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# CHOOSING AND RANKING IRRIGATION METHODS AND THE STUDY OF EFFECTIVE FACTORS OF ADOPTION IN KHORASAN RAZAVI PROVINCE IN IRAN

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## Abstract

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The main objective of this study is ranking sprinkler and traditional irrigation systems in Khorasan Razavi province, determining the best irrigation methods, and finally studying effective factors in the adoption of sprinkler irrigation in this province. Data and information were obtained from 186 questionnaires for farmers of two regions of Khorasan Razavi province; i.e., Mashad and Sabzevar, in 2007. For this purpose, the Compromise Programming method (CP) and Logit model were used.

In this study, the results obtained from four groups of farmers and farmlands showed that in two groups of farmers, the best irrigation system is “sprinkler irrigation” (solid-set sprinkler and hand move sprinkler) and in the other groups, the best irrigation system is “traditional irrigation”. The results of this study also showed that linier sprinkler and center pivot sprinkler are the worst irrigation systems. The findings also illustrated that farmer’s age and number of family labors does not have a significant effect on adoption. Also, land fragmentation, land slope, heterogeneity of soil and access to loan has a positive and significant effect on adoption of sprinkler irrigation. Other variables such as farm size, graduation level, farming as the first job, land slope, heterogeneity of soil and access to loan are factors that have a positive effect on adoption of sprinkler irrigation.

*Key words:* sprinkler irrigation, traditional irrigation, choice of technology, adoption, compromise programming, logit model

## Introduction

The average, annual rainfall in Iran is about 240 mm which is even less than one-third of the global annual average (860 mm). Moreover there is not any balance between rainfall (place of rainfall and timing of rainfall) and farmer’s needs as the main consumers of water that lead to the drought in Iran So, policies and programming should be consistent with this reality (Alizadeh, 1998).

The main policy against drought is using sprinkler and drip irrigation systems. In comparison with tradi-

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tional methods, sprinkler and drip irrigation methods have more efficiency (efficiency of traditional irrigation is 30-40 percent, while the efficiency of sprinkler irrigation is about 60-80 percent and the efficiency of drip irrigation is about 90 percent), so attention to these systems in programming and policies is very important, especially in arid regions (Valizadeh, 2003).

Khorasan Razavi is one of the provinces in Iran that is located in an arid and semi arid region, and water scarcity is the main problem for farmers. Of 11.9 billion $m^3$ of water resources in this province, 8 billion $m^3$ consists of ground water, and 3.9 billion $m^3$ comprises surface water. 9.7 billion $m^3$ of surface water is from ground water resources, so it has faced 1.7 billion $m^3$ of annual depletion (Khorasan Razavi Regional Water Authority, 2007).

On the other hand, the area that has been devoted to sprinkler and drip irrigation is about 15048 (ha). In comparison with the total area (1380922 ha), it covers just 1.1 percent, so the extension of sprinkler and drip irrigation systems in this province is very low and also faces different problems. A current problem is the unsuitability between the introduced sprinkler irrigation system and the regions that this system introduces; due to this problem, some of the projects have been failed. Therefore, choosing the best irrigation method and determination of which irrigation method is more appropriate for farms in special regions, are important topics in the extension sprinkler irrigation method.

There are many studies in choosing and ranking irrigation methods; for example, Karami (2006), Rafiei Darani (2005), Ziaee (2000), Junedi (1998), Khalili (1996) and Tecle and Yitayew (1990) all focus on this aspect.. Another problem is the adoption of sprinkler irrigation among farmers. Just like most of the new agricultural technologies, one of the main problems about introducing a new irrigation system in a region is the adoption and extension of the new technology by target groups, and especially farmers that the new technology is appropriate for them. For more information about the adoption of sprinkler irrigation, see Amiri Ardakani and Zamani (2003), Karami and Rezaee Moghadam (2002), Jahannama (2001), Torkamani and Jafari (1998), Sherestha and Gopalakrishnan (1993), Dinar and Yaroon (1992) and Schaible et al. (1991).

The main objective of this study is ranking different methods of traditional and sprinkler irrigation systems in addition to studying the effective factors adoption of sprinkler irrigation in Khorasan Razavi province in Iran.

## Methods

In this study, we used the Compromise Programming (CP) model in order to determine the best method for ranking different methods of irrigation. Also, the Logit model was used to study the adoption of sprinkler irrigation.

### *Compromise Programming*

Criteria Decision Making (MCDM) includes of numerous mathematical techniques in multiple that can be used based on studies. MCDM includes Multiple Objective Decision-Making (MODM) and Multiple Attribute Decision Making (MADM). MODM programming is used to design the models. The main objective of MADM is ranking and choosing the best alternatives. In this study, based on objectives and different criteria related to various irrigation methods, we used the Compromise Programming (CP), which is one of the MADM that can be used in ranking irrigation methods and also determining the best system.

CP is a distance – based technique designed to identify nondominated solutions which are closest to an ideal solution using a quasi–distance measure (Cochrane and Zeleny (1973) and Zeleny (1974 and 1982)). The operative structure of CP is summarized in the following way.

First, the degree of closeness $d_j$ between the *j*th objective and its ideal is defined by

(1) $d_j = Z_j^* - Z_j(x)$

when the *j*th objective is maximized, or as

(2) $d_j = Z_j(x) - Z_j^*$

When the *j*th objective is minimized, where $Z_j^*$ is the ideal value? When the units used to measure the objectives are different, relative deviations rather than absolute deviations must be used. Thus, the degree of closeness is given by

(3) $d_j = (Z_j^* - Z_j(x))/(Z_j^* - Z_{*j})$

Where $Z_{*j}$ is the anti – ideal point for the *j*th objective, in order to measure the distances between each solution and the ideal point, CP introduces the following family of distance functions:

(4) $L_p(A_i) = \left[ \sum_{j=1}^{k} (u_j d_j)^p \right]^{1/p}$

Where $L_p(A_i)$ is the distance metric which is a function of the decision alternative $A_i$. Parameter P, $u_j$ is the standardized form of the criterion weight where $1 \le P \le \infty$ that shows the sensitivity of decision maker about evaluations.

In this study, various criteria are used to evaluate and rank irrigation systems that are shown in Table 1.

In this study, we also evaluated and ranked all practical traditional irrigation methods such as: border irrigation, furrow irrigation, basin irrigation; and sprinkler irrigation methods such as: linear move sprinkler, Center pivot sprinkler, Gun sprinkler, side roll sprinkler, solid-set sprinkler and hand move sprinkler that are shown in Table 2.

In order to investigate further, we consider different criteria. Thus, we consider 3 weight groups. In the first group, all criteria have the same weight. In the second and third groups, criteria of 5, 6, 10, 12, 13 and 16, with a 20 and 50 percent increase, are more important than other criteria.

***Logit model***

Regression models with binary variables are used in order to study effective factors in sprinkler irrigation in Khorasan Razavi province. In this study, the farmer's decision in the adoption/ non-adoption of a new system is considered as the dependent variable. Among the regression models, i.e. linear probability model and Logit and Probit model, the Logit model is used in this study as:

(5) $Z_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_5 X_5 + \gamma_1 D_1 + \gamma_2 D_2 + ... + \gamma_9 D_9$

where $Z_i$ is the farmers' attitude towards the system adoption and $X_i$ and $D_i$ are vectors of individual, social, economic and physical factors of farmland (Tables 3 and 4). The dependant variable used in the regression here is made up of two groups of farmers and is in fact a binary variable of zero and one. Effective factors in farmer's decisions are individual, social, economic and physical factors of farmland.

The probabilities of accepting and rejecting the technology are respectively defined as $P_i$ and 1-$P_i$:

(6) $P_i = F(Z_i) = F(\alpha + \beta X_i + \gamma D_j) = 1/(1+e^{-Z_i}) = 1/(1+e^{-(\alpha+\beta X_i+\gamma D_j)})$

(7) $1 - P_i = 1/(1+e^{Z_i}) = 1/(1+e^{\alpha+\beta X_i+\gamma D_j})$

Finally, we may rewrite these equations as follows:

(8) $P_i/(1-P_i) = (1+e^{Z_i})/(1+e^{-Z_i}) = e^{Z_i}$

(9) $L_i = Ln(P_i/(1-P_i)) = \alpha + \beta X_i + \gamma D_j$

Hence, if the estimated coefficient of a particular variable is positive, it means that the higher value of that variable implies a higher probability of adoption. A lower value implies a lower probability of adoption.

***Data sources***

Data and information were obtained from questionnaires for farmers and related offices and organizations such as Khorasan Razavi Jahad Agriculture Organization.

Technical and economic information of systems, physical and climate conditions of each farmland and also personal and economic information of farmers were gathered from questionnaires filled out by farmers. Interviews were also conducted.

Two stages of sampling were used to provide questionnaires; therefore, two regions, Mashad and Sabzevar, were selected as representative regions, because in these regions sprinkler irrigation system is used more than other regions. Then some villages that rarely installed sprinkler irrigation were omitted from sampling. So, among other villages, we selected 186 samples. 90 samples were farmers that used the sprinkler irrigation method and 96 samples were related to

**Table 1**
**Criteria for studying irrigation methods**

| Code | Criterion | Code | Criterion |
|---|---|---|---|
| 1 | Application efficiency | 10 | Farm area |
| 2 | Water flow rate | 11 | Geometric shapes of a farm |
| 3 | Chemical quality of water | 12 | Farm slope |
| 4 | Sedimentary load | 13 | Farm topography |
| 5 | Initial cost | 14 | Existence of hindrance |
| 6 | Soil condition | 15 | Land fragmentation |
| 7 | Chemical quality of soil | 16 | Wind speed |
| 8 | Soil heterogeneity | 17 | Temperature |
| 9 | Stony farm | | |

**Table 2**
**The analysis of irrigation methods**

| Method | | Index |
|---|---|---|
| Surface irrigation | Furrow irrigation | $A_1$ |
| | Border irrigation | $A_2$ |
| | Basin irrigation | $A_3$ |
| Sprinkler irrigation | Linear move sprinkler | $A_4$ |
| | Center pivot sprinkler | $A_5$ |
| | Gun sprinkler | $A_6$ |
| | Side roll sprinkler | $A_7$ |
| | Solid-set sprinkler | $A_8$ |
| | Hand move sprinkler | $A_9$ |

**Table 3**
**Variables, effect on sprinkler irrigation**

| Variable | Definition |
|---|---|
| $X_1$ | Age |
| $X_2$ | Number of family labors |
| $X_3$ | Area |
| $X_4$ | Land fragmentation |
| $X_5$ | Number of products |

farmers that did not install sprinkler irrigation and used traditional systems. We used two kinds of questionnaires for each sample: a questionnaire for farmers, and another one for experts.

## Results

For studying subjects that are intertwined with agriculture through mathematics programming, representative farmlands are usually used. Generally, these farmlands are representatives of farmers in a special region or a special group of farms that are different based on individual characteristics, social and economic aspects, or specifications of their farmlands (area, slope, soil…).Due to the diversity of farm specifications in this study, we used representative farms for different groups of farmers. Cluster analysis was used to classify the sample farmers into homogeneous groups based on size variable and slope farm variable, because these variables were assumed to be determining factors in the selection of irrigation meth-

**Table 4**

**Dummy variables, effect on sprinkler irrigation**

| Variable | Definition | | Value: 1 | Value: 0 |
|---|---|---|---|---|
| $D_1$ | Literacy level | | More than diploma | Less than diploma |
| $D_2$ | Farming as the first job | | Main job | Second job |
| $D_3$ | Slope land | | High | In otherwise |
| $D_{41}$ | | D41 | Clay | In otherwise |
| $D_{42}$ | Soil type1 | D42 | Sandy | In otherwise |
| $D_{43}$ | | D43 | Heterogeneous | In otherwise |
| $D_5$ | Water condition | | High | In otherwise |
| $D_6$ | Access to loan | | Access to loan | In otherwise |

1-Base category: Sandy-clay soil

**Table 5**

**Ranking of irrigation methods in the first group of farmers**

| Alternative | First weight group | | | | Second weight group | | | | Third weight group | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P=1 | | P=2 | | P=1 | | P=2 | | P=1 | | P=2 | |
| | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank |
| A1 | 0.298 | 3 | 0.515 | 4 | 0.301 | 3 | 0.514 | 4 | 0.305 | 3 | 0.513 | 4 |
| A2 | 0.415 | 6 | 0.619 | 6 | 0.411 | 6 | 0.611 | 6 | 0.405 | 6 | 0.602 | 6 |
| A3 | 0.5 | 7 | 0.697 | 7 | 0.505 | 7 | 0.699 | 7 | 0.513 | 7 | 0.703 | 7 |
| A4 | 0.532 | 8 | 0.706 | 8 | 0.545 | 8 | 0.714 | 8 | 0.562 | 8 | 0.724 | 8 |
| A5 | 0.575 | 9 | 0.746 | 9 | 0.592 | 9 | 0.758 | 9 | 0.613 | 9 | 0.773 | 9 |
| A6 | 0.329 | 4 | 0.51 | 3 | 0.333 | 4 | 0.51 | 3 | 0.338 | 4 | 0.511 | 3 |
| A7 | 0.36 | 5 | 0.565 | 5 | 0.363 | 5 | 0.567 | 5 | 0.366 | 5 | 0.57 | 5 |
| A8 | 0.239 | 1 | 0.464 | 1 | 0.242 | 1 | 0.468 | 1 | 0.247 | 1 | 0.472 | 2 |
| A9 | 0.264 | 2 | 0.472 | 2 | 0.262 | 2 | 0.47 | 2 | 0.26 | 2 | 0.468 | 1 |

ods. The average of farmers based on different indices of different groups gets a matrix of criteria versus alternatives of irrigation. This matrix has been achieved through the average of farmer's specifications in each group for each criterion.

Values of $L_p$-Metric and the ranking of irrigation methods by using compromise programming are shown for all four groups in Tables 5, 6, 7 and 8.

Table 5 illustrates that in the first group sprinkler irrigation method (solid-set sprinkler and hand move sprinkler respectively) takes the highest priority that followed by traditional method (furrow). Based on P value and weight, this ranking can be different. The findings presented in Table 5 show that the worst methods in this group are linear move sprinkler and center pivot sprinkler.

The problems in this group are the inappropriateness of farm size, geometric shapes of the farmland, existence of hindrances in the farmland and land slope for linear move sprinkler and center pivot sprinkler, whereas the area and farm topography indices have the highest performance and efficiency in solid-set sprinkler and hand move sprinkler. It is considerable that the furrow method takes priority over the linear move sprinkler and center pivot sprinkler; that is, the furrow method has more efficiency than the other sprin-

**Table 6**
**Ranking of irrigation methods in the second group of farmers**

| Alternative | First weight group | | | | Second weight group | | | | Third weight group | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P=1 | | P=2 | | P=1 | | P=2 | | P=1 | | P=2 | |
| | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank |
| A1 | 0.239 | 1 | 0.454 | 1 | 0.246 | 1 | 0.457 | 1 | 0.255 | 1 | 0.461 | 1 |
| A2 | 0.415 | 3 | 0.619 | 3 | 0.422 | 3 | 0.62 | 3 | 0.43 | 3 | 0.623 | 4 |
| A3 | 0.353 | 2 | 0.594 | 2 | 0.352 | 2 | 0.593 | 2 | 0.35 | 2 | 0.592 | 2 |
| A4 | 0.522 | 7 | 0.698 | 6 | 0.53 | 6 | 0.7 | 6 | 0.541 | 7 | 0.704 | 6 |
| A5 | 0.594 | 9 | 0.767 | 9 | 0.61 | 8 | 0.778 | 9 | 0.63 | 9 | 0.791 | 9 |
| A6 | 0.496 | 5 | 0.652 | 5 | 0.5 | 5 | 0.652 | 5 | 0.505 | 6 | 0.653 | 5 |
| A7 | 0.576 | 8 | 0.74 | 8 | 0.586 | 7 | 0.747 | 8 | 0.6 | 8 | 0.755 | 8 |
| A8 | 0.503 | 6 | 0.724 | 7 | 0.5 | 5 | 0.72 | 7 | 0.497 | 5 | 0.714 | 7 |
| A9 | 0.46 | 4 | 0.634 | 4 | 0.451 | 4 | 0.626 | 4 | 0.44 | 4 | 0.615 | 3 |

**Table 7**
**Ranking of irrigation methods in the third group of farmers**

| Alternative | First weight group | | | | Second weight group | | | | Third weight group | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P=1 | | P=2 | | P=1 | | P=2 | | P=1 | | P=2 | |
| | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank |
| A1 | 0.278 | 5 | 0.482 | 5 | 0.279 | 5 | 0.477 | 5 | 0.28 | 5 | 0.47 | 5 |
| A2 | 0.337 | 6 | 0.54 | 6 | 0.334 | 6 | 0.531 | 6 | 0.33 | 6 | 0.521 | 6 |
| A3 | 0.343 | 7 | 0.562 | 7 | 0.341 | 7 | 0.556 | 7 | 0.338 | 7 | 0.55 | 7 |
| A4 | 0.365 | 8 | 0.577 | 8 | 0.369 | 8 | 0.579 | 8 | 0.374 | 8 | 0.582 | 8 |
| A5 | 0.516 | 9 | 0.705 | 9 | 0.526 | 9 | 0.713 | 9 | 0.538 | 9 | 0.723 | 9 |
| A6 | 0.261 | 4 | 0.439 | 4 | 0.267 | 4 | 0.443 | 4 | 0.276 | 4 | 0.448 | 4 |
| A7 | 0.233 | 3 | 0.421 | 3 | 0.235 | 3 | 0.418 | 3 | 0.237 | 3 | 0.414 | 1 |
| A8 | 0.18 | 1 | 0.396 | 1 | 0.187 | 1 | 0.405 | 1 | 0.197 | 1 | 0.415 | 2 |
| A9 | 0.224 | 2 | 0.412 | 2 | 0.229 | 2 | 0.416 | 2 | 0.235 | 2 | 0.421 | 3 |

kler irrigation methods, although the solid-set sprinkler and hand move sprinkler methods have generally more efficiency than traditional methods and other sprinkler irrigation methods.

The findings in Table 6 show that in the second group of farmers, traditional methods (furrow, border and basin) have the highest priorities followed by the sprinkler irrigation methods. This is due to small farms, inappropriateness of geometric shapes of the land and abundant land fragmentations.

Table 7 illustrates the priorities of irrigation methods in the third group of farmers. The results achieved from the Compromise Programming show that the solid-set sprinkler in most of the P value and weights has the highest priority. So, the best method in this group is the solid-set sprinkler followed by hand move sprinkler, side roll sprinkler and gun sprinkler.

The priorities of irrigation methods in the fourth group are shown in Table 8. The findings show that furrow, border and basin methods take precedence over other irrigation methods. It is considerable that traditional irrigation takes priority over sprinkler irrigation. This finding also holds true for the second group of farmers.

**Table 8**
**Ranking of irrigation methods in the fourth group of farmers**

| Alternative | First weight group | | | | Second weight group | | | | Third weight group | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P=1 | | P=2 | | P=1 | | P=2 | | P=1 | | P=2 | |
| | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank | Value | Rank |
| A1 | 0.17 | 2 | 0.373 | 2 | 0.165 | 2 | 0.364 | 2 | 0.159 | 2 | 0.353 | 2 |
| A2 | 0.17 | 2 | 0.373 | 2 | 0.165 | 2 | 0.364 | 2 | 0.159 | 2 | 0.353 | 2 |
| A3 | 0.118 | 1 | 0.343 | 1 | 0.11 | 1 | 0.331 | 1 | 0.1 | 1 | 0.316 | 1 |
| A4 | 0.581 | 7 | 0.758 | 7 | 0.585 | 7 | 0.761 | 7 | 0.591 | 7 | 0.763 | 7 |
| A5 | 0.653 | 8 | 0.805 | 8 | 0.665 | 8 | 0.812 | 8 | 0.68 | 8 | 0.822 | 8 |
| A6 | 0.467 | 6 | 0.64 | 5 | 0.467 | 6 | 0.64 | 5 | 0.468 | 6 | 0.638 | 5 |
| A7 | 0.458 | 5 | 0.656 | 6 | 0.455 | 5 | 0.652 | 6 | 0.45 | 5 | 0.648 | 6 |
| A8 | 0.356 | 4 | 0.577 | 4 | 0.352 | 4 | 0.573 | 4 | 0.347 | 4 | 0.568 | 4 |
| A9 | 0.342 | 3 | 0.56 | 3 | 0.335 | 3 | 0.554 | 3 | 0.327 | 3 | 0.545 | 3 |

**Table 9**
**Estimation of Logit model by using maximum likelihood**

| Variable | | | Coefficient | Standard Error | Marginal effect |
|---|---|---|---|---|---|
| Coefficient | | C | -2.5178 | 2.0111 | -0.62595 |
| Age | | X1 | -0.021641 | 0.021408 | -0.00538 |
| Number of family labors | | X2 | -0.054586 | 0.13635 | -0.01357 |
| Area | | X3 | 0.14802 | 0.034240*** | 0.036799 |
| Land fragmentation | | X4 | -0.7701 | 0.333338** | -0.19145 |
| Number of products | | X5 | -0.4859 | 0.24068** | -0.12047 |
| Graduation level | | D1 | 2.68 | 0.75932*** | 0.666275 |
| Farming as the first job | | D2 | 2.4397 | 1.6274* | 0.606524 |
| Land slope | | D3 | 1.3123 | 0.47466*** | 0.3265 |
| | Clay | D41 | 0.79807 | 0.54901 | 0.198408 |
| Soil type[1] | Sandy | D42 | 0.31906 | 0.55139 | 0.079322 |
| | Heterogeneous | D43 | 1.8911 | 0.66648*** | 0.470146 |
| Water condition | | D5 | -0.99528 | 0.46573** | -0.24744 |
| Access to loan | | D6 | 0.67743 | 0.43557* | 0.168416 |

Factor for the caculation of marginal effects: 0.24861

Maximized value of the log-likelihood function: -84.2629

Goodness of fit: 0.81

*P<0.1 **P<0.05 ***P<0.01

[1]-Base category: Sandy-clay soil

## Effective Factors in Adoption of Sprinkler Irrigation

The Logit model was used for studying factors that affect the adoption of sprinkler irrigation. For the estimation of this model, we used the maximum likelihood estimation and Microfit software (version 4.1)

Table 9 illustrates the results obtained from the estimation of the Logit model. Based on Table 9, goodness of fit is 0.81 that is fairly high, and also implies the usefulness of the model in illustrating variable behaviors. The marginal effect factor of this model equals 0.24861. By multiplying the value of this factor by coefficients, the marginal effect of coefficients can be calculated (the last column of the table).

The findings also reveal that the effect of farmer's age on adoption sprinkler irrigation is negative, but it is not significant at the 10 percent level even though its effect is in line with expectations. By increasing the age of farmers the probability of adoption sprinkler irrigation becomes less; it depends on personal specifications and also depends on risk diversity in high age.

The number of family labors is another variable that has a negative effect on adoption sprinkler irrigation. Due to using family labors in farming, especially in irrigation, the farmers do not need to use new technology. This variable does not significantly affect adoption.

Cultivation area has a positive and significant effect (at 1 percent level) on adoption sprinkler irrigation. By increasing area, probability of adoption increases too. The marginal effect of this variable is 0.037 it shows that by increasing 1 (ha) to cultivation area, adoption of sprinkler irrigation increases by 3.7 percent. It is because of more efficiency and performance of all sprinkler irrigation methods in medium and large farmlands that these methods can be installed. On the other hand, by increasing area, farmers are more willing to use labor-saving methods and increase the efficiency of inputs. So, by increasing farmland area, farmers are more attitudes to use and adopt sprinkler irrigation than farmers with small farmlands.

Land fragmentation is another variable that has a significant effect (at 5 percent level) on adoption sprinkler irrigation. Its coefficient is negative which is in line with expectations; that is, by increasing fragmentations, the probability of adoption becomes less due to the impossibility of the installation of most of the systems and irrigation problems. The marginal effect of this variable is -0.19 which indicates a 19-percent reduction in probability of adoption sprinkler irrigation by increasing one plot. As a result, for the installation of sprinkler irrigation in farmlands with many plots, farmers should cluster and integrate their farms that need acculturate. Another variable in this study is the number of products that has a negative and significant (at 5 percent level) effect on adoption sprinkler irrigation. Its marginal effect is -0.12 which shows a 12-percent reduction in the probability of adoption sprinkler irrigation by increasing one product; in other words, farmers with more products are fewer willing to adoption sprinkler irrigation than farmers with fewer products. On the one hand, it related to risk and number of products that is, farmers with more products are farmers with lower risk so their adoption is low. On the other hand, negative effect of the number of products on adoption sprinkler irrigation is related to the poor management of farmers.

Literacy level is another variable with a positive and significant (at 1 percent level) effect on adoption sprinkler irrigation. It has a fairly high marginal effect (0.67) that shows the probability of adoption sprinkler irrigation in farmers who hold a Diploma or a higher degree is 67 percent more than farmers with less education. So, this reality is useful for policy-maker to determine target group for installation sprinkler irrigation.

The first job of farmers is a variable with positive and significant (at 10 percent level) effects on adoption sprinkler irrigation. Its marginal effect is approximately 0.61. This fact demonstrates that the probability of adoption sprinkler irrigation in farmers which their first job is farming is 61 percent more than others.

Another variable is land slope that has positive and significant (at 1 percent level) effects on adoption sprinkler irrigation. Increasing the slope of the land increases the probability of adoption of sprinkler irrigation. Its marginal effect is approximately 0.33, showing that the probability of adoption sprinkler irrigation in farmers with a medium and large slope of land is 33 percent more than others because irrigation in farmlands with a medium and large slope is more difficult than a low slope. So, this group of farmers adopt more easily than farmers with flat farmlands.

Soil texture is another variable in this study that includes 3 dummy variables and sandy-clay soil which is considered as a base variable for these 3 variables. Table 9 illustrates that sandy and clay soils do not have a significant effect; variables of heterogeneous soils have a positive and significant (at 1 percent level) effect on adoption. Its marginal effect is 0.47 which shows that the probability of adoption sprinkler irrigation in farmlands with heterogeneous soils is 47 percent more than farmlands with sandy-clay soils. That is because farm practice in farmlands with heterogeneous soils is more difficult than farmlands with homogeneous (sandy or clay) soils. So, for increasing the efficiency of irrigation, this group of farmers is more willing to installation sprinkler irrigation.

Another variable is access to water that has a negative and significant (at 5 percent level) effect on adoption sprinkler irrigation which is in line with expectations. Its marginal effect is 0.25, which shows a 25-percent reduction in adoption by providing farmers with access to more water. It implies that farmers who encounter a shortage of water are more willing to install sprinkler irrigation than other farmers.

Access to the loan is a variable with a positive and significant effect on adoption sprinkler irrigation. Its marginal effect is about 0.17 which shows the probability of adoption in farmers that have access to the loan is 17 percent more than others. Therefore it is necessary to solve the problems and restrictions of access to financial resources, especially agricultural loans.

## Conclusions and Recommendations

In this study appropriateness of different irrigation methods of traditional and sprinkler irrigation for farmers in Khorasan Razavi province was studied. Accordingly, Compromise Programming was used. Ranking irrigation systems by this method in 4 groups of farmers with different specifications showed that the sprinkler irrigation method is not appropriate for all farmlands, as in the second and fourth group of farmers; the best method is the traditional system. By considering enormous investments in the installation of the sprinkler irrigation method, the study of different specifications of farmlands in different aspects is necessary and investigating different aspects of farmlands is also needed. In some farmlands, especially those placed in the regions with tropical problems or input limitations (salty soil or water scarcity), which traditional irrigation systems are the best (second and fourth group), it is necessary for policy-makers and planers to consider innovative methods of irrigation systems that have considerable effects on increasing the efficiency. It is recommended in regions that sprinkler irrigation method is not suitable; the emphasis of policy-makers should be placed on increasing the efficiency of the traditional irrigation method by using innovative methods of irrigation systems.

In the regions of Khorasan Razavi which the sprinkler irrigation method is appropriate, the best systems are the solid-set sprinkler and hand move sprinkler. In practice, these systems have been installed rarely. Instead of these systems, the side roll sprinkler has been installed while it is not as important as the solid-set sprinkler and hand move sprinkler. So, it is recommended that in installing irrigation methods, policy-makers and active firms emphasize the promotion of the solid-set sprinkler and hand move sprinkler. Results also showed that graduation level has the most effect on adoption sprinkler irrigation. Thus, on the one hand, it is necessary to increase farmers' information about the sprinkler irrigation method and its positive effects on economics which requires the promotion of sprinkler irrigation. On the other hand, it is recommended that in determining target groups for the promotion of sprinkler irrigation, farmers with high levels of education be considered since the probability of adopting this system in these groups is more than others.

Findings illustrate that land fragmentation has negative and significant effects on adopting the sprinkler irrigation, so clustering and integration of farmlands should be policy-makers top priority. Extension of the sprinkler irrigation method in large farmlands is more important and also technically, more practical. So, by considering the positive and significant effects of farmland size on the adoption of sprinkler irrigation, it is essential that farmers with large farmlands place on top of installation priorities of the sprinkler irrigation method, and special policies should be considered for the extension of sprinkler irrigation among this group of farmers. By considering positive and significant effects of the loan on the adoption of sprinkler irrigation method, it is recommended that problems in obtaining agriculture loans should be modified. Also, it is crucial to inform farmers of the different methods of taking out loans and regulation of the bank system.

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