENUR	250	0.00	1.00	0.3400	0.47466
OFFA	250	0.00	1.00	0.3400	0.47466
CRED	250	0.00	1.00	0.0800	0.27184
CBOS	250	0.00	1.00	0.0720	0.25901
VLVST	250	0.00	1.00	0.6580	0.29048
CONT	250	0.00	24.00	0.2320	1.66048
CapBui	250	0.00	1.00	0.1600	0.36734
LFRA	250	0.25	100.00	4.7607	8.51697
FSR	250	0.00	6.10	0.5340	0.68551

Source: Own elaboration from survey (2015).

In order to test the existence of multi-collinearity, both continuous and discrete explanatory variables were checked using a Variance Inflation Factor (VIF). There would appear to be minimal correlation between the variables (Table 4). Based on this, all the explanatory variables were included within the final analysis.

Table 4: Variance Inflation Factor (VIF) for continuous explanatory variables (N=250)

Variables	Collinearity Statistics	
	Tolerance	Variance Inflation Factor (VIF)
AGE	0.378	2.646
EDUC	0.868	1.152
FSIZ	0.878	1.139
FEXP	0.379	2.642
LABE	0.940	1.064
TENUR	0.794	1.260
OFFA	0.743	1.346
CRED	0.873	1.145
CBOS	0.775	1.290
VLVST	0.794	1.260
CONT	0.777	1.287
CapBui	0.846	1.182
LFRA	0.927	1.079
FSR	0.868	1.153
a. Dependent Variable: ADOP		

Source: Own elaboration from survey (2015).

The Maximum Likelihood method of Estimation (MLE) was used to draw parameter estimates from the binominal logistic regression model. Of the fourteen explanatory variables, four were found to be significant at less than or equal to ten percent probability level (farming experience, farmer membership within community based organization/cooperative, plot area, flock size). Table 5 shows the signs, magnitude and statistical significance of the estimated parameters and whether observed values were correctly predicted by the logistic regression model.

The likelihood ratio test statistic exceeds the Chi-square critical value with 15 degree of freedom. The result is significant at ($P<0.01$) probability level indicating that the hypothesis that all coefficients, with the exception of the intercept equal to zero is rejected. The results on the validity of the model using the Hosmer and Lemeshow statistic indicates a good fitness of this model (as the significant value is about 0.496 which is more than 0.05). This implies that we fail to reject the null hypothesis that there is no difference between the observed and predicted values of the dependent, implying that the model's estimates very well fit the data at an acceptable level. The overall percentage of correct predictions is 66.8%. The column, Exp(B), in Table 5 gives the exponential of expected value of β raised to the value of the logistic regression coefficient, which is the predicted change in odds for a unit increase in the corresponding explanatory variable.

The interpretation of the four significant explanatory variables is discussed below.

Farming Experience (FEXP): farming experience affects SWCT adoption positively and significantly at ($p<0.1$). The odds ratio of 1.021 indicates that, holding all other independent variables constant, the odds of adopting soil and water conservation technologies increases by a factor of 1.021 as farming experience of household head increases by one year.

Farmer membership within CBO's/cooperative (CBOS): being a member of a community based organization (CBO) or cooperative affects the adoption decision of farmers positively and significantly at ($P<0.01$). This most likely indicates that CBOS/cooperative members acquire relevant knowledge and skills related to soil and water conservation techniques, thereby favoring adoption. The odds ratio of 5.311 indicates that holding all other explanatory variables constant, for every one unit increase in the CBO score, we expect a 5.311 times increase in the log-odds of adoption (probability of adoption).

Farmer attendance at training meetings (CapBui): The variable is significant at ($p<0.05$) and negatively related with SWCT adoption. The result is not consistent with the hypotheses in that those farmers who have participated in trainings should have a higher probability to adopt such technologies. However, in this case, the indicator included all types of trainings, not only those specifically targeting SWCT. It is not clear, therefore, whether there were other competing technologies which were adopted or other compelling explanations for the negative coefficient. Further research is required in this regard in order to provide an explanation for this counter-intuitive result.

Livestock holding (VLVST): The variable is significant at ($p<0.05$) and related negatively with SWCT adoption. This negative trend has significant implications for adoption. Overgrazing is of significant concern with the study area. The observations that livestock producers would appear to be less keen to adopt conservation practices is consistent with a hypothesis that SWC technologies and conventional livestock rearing practices many not necessarily be compatible. The odds ratio of 0.362 suggests that, ceteris paribus, the odds ratio in favor of adoption decreases by a factor of 0.362 as income from livestock (correlated with flock size) increases.

Table 5: Parameter estimates of the logistic regression model (N=250)

Variables	B	S.E.	Wald	D.f	Sig	Exp(B)
AGE	-0.019NS	0.015	1.553	1	0.213	0.982
EDUC	-0.038NS	0.292	0.017	1	0.896	0.963
FSIZ	-0.040NS	0.049	0.646	1	0.421	0.961
FEXP	0.021*	0.014	2.093	1	0.148	1.021
LABE	-0.031NS	0.083	0.138	1	0.710	0.969
TENUR	-0.037NS	0.315	0.013	1	0.908	0.964
OFFA	-0.185NS	0.321	0.331	1	0.565	0.831
CRED	-0.389NS	0.530	0.538	1	0.463	0.678
CBOS	1.670***	0.635	6.914	1	0.009	5.311
CONT	-0.004NS	0.091	0.002	1	0.965	0.996
CapBui	-0.790**	0.439	3.245	1	0.072	0.454
LFRA	0.002NS	0.016	0.012	1	0.914	1.002
FSR	0.222NS	0.206	1.159	1	0.282	1.248
VLVST	-1.016**	0.515	3.896	1	0.048	0.362
Constant	0.897NS	0.812	1.221	1	0.269	2.453

a. Variable(s) entered on step 1: AGE, EDUC, FSIZ, FEXP, LABE, TENUR, OFFA, CRED, CBOS, CONT, CapBui, LFRA, FSR, VLVST.
b. LR chi2(15) 85.844
c. Probability > chi2 0.0000
d. Overall % of correct predictions 66.8
e. Log likelihood 308.078
f. Number of observations 250
g. *** Significant 1%, ** 5% and * 10% probability level, NS= not significant

Source: Own elaboration from survey (2015).

The findings suggest that there is significant scope for improving farmers' income through increased use of SWCT. Despite some level of existing adoption, findings indicate a need to better provide adequate incentives, particularly technical assistance to farmers aimed at influencing the adoption of SWCT options.

Conclusions and recommendations

This study has identified a number of socio economic, institutional and natural physical factors that affect adoption of soil and water conservation technologies in Sidi Bouzid (Central Tunisia). Results indicate that the extension and promotion of SWCT should incorporate consideration of farmer experience, educational attainment, active labor force members as well as the important role of farmer's groups/cooperatives. Many earlier efforts to promote and extend SWCT were based on purely agronomic and biophysical characteristics.

On the basis of learning from this study, we argue that there is likely to be greater need to foster more pluralistic and dynamic systems of knowledge generation and dissemination, in line with an ongoing interest in promoting effective innovation systems (Doloreux *et al.,* 2004; Douthwaite *et al.,* 2009; Asheim *et al.,* 2011). This necessarily includes the important role of rural organizations such as community based organizations and producer cooperatives within the process of innovation (technology generation through to adoption) as well as other important public and private service providers and particularly so within the Middle East and North Africa region (Kassam and Lamprinakis, 2014)). Inclusive innovation systems, relative to a historical tradition of linear technology dissemination (research to farmer through public extension) may also have a large role to play in mediating potential tradeoffs between the adoption of soil and water conservation technologies and conventional practices for livestock rearing within regions exhibiting strong crop-livestock interactions.

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