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Investigating Determinants of Sprinkler Irrigation Technology Discontinuance in Iran: Comparison of Logistic Regression and Discriminant Analysis

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Abstract: In this study, the factors may predispose farmers to discontinue the adoption of sprinkler irrigation investigated using a logit regression as well as a linear discriminate analysis to a sample of 242 farmers in Fars province in southern of Iran. Both models were recognized robust enough to discriminate farmers who discontinue to adopt from others. The findings of both models revealed that economic aspects of adoption and recognition of sprinkler irrigation as appropriate technology are amongst the main factors to encourage farmers to keep their system after they previously adopted it.

Key words: Adoption discontinuity · Sprinkler irrigation · Logit regression · Linear discriminant analysis · Iran

INTRODUCTION

Iran is a semiarid country with great need to utilize and control all its water resources. Rapid population growth mainly in the urban areas during the past few decades that in turn raised the need for cultivating extra lands as well as directing production patterns towards high water consuming products. Such trend resulted in developing further water resources in the country and caused policy markers to be worried about balancing its supply and demand. Although the country has invested heavily in building dams, it is facing a water crisis on several fronts. As in many other parts of the country, Fars province that is a major region in term of agriculture production encounters water shortages year by year. To cope with this problem, the additional demand for irrigation water was met through pumpage of groundwater. This resulted in lowering groundwater table at a faster rate because of an imbalance in total recharge and total withdrawal in such a way that most of the plains (67 out of 90) in the province now experiencing negative balance. In this context, policy should be directed toward capturing instabilities in water resources. Although water supply policy has to be taken into account, more attentions on demand side of water management have to be emphasized as complementary policy [1]. According to the literature, technological advances for irrigation equipment permit more effective and timely application of water and lower per unit cost of irrigation [1]. Improving water use efficiency also can result in reducing up to 10-50% water consumption in the farms. To conduct water demand management policy, we need to understand the social system, the time sequence of adoption decisions and the innovation-decision process to effectively gain adoption or rejection. In the light of enhancing water use efficiency and saving water in irrigated agriculture, the Iranian government is encouraging farmers to utilize modern systems of irrigation by devoting low interest credits, however diffusion and adoption of such systems in Fars province has not been so high and many farmers prefer to keep their conventional irrigation technology and a considerable number of farmers have returned to conventional irrigation system due to various problems such as high costs for pumping and maintaining equipments, improper operation and maintenance, etc. As stated by Sofranko *et al.* [5], there are few empirical studies about the discontinuance of innovations and while a number of different studies have explored the domain of adoption of innovations, factors leading to discontinuance have been sparsely explored. However, findings of available studies reveal that new technologies are substituted for conventional ones after adopting in numerous cases due to various factors such as natural disasters, climate uncertainty, economic problems [2-6] and or as results of income reductions [5].

The objective of this paper is to determine the propensity of farmers to discontinue adoption of agricultural technology using evidences from farmers in Fars province in Iran. We investigate factors affecting the

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discontinuity of using sprinkler irrigation technology in Fars province comparing Linear Discriminant Analysis (LDA) and Logistic Regression (LR) with an aim to find a model to be able to determine if a typical farmer will adopt a new irrigation technology and whether he or she will continue to utilise it in future [1, 2].

MATERIALS AND METHODS

Methods: In this study, used the following expression of LR to obtain the probability of dependent variable Y (sprinkler irrigation continuance in Fars province) was used that express the odds or likelihood ratio that Y is 1 given explanatory variables x_i:

$$P_i = E(Y=1|x_1, x_2, \ldots, x_k) = \frac{1}{1+e^{-Z_i}} = \frac{e^{Z_i}}{1+e^{Z_i}} = F(X_i'\beta) \quad (1)$$

Where $Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki}$ and β_s are parameters to be plugged into this formula. Equation (1) represents what is known as the logistic distribution function. If P_i, the probability of sprinkler irrigation continuance, is given by (1), then $(1-P_i)$, the probability of sprinkler irrigation discontinuance is:

$$1 - P_i = \frac{1}{1+e^{Z_i}} \quad (2)$$

Therefore, we can write

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \quad (3)$$

What we want to predict from knowledge of relevant independent variables is not a precise numerical value of a dependent variable, but rather the probability (*p*) that it is 1 rather than 0. Such interpretation can also be made by a logistic transformation of *p*, Logit(*p*), also called taking the logit of *p*. Logit(*p*) is the log of the likelihood ratio that the dependent variable is 1. The LR model used in this study involves fitting to the data an equation of the form (4) and is estimated by maximum likelihood (ML) method:

$$\text{logit}(p) = \ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_0 + \beta_1 x_{1i} + \beta_{2i} + \ldots\ldots + \beta_k x_{ki} \quad (4)$$

The marginal effects of the independent variables are calculated as:

$$\frac{\partial \hat{P}_i}{\partial X_{ki}} = \text{Scale} \cdot \hat{\beta}_k \quad (5)$$

$$\text{Scale} = \frac{e^{(-X'\hat{\beta})}}{\left[1+e^{(-X_i'\hat{\beta})}\right]^2} \quad (6)$$

Furthermore, a complementary LDA is used to determine which variables discriminate between two occurring groups of our study and to compare its results with those of the above LR model estimates. Hence, in this two-group case, discriminant function analysis can be thought of as multiple regressions.

Materials: Applying a stratified random sampling, data in 2004 were collected by completing questionnaire from a sample of 242 farmers who had adopted sprinkler irrigation technology in Fars province in Iran. Out of this sample, 140 farmers continue using the system in their farms whilst the rest discontinue its using. A total of 48 farmers were excluded from total interviewed farmers to be considered for testing accuracy of the LDA and LR methods and therefore, the models were applied to 192 observations. The explanatory variables *x* in equation 1 as well as in the LDA include socio economic and personal profile of farmers, such as age, education status, occupation, family size, farming experience, annual income, extension contact and some farm specific variables such as farm size, type of soil, slope of land, etc.

RESULTS AND DISCUSSION

The results for the LR model of farmers' propensity to discontinued adoption of sprinkler irrigation technology in Fars province are presented in Table 1 where non-significant variables are not reported. Based on the log likelihood ratio (LR test), the null hypothesis, that is all the coefficients in the regression equation take the value zero is strongly rejected revealing that there is at least one regression variable in the equation having a significant coefficient. The included explanatory variables explain 48% to 67.1% of changes in the dependent variable as shown by various measures of R^2.

From the included regressors in the model, seven were found to be significant at least at 5% level and five have positive effects on dependent variable. Considering that the logistic coefficients of the LR model represent the change in the logit(*p*), that is of the ratio of continuity to utilize the technology with respect to one unit change in

Table 1: Estimated coefficients of the LR model

Variable	Coefficient	Standard error	T ratio	Marginal effect	Elasticity at mean
Constant	-5.824	1.578	-3.689	-	-1.130
Economic consequences	0.105	0.021	4.993	0.016	0.489
The propriety of technology	0.378	0.102	3.695	0.059	0.856
Labour costs	1.023	0.517	1.979	0.160	0.131
Soil texture	1.317	0.517	2.547	0.206	0.184
Land slope	-1.291	0.549	-2.352	-0.202	-0.144
Water quality	-1.905	0.652	-2.923	-0.298	-0.276
Climatic condition	1.090	0.564	1.933	0.170	0.165

Scale Factor=0.15638, Likelihood Ratio Test = 126.128, P-Value=0.0000, Estrella R-Square=0.0603, Maddala R-Square=0.480, Cragg-Uhler R-Square=0.671, Mcfadden R-Square=0.520, Chow R-Square=0.574, Adjusted R-Square=0.50233

Table 2: The LDA results

Variables	Standardized canonical discriminant function coefficients	Correlation between discriminating variables and standardized canonical discriminant function
Economic consequences	0.566	0.565
The propriety of technology	0.604	0.545
Land slope	-0.270	-0.334
Soil texture	0.313	0.262
Farm size	0.093	-0.193
Climatic condition	0.268	0.182
Water quality	-0.372	-0.170
Labour cost	0.200	0.167
Investment	-0.078	-0.128
Loan	0.009	-0.111
Water limitation	0.041	0.102
Wind condition	0.064	0.037
Land fragmentation	0.033	0.001

Wilks Lambda=0.498, χ^2=127.905, Sign=0.0000, Eigenvalue=1.008, Canonical correlation=0.708

the corresponding variables, holding others unchanged, it can be concluded that the probability that farmers will continue to utilize sprinkler irrigation technology increase by 0.160 as labour cost increase by 1 unit. Similar interpretation can be made for explanatory variables of relevant technology, utilizing outcomes and also if the technology is used at regions with moderate and/or cold climates as well as when it is used for fertilized soils. The farmers were recognised to discontinue sprinkler irrigation if their land is almost flat. The coefficient of water quality that appears in the model as a dummy (1 for good quality and 0 otherwise) is-1.905 and therefore the probability that the dependent variable (the probability to continue the technology) takes the value 1 change by-0.298, if water quality increases by 1, that is if water quality is good and not salty for instance.

Referring to the elasticity coefficients shown at the last column of the table, in cases that sprinkler technology is not consistent with other conditions of farm and or if there are not enough economic motivations to use modern irrigation systems, farmers are likely to discontinue such systems. Soil type, climate and labour cost have positive elasticities of 0.184, 0.165 and 0.131, respectively. Thus, the odds of continuity of using sprinkler technology increase in farms with loamy soil in moderate climate regions and if the labour cost is relatively high. Slope and water quality have more or less the same importance as climate and labour cost do, however, their impacts are opposite.

Parallel to the LR carried out above, we begin this section with the LDA estimates in order to find out possible similarities and differences between these two techniques. The results for the LDA model are shown in Table 2.

The coefficients in second column of the table indicate whether the multivariate association between the

Table 3: Classification results based on logit and discriminant analysis

	Dependent variable	
Model	Count	%
Logit analysis		
Cases selected original	0	0
	1	1
Cases not selected original	0	0
	1	1
Discriminant analysis		
Cases selected original	0	0
	1	1
Cases not selected original	0	0
	1	1

Predicted group membership		
0	1	Total
45	16.0	61
10	121.0	131
73.8	26.2	100
7.6	92.4	100
24	12.0	36
4	8.0	12
66.7	33.3	100
33.3	66.7	100
41	20.0	61
10	121.0	131
67.2	32.8	100
7.6	92.4	100
23	13.0	36
4	8.0	12
63.9	36.1	100
33.3	66.7	100

In logit analysis model:

86.53%of selected original grouped cases correctly classified.

66.70% of unselected original grouped cases correctly classified.

In discriminant analysis model:

84.4%of selected original grouped cases correctly classified

64.6% of unselected original grouped cases correctly classified

independent and dependent variables is statistically significant and reveal whether the LDA discriminates between the two groups of farmers, i.e. those who continue and those who discontinue using sprinkler irrigation, to a degree that is unlikely to be due to chance [5, 6].

The null hypothesis that there is no multivariate association in the population is tested using chi square, which is found to be 127.905 and statistically significant with a p value of close to zero. The magnitude of the relationship can be judged by a multivariate version of Wilks's lambda having a value of 0.498 in this study indicating that the LDA or composite variable fails to account for 49.8% of the variance in continuity of sprinkle irrigation technology in Fars. The canonical correlation (equivalent to eta statistic) is 0.708 that is the square root of 0.502, the magnitude of unexplained variance. The magnitude of eigenvalue indicating the robust of model for discriminating [7].

Based on the correlation coefficients between the regressors and standardized LDA, economic outcome of utilizing sprinkler irrigation with coefficient of 0.565 is the main determinant in discriminating the two groups. As the correlation coefficient of $a1$ indicates, in cases that irrigation system does not consist with other farm conditions, farmers are also predisposed to discontinue adoption of the technology. Whilst variables such as ground slop, soil type, farm size, climate, water quality and labour cost, with correlation coefficients of between 0.167 and 0.334 have the second priority in discriminating the groups of farmers, initial investment, bank credits, water limitation, wind condition and land fragmentation that have relatively low correlation coefficients are realised not to be so important in influencing farmers to decide whether or not continue the system.

In summary, both LR and LDA reveal that economic aspects of continuity as well as recognition of sprinkler irrigation as relevant technology are the main factors to encourage farmers to keep their system. Table 3 shows the robust of the two models in evaluating its ability to classifying included and excluded farmers in term of continuity of the system. As can be seen, the percentage accuracies of forecasts for included and excluded farmers are respectively 86.53% and 66.75% in LR model and 84.4% and 64.4% in LDA model revealing high accuracy levels of the models [3-7].

CONCLUSIONS

This study was performed to investigate factors that predisposes discontinued adoption of sprinkler irrigation technology in Fars province in Iran and has been able to empirically provide insights in to the problems that are likely to occur after the dissemination and acceptance of innovation by farmers.

The overall accuracy of classification was good for both model and either would be useful for the prediction of sprinkler irrigation continuity. However, the findings of the models showed that important factors that stimulate adoption of modern irrigation technology such as saving water are not strong enough to keep farmers to continue such innovation. Whilst sprinkler systems are costly and many farmers need to be supported by cheap credits to afford installation of such systems, they may return to their conventional irrigation after adoption mainly because of diseconomies of keeping them. It is therefore important to financially and economically evaluate installing such systems beforehand and to make sure that they are reasonable over the conventional methods of irrigation from farmers' point of views. Similarly, the adoption behaviour is recognised to be highly affected by the relevancy of the sprinkler method and so, technical issues should also be taken to account [5, 6].

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