



Analysis of Water User Cooperatives Using a Fuzzy Regression Model in Jarghoyeh Region, Isfahan Province, Iran

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Abstract: Water user cooperative (WUC) is an organization for promoting optimum use and management of water, emphasizing the participation of all beneficiary groups. The aim of this study is to determine the factors that deter WUC from being successful in accomplishing its objective in Jarghoyeh Region, Isfahan Province, Iran. These factors are enumerated through five indices: notification, participation, economic incentives, social incentives, and organization-farmer communication, using fuzzy regression model and symmetric and non-symmetric fuzzy triangular numbers. The values of indices estimated in the study indicate that economic incentives neither have been defined for the beneficiary groups nor attempts have been made in this regard in practice. Influences of other indices on forming cooperatives are poorly evaluated.

Keywords: Water user cooperative, Fuzzy numbers, Fuzzy Regression, Unsuccessful analysis

INTRODUCTION

After a period of rapid growth in world's irrigated farmlands during the period of 1950-1980, irrigation systems in developing countries were designed by their governments without the participation of users for whom the systems were meant. This lack of participation and consequent lack of commitment on the part of users resulted in high operation and maintenance costs in the long term. Besides heavy capital investment, many farmers were also inefficient in using the water. This led to the idea of contributory irrigation management. Nowadays, there are local user groups that play an important role in the management and development of irrigation canal networks. Various countries have promoted the formation of basic social elements for irrigation systems and have invested in enhancing their capacities. One of the most important such groups is water user cooperative (WUC).

The purpose of establishing a WUC is to help farmers optimally use the available water through a participatory process in decision making and agricultural water management [1-12]. The cooperatives are generally formed through a legal framework for consolidated or partial construction, operation, development, and maintenance of irrigation canal networks in an efficient manner, proportional to their capacities [13].

Now a day, water deficit is one of the main crises in the world, much more than before. Iran, as a wide arid and semi-arid zone, has witnessed farmer conflicts and these conflicts call for collective efforts by users for

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optimal water use. The economic, social and cultural value of water on Iranian rural community can hardly be overemphasized. The shortage of water has impeded the development of lands for production and harmed social relationships. The limited availability of water and the necessity for optimum management have given rise to the development of various indigenous operating systems in naturally and socially diverse conditions of Iranian villages. One of the systems is named “Bone system” which is a valuable heritage of traditional farming in the majority of Iranian low rainfall regions and deserts. Safinejad (1989) stated that “Bone” was created by organizing rural socio-economic forces for controlling severe environmental conditions. Although water was the most important reason for forming “Bones,” they were also used for meeting other needs, such as supplying production materials, ganat improvements, and participation in agricultural duties. In addition to “Bone,” large numbers of local and traditional organizations have been active from ancient times in view of production, service, and social affairs. Examples include specific agricultural organizations for nomination of persons as “Mir-ab” (Water King) to manage agricultural water office and “Ab-mal’s” (Water Distributors) for distributing and conveying water to farmlands through conventional irrigation modules for different crops. The same organization can be referred to “Shir-vare” (Milk Managing) systems for collecting milk and dairy production and “Kharman-paei” (Harvest Holding) system for protecting croplands and harvested crops. Although Iranian Land Reclamation in 1962-1972 had basically modified social structures and economic affairs of villages and rural cooperatives, these could not function satisfactorily as an alternative. After this event and more recently in particular, farmer participation and working groups for managing villages have encountered myriad problems which can be evaluated at two levels: (1) when a working group is established for achieving the goal and (ii) continuously controlling the activities at a standard level. In the first level, the feasibility and providing the base line for accepting these working groups is the primary consideration and lack of this consideration imposed high costs on rural communities [14-17].

In this way, Isfahan water board has attempted to construct water canals and organizing WUC for management, distributing, and charging for the water used in farmlands and gardens in Jarghoyeh, Isfahan Province, Iran. On account of not instituting a non-governmental organization, the plan was unsuccessful in the first step. This study tests the hypothesis that lack of constraints when making such cooperatives prevents a WUC plan in this region from being successful.

PREVIOUS STUDIES

Narayan (1995) reviewed 121 WUCs in Asia, Africa, and Latin America [10]. He found that skills and knowledge of the beneficiary groups in relation to their contribution to water management and their mechanism had an extensive positive impact on prospective formation and continuous activities of WUCs. Also, restricting local organizations and leaders often made formation of cooperatives easy. Another point is to compare the two regions: First, economic-social characteristics of farmers were considered in forming a WUC. Second, private and government organizations were careless for the views, interests and needs of the farmers, which led to the failure of WUCs in any region.

Garces-Restrepo (2001) stated the following factors when answering the question why the development of irrigation management was speeded with minimum conflict offarmers [6]:

- using the existing robust organization principle.
- Irrigation management transfer was considered as part of the series of extensive improvements in agricultural division which privatized the majority of agricultural services before.
- Extensive educational programs were presented for water user representatives and operational level staff.

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-For purposes of transfer, scope, process, water user rights and future commitments, the required information was made available.

-Simplified and supportive regulations were defined.

Koppen et al. (2002) investigated these factors in Andhra Pradesh and Gujarat, India [7]. They showed that poverty was inversely proportional to water resources management transfer. Also, numerous operational systems in these states had a negative effect on farmer participation in irrigation network management, while the farm size, as a transition variable, through income had a positive effect on farmer participation. It should be noted that the location of cropland units in up and down basin influenced the farmer participation, such that downstream farmers highly tended to participate in water management for water uptake based on planning.

MATERIALS AND METHODS

The proposed method consists of two parts: Index making (operationalization) and fuzzy regression using symmetric and non-symmetric fuzzy triangular numbers [15].

Index Making

The most important step toward operationalization is providing indices that can measure the concepts considered [4-5]. The main concepts included five indices: notification, economics incentives, social incentives, participation, and relationships between local and governmental organizations and farmers (Table 1).

Table 1. Procedure for operationalization of research concepts (index making)

Variable Type	Primary Concepts	Indices
Dependent	Forming WUC	Prospective Formation of WUC
Independent	Effective factors and necessities of forming WUC	Notification
		Economics Incentives
		Social Incentives
		Participation
		Evaluation of farmers from their communications with the governmental and local organizations

Sampling

Jarghoyeh region consists of eight villages and three cities which in total include 227 beneficiaries. Due to financial and time constraints, filling up of questionnaire from all beneficiaries was not possible. Therefore, using a random stratified sampling method 217 observations were collected for this purpose. Then, for collecting field data, a questionnaire included 28 closely based answers and 21 openly based answers. For validation of results, factor analysis by the determining Kaiser-Meyer-Olkin (KMO) values and Bartlett test was used. The Cronbach coefficient (α) was employed for reliability analysis.

As shown in Table 2, x_1 , x_3 and x_4 indices had relatively high validity and the indices of y , x_2 and x_5 had high validity. Indices of y , x_3 and x_4 also displayed relatively high reliability, the x_1 and x_2 indices showed high reliability, and the x_5 index had a very high reliability. Consequently, each index and the index set generally demonstrated a sufficient accuracy for covering the considered concepts into indices.

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Table2. *Validity and reliability rates of research indices*

Indices	Notation	Validity			Reliability
		Significant level	Bartlett	KMO	α
Prospective Formation of WUC	y	<0.0001	176.856	0.725	0.701
Notification	X_1	<0.0001	444.367	0.639	0.872
Economics Incentives	X_2	<0.0001	592.809	0.701	0.802
Social Incentives	X_3	<0.0001	192.241	0.659	0.659
Participation	X_4	<0.0001	197.593	0.693	0.693
Evaluation of farmers from their communications with the governmental and local organizations	X_5	<0.0001	2643.113	0.832	0.929

Choice of membership function

Since the variables were expressed ambiguously and sensed in a sequential scale, fuzzy logic was used for analysis [14]. The scale employed in this work contained a range of literal variables from “none” to “very high” and the membership function is shown in Figure 1[2].

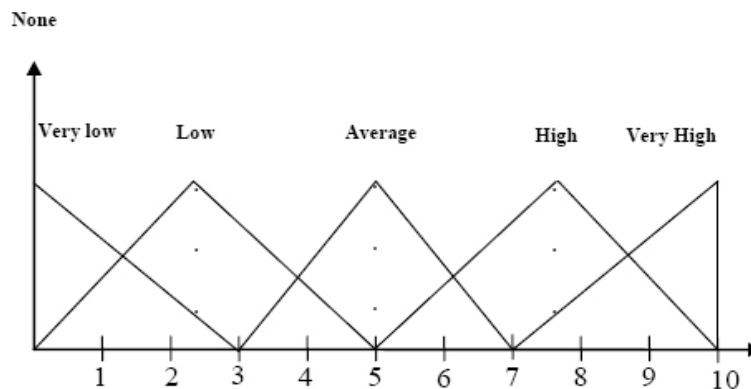


Fig1. *Membership function of the research*

Fuzzy Sets

In folklore and human conventional discussions, the variables, such as low, high, good, and fair, whose amounts are inaccurate and ambiguous, are frequently used in comparison with the usual variables whose amounts are accurate and completely definable. Such variables, whose amounts are words or sentences of natural or artificial languages, are named literal variables that are the subject of fuzzy set theory [1].

Fuzzy Triangular Numbers

Fuzzy numbers $A = (S^L, S^C, S^R)$ are named triangular, if the left and right bands of fuzzy triangular number \tilde{A} are equal (3). In such a condition, \tilde{A} is named “symmetric fuzzy triangular number” and demonstrated as $A = (\alpha^C, S_L)$. The membership function \tilde{A} is shown below [8]:

$$\mu_{\tilde{A}}(a) = \begin{cases} 1 - \frac{a - a^c}{s} & a^c - s \leq a \leq a^c \\ 1 - \frac{a^c - a}{s} & a^c \leq a \leq a^c + s \end{cases} \quad (1)$$

The membership function diagram of a symmetric fuzzy triangular number is shown in Figure 2[17]:

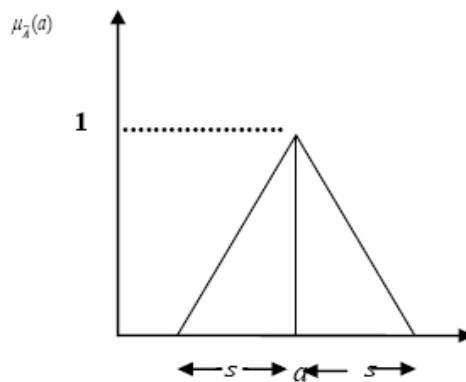


Fig2. Membership function of a symmetric fuzzy triangular

If the left and right bands of fuzzy triangular number \tilde{A} are not equal ($S^L \neq S^R$), \tilde{A} is named “non-symmetric fuzzy triangular number.” In this condition, the membership function is expressed using a^c , S^L and S^R as follows:

$$\mu_{\tilde{A}}(a) = \begin{cases} 1 - \frac{a^c - a}{s^L} & a^c - s^L \leq a \leq a^c \\ 1 - \frac{a - a^c}{s^R} & a^c \leq a \leq a^c + s^R \end{cases} \quad (2)$$

The membership function diagram of a non-symmetric fuzzy triangular number is also shown in Figure 3[17].

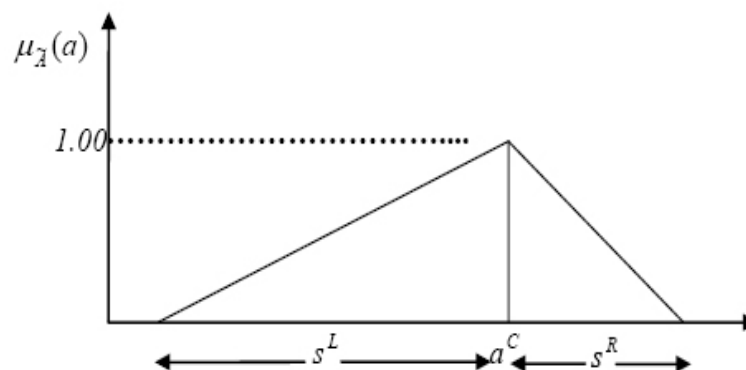


Fig3. Membership function of a non-symmetric fuzzy triangular number

Subcategory of elements of X whose membership degree in fuzzy category \tilde{A} has at least the magnitude of α ($\alpha > 0$), α cut is named (\tilde{A}_α) and expressed by:

$$\tilde{A}_\alpha = \{x \in X \mid \tilde{A}(x) > \alpha\} \quad (3)$$

Fuzzy Regression

The general form of fuzzy regression equation is as follows:

$$\tilde{Y} = f(x, \tilde{A}) = \tilde{A}_0 + \tilde{A}_1 x_1 + \cdots + \tilde{A}_n x_n \quad (4)$$

where \tilde{Y} is the dependent variable (fuzzy output), $x=[x_1, x_2, \dots, x_n]$ is an input vector or independent variables having crisp, $\tilde{A} = \{\tilde{A}_0 + \tilde{A}_1 + \dots + \tilde{A}_n\}$ is a category from fuzzy numbers. The objective of regression analysis is to use a category of real numbers as $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$, and fuzzy parameters $\tilde{A}_0, \tilde{A}_1, \dots, \tilde{A}_n$ would be determined such that model (4) has the best fit to the given data points [8]. For determining the goodness-of-fit of fuzzy regression model, the mean of sum of square errors (MSE) is used:

$$MSE = \frac{\sum (e_i)^2}{N} \quad (5)$$

where $e_i = y_i - \hat{y}_i$, y_i is the observed value and \hat{y}_i denotes the predicted value [9-16].

The purpose of fuzzy regression associated with non-fuzzy data is the determination of coefficients of \tilde{A}_i ($i=0,1,2, \dots, n$) in model (4) such that first the fuzzy output as \tilde{Y} , for all Y_j amounts ($j=0,1,2, \dots, m$), at least has the membership degree with the h magnitude, as:

$$\mu_{\tilde{Y}}(Y_j) \geq h, \quad \forall j = 1, 2, \dots, m \quad (6)$$

Second, the fuzzy coefficients of \tilde{A}_i ($i=0,1,2, \dots, n$) should be in a way that ambiguity or fuzziness of the output would be minimum. Considering as much as the band of fuzzy triangular number being wider, it would be more ambiguous, therefore, the summation of fuzzy output bands \tilde{Y} related to all data categories should be minimized. But, before minimizing the objective function, there is a need for obtaining the limitations of regression model. When \tilde{A}_i 's are symmetric fuzzy numbers and x_i 's refer to the positive real numbers, according to Equation (6) and symmetric membership function, the fuzzy output will also be a symmetric fuzzy triangular number which the model limitations obtain as follows:

$$(1-h)s_0 + (1-h)\sum_{i=1}^n s_i x_{ji} - y + \sum_{i=1}^n a_i^C x_{ji} + a_0^C \geq y_j, \quad \forall j = 1, 2, \dots, m \quad (7)$$

$$(1-h)s_0 + (1-h)\sum_{i=1}^n s_i x_{ji} - y + \sum_{i=1}^n a_i^C x_{ji} + a_0^C \geq -y_j, \quad \forall j = 1, 2, \dots, m \quad (8)$$

While \tilde{A}_i 's and x_i 's are non-symmetric fuzzy numbers and positive real numbers, respectively, according to Equation (6) and non-symmetric membership function the fuzzy output will be a non-symmetric fuzzy triangular number for which the model limitations could be written in terms of kurtosis coefficient k_i as follows [3]:

$$(1-h)k_0 s_0^L + (1-h)\sum_{i=1}^n k_i s_i^L x_{ji} - y + \sum_{i=1}^n a_i^C x_{ji} + a_0^C \geq y_j, \quad \forall j = 1, 2, \dots, m \quad (9)$$

$$(1-h)k_0 s_0^L + (1-h)\sum_{i=1}^n k_i s_i^L x_{ji} - y + \sum_{i=1}^n a_i^C x_{ji} + a_0^C \geq -y_j, \quad \forall j = 1, 2, \dots, m \quad (10)$$

In the above equations, h is the α -cut and x_{ji} indicates the j th observation for the i th variable. The objective function can be minimized, considering $2m$ produced limitations by m observations. Minimizing the objective function is accounted for in linear programming and solved by GAMS software. The general shape of the programming model for two conditions of symmetric and non-symmetric can be written as:

$$\min : Z = s_0 + \sum_{i=1}^n \left[s_i \sum_{j=1}^m x_{ji} \right] \quad (11)$$

$$Z = (s_0^L + s_0^R) + \sum_{i=1}^n \left[(s_i^L + s_i^R) \sum_{j=1}^m x_{ji} \right] \quad (12)$$

$$\text{subject to } \mu_{\tilde{y}}(y_j) \geq h, \quad \forall j = 1, 2, \dots, m \quad (13)$$

RESULTS AND DISCUSSIONS

For determining model coefficients, as explained before, the objective function should be first identified and then for the defined constraints, this function will be minimized.

Model Coefficients in Symmetric State

Fitting regression models for the various amounts in Table 3 indicates that the minimum value of objective function and MSE of different models for various values of h are the same [19-21]. Therefore, the regression models in the symmetric state are as follows:

$$\tilde{Y} = [0, 1.3] \times X_1 + [0, 0] \times X_2 + [0, 0] \times X_3 + [0, 2.5] \times X_4 + [0, 1.8] \times X_5 \quad (11)$$

Very Low None None Very Low Very Low

Table 3. Fuzzy coefficients of regression models for different values of h

h	s_0	s_1	s_2	s_3	s_4	s_5	a_0^C	a_1^C	a_2^C	a_3^C	a_4^C	a_5^C	Z	MSE
0.3	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.32	4.0496
0.5	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.32	4.0496
0.6	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.32	4.0496
0.7	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.32	4.0496
0.8	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.32	4.0496
0.9	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.35	4.0496
1	0	1.3	0	0	2.5	0	0	0	0	0	0	0	25.35	4.0496

Model Coefficients in Asymmetric State

Due to the fact that the same models would be obtained having different cuts of h in symmetric state, this is optional such that h=0.5 for non-symmetric state. For obtaining the most appropriate model (with minimum MSE), K_i should be set constant (Table 4). Then, the K_i values would be changed to two different forms. For the three prior models, the K_i values should be gradually increased from K_0 to K_5 and this will be analyzed vice versa for the three next models (Table 5). This analysis shows that the most appropriate models will be obtained by increasing the K_i values. Therefore, the final step for obtaining the most proper models is simultaneously increasing the K_i values in both rows and columns of Tables 4 and 5.

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Table4. Regression models having the same K_i values

h	k_0	k_1	k_2	k_3	k_4	k_5	s_5^L	a_1^C	a_3^C	a_4^C	Z	MSE
0.5	1.6	1.6	1.6	1.6	1.6	1.6	1.1	2.5	0.84	1.2	83.92	3.4824
0.5	1.8	1.8	1.8	1.8	1.8	1.8	1.1	2.5	0.84	1.2	83.92	3.4824
0.5	2	2	2	2	2	2	1.1	2.5	0.84	1.2	83.92	3.4824
0.5	2.5	2.5	2.5	2.5	2.5	2.5	1.1	2.5	0.84	1.2	83.92	3.4824
0.5	3	3	3	3	3	3	1.1	2.5	0.84	1.2	83.92	3.4824
0.5	5	5	5	5	5	5	1.1	2.5	0.84	1.2	83.92	3.4824

In Table 5, different models are shown with different K_i values. The models that their K_i values are gradually increased have the lowest MSE and consequently display the best fit to data. Therefore, the third model with $MSE=2.8534$ is evaluated and is found as the most suitable model [22-23].

Table5. Regression models having different K_i values for the first run

h	k_0	k_1	k_2	k_3	k_4	k_5	s_5^L	a_1^C	a_3^C	a_4^C	Z	MSE
0.5	3	3.3	3.6	3.9	4.3	4.6	1.1	2.5	0.8	1.3	94.37	3.5712
0.5	3.3	3.6	3.9	4.3	4.6	4.9	1.1	2.5	0.8	1.2	83.92	3.4824
0.5	3.4	3.7	4	4.4	4.7	5	1.1	2.5	0.8	1	78.92	2.8534
0.5	4.6	4.3	3.9	3.6	3.3	3	1.1	2.5	0.8	0.9	97.56	3.6025
0.5	4.9	4.6	4.3	3.9	3.6	3.3	1.1	2.5	0.8	0.8	104.3	3.6313
0.5	5	4.7	4.4	4	3.7	3.4	1.1	2.5	0.8	0.7	109.4	3.7619

Considering results in Table 5, the K_i values are simultaneously increased in both rows and columns in order to find a better model (Table 6). The values for all models are $S_4^L, S_3^L, S_2^L, S_1^L, a_2^C = 0$.

Based on results in Table 6, the model with $MSE=2.2134$ indicates the goodness of fit for data. Comparing different models from Tables 4 to 6, the sixth model (Table 6) is selected as the optimum model due to its minimum MSE. The fuzzy regression equation for this model is as follows:

$$\tilde{Y} = [1.1, 0] \times X_1 + [0, 0] \times X_2 + [0.84, 0] \times X_3 + [1.5, 0] \times X_4 + [0, 1.4] \times X_5 \quad (12)$$

Very Low None Very Low Very Low Very Low

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Table6. Regression models having different Kivalues for the second run

h	k_0	k_1	k_2	k_3	k_4	k_5	s_5^L	a_1^C	a_3^C	a_4^C	Z	MSE
0.5	3	3.3	3.6	3.9	4.3	4.6	1.1	2.5	0.84	1.3	94.37	2.3782
0.5	3.3	3.6	3.9	4.3	4.6	4.9	1.1	2.5	0.84	1.2	83.92	2.3258
0.5	3.4	3.7	4	4.4	4.7	5	1.1	2.5	0.84	1	78.92	2.3197
0.5	4.5	4.8	4.1	3.5	3.8	3.9	1.4	1.1	0.85	1.1	80	2.3015
0.5	4.6	4.9	4.2	3.6	3.8	5	1.4	1.1	0.86	1.4	84.24	2.2685
0.5	4.7	4	4.4	4.6	3.9	5	1.4	1.1	0.87	1.5	85.47	2.2134

It should be noted that Equation 12 is more valid in comparison with Equation 11.

As explained before, the questionnaire were designed in both forms of open and close based answers. In open based ones, an explanation was requested regarding the reasons for answering the close based questions. The coefficients of Equation 12 can be interpreted, considering these explanations and the performed interviews with the target groups, local and state officers as follows:

The required economic Incentives for the farmers were not considered and they did not have any information about the existing few facilities in this regard. The coefficient belonging to this index also works well where there isnegligencein presenting economicIncentivesfor forming WUPs. The economic incentives are looking for the point that in a comprehensive plan for forming WUPs, the farmers should benefit from planting patterns, packing, storing, marketing, and banking facilities. The mentioned points are often persuasiveafter organizing water users in parties, but its correct definition and presentation of promise could be the robust incentives for forming WUP's, for which unfortunately there is no plan in this regard for the study area. According to membership function, the indices of the X_1 , X_3 , X_4 , X_5 coefficientsindicate that the indices, such as notification, social incentives, participating users in the plan, and the communication of organization-user were considered very low towards forming WUPs.

CONCLUSIONS AND RECOMMENDATIONS

As mentioned earlier, indices, such as notification, social incentives, participating users in the plan, and communication of organization-user act insufficient for performing WUPs. These indices are separately analyzed here:

Notification

The notificationindex was sensed in three categories: reason for forming cooperatives, the goals, and member duties. Answers show that very low notification was given to users in all three categories. The reason can be attributed to the lack of an active training and information system. The Iranian Ministry of Agriculture (IMA), responsible for agricultural training and extension, has done nothing in this regard. Due to the lack of communication and coordination between this and the other responsible organizations with farmers, IMA does not even haveany information about the existence of such a plan for forming WUCs in the study region.

Social Incentives

This index was investigated in three categories: the suitable management of water by farmers, arranging water distribution and cooperation rate of people in solving their problems. Water distribution and judgment approach for compromising between members are the main mental disturbances for farmers that agreement in detail causes efficient social motivation in organizing target groups. The lack of a specific plan for distributing water, not delivering on regional water board promises in sufficient and in-time water delivery to farmers, and the lack of guarantee for agreements between regional water boards and some local officers due to the lack of local participation not only cause declination of farmer motive for water delivery through WUPs, but also destroys the required local social basis. Conflicts between farmers for keeping more water upstream and downstream, which originate from “very low” attention to forming elements of this index, not only no opportunity provided for water management by farmers, but also increased struggles for obtaining water benefit. This highlights the desire for cooperation for making rearrangements in local communities [24-26].

Participation

Participation index is investigated in two categories of physical and consulting participation. Physical participation mainly contains participating farmers in canal construction and is seen employing Afghani and non-native workers with lower salaries who are preferred to target group workers. Also, decision making without user participation was done, even in the beginning steps of cooperative formation and user decisions were only limited to confirming some preplanned activities for farmers.

Communication between Local and Governmental Organizations

To develop this index, the relationship between regional water board, agriculture department and cooperative office in province and county and also the relationship between city and village consuls with farmers at local level were evaluated. As the coefficient for this index was shown before, the governmental authorities and local organizations had a “very low” role in forming cooperatives. In other words, not involving some authorities in this area and the limited communication with regional water board, which was done through rural and city consul members, caused such poor evaluation. The individual interviews with each of the governors and some local officers showed that there were communication and association for promoting the cooperative formation plan between none of these three organizations at the province level. The cooperative office has not even any information about such plans and agriculture department also responded negatively to the invitation of water board directors regarding cooperation with them for forming WUPs. This led to the fact that water board lonely performed this plan due to the nature of their activities and forgot the technical aspects of the prioritized plan and the software dimensions based on the target community approach and characteristics. Finally, the lack of communication and association at the horizontal level between responsible organizations caused an imperious relationship between governmental officers and local community. In fact, these disturbances in and between organizations were the main reason for “very low” influence of other indices on forming WEPs [27-29].

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