Dear Editor in Chief,

My Paper has been revised based on reviewers comment. You can see the revised parts with different color.

Best Regards

Hassan Khosravi

Response to comments:

The paper submitted by Sadeghravesh et al is very confusing and mix materials and methods, results and discussions. The discussions of the paper are very poor. In the present form the paper cannot be accepted to be publish in SE and needs a very strong revision,

--- The paper is thoroughly revised with enormous changes in grammatical structure. Besides, all sections (Abstract, Introduction, Study Area, Result and Discussion and Conclusion) were revised in detail and some resources were added to this paper. It should be noted that all comments of judges were taken into account.

1) Encourage the authors to please revise the English. It is not possible to send for review and possible publication a paper in which this issue has not been taken into account. Repetitive expressions, bad use of commas, missing capital letters, etc.

--- The paper is now fully revised in term of grammatical structure and other mentioned issues.

2) References are missing all the way through the paper. Also, please check the guidelines of the Journal in order to know how to cite scienctific work. As it is now it seems like the authors did not have this in mind. I would like to recommend the authors to deeply revise their work and make it suitable for publication. The world (including the scientific community) needs to know what is happening nowadays in Iran and the nearby countries.

--- The paper is now adjusted with Solid Earth Journal’s format. Meanwhile, new resources were added to the paper.

ABSTRACT: Please provide in the abstract: 1) problem in Iran to be solved, 2) hypothesis of the work, 3) research area, 4) methodology used in order to check/solve the hypothesis, 5) results.

--- The abstract was revised and we tried to point out the problem of Iran in the abstract section. Moreover, methodology and results revised according to judges comments (a suggestion added to the end).

INTRODUCTION: In this part you should give references to the reader about the problem you want to solve, or at least, the wanted you are presenting to the scientific community. To do so, please enter to the Web of Knowledge site, or look on Google Scholar for already published scientific work worldwide. Also, in the introduction section you have to present your hypothesis and the steps followed to solve it (steps that will be explain later on in the Methodology and Results section).

--- Changes were done based on this comment.

MATERIALS AND METHODS: Here is where you have to present your study area and be extremely concise on the methodology you have followed. It needs to be so concise so other researchers in different parts of the world could apply it. For instance, in Line5 of the 'Study area' C2

section you talk about the"Amberje classification'. What is this classification? It is not cited and it is not an international way of climate classification as Köppen. Also, the description is weak. More data to understand how the area is can be interesting. Pictures might help as well.

--- For Biochemical Ambereger Classification the following method was used; however, the limitation of pages' number didn't allow us to insert this part in the paper and it only mentioned in the references of article.

**Climate Classification of the study area**

To determine bioclimatic classification of the study area De Martonne, Koppen and Emberger climate classification methods were used.

**De Martonne aridity index.** Early studies on aridity in Dobrudja were made by Ioan (1929), and continued afterwards by several other authors, including Cernescu (1961), Berbecel (1984), and others. A suggestive indicator for the characterization of the aridity index is De Martonne's (Iar-DM), described by the Eq.

Iar-DM = P/(Tm + 10) ()

*where*: P = total annual precipitation and Tm = mean annual temperature.
The denominator contains additionally the value of 10°C to produce positive results in regions with negative average annual temperatures, such as mountainous regions or deserts from median latitudes. This indicator was introduced by De Martonne (1926) to characterize the climate, and was subsequently used in the characterization of soil hydrologic regime, including in our country. In general, low values of Iar-DM show dry conditions, while higher values show wet conditions. Table 1 presents De Martonne's climatic classification (1926) according to the Iar-DM indicator.

Tab. - Climatic classification according to De Martonne (1926)

| Type of climate | I |
| --- | --- |

| | |
|---|---|
| Very dry = desert (arid) | 0-5 |
| Dry = steppe, semiarid (semi desert) | 5-15 (5-12) |
| Semi-dry (dry sub-humid) | 15-20 |
| Mildly wet (moist sub-humid) | 20-30 |
| Wed (wet) | 30-60 |
| Very wet (humid) | Over 60 |

Based on the climatologic stations near the study area and through using Eq. the aridity index was calculated and compared to the De Martonne aridity index (Tab. ). The results shown all the stations had arid climate (Tab. ).

Tab. De Martonne aridity Index of climatologic stations of study area

| Station | Aridity Index (I) | Climate (De Martonne) | Modifies De Martonne |
|---|---|---|---|
| Khezr-abad | 2.83 | arid | dry cold |
| Ashkzar | 2.06 | arid | Very dry cold |
| Nasr-abad | 7.3 | arid | Very dry cold |
| Nadoshan | 4.04 | arid | Very dry cold |
| Khezr-abad basin | 5.05 | arid | Very dry cold |

It should be mentioned that the average daily minimum temperature of the coldest day in the year added to modified De Martonne (Tab. ) (Khalili, 1996).

Tab. Identified climate by Modified De Martonne

| Climate | Average daily minimum temperature |
|---|---|
| Very cold | < -7 |
| cold | (-7) - 0 |
| moderate | 0 - 5 |
| warm | > 5 |

According to the Tab () average daily minimum temperature of all stations (-7.9) climate of the study area is very cold dry.

Köppen Climate Classification System.

Köppen's classification is based on a subdivision of terrestrial climates into five major types, which are represented by the capital letters A, B, C, D, and E. Each of these climate types except for B is defined by temperature criteria. Type B designates climates in which the controlling factor on vegetation is dryness (rather than coldness). Aridity is not a matter of precipitation alone but is defined by the relationship between the precipitation input to the soil in which the plants grow and the evaporative losses. Since evaporation is difficult to evaluate and is not a conventional measurement at meteorological stations, Köppen was forced to substitute a formula that identifies aridity in terms of a temperature-precipitation index (that is, evaporation is assumed to be controlled by temperature). Dry climates are divided into arid (BW) and semiarid (BS) subtypes, and each may be differentiated further by adding a third code, h for warm and k for cold.

A - Tropical Moist Climates: all months have average temperatures above 18° Celsius.

B - Dry Climates: with deficient precipitation during most of the year.

C - Moist Mid-latitude Climates with Mild Winters.

D - Moist Mid-Latitude Climates with Cold Winters.

E - Polar Climates: with extremely cold winters and summers.

The annual evapotranspiration of the Khezr-abad basin (1610.44 mm) is more than its annual precipitation (120 mm), so the climate of the basin is in category (B). Besides, more than 55 percent of precipitations in the Khezr-abad basin happen in cold seasons, and the average temperature of that is 15.72º C. Therefore, the climate of basin is in subtype BSK which represents desert climate (Tab ).

Amberegerr Climate Classification System:

This method is based on average minimum and maximum temperature of coldest and warmest months of the year and is calculated through Eq.

$$Q = \frac{2000P}{M^2 - m^2} \qquad ()$$

Where: Q= Aridity index of Ambereger, P= Annual average precipitation (mm), M= average daily maximum temperature of the warmest month in the year (K), m= average daily minimum temperature of the coldest month in the year (K).

The Ambereger index was calculated for all climatologic stations of the study area and the whole basin (Tab .).

Tab. Ambereger index of climatologic stations in the study area

| Station | P(mm) | M(c$^o$) | m(c$^o$) | Q |
|---|---|---|---|---|
| Ashkzar | 59 | 43 | 8 | 3.98 |
| Nadoshan | 98.7 | 36.8 | 11.2 | 7.19 |
| Nasr-abad | 158 | 34.85 | 12.32 | 11.77 |
| Khezr-abad | 81.8 | 39.68 | 3.6 | 6.55 |
| Khezr-abad basin | 121 | 38.3 | 7.9 | 9.08 |

Finally, by taking the Q and m parameters into account and using Ambereger climagram the climatic circumstance of the study area defined as dry and clod climate.

DISCUSSION: Weak, short and with lack of references. Here is where you have to link your results with other results presented by different scientist all over the world. Also, here is where you have to show the relevance of your findings and possible difficulties you had.

--- This comment also was considered, and tried to point out the result of other researches to our paper to make a comparison with the other papers.

REFERENCES: Please cite properly!

--- The citation modified properly.

# Assessment of combating desertification strategies using the linear assignment method

M. H. Sadeghravesh[a], H. Khosravi*[b], S. Ghasemian[b]

[a] Department of Environment, College of Agriculture, Takestan Branch, Islamic Azad University, Takestan, Iran
b Department of Arid and Mountainous Reclamation Region, Faculty of Natural Resources, University of Tehran, Tehran, Iran.

*Correspondence to*: h. khosravi (hakhosravi@ut.ac.ir)

***Abstract***

Nowadays desertification, as a global problem, affects many countries in the world especially developing countries such as Iran. With respect to increasing importance of desertification and its complexity, the necessity of attention to the optimal combating desertification alternatives is essential. Select appropriate strategies according to all effective criteria in combating desertification process can be so useful in ~~controlling and rehabilitation~~ rehabilitating ~~of~~ degraded lands~~,~~ and avoid degradation in vulnerable fields. This study provides systematic and optimal strategies of combating desertification by group decision-making model. To this end, the preferences of indexes were obtained through using Delphi model; in the framework of Multi Attribute Decision Making (MADM)~~. and by using Delphi model (Delphi), the preferences of indexes were obtained~~. Then, priorities of strategies were evaluated by using linear assignment (LA) method. According to the results, the strategies to prevent improper change of land use (A18), development and reclamation of plant cover (A23), and ~~adjustment for harvesting from~~control overcharging of groundwater resources (A31~~),~~ ); respectively, were identified as the most important strategies for combating desertification in this study area. Therefore, it ~~was~~ is suggested ~~to consider~~ that the aforementioned ranking results be considered in projects which control~~s~~ and reduce~~s~~ the effects of desertification and rehabilitate~~s~~ degraded lands.

**Keywords:** desertification, Multi Attribute Decision Making, Linear Assignment model, pair wise comparisons.

**1Introduction**

Desertification is a significant global ecological and environmental problem. ~~Desertification~~ That is a type of land degradation in which a relatively dry land region becomes increasingly arid~~,~~ typically losing its bodies of water, ~~as well as~~ vegetation and wildlife. It is caused by a variety of factors~~,~~ such as ~~climate change~~climatic changes and human ~~activities~~interferences. ~~Desertification is a significant global ecological and environmental problem.~~ According to United Nations Conference on Desertification (UNCOD), desertification process threatens more than 785 million people living in the arid regions. Of this number, 60 to 100 million people are affected directly due to the loss of land fertility and others desertification processes

(Meshkat, 1998). In IranThere are 100 million hectares in Iran are affected by desertification processes especially wind erosion, water erosion and physicochemical destruction (Forest, Rangeland and Watershed Institute, 2005).

""combating desertification"" includes activities which are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development which are aimed at:(i) prevention and/or reduction of land degradation; , (ii) rehabilitation of partly degraded land; and (iii) reclamation of desertified land (Law Office of Environment and Parliamentary Affairs, 2004). Based onBy taking this framework into account, this paper study tries to present a systematic method to for provide providing effective solutions among the several solutions based on different desertification criterion. Therefore, in order to achieve this goal in the context of decision-making models and linear assignment (LA) method were used to rank combat to desertification alternatives.

Managing desert ecosystems is a collectionconsist of various managements in order to to optimize control of desertification phenomenon and minimize the loss of economyeconomical, society social and environmental loss. Making decision in management of desert areas is abecomes a complex issue process due to existence of various indexes and various criterions for decision in such areas. There are several ways methods in managing desert regions to achieve a specific purpose since, and each has different preferences for the different issues of environmental, social, political, and economical and organizational issues. These requirementsAmong these different methods lead to the use of Multi Attribute Decision Making (MADM) which its purpose is tocan choose providethe best answers among the different solutions in comparison with the others. The purpose of this study, by considering limitation of inputs, while considering the limitation of inputs is tois assessing desertification strategies to achieve the optimal strategies in the framework of sustainable management of desert area. To achieve this goal, with framework of MADM, using Linear Assignment (LA) which is kind of Concordance Methods werewas considered used to rank combating desertification combating desertificationstrategies. which is a kind of Concordance Methods. This method having has a simple algorithm that has this ability tocan engage simultaneously a large number of quantitative and qualitative criteria in the decision process. IBesidesn, in different intervals of time and place, it is also capable to change the input data and provide new assessment according to this change. Therefore comparative studies are would be easy to do (Asgharpour, 1999).

According toSince LA using uses descriptive data instead of principal data, in this method, so , and it is easy to understand and has been usedit has been applied in various fields of science (Bernardo and Blin, 1977). Some of these studies including include; assessment of environmental sustainability (Hosseinzadeh et al., 2011), Assessing assessing and ranking risks (Sayadi et al, 2011), Monitoring monitoring sensitivity to of desertification (Symeonakis et al., 2014), footprint of research in desertification management (Miao et al., 2015), Characterization characterization and interaction of driving factors in desertification (Xu et al., 2014), Identifying identifying susceptible areas susceptible to toward desertification (Vieira et al., 2015), Evaluation evaluation of soil fertility in the succession of karst rocky desertification (Xie et al., 2014), Assessing assessing Environmental environmental Sensitivity sensitivity of Areas areas toward Desertification desertification (Sobhand and Khosravi, 2015), Financial financial assessment of companies (Mohammadi, 2011), assessment of strategies of water supply (Mianabadi and Afshar, 2008), Zoning zoning watersheds (Ramesht and Arabameri, 2012), Assignment assignment of water resource in order to minimize the energy consumption (Joung et al, 2012), ~~Programming~~ programming of robots (Ji et al, 1992), ~~Programming~~ programming for dispatching helicopter in emergency missions (Celi, 2007) ~~And~~ and so on. By studying the research literature, using decision models to provide optimal strategies in desert management is limited to research of Grau et al, ~~and~~ Sadeghi ravesh et al, and Sepehr and Peroyan. In order to select the optimal strategies for providing an integrated plan to control erosion and desertification, Grau used three decision models in his research; ELECTRE, AHP and PROMETHEE (Grau et al, 2010). The results indicate the high efficiency of these models to provide optimal strategy of desertification ~~,~~ despite complex methods which are used in each model; the results were largely the same. Sadeghi ravesh prioritize the strategies in Khezr Abad region~~,~~ by using the following models; Analytical Hierarchy Process (AHP) (Sadeghi Ravesh et al, 2010), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Sadeghi Ravesh et al, 2012), Elimination et Choice Translating Reality (ELECTRE) (Sadeghi Ravesh and Khosravi, 2014), Weighted Sum Model (WSM) (Sadeghi Ravesh and Zehtabian, 2013), BORDA (Sadesghi Ravesh, 2014), and PERMUTATION (Sadeghi Ravesh, 2013), Preference Ranking Organization Method For Enrichment Evaluation (PROMETHEE) (Sadeghi Ravesh et al, 2016). The results of these studies are same and largely similar to the results of previous research. Sepehr and Proyan zoned vulnerability of desertification in the ecosystems of Khorasan Razavi Province and evaluated these strategies to combat desertification (Sepehr and Peroyan, 2011).

All in all, determining the effective combating desertification alternatives and criteria are essential for achieving efficient combating desertification projects. Hence, this research presents linear assignment method to objectively select the optimal combating desertification alternatives based on the results of interviews with experts in Khezr Abad region in Yazd province, Iran as the case study.

**Formatted:** Font: 10 pt, Complex Script Font: 10 pt

**Formatted:** Font: 10 pt, Font color: Dark Red, Complex Script Font: 10 pt

**Formatted:** Font: 10 pt, Complex Script Font: 10 pt

**Formatted:** Font: 10 pt, Font color: Dark Red, Complex Script Font: 10 pt

**Formatted:** Font color: Dark Red

**Formatted:** Font: 10 pt, Font color: Dark Red, Complex Script Font: 10 pt

**Formatted:** Font: 10 pt, Font color: Auto, Complex Script Font: 10 pt

**Formatted:** Font: (Default) Times New Roman, Font color: Dark Red, Complex Script Font: Times New Roman

**Formatted:** Font: 10 pt, Font color: Auto, Complex Script Font: 10 pt

## 2 Material and Methods

### 2.1 Study area

The Khezr Abad region in Yazd province, central Iran, was considered for optimal determination of alternatives to combat desertification. The study area is located nearly 10 km west of Yazd. The region extends from 53°55´ to 54°20´ East in longitude and from 31°45´ to 32°15´ North in latitude, covering an area of about 78,180 ha (Fig.1). The climate of the region is cold and arid, based on the Amberje climate classification method (Sadeghiravesh, 2008). About 12,930 ha (16%) of the region is hilly, a sand-dune area[1], which is a part of the Ashkezar Great Erg[2], located in the northern part of the study area.

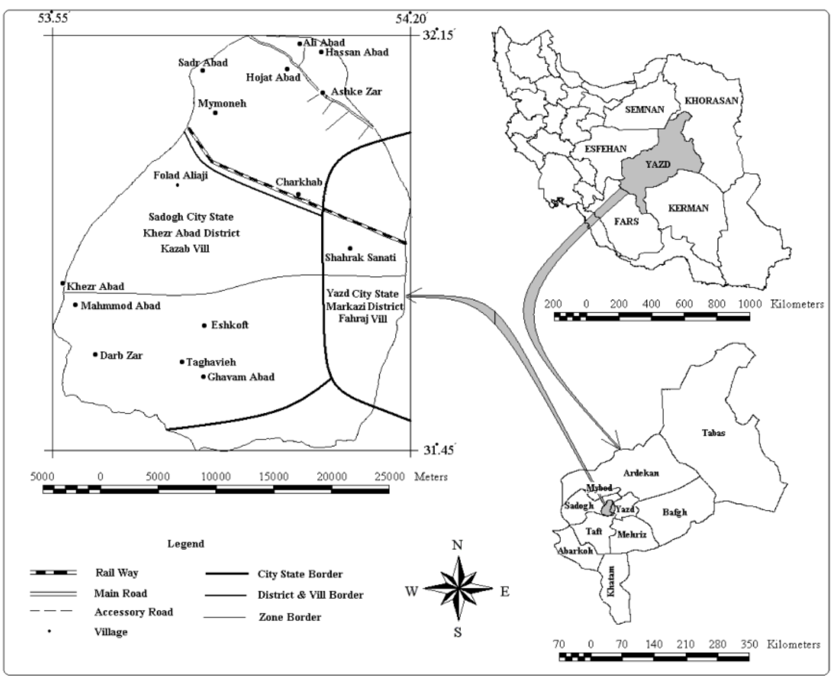
**Formatted:** Font: 10 pt, Not Bold, Font color: Auto, Complex Script Font: 10 pt, Not Bold, English (United States)

**Formatted:** Font: 10 pt, Not Bold, Font color: Auto, Complex Script Font: 10 pt, Not Bold, English (United States)

1 . An isolated hill, knob, ridge, outcrop, or small mountain.

2 . An erg (also sand sea or dune sea, or sand sheet if it lacks dunes) is a broad, flat area of desert covered with wind-swept sand

About 9,022 ha (12%) of the area consists of bare lands, clay plain and desert pavement[3] (Sadeghi Ravesh, 2008; Kazemi Nejad, 1996). About 1,995 ha (26.5%) of all the agricultural land in the region consists of degraded or abounded lands with human activities such as traditional irrigation and natural processes like wind erosion and dust. The study area shows an absolutely typical condition of desertification, so effective solutions and optimal means of combating desertification must be pursued.




3. A desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size.

**Figure~~.~~ 1. Location of the study area**

**2.2 Methodology**

Linear Assignment is one of the most important methods of Multi Attribute Decision Making (MADM) and subset of Concordance Methods.~~,~~ LA~~which~~ can help decision makers to choose the best option~~,~~ due to combining qualitative and quantitative indexes and providing appropriate weighting for each criterion. The output of this model is a collection of ranks, so it provides the required coordination in the most suitable way. In this method~~,~~ given choices of moot point are ranking according to their scores on each index~~,~~ then the final ranking of the alternatives will be characterized through linear compensation process (for every possible interaction between indexes) (Asgharpour, 1999). Based on the property simplex solution space of ~~Linear Assignment~~LA~~, while considering all the arrangements implicitly,~~, the optimum solution ~~in a~~ is extracted in a convex space simplex ~~is extracted~~ and by considering all the arrangements implicitly. ~~In addition~~Moreover, the compensation property of the indexes is obtained from exchange between rank and options (Pomerol and Romero, 2000)~~.~~; however, the weight vector of indexes has been obtained through expert opinion and Delphi model.

~~Although the weight vector of indexes have been obtained through expert opinion and Delphi model~~:

Formatted: Line spacing: 1.5 lines

**2.2.1 Selection criteria and effective strategies**

Selecting criteria and alternatives can be done individually according to expert experience, resources~~, and~~, field studies ~~or~~ and ~~using~~ Delphi method~~,~~ ; distributed a structured questionnaire among experts familiar with the study area. The experts were asked to rate effective criteria and alternatives between 0 and 9~~. F~~ and finally~~,~~ mean values were calculated. In this case, if the mean value was less than 7 ($\overline{X}$ <7)~~,~~ related criterion and alternative was removed, and if the mean value was more or equal to 7 ($\overline{X}$ ≥7) related criterion and alternative was used as effective criteria (Azar and Rajabzadeh 2002; Azar and Memariani, 2003). Tables 1 and 8 show the recommended alternatives, offering criteria, respectively.

Formatted: Font: 10 pt, Font color: Auto, Complex Script Font: 10 pt

**Table 1.** The criteria and their importance mean according to the group

| Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| Criteria | Expenses-benefit | Time | Participation of local communities | Beauty of landscape | Access to the technologies and scientific methods and devices | Access to the related expert |
| Code | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
| Criteria | Proportion and adaptation to the environment (sustainability) | Traditional managemen t and local knowledge | Democratic government authority in combating- | Oil income of government | Temporary management of projects | The problems resulted from innovation |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | desertification projects | | | and method changes |
| Code | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ | | |
| Criteria | Indolence state administrative systems | Social and political pressures | Emergency issues related to desertification occurrence | Destruction of resources, human and social damages | | |

**2.2.2 Calculate local priority of criteria and alternatives and establish group pairwise comparisons matrix**

in order to achieve Local Priority, the structured questionnaire was designed based on literature and the nine-point Sa'aty scale, ~~from~~ 1(least important) to 9 (most important), were used to measure the relative importance of criteria and priority of combating desertification alternatives (Table ~~1~~2).

The questionnaire was distributed among experts familiar with the study area. ~~In continuation, U~~Using geometric mean and assumption of ~~uniform~~ expert's opinion (considering all opinions have same value~~,~~ ) pairwise comparisons matrixes were obtained according to Eq.1 and formed in a group format ~~of each expert~~ (Table ~~2~~3) ~~were composed according to Eq. 1; and pairwise comparisons were formed regarding to group.~~ .

$$\bar{a}_{ij} = \left(\pi_{k=1}^{N} a_{ij}^{\ k}\right)^{\frac{1}{N}} \qquad (1)$$

In this equation aijk = component of k expert to comparison i and j. So, āij (geometric mean) for all corresponding components is obtained by Eq. 1 (Azar and Rajabzadeh, 2002; Ghodsipour, 2002).

**Table ~~1~~2.** Importance and priority degree of nine-point Satty's scale

| Score | Importance Degree | Priority Degree in Pair wise Comparison |
|---|---|---|
| 1 | Non-importance | Equal |
| 2 | Very low | Equal-Moderately |
| 3 | Low | Moderately |
| 4 | Relatively low | Moderately - Strongly |
| 5 | Medium | Strongly |
| 6 | Relatively high | Strongly-Very strongly |
| 7 | High | Very strongly |
| 8 | Very high | Very strongly-Extremely |
| 9 | Excellent | Extremely |
| 1/2, 1/3,1/4, …., 1/9 | | Mutual Values |

**Table ~~2~~3.** Pair wise comparisons matrix

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \qquad A=[a_{ij}] \quad i,j=1,2,\ldots,n$$

$a_{ij=}$ preference of i criteria to j criteria

### 2.2.3 Compute the priorities based on group pair wise of comparisons tables

At this stage, the ~~numbers~~data of group pairwise comparison~~s~~ matrix~~es~~ ~~(values of criteria importance and alternatives priority to each criterion)~~ were imported in EC software to evaluate criteria importance and alternatives priority to each criteria (Godsipour, 2002). After normalization by using Eq. 2~~,~~ importance and priorities percent were showed as bar graphs using harmonic mean method or average of each level of normalized matrix (Tables ~~4~~ 5 and ~~5~~6).

$$\bar{r}_{ij} = \frac{\bar{a}_{ij}}{\sum_{i=1} \bar{a}_{ij}} \qquad (2)$$

In this equation:

$\bar{r}_{ij}$ = normal component

ij ā = group pair wise comparison component of i to j

Σāij = total column of group pair wise comparisons

### 2.2.4 Formation of Normalized Decision Matrix (NDM)

~~At this stage, T~~The weight values of criteria importance (Wj) and alternative~~s~~ ~~priority~~ priorities (Pij) is considered in the form of a decision matrix based on any criteria (Table ~~3~~4).

**Table ~~3~~4.** Normalized Decision Matrix

| Alt | Criterion | | | | |
|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | ----------- | $C_n$ |
| | $W_1$ | $W_2$ | $W_3$ | ----------- | $W_n$ |
| $A_1$ | $P_{11}$ | $P_{12}$ | $P_{13}$ | -------- | $P_{1n}$ |
| $A_2$ | $P_{21}$ | $P_{22}$ | $P_{23}$ | ----------- | $P_{2n}$ |
| : | : | : | : | : | : |
| $A_m$ | $P_{m1}$ | $P_{m2}$ | $P_{m3}$ | ----------- | $P_{mn}$ |

In this matrix: m= the number of choices or alternatives, n= number of criteria, C= title of criteria, W= Weight value of related criteria, $a_{ij}$= weight value each alternative gains in relation to related criteria

**Table ~~4~~5.** Comparison of proposed criteria importance to access the goal

| Criterion | Preference Degree |
|---|---|
| $C_7$ | 33.3 |
| $C_{16}$ | 31.3 |
| $C_6$ | 15.7 |
| $C_5$ | 11 |
| $C_2$ | 8.9 |
| Inconsistency Ratio=0.01 | |

**Table ~~5~~6.** Comparison of alternatives preference according to the criteria of ~~"~~proportion and adaptation to the environment

| Alternative | Degree |
|---|---|
| $A_{18}$ | 26.6 |
| $A_{23}$ | 22.7 |
| $A_{31}$ | 19.2 |
| $A_{33}$ | 15.9 |
| $A_{20}$ | 15.5 |
| Inconsistency Ratio=0.02 | |

### 2.2.5 Ranking each option for each index

After forming the decision making matrix, attempted to rank the alternatives (Ai) for each criteria (Ci) with respect to the ~~desirability of~~ increasing or decreasing trends and ~~with~~ n×m matrix framework (Table ~~6~~7).

**Table ~~6~~7.** Matrix ranking of each option against each index

| Criteria (C) ► / Rank (A) ▼ | $C_1$ | $C_2$ | $C_3$ | …….. | $C_n$ |
|---|---|---|---|---|---|
| First | $A_{11}$ | $A_{12}$ | $A_{13}$ | …….. | $A_{1n}$ |
| Second | $A_{21}$ | $A_{22}$ | $A_{23}$ | …….. | $A_{2n}$ |
| Third | $A_{31}$ | $A_{32}$ | $A_{33}$ | …….. | $A_{3n}$ |
| …….. | | | | …….. | |
| …….. | | | | …….. | |
| m | $A_{m1}$ | $A_{m2}$ | $A_{m3}$ | …….. | $A_{mn}$ |

In this matrix: m= the number of choices or alternatives, n= number of criteria, C= title of criteria, $a_{ij}$= each alternative in relation to related criteria

### 2.2.6 Forming two-dimensional matrix, Gamma (γ)

Two-dimensional gamma matrix (γ) ( ~~or~~ assignment matrix) is formed according to weight vector of the estimated criteria of group pairwise ~~-~~comparison. This matrix is a square matrix ($\gamma_{m.m}$) which has element i in row and element k in column. Matrix elements include the total weight of indexes which alternative i has rank k. Gamma matrix is a assignment matrix, so the optimal solution can be obtained by any kind of assignment methods such as shipping method, ~~Hungarian~~ hungarian method,

**Formatted:** Not Superscript/ Subscript grid method and one and zero linear programming method. The most common method for solving the linear assignmentLA is assignment programming method (Pomerol and Romero, 2000).

**2.2.7 Calculating the final rank for each alternative ($A_i$)**

At this stage tThe final ranking/optimal solution of alternatives or in other words the optimal solution is obtained by linear programming method and through the following model:

$$\text{Maximize: } \sum_{i=1}^{m} \sum_{k=1}^{m} \gamma_{ik} . h_{ik} \qquad (3)$$

$$\text{subject to: } \sum_{k=1}^{m} h_{ik} = 1 \quad ; i = 1,2,3,\ldots,m \qquad (4)$$

$$\sum_{i=1}^{m} h_{ik} = 1 be \quad ; k = 1,2,3,\ldots,m \qquad (5)$$

$$h_{ik} \begin{cases} = 1 \\ = 0 \end{cases}$$

After solving the linear programming model, if $h_{ik}$ be 1 a a square matrix ($H_{m\times m}$) is considered sothe one that -$A_i$ is given to the final rank ok K-th rank ($h_{ik}$=1). In others ways ;otherwise $h_{ik}$=0 (Burkard and Qela, 1999; Liu, 2000)
The obvious featuress of this method method are mentioned as follows:is This method with a a simple ranking for alternatives that caused exchanged between theamong indexes and have no complex calculations. Also in this method there is no need for unification scale, and indexes can be of any scale (Saaty and Vargas, 2006; Asgharpour, 1999). Meanwhile, other methods such as MADM need the both alternatives and indexes for calculating, but in LA the process of rankingranking process of LA can be done without alternative (Tajoddini, 2003).

**3Result and Discussion**

In the process of combating-desertification alternatives assessment in the study area the Delphi method and questionnaire were used to identify the main criteria and alternatives among 16 criteria and 40 combating-desertification alternatives and establishing hierarchical structure (Saaty, 1995) according to the group. Tables 8 and 9 show the average of alternative priorities and criteria important respectively.

The obtained results of presented questionnaire to determine importance and priority of criteria and alternatives to establish decision hierarchical structure show that among studied criteria and alternatives, only criteria and alternatives have group mean more than 7 that considered establishing decision hierarchical chart and providing pairwise comparisons questionnaires. Figure 2 show hierarchical decision structure provided based on effective criteria and alternatives to combating desertification.

In the process of combating - desertification alternatives assessment in the study area, the Delphi method and questionnaire were used first to identify the main criteria and alternatives among 16 criteria and 40 combating- desertification alternatives, and to establish hierarchical structure (Saaty, 1995) according to the group. groupFor this aim, the structured questionnaire in two parts including criteria and alternatives was distributed among experts familiar with the study area. In continuation, arithmetical mean was used to calculate the mean of obtained results. Finally, mean values were calculated. In this case, if the mean value was less than 7 ($\bar{X}$<7), related criterion and alternative was removed and if the mean value was more or equal to 7 ($\bar{X}$≥7) related criterion and alternative was used to design hierarchical decision structure. Tables 7, 8 and 9 show the recommended alternatives, offering criteria and alternative priority average, respectively. Then, these were used to establish hierarchical decision making graphs (Fig. 2) and a fuzzy pair-wise comparison questionnaire.

**Table 8.** The criteria importance mean according to the group

| Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average values | 5.38 | 7.1 | 5.78 | 5.1 | 7.1 | 7.53 | 8.15 | 5.23 | 5.28 | 5.72 | 2.39 | 2.84 | 2.29 | 5.35 | 6.34 | 7.99 |

**Table 9.** the recommended alternatives to combat desertification and their priority according to the groups

| Code | Alternative | values |
|---|---|---|
| $A_1$ | Reducing population growth rates | 5 |
| $A_2$ | poverty alleviation | 5.68 |
| $A_3$ | Establishment and development of rural organizations | 5.35 |
| $A_4$ | Increasing employment | 6.7 |
| $A_5$ | Increasing participation of local community and supporting NGOs | 6.1 |
| $A_6$ | Application of local forces and technology in projects (local knowledge) | 6.56 |
| $A_7$ | Training people in utilization of new methods and use of new knowledge for optimal use of resources | 6.47 |
| $A_8$ | Approval, promotion and implementation of laws and adaptation punishments with the crime | 5.73 |
| $A_9$ | providing needs of local residents | 5.89 |
| $A_{10}$ | modification of unsustainable consumption patterns, changing and improving people's livelihood patterns | 5.6 |
| $A_{11}$ | Considering the role of women and youth in combating - desertification process | 4.5 |
| $A_{12}$ | Organization of urban areas and prevent migration | 5.23 |
| $A_{13}$ | Coordination between responsible agencies and organizations in combating - desertification and environmental protection | 6.86 |

**Formatted:** Font: 10 pt, Font color: Auto, Complex Script Font: 10 pt, (Complex) Persian

**Formatted:** Font: 10 pt, Font color: Auto, Complex Script Font: 10 pt, (Complex) Persian

| | | |
|---|---|---|
| $A_{14}$ | Raising the literacy rate | 4.8 |
| $A_{15}$ | Development of desert ecotourism | 5.32 |
| $A_{16}$ | multi- utilization from desert instead of mono utilization | 5.27 |
| $A_{17}$ | Allocation combating - desertification issue to the private sector | 3.79 |
| $A_{18}$ | Prevention of unsuitable land use changes | 7.5 |
| $A_{19}$ | mapping land use planning and determination of desert and salt desert boundaries | 6.44 |
| $A_{20}$ | livestock grazing control | 7.34 |
| $A_{21}$ | Forage Production and increasing economic potential of sustainable husbandry | 6.6 |
| $A_{22}$ | Prevention of plant cutting | 6.46 |
| $A_{23}$ | Vegetation cover Development and reclamation | 7.56 |
| $A_{24}$ | Protection of *Haloxylon spp*. | 6.76 |
| $A_{25}$ | Protection of gravel surfaces (Reg) | 6.45 |
| $A_{26}$ | prevention and reduction in heavy agricultural and industrial machineries traffics | 5.57 |
| $A_{27}$ | Create living and non- living wind break for soil conservation | 6.86 |
| $A_{28}$ | Improvement of soil texture | 4.66 |
| $A_{29}$ | modification of crop rotation and follow methods | 5.42 |
| $A_{30}$ | Modification of ploughing, fertilization, spraying methods | 5.1 |
| $A_{31}$ | Modification of groundwater harvesting | 7.24 |
| $A_{32}$ | Reduction in water consumption (water optimal consumption in farms) | 6.6 |
| $A_{33}$ | Change of irrigation patterns | 7.49 |
| $A_{34}$ | Changing traditional irrigation systems with low to modern systems with high efficiency | 6.53 |
| $A_{35}$ | optimal Collecting and harvesting of water resources (including rivers isolating, Qanat repairing and dredging, utilization of canals and streams and desalination of salty waters) | 6.64 |
| $A_{36}$ | Groundwater feed | 6.08 |
| $A_{37}$ | Construction of flood broadcast networks and the use its alluviums | 5.3 |
| $A_{38}$ | Creation of artificial precipitation to feed aquifers | 3.47 |
| $A_{39}$ | Promotion of greenhouse cultivation | 6.2 |
| $A_{40}$ | Introduction of new plant varieties, resistant to drought and dehydration stress by genetic engineering | 6 |

Table 7 the recommended alternatives to combat desertification

| | |
|---|---|
| **Modification, creation and development of economical- social infrastructures in marginal areas** | $A_{22}$ - Prevention of plant cutting |
| $A_1$ - Reducing population growth rates | $A_{23}$ - Vegetation cover Development and reclamation |
| $A_2$ - poverty alleviation | $A_{24}$ - Protection of Haloxylon spp. |
| $A_3$ - Establishment and development of rural organizations | **Soil conservation** |
| $A_4$ - Increasing employment | $A_{25}$ - Protection of gravel surfaces (Reg) |
| $A_5$ - Increasing participation of local community and and supporting NGOs | $A_{26}$ - prevention and reduction in heavy agricultural and industrial machineries traffics |
| $A_6$ - Application of local forces and technology in projects (local knowledge) | $A_{27}$ - Create living and non- living wind break for soil conservation |
| $A_7$ - Training people in utilization of new methods and use of new knowledge for optimal use of resources | $A_{28}$ - Improvement of soil texture |
| $A_8$ - Approval, promotion and implementation of laws and adaptation punishments with the crime | **Development of sustainable agriculture** |
| $A_9$ - providing needs of local residents | $A_{29}$- modification of crop rotation and follow methods |
| $A_{10}$ - Modification of unsustainable consumption patterns, changing and improving people's livelihood patterns | $A_{30}$- Modification of ploughing, fertilization, spraying methods |
| $A_{11}$ - Considering the role of women and youth in combating - desertification process | **Sustainable development and management of water resources** |
| $A_{12}$ - Organization of urban areas and prevent migration | $A_{31}$ - Modification of groundwater harvesting |
| $A_{13}$ - Coordination between responsible agencies and organizations in combating - desertification and environmental protection | $A_{32}$ - Reduction in water consumption (water optimal consumption in farms) |
| $A_{14}$ - Raising the literacy rate | $A_{33}$ - Change of irrigation patterns |
| $A_{15}$ - Development of desert ecotourism | $A_{34}$ - Changing traditional irrigation systems with low to modern systems with high efficiency |
| $A_{16}$ - multi- utilization from desert instead of mono utilization | $A_{35}$ - optimal Collecting and harvesting of water resources (including rivers isolating, Qanat repairing and dredging, utilization of canals and streams and desalination of salty waters) |
| | $A_{36}$ - Groundwater feed |
| | $A_{37}$ - Construction of flood broadcast networks and the use its alluviums |

| | |
|---|---|
| $A_{17}$ – Allocation combating desertification issue to the private sector<br>$A_{18}$ – Prevention of unsuitable land use changes<br>$A_{19}$ – mapping land use planning and determination of desert and salt desert boundaries<br>**Vegetation cover conservation**<br>$A_{20}$ – livestock grazing control<br>$A_{21}$ – Forage Production and increasing economic potential of sustainable husbandry | $A_{38}$ – Creation of artificial precipitation to feed aquifers<br>$A_{39}$ – Promotion of greenhouse cultivation<br>$A_{40}$ – Introduction of new plant varieties, resistant to drought and dehydration stress by genetic engineering |

Table 8 The criteria and their importance mean according to the group

| Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
| --- | --- | --- | --- | --- | --- | --- |
| Criteria | Expenses-benefit | Time | Participation of local communities | Beauty of landscape | Access to the technologies and scientific methods and devices | Access to the related expert |
| Average values | 5.38 | 7.1 | 5.78 | 5.1 | 7.1 | 7.53 |
| Symbol | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
| Criteria | Proportion and adaptation to the environment (sustainability) | Traditional management and local knowledge | Democratic government authority in combating-desertification projects | Oil income of government | Temporary management of projects | The problems resulted from innovation and method changes |
| Average values | 8.15 | 5.23 | 5.28 | 5.72 | 2.39 | 2.84 |
| Symbol | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ | | |
| Criteria | Indolence state administrative systems | Social and political pressures | Emergency issues related to desertification occurrence | Destruction of resources, human and social damages | | |
| Average values | 2.29 | 5.35 | 6.34 | 7.99 | | |

~~Table 9 The average alternative priority according to the groups~~

| ~~Alternative~~ | ~~$A_{1}$~~ | ~~$A_{2}$~~ | ~~$A_{3}$~~ | ~~$A_{4}$~~ | ~~$A_{5}$~~ | ~~$A_{6}$~~ | ~~$A_{7}$~~ | ~~$A_{8}$~~ | ~~$A_{9}$~~ | ~~$A_{10}$~~ |
|---|---|---|---|---|---|---|---|---|---|---|
| ~~Average values~~ | ~~5~~ | ~~5.68~~ | ~~5.35~~ | ~~6.7~~ | ~~6.1~~ | ~~6.56~~ | ~~6.47~~ | ~~5.73~~ | ~~5.89~~ | ~~5.6~~ |
| ~~Alternative~~ | ~~$A_{11}$~~ | ~~$A_{12}$~~ | ~~$A_{13}$~~ | ~~$A_{14}$~~ | ~~$A_{15}$~~ | ~~$A_{16}$~~ | ~~$A_{17}$~~ | ~~$A_{18}$~~ | ~~$A_{19}$~~ | ~~$A_{20}$~~ |
| ~~Average values~~ | ~~4.5~~ | ~~5.23~~ | ~~6.86~~ | ~~4.8~~ | ~~5.32~~ | ~~5.27~~ | ~~3.79~~ | ~~7.5~~ | ~~6.44~~ | ~~7.34~~ |
| ~~Alternative~~ | ~~$A_{21}$~~ | ~~$A_{22}$~~ | ~~$A_{23}$~~ | ~~$A_{24}$~~ | ~~$A_{25}$~~ | ~~$A_{26}$~~ | ~~$A_{27}$~~ | ~~$A_{28}$~~ | ~~$A_{29}$~~ | ~~$A_{30}$~~ |
| ~~Average values~~ | ~~6.6~~ | ~~6.46~~ | ~~7.56~~ | ~~6.76~~ | ~~6.45~~ | ~~5.57~~ | ~~6.86~~ | ~~4.66~~ | ~~5.42~~ | ~~5.1~~ |
| ~~Alternative~~ | ~~$A_{31}$~~ | ~~$A_{32}$~~ | ~~$A_{33}$~~ | ~~$A_{34}$~~ | ~~$A_{35}$~~ | ~~$A_{36}$~~ | ~~$A_{37}$~~ | ~~$A_{38}$~~ | ~~$A_{39}$~~ | ~~$A_{40}$~~ |
| ~~Average values~~ | ~~7.24~~ | ~~6.6~~ | ~~7.49~~ | ~~6.53~~ | ~~6.64~~ | ~~6.08~~ | ~~5.3~~ | ~~3.47~~ | ~~6.2~~ | ~~6~~ |

**3.2 Calculate relative weight of criteria and alternatives and format group decision matrix (DM)**

In order to estimate the relative weight or priority of criteria and alternatives, pairwise comparisons questionnaire was prepared and distributed among the experts. In continuation, the group pair-wise comparison~~s~~ matrixes of criteria importance ~~to goal~~ and alternatives priority to each criterion ~~was~~ were formed by obtaining expert opinions and combining their ideas by geometric mean. To prevent the prolongation of the Word, just matrix of criteria importance is presented (Table ~~7~~10), and alternative~~s~~ ~~priority~~ priorities to each criteria calculated by this method.

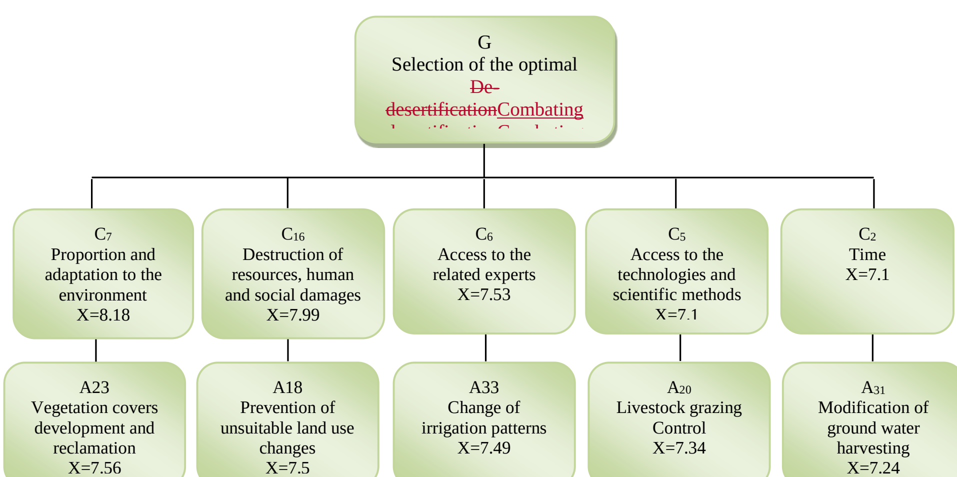


**Figure 2.** Hierarchical decision structure to select optimal combating desertification alternatives in study area

**Table ~~7~~10.** Pairwise comparisons matrix of the criteria importance to access the goal of "offering optimal combating desertification alternatives"

| Criterion | $C_{16}$ | $C_6$ | $C_5$ | $C_2$ |
|---|---|---|---|---|
| $C_7$ | 1.2 | 2.5 | 2.5 | 3.4 |
| $C_{16}$ | | 2.3 | 3.1 | 3.1 |
| $C_6$ | | | 1.7 | 2 |
| $C_5$ | | | | 1.3 |

In continuation, matrix values of criteria importance and alternatives priorities (~~Table7~~Table10) were entered to EC software based on each criterion~~, and~~ importance ~~and priority~~ of combating desertification criteria. ~~and a~~Alternatives were obtained ~~according to~~in ~~group~~a group ~~in the study area~~format. ~~as bar~~ Besides, graphs prepared based on percentage using normalization and harmonic mean (~~Table8~~Table11).

**Table ~~8~~11.** Comparison of proposed criteria importance to access the goal

| Criterion | Preference Degree |
|---|---|
| $C_7$ | 33.3 |
| $C_{16}$ | 31.3 |
| $C_6$ | 15.7 |
| $C_5$ | 11 |
| $C_2$ | 8.9 |

Inconsistency Ratio=0.01

Considering these graphs, it is observed that the alternatives are different based on each criterion. Therefore, decision making matrix of optimal combating desertification alternatives according to the group (Table ~~9~~12) was formed to select final alternatives and classification of their priorities~~,~~ in general framework of MADM (Table ~~3~~4).

**Table ~~9~~12.** Decision matrix of optimal combating desertification alternatives according to group

| Criteria importance (C) ► Alternatives priority (A) ▼ | C2<br>0.0892 | C5<br>0.1095 | C6<br>0.1576 | C16<br>0.3074 | C7<br>0.3365 |
|---|---|---|---|---|---|
| A23 | 0.2509 | 0.2387 | 0.2488 | 0.1805 | 0.2257 |
| A18 | 0.1960 | 0.1635 | 0.1983 | 0.2383 | 0.2643 |
| A33 | 0.1620 | 0.2565 | 0.2093 | 0.1510 | 0.1599 |
| A20 | 0.2229 | 0.1762 | 0.1608 | 0.2209 | 0.1582 |
| A31 | 0.1682 | 0.1633 | 0.1826 | 0.2092 | 0.1918 |

**3.3 Ranking each option for each index**

After forming the decision making matrix~~,~~ attempted to rank the alternatives (Ai) for each criteria (Ci) in a 5×5 matrix which the rows represent rank and columns represent the index (~~Table10~~Table13). Decision ~~Matrix~~ matrix of combating desertification alternatives has increasing ~~desirability~~trend~~, it~~ that means if the allocate number to each alternative priority associated with each criterion be more, then it represents the more priority of this alternative to achieve the goal~~,~~. Therefore, ~~in~~ any criterion which gain the highest priority is the optimal alternative.

**Table ~~10~~13.** Matrix of alternative ranking

| **Criteria (C) ►** / **Rank (A) ▼** | $C_7$ | $C_{16}$ | $C_6$ | $C_5$ | $C_2$ |
|---|---|---|---|---|---|
| First | $A_{18}$ | $A_{18}$ | $A_{23}$ | $A_{33}$ | $A_{23}$ |
| Second | $A_{23}$ | $A_{20}$ | $A_{33}$ | $A_{23}$ | $A_{20}$ |
| Third | $A_{31}$ | $A_{31}$ | $A_{18}$ | $A_{20}$ | $A_{18}$ |
| Forth | $A_{33}$ | $A_{23}$ | $A_{31}$ | $A_{18}$ | $A_{31}$ |
| Fifth | $A_{20}$ | $A_{33}$ | $A_{20}$ | $A_{31}$ | $A_{33}$ |

### 3.4 Forming $\gamma_{5\times5}$ matrix according to criteria weights (W)

At this stage a 5 × 5 gamma matrix is formed~~, Matrix~~ , and it was estimated by sum of indexes weights which the alternative of i has rank of k. As mentioned, the weight of each index was calculated by survey of experts and based on Delphi method (Table ~~11~~14).

Gamma matrix is an assignment matrix, and ~~as mentioned~~ the optimal answer can be obtained by any of assignment methods. The most common method for solving the linear assignment method is linear programming.

**Table ~~11~~14.** The matrix of number time weight of ranking options

| **Rank (C) ►** / **Alternative Priority (A) ▼** | First | Second | Third | Forth | Fifth |
|---|---|---|---|---|---|
| $A_{23}$ | 0.2468 | 0.446 | 0 | 0.3074 | 0 |
| $A_{18}$ | 0.6439 | 0 | 0.2468 | 0.1095 | 0 |
| $A_{33}$ | 0.1095 | 0.1576 | 0 | 0.3365 | 0.3966 |
| $A_{20}$ | 0 | 0.3966 | 0.1095 | 0 | 0.4941 |
| $A_{31}$ | 0 | 0 | 0.6439 | 0.2468 | 0.1095 |

### 3.5 Ranking alternatives

~~At this stage for~~For final ranking of alternatives ~~by using~~ linear programming was used (Eq. 1 to 3), and scoring table of options or optimal matrix was formed (Table 11). Since, the decision ~~variable contain~~variable contains zero and one ~~values~~value~~, so~~ the output of this program is provided only based on the number 1 in Table ~~12~~15, and ~~then according to this table,~~ scoring table of options was formed (Table ~~13~~16).

**Table ~~12~~15.** The options scoring

$$H^{*}=\begin{vmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{vmatrix}$$

The optimal objective function = 2.6245

**Table ~~13~~16.** The matrix of options optical order

$$\vec{A}=H^{*}\times\vec{A}=\begin{vmatrix} 0 & A_{18} & 0 & 0 & 0 \\ A_{23} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & A_{31} \\ 0 & 0 & 0 & 0 & A_{33} \\ 0 & 0 & A_{33} & 0 & 0 \end{vmatrix}$$

**Table ~~14~~17.** The options ranking

$$\vec{A} = \begin{vmatrix} A_{18} & A_{23} & A_{31} & A_{33} & A_{20} \end{vmatrix}$$

Based on Table ~~14~~17, the preference of alternatives was obtained as $A_{18} > A_{23} > A_{31} > A_{33} > A_{20}$; and after evaluating the $A_{18}$ alternative considered as the best one among all alternatives.

## 4 Discussions

In this study a new method was presented to rank combating desertification alternativess ~~priority~~priority. The results of final prioritization of alternatives by using ~~linear assignment~~LA method~~,~~ was similar to the results of the following methods; AHP (Sadeghiravesh et al, 2010), TOPSIS, (Ivani1 and Sofi, 2014), ELECTER (Sadeghiravesh et al., 2014) –and WSM (Sadeghiravesh and Zehtabian, 2013). This means ~~that~~ alternatives $A_{18}$, $A_{23}$ and $A_{31}$~~,~~ were ranked respectively first to third. ~~While~~ It should be mentioned that LA method ~~as well as above mentioned methods,~~ has ~~the~~ limitation of ignoring decision-makers fuzzy judgment as well as aforementioned methods. ~~Also~~Besides, some criteria have qualitative or unknown structure that cannot be accurately measured. In such case, fuzzy numbers can be used in order to achieve evaluation matrix. Prioritization method can be developed using fuzzy method. Another disadvantage of ~~this~~ LA method is~~:~~ ~~regardless~~ regarding the amount of data and ~~just~~ considering only the data ranks~~,~~. Therefore, ~~so large amounts of data is~~large amounts of data are lost and achieving ~~results with~~ high accuracy results ~~is~~ would not be possible (Mohammadi, 2011). ~~Therefore~~ Consequently, it is better to~~try to~~ do not use rating models as ELECTER and LA when accurate amounts of data are available. Further, following results were obtained using pairwise comparisons questionnaires, mean of expert's opinion, group pairwise comparisons matrix of importance and priority of criteria and alternative. According to table of decision matrix of optimal de-desertification alternatives according to group (Table 12) criteria of proportion and adaptation to environment ($C_7$) and time ($C_2$) have the highest and lowest importance, respectively. Criterion proportion and adaptation to the environment ($C_7$) with the importance degree of 33.6% and destruction of resources, human and social damages ($C_{16}$) with 30.7% were placed in first

**Formatted:** Font color: Dark Red

**Formatted:** Font color: Dark Red

**Formatted:** Font color: Dark Red

**Formatted:** Font color: Dark Red

**Formatted:** Font color: Dark Red

and second order, respectively. This indicates that expert are more concern about environmental issues and challenges raised in environmental degradation. Also, these tables represent alternatives priority to each criterion. As is taken from the table, selected alternatives will be different according to each criterion. Therefore, to select final alternatives and rank their priority, combination was conducted on decision matrix by Linear Assignment model, and alternatives priorities were formed base on set of criteria. In general according to the results of final alternatives' prioritization and by considering all the alternatives, execution of prevention of unsuitable land use changes ($A_{18}$), vegetation cover development and reclamation ($A_{23}$), and modification of ground water harvesting ($A_{31}$), the desertification process can be stopped, and the degraded lands can be rehabilitate.In general according to the results of final prioritization of alternatives, by implementation of following alternatives; Prevent improper land use change ($A_{18}$), Vegetation development and reclamation ($A_{23}$) And adjusting the withdrawal of groundwater resources ($A_{31}$); the desertification process can be prevented and the degraded lands can be restored. So Therefore, it can be expressed in the study area, that land use changes are resulting mainly caused by: increasing population, unemployment, growth of industry and increase increasing in desire of urbanization's desires. As an illustration, Lland use changes is are largely occurred happened in recent years by;because of pressure of drought and industrial growth which lead to conversion of pasture landpastures to into farms and gardens. As a consequent result, on the effect of enormous amounts of deep and semi-deep motorized wells have installed in the study area. , conversion of garden land to agricultural land on the effects of successive droughts, conversion of pasture lands to urban and industrial lands due to growth of industry and increasing urbanization. The density of range types isRangelands consist of 6 to 15 percent of case area which is strongly influenced by human activities in terms of cutting brush and livestock overgrazing, so that 40 to 50 percent of plant cover are destroyed because of cutting brush for grazing, fuel and building materials. . Irrigation in agricultural lands is mostly flooding with outdoor pools and outdoor streams with large pores in bed, therefore, s o that more than 50% of used water's consumption is wasted and the efficiency of irrigation and transmission is estimated less than 40 percent.

## 5 Conclusions

Desertification is the persistent degradation of dry land ecosystems by variations in climate and human activitieswhich is caused mainly by climatic changes and human interferences. Home to a third of the human population in 2000, dry lands occupy nearly half of Earth's land area. More than 85% of Iran is occupied byconsist of arid, semi-arid and hyper-arid regions with 34 million ha of desert zones. SoTherefore,, the major part of the country is susceptible to desertification. Although, the government has performed many projects to combat desertification in recent years, it seems that they are not adequate due to the country's extensive arid regions. The problem needs more attention in addition toand effective national cooperation in the national as well as international scene one over the long term time.

In this research, the linear assignmentLA method methods were used to give optimum alternatives in de-desertification combating desertification. In accordance with the results, prevention of unsuitable land use changes was estimated as the most important strategy in regionthe study area. And Besides, other alternatives of such as vegetation cover development and reclamation, ~~modification~~ balancing charging of groundwater ~~harvesting~~resources, respectively, were placed in subsequent priorities. ~~So~~Hence, in the framework of macro strategies~~,~~ executive offers are recommended in following:

- Taking serious spatial planning and ~~estimation~~ estimating~~of~~ ecological potential at national, regional and local levels and adapting the applications to the land potential.

- Avoiding land use changes ~~from~~ in poor range lands ~~to farming land with low yield~~with low fertility.

- Avoid the development of ~~industrial and workshop infrastructure~~industries in sensitive and fragile regions~~ of desert and marginal lands.~~.

- In terms of development and reclamation of vegetation ~~try~~ it is better to use endemic and resistant species and pressurized irrigation systems.

- Prevent degradation of *Haloxylon* habitats and ~~effort taken towards~~take especial attention to their rehabilitation.

- ~~Consider the balance~~Balance ~~of~~ the number of livestock and pasture's capacity.

~~- Considering the suitability of livestock to the pastures.~~ Try to reduce the number of goats in poor pastures because ~~this animal is considered as an escalation potential factor in~~of their high potential in degrading rangelands.

- Avoid grazing off-season in desert rangelands (early and late grazing) ~~because of~~due to degradation of poor vegetation.

- According to protect rangelands and support ranchers, ~~used to produce and import forage increase~~forages should be cultivated more or be imported from another countries; in other words, when government supports ranchers in providing forages they may stop cutting brush or overgraze their livestock in rangelands during winter or nights. ~~the sustainable economic potential of ranches to stop them from residue grazing of farms and gardens and cutting brush which they do for night and winter livestock grazing, so acceleration of the degradation is prevented.~~

The results of this research can be used in future investments aiming at obtaining a sustainable development, so that the marginal ecosystems and investments in arid and semi-arid region will be protected. On the other hand, it will help the managers of desert lands to perform restricted facilities in susceptible areas to get better and suitable results and avoid investments wasting.

Finally, it is recommended ~~to~~ that all ~~combating~~ combating desertification's projects ~~schemes~~ in the study area be done based on ~~these~~ all aforementioned alternatives. In this case, ~~is to prevent loss of limited investments~~less investment would be wasted and ~~increase~~ the efficiency ~~of control~~of such rehabilitation projects~~,~~ may increase. ~~reclamation and construction plans~~. The results of this study will allow desert managers to apply limited investment and facilities in efficient ways ~~,~~ which are assigned to control the process of desertification. ~~So~~ In that case,~~either~~ we can achieve better results ~~or~~ and avoid wasting the national investments.

The results of this research can be ~~used~~ applied in future investments aiming ~~at~~ to obtain~~ing~~ a sustainable development, so ~~that~~ the marginal ecosystems and investments in arid and semi-arid region will be protected. ~~On the other hand~~Meanwhile, it will help the managers of desert lands to perform restricted facilities in susceptible areas to get better and suitable results and avoid investments wasting.

**References**


Asgharpour, M. J.: Multiple criteria decision making, University of Tehran, Tehran, p. 397, 1999.

Azar, A., Memariani, A.: AHP new technique for group decision, *Knowledge Management* Magazine, 28(4), 22-32, 2003.

Azar, A., Rajabzadeh, A.: Applied decision making (1st ed., p. 185). Tehran: Negahe Danesh, 2002.

Bernardo, J. J., Blin, J. M.: A programming model of consumer choice among multi-attributed brands. J Consum Res, 4, 111-118, DOI: http://dx.doi.org/10.1086/208686,1977.

Burkard R. E., Qela, E.: Linear assignment problems and extensions, in Handbook of Combinatorial Optimization, Springer, 75–149, 1999.

Celi, R.: Rotorcraft dispatching in large-scale emergencies using sequential linear assignment techniques, Presented at the at the AHS 63rd Annual Forum, Virginia Beach, VA, 2-4 May, 2007.

Forest, Rangeland and Watershed Institute: summary of management program of Iran desert area (2005-2024), 61 p., 2005.

Ghodsipour, S. H.: Analytical Hierarchy Process (AHP), Amirkabir University, Tehran, 220 p, 2002.

Grau, J. B., Anton, J. M., Tarquis, A. M., Colombo, F., Rios, L. and Cisneros, J. M.: Mathematical model to select the optimal alternative for an integral plan to desertification and erosion control for the Chaco Area in Salta Province (Argentine), Biogeosciences Discussion, 7, 2601–2630, DOI: 10.5194/bg-7-3421-2010, 2010.

Hosseinzadeh, S. Y., Khosravibaygi, R., Istageldi, M., Shamsodini, R.: An assessment of environmental assessment of urban area Using the technique of linear allocation Multiple Criteria Decision Makin (Case study: Bandar-e Turkaman city, Iran), Journal of Geographical Landscape, 16(1), 31-51, 2011.

Ivani1, H., Sofi, M.: Assessment of Regional Development Using Taxonomy Model (A Case of Razavi Khorasan, Iran), American Journal of Engineering Research, 3(11), 12-17, 2014.

Ji, Z., Leu, M. C., Wong, H.: Application of Linear Assignment Model for Planning of Robotic Printed Circuit Board Assembly. J Electron Packag, 114 (4), 455-460, doi:10.1115/1.2905480, 1992.

Law Office of Environment and Parliamentary Affairs, International Contract, Laws and regulations the environment protection, Publication of Environment Organization, 847 p., 2004.

Liu, S. C.: A Fuzzy Multiple Attribute Decision Making Approach for Linear Assignment Problems. Fifth Asia Pacific Decision Sciences Institute Conference Waseda University, Tokyo, Japan, July 24-27, 2000.

Meshkat, M. A.: Integrated methods for monitoring and assessing desertification, publication of Forest, Rangeland and Watershed Institute, 145 p., 1998.

Mianabadi, H., Afshar, A.: Multi attribute decision making to rank urban water supply schemes*",* Water & Wastewater Journal, 19(66), 34-45, 2008.

Miao, L., Moore, J.C., Zeng, F., Lei, J., Ding, J., He, B., Cui, X.: Footprint of Research in Desertification Management in China, Land Degrad. Dev., 26 (5), pp. 450-457, 2015. DOI: 10.1002/ldr.2399

Mohammadi, A.: A comparative applied study of linear allocation TOPSIS method and Taxonomy in financial evaluation, Economic Research, 11 (1), 273-302, 2011.

Pomerol, J. C., Romero, S.B.: Multi-Criterion Decision in Management: Principles and practice, (International Series in Operations Research & Management Science) Netherlands: Kluwer Academic, Dordrecht, 2000.

Ramesht, M. H., Arabameri, A. R.: Shahrood-Bastam Basin Zoning for the Purpose of Artificial Underground Aquifer Recharge by Using Linear Assignment Method and GIS Technique, Geographic Space 40(4),134-149, 2012.

Saaty, T. L., Vargas, L. G.: Decision, making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks, New York: Springer, 2006.

Saaty. T. L,: Decision making for leaders: The Analytic Hierarchy Process for Decision in a complex world ,vo1 H,Rws, 1995.

Sadeghiravesh, M. H.: Assessment of Combat Desertification Alternatives Using Permutation method, case study: Khezr Abad region, Yazd province, J. Environ. Plan. Manage. 10, 1-10, 2013.

Sadeghiravesh, M. H.: Evaluation of combat desertification alternatives by using BORDA ranking model, Case study: Khezr Abad region, Yazd province. Journal of environmental management and planning, 1, 13-24, 2014.

Sadeghiravesh, M. H., Khosravi, H., Ghasemian, S.: Application of fuzzy analytical hierarchy process for assessment of combating-desertification alternatives in central Iran, Nat Hazards, 75 (1), 653-667, 2015.

Sadeghiravesh, M. H., Ahmadi, H., Zehtabian, G.H., Tahmores, M.: Application of analytical hierar- chy process (AHP) in assessment of dedesertification alternatives, case study: Khezrabad region, Yazd province, Iranian journal of Range and Desert Research, 17(1): 35-50, 2010.

Sadeghiravesh, M. H., Khosravi, H., Abolhasani, A., Shekoohi, S., Evaluation of Combating Desertification Alternatives using PROMETHEE Model, Journal of Geography and Geology, 8(1), 28-41, 2016.

Sadeghiravesh, M. H., Zehtabian, G. R., Ahmadi, H., Khosravi, H.: Using Analytic Hierarchy Process method and Ordering Technique to Assess Combating desertification Alternatives (Case study: Khezrabad, Yazd, Iran), Carpath J of Earth and Env Sci, 7(3), 51-60, DOI: 10.1007/s11069-014-1345-7, 2012.

Sadeghiravesh, M. H., Zehtabian, G.: Combat desertification alternatives classification with using of Multi Attribute Decision Making (MADM) view point and Weighted Sum Model (WSM), Case study: Khezr Abad region, Yazd province, Journal of Pajouhesh & Sazandeghi, 100, 1-11, 2013.

Sadeghiravesh, M. H., Zehtabian, G. R.: Assessment of Combating ~~desertification~~Desertification Alternatives Using Analytic Hierarchy Process method and Technique for Order Preference by Similarity to Ideal Solution, Journal of Sciences and Techniques in Natural Resources, 6(3), 17-30, 2012.

Sadeghiravesh, M. H., Zehtabian, Gh., Khosravi, H.: Application of AHP and ELECTRE models for assessment of combating desertification alternatives, Desert, 19(2), 141-153, 2014.

Sayyadi, A. R., Hayati M., Azar, A.: Assessment and Ranking of Risks in Tunneling Projects Using Linear Assignment Technique, International Journal of Industrial Engineering and Protection Management, 22 (1), 27-38, 2011.

Sepehr, A., Peroyan. N.: vulnerability Mapping of desertification and combat desertification alternative ranking in Korasan-e-razavi province ecosystems with application PROMETHEE model, Journal of Earth science research, 8, 58-7, 2011.

Sobhani, A., Khosravi, H.: Assessing Environmental Sensitivity Areas to Desertification in North of Iran, Curr World Environ, 10(3), 890-902, doi.org/10.12944/CWE.10.3.19, 2015.

Symeonakis, E., Karathanasis, N., Koukoulas, S., Panagopoulos, G.: Monitoring sensitivity to land degradation and desertification with the environmentally sensitive area index: The case of lesvos island. Land Degrad. Dev. DOI: 10.1002/ldr.2285, 2014.

Tajoddini, I.: Identification and prioritization of quality standard Prerequisites in industry, Modiriat farda, 2 (1), 82-88, 2003.

Vieira, R.M.S.P., Tomasella, J., Alvalá, R.C.S., Sestini, M.F., Affonso, A.G., Rodriguez, D.A., Barbosa, A.A., Cunha, A.P.M.A., Valles, G.F., Crepani, E., De Oliveira, S.B.P., De Souza, M.S.B., Calil, P.M., De Carvalho, M.A., Valeriano, D.M., Campello, F.C.B., Santana, M.O.: Identifying areas susceptible to desertification in the Brazilian northeast. Solid Earth, 6 (1), 347-360, 2015. DOI: 10.5194/se-6-347-2015

Xie, L.W., Zhong, J., Chen, F.F., Cao, F.X., Li, J.J., Wu, L.C.; Evaluation of soil fertility in the succession of karst rocky desertification using principal component analysis. Solid Earth, 6 (2), 515-524, 2015. DOI: 10.5194/se-6-515-2015

Xu, E.Q., Zhang, H.Q.: Characterization and interaction of driving factors in karst rocky desertification: A case study from Changshun, China. Solid Earth, 5 (2), 1329-1340, 2014. DOI: 10.5194/se-5-1329-2014

# Assessment of combating desertification strategies using the linear assignment method

M. H. Sadeghravesh[a], H. Khosravi*[b], S. Ghasemian[b]

[a] Department of Environment, College of Agriculture, Takestan Branch, Islamic Azad University, Takestan, Iran
b Department of Arid and Mountainous Reclamation Region, Faculty of Natural Resources, University of Tehran, Tehran, Iran.

*Correspondence to*: h. khosravi (hakhosravi@ut.ac.ir)

***Abstract***

Nowadays desertification, as a global problem, affects many countries in the world especially developing countries like Iran. With respect to increasing importance of desertification and its complexity the necessity of attention to the optimal combating desertification alternatives is essential. Selecting appropriate strategies according to all effective criteria in combating desertification process can be so useful in rehabilitating degraded lands and avoid degradation in vulnerable fields. This study provides systematic and optimal strategies of combating desertification by group decision-making model. To this end, the preferences of indexes were obtained through using Delphi model; in the framework of Multi Attribute Decision Making (MADM). Then, priorities of strategies were evaluated by using linear assignment (LA) method. According to the results, the strategies to prevent improper change of land use (A18), development and reclamation of plant cover (A23), and control overcharging of groundwater resources (A31) respectively were identified as the most important strategies for combating desertification in this study area. Therefore, it is suggested that the aforementioned ranking results be considered in projects which control and reduce the effects of desertification and rehabilitate degraded lands.

**Keywords:** desertification, Multi Attribute Decision Making, Linear Assignment model, pair wise comparisons.

## 1Introduction

Desertification is a significant global ecological and environmental problem. That is one type of land degradation in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water, vegetation and wildlife. It is caused by a variety of factors such as climatic changes and human interferences. According to United Nations Conference on Desertification (UNCOD), desertification process threatens more than 785 million people living in the arid regions. Of this number, 60 to 100 million people are affected by this phenomenon directly due to the loss of land fertility and other desertification processes (Meshkat, 1998). There are 100 million hectares in Iran faced desertification especially wind erosion, water erosion and physicochemical destruction (Forest, Rangeland and Watershed Institute, 2005).

combating desertification includes activities that are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development which are aimed at:(i) prevention and/or reduction of land degradation, (ii) rehabilitation of partly degraded land and (iii) reclamation of desertified land (Law Office of Environment and Parliamentary Affairs, 2004). By taking this framework into account, this study tries to present a systematic method for providing effective solutions among the several solutions based on different desertification criterion. Therefore, in order to achieve this goal decision-making models and linear assignment (LA) method were used to rank desertification alternatives.

Managing desert ecosystems consist of various managements in order to control desertification phenomenon and minimize economic, social and environmental loss. Making decision in management of desert areas becomes a complex process due to existence of various indexes and various criterions for decision in such areas. There are several methods in managing desert regions, and each has different preferences for environmental, social, political, economic and organizational issues. Among these different methods Multi Attribute Decision Making (MADM) can provide best answers in comparison with the others. The purpose of this study, by considering limitation of inputs, is assessing desertification strategies to achieve the optimal strategies in the framework of sustainable management of desert area. To achieve this goal Linear Assignment (LA) method which is one kind of Concordance Methods was used in the framework of MADM to rank combating desertification strategies. This method has simple algorithm that can engage simultaneously a large number of quantitative and qualitative criteria in the decision process. Besides, in different intervals of time and place, it is also capable to change the input data and provide new assessment according to this change. Therefore comparative studies would be easy to do (Asgharpour, 1999).

Since LA uses descriptive data instead of principal data, and it is easy to understand it has been applied in various fields of science (Bernardo and Blin, 1977). Some of these studies include; assessment of environmental sustainability (Hosseinzadeh et al., 2011), assessing and ranking risks (Sayadi et al, 2011), monitoring sensitivity of desertification (Symeonakis et al., 2014), footprint of research in desertification management (Miao et al., 2015), characterization and interaction of driving factors in desertification (Xu and Zhang, 2014), identifying susceptible areas toward desertification (Vieira et al., 2015), evaluation of soil fertility in the succession of karst rocky desertification (Xie et al., 2014), assessing environmental sensitivity of areas toward desertification (Sobhand and Khosravi, 2015), financial assessment of companies (Mohammadi, 2011), assessment of strategies of water supply (Mianabadi and Afshar, 2008), zoning watersheds (Ramesht and Arabameri, 2012), assignment of water resource in order to minimize the energy consumption (Joung et al, 2012), programming of robots (Ji et al, 1992), programming for dispatching helicopter in emergency missions (Celi, 2007) and so on and so forth.

By studying the research literature using decision models to provide optimal strategies in desert management is limited to research of Grau et al, Sadeghiravesh et al, and Sepehr and Peroyan. In order to select the optimal strategies for providing an integrated plan to control erosion and desertification, Grau used three decision models in his research; ELECTRE, AHP and PROMETHEE (Grau et al, 2010). The results indicate the high efficiency of these models to provide optimal strategy of desertification. Because of using complex methods in each model the results were largely the same. Sadeghiravesh prioritize the strategies in Khezr Abad region by using the following models; Analytical Hierarchy Process (AHP) (Sadeghiravesh et al, 2010), Elimination et Choice Translating Reality (ELECTRE) (Sadeghiravesh et al., 2014), Weighted Sum Model (WSM) (Sadeghiravesh and Zehtabian, 2013), BORDA (Sadesghi Ravesh, 2014), and PERMUTATION (Sadeghiravesh , 2013), Preference Ranking Organization Method For Enrichment Evaluation (PROMETHEE) (Sadeghiravesh et al, 2016). The results of these studies are same and largely similar to the results of previous research. Sepehr and Proyan zoned vulnerability of desertification in the ecosystems of Khorasan Razavi Province and evaluated these strategies to combat desertification (Sepehr and Peroyan, 2011).

All in all, determining the effective combating desertification alternatives and criteria are essential for achieving efficient combating desertification projects. Hence, this research presents linear assignment method to objectively select the optimal combating desertification alternatives based on the results of interviews with experts in Khezr Abad region in Yazd province, Iran as the case study.

## 2 Material and methods

### 2.1 Study area

The Khezr Abad region in Yazd province, central Iran, was considered for optimal determination of alternatives to combat desertification. The study area is located nearly 10 km west of Yazd. The region extends from 53°55´ to 54°20´ east in longitude and from 31°45´ to 32°15´ north in latitude and covering an area of about 78,180 ha (Fig.1). The climate of the study area is cold and arid; based on the Amberje climate classification method (Sadeghiravesh, 2008). About 12,930 ha (16%) of the region is hilly, a sand-dune area[4], which is a part of the Ashkezar Great Erg[5], located in the northern part of the study area. About 9,022 ha (12%) of the area consists of bare lands, clay plain and desert pavement[6] (Sadeghiravesh, 2008; Kazemi Nejad, 1996). About 1,995 ha (26.5%) of all the agricultural land in the region consists of degraded or abounded lands with human activities such as traditional irrigation and natural processes like wind erosion and dust. The study area shows an absolutely typical condition of desertification, so effective solutions and optimal means of combating desertification must be pursued.

4 . An isolated hill, knob, ridge, outcrop, or small mountain.
5 . An erg (also sand sea or dune sea, or sand sheet if it lacks dunes) is a broad, flat area of desert covered with wind-swept sand
6. A desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size.

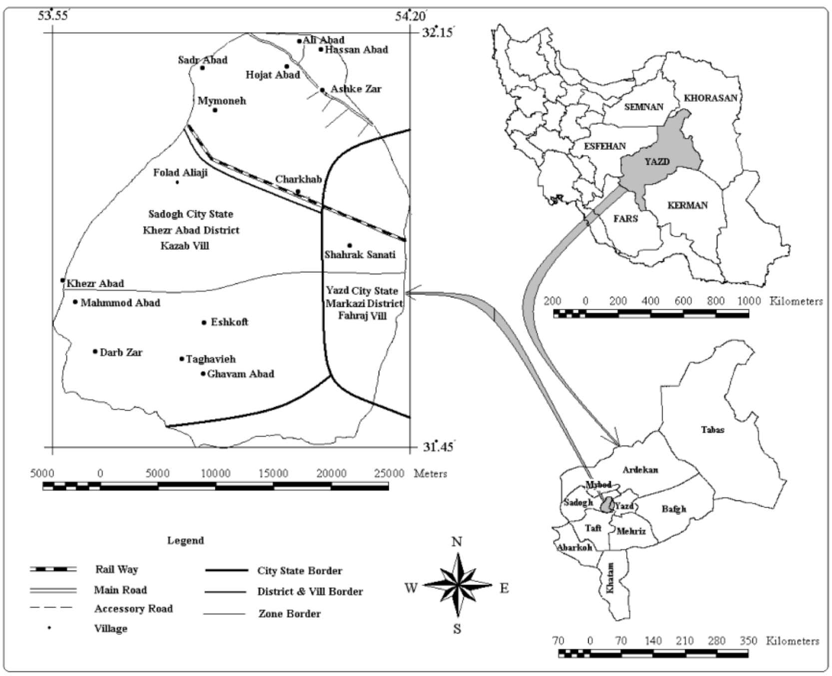



**Figure1.** Location of the study area

**2.2 Methodology**

Linear Assignment is one of the most important methods of Multi Attribute Decision Making (MADM) and subset of Concordance Methods. LA can help decision makers to choose the best option due to combining qualitative and quantitative indexes and providing appropriate weighting for each criterion. The output of this model is a collection of ranks, so it provides the required coordination in the most suitable way. In this method given choices of moot point are ranking according to their scores on each index and the final ranking of the alternatives will be characterized through linear compensation process (for every possible interaction between indexes) (Asgharpour, 1999). Based on the property simplex solution space of LA, the optimum solution is extracted in a convex space simplex and by considering all the arrangements implicitly. Moreover, the compensation property of the indexes is obtained from exchange between ranks and options (Pomerol and Romero, 2000); however, the weight vector of indexes has been obtained through expert opinion and Delphi model.

**2.2.1 Selection criteria and effective strategies**

Selecting criteria and alternatives can be done individually according to expert experience, resources, field studies and Delphi method. For this aim, the structured questionnaire in two parts including 16 criteria and 40 alternatives was distributed among experts familiar with the study area. The experts were asked to rate effective criteria and alternatives between 0 and 9. Finally, arithmetical mean was used to calculate the mean of obtained results, and mean values were calculated. In this case, if the mean value was less than 7 ($\overline{X}$ <7) related criterion and alternative was removed, and if the mean value was more or equal to 7 ($\overline{X}$ ≥7) related criterion and alternative was used as effective criteria (Azar and Rajabzadeh 2002; Azar and Memariani, 2003). Tables 1 and 8 show the recommended alternatives, offering criteria respectively.

**Table1.** The criteria and their importance mean according to the group

| Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| Criteria | Expenses-benefit | Time | Participation of local communities | Beauty of landscape | Access to the technologies and scientific methods and devices | Access to the related expert |
| Code | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
| Criteria | Proportion and adaptation to the environment (sustainability) | Traditional managemen t and local knowledge | Democratic government authority in combating-desertification projects | Oil income of government | Temporary management of projects | The problems resulted from innovation and method changes |
| Code | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ | | |
| Criteria | Indolence state administrative systems | Social and political pressures | Emergency issues related to desertification occurrence | Destruction of resources, human and social damages | | |

**2.2.2 Calculate local priority of criteria and alternatives and establish group pairwise comparisons matrix**

In order to achieve Local Priority, the structured questionnaire was designed based on literature and the nine-point Sa'aty scale; 1(least important) to 9 (most important). They were used to measure the relative importance of criteria and priority of combating desertification alternatives (Table 2).

The questionnaire was distributed among experts familiar with the study area. Using geometric mean and assumption of expert's opinion (considering all opinions have same value) pairwise comparisons matrixes were obtained according to Eq.1 and formed in a group format (Table 3).

$$\bar{a}_{ij} = \left(\pi_{k=1}^{N} a_{ij}^{\ k}\right)^{\frac{1}{N}} \qquad (1)$$

In this equation aijk = component of k expert to comparison i and j. So, āij (geometric mean) for all corresponding components is obtained by Eq. 1 (Azar and Rajabzadeh, 2002; Ghodsipour, 2002).

**Table2.** Importance and priority degree of nine-point Satty's scale

| Score | Importance Degree | Priority Degree in Pair wise Comparison |
|---|---|---|
| 1 | Non-importance | Equal |
| 2 | Very low | Equal-Moderately |
| 3 | Low | Moderately |
| 4 | Relatively low | Moderately - Strongly |
| 5 | Medium | Strongly |
| 6 | Relatively high | Strongly-Very strongly |
| 7 | High | Very strongly |
| 8 | Very high | Very strongly-Extremely |
| 9 | Excellent | Extremely |
| 1/2, 1/3,1/4, …., 1/9 | | Mutual Values |

**Table 3.** Pair wise comparisons matrix

$$A= \begin{matrix} a_{11} & a_{12} & \ldots\ldots\ldots\ldots & a_{1n} \\ a_{21} & a_{22} & \ldots\ldots\ldots\ldots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \ldots\ldots\ldots\ldots & a_{nn} \end{matrix} \qquad A=[a_{ij}] \quad i,j=1,2,\ldots,n$$

$a_{ij=}$ preference of i criteria to j criteria

**2.2.3 Compute the priorities based on group pair wise of comparisons tables**

At this stage, the data of group pairwise comparison matrixes were imported in EC software to evaluate criteria importance and alternatives priority to each criterion (Godsipour, 2002). After normalization by using Eq. 2 importance and priorities percent were showed as bar graphs using harmonic mean method or average of each level of normalized matrix (Tables 5 and 6).

$$\overline{r}_{ij} = \frac{\overline{a}_{ij}}{\sum_{i=1} \overline{a}_{ij}} \qquad (2)$$

In this equation:

$\overline{r}_{ij}$ = normal component

ij ā = group pair wise comparison component of i to j

Σāij = total column of group pair wise comparisons

**2.2.4 Formation of Normalized Decision Matrix (NDM)**

The weight values of criteria importance (Wj) and alternative priorities (Pij) is considered in the form of a decision matrix based on any criteria (Table 4).

**Table4.** Normalized Decision Matrix

| Alt | Criterion | | | | |
|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | ----------- | $C_n$ |
| | $W_1$ | $W_2$ | $W_3$ | ----------- | $W_n$ |
| $A_1$ | $P_{11}$ | $P_{12}$ | $P_{13}$ | -------- | $P_{1n}$ |
| $A_2$ | $P_{21}$ | $P_{22}$ | $P_{23}$ | ----------- | $P_{2n}$ |
| : | : | : | : | : | : |
| $A_m$ | $P_{m1}$ | $P_{m2}$ | $P_{m3}$ | ----------- | $P_{mn}$ |

In this matrix: m= the number of choices or alternatives, n= number of criteria, C= title of criteria, W= Weight value of related criteria, $a_{ij}$= weight value each alternative gains in relation to related criteria

**Table5.** Comparison of proposed criteria importance to access the goal

| Criterion | Preference Degree |
|---|---|
| $C_7$ | 33.3 |
| $C_{16}$ | 31.3 |
| $C_6$ | 15.7 |
| $C_5$ | 11 |
| $C_2$ | 8.9 |

Inconsistency Ratio=0.01

**Table6.** Comparison of alternatives preference according to the criteria of proportion and adaptation to the environment

| Alternative | Degree |
|---|---|
| $A_{18}$ | 26.6 |
| $A_{23}$ | 22.7 |
| $A_{31}$ | 19.2 |
| $A_{33}$ | 15.9 |
| $A_{20}$ | 15.5 |

Inconsistency Ratio=0.02

### 2.2.5 Ranking each option for each index

After forming the decision making matrix, attempted to rank the alternatives (Ai) for each criteria (Ci) with respect to the increasing or decreasing trends and n×m matrix framework (Table 7).

**Table7.** Matrix ranking of each option against each index

| **Criteria (C) ►** | $C_1$ | $C_2$ | $C_3$ | …….. | $C_n$ |
|---|---|---|---|---|---|

| Rank (A) ▼ | | | | | |
|---|---|---|---|---|---|
| First | $A_{11}$ | $A_{12}$ | $A_{13}$ | …….. | $A_{1n}$ |
| Second | $A_{21}$ | $A_{22}$ | $A_{23}$ | …….. | $A_{2n}$ |
| Third | $A_{31}$ | $A_{32}$ | $A_{33}$ | …….. | $A_{3n}$ |
| …….. | | | | …….. | |
| …….. | | | | …….. | |
| m | $A_{m1}$ | $A_{m2}$ | $A_{m3}$ | …….. | $A_{mn}$ |

In this matrix: m= the number of choices or alternatives, n= number of criteria, C= title of criteria, $a_{ij}$= each alternative in relation to related criteria

### 2.2.6 Forming two-dimensional matrix, Gamma (γ)

Two-dimensional gamma matrix (γ) (assignment matrix) is formed according to weight vector of the estimated criteria of group pairwise comparison. This matrix is a square matrix ($\gamma_{m.m}$) which has element i in row and element k in column. Matrix elements include the total weight of indexes which alternative i has rank k. Gamma matrix is a assignment matrix, so the optimal solution can be obtained by any kind of assignment methods such as shipping method, hungarian method, grid method and one and zero linear programming method. The most common method for solving the LA is assignment programming method (Pomerol and Romero, 2000).

### 2.2.7 Calculating the final rank for each alternative ($A_i$)

The final ranking/optimal solution of alternatives is obtained by linear programming method and through the following model:

$$\text{Maximize: } \sum_{i=1}^{m} \sum_{k=1}^{m} \gamma_{ik}.h_{ik} \qquad (3)$$

$$\text{subject to: } \sum_{k=1}^{m} h_{ik} = 1 \quad ; i = 1,2,3,\ldots,m \qquad (4)$$

$$\sum_{i=1}^{m} h_{ik} = 1 be \quad ; k = 1,2,3,\ldots,m \qquad (5)$$

$$h_{ik} \begin{cases} = 1 \\ = 0 \end{cases}$$

After solving the linear programming model a square matrix ($H_{m\times m}$) is the one that $A_i$ is given to the final Kth rank ($h_{ik}$=1) ;otherwise $h_{ik}$=0 (Burkard and Qela, 1999; Liu, 2000)

The obvious feature of this method is a simple ranking for alternatives that caused exchanged among indexes and have no complex calculations. Also in this method there is no need for unification scale (Saaty and Vargas, 2006; Asgharpour, 1999). Meanwhile, other methods such as MADM need the both alternatives and indexes for calculating, but ranking process of LA can be done without alternative (Tajoddini, 2003).

**3Result and Discussion**

In the process of combating-desertification alternatives assessment in the study area the Delphi method and questionnaire were used to identify the main criteria and alternatives among 16 criteria and 40 combating-desertification alternatives and establishing hierarchical structure (Saaty, 1995) according to the group format. Tables8 and 9 show the average of alternatives priority and criteria important respectively.

The obtained results of presented questionnaire (to determine importance and priority of criteria and alternatives to establish decision hierarchical structure) show only criteria and alternatives with group mean more than 7. This considered establishing decision hierarchical chart and providing pairwise comparisons questionnaires. Figure 2 show hierarchical decision structure provided based on effective criteria and alternatives to combat desertification.

**Table8.** The criteria importance mean according to the group

| Code | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ | $C_{13}$ | $C_{14}$ | $C_{15}$ | $C_{16}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average values | 5.38 | 7.1 | 5.78 | 5.1 | 7.1 | 7.53 | 8.15 | 5.23 | 5.28 | 5.72 | 2.39 | 2.84 | 2.29 | 5.35 | 6.34 | 7.99 |

**Table9.** The recommended alternatives to combat desertification and their priority according to the groups

| Code | Alternative | values |
|---|---|---|
| $A_1$ | Reducing population growth rates | 5 |
| $A_2$ | poverty alleviation | 5.68 |
| $A_3$ | Establishment and development of rural organizations | 5.35 |
| $A_4$ | Increasing employment | 6.7 |
| $A_5$ | Increasing participation of local community and supporting NGOs | 6.1 |
| $A_6$ | Application of local forces and technology in projects (local knowledge) | 6.56 |
| $A_7$ | Training people in utilization of new methods and use of new knowledge for optimal use of resources | 6.47 |
| $A_8$ | Approval, promotion and implementation of laws and adaptation punishments with the crime | 5.73 |
| $A_9$ | providing needs of local residents | 5.89 |
| $A_{10}$ | modification of unsustainable consumption patterns, changing and improving people's livelihood patterns | 5.6 |
| $A_{11}$ | Considering the role of women and youth in combating - desertification process | 4.5 |
| $A_{12}$ | Organization of urban areas and prevent migration | 5.23 |
| $A_{13}$ | Coordination between responsible agencies and organizations in combating - desertification and environmental protection | 6.86 |

| | | |
|---|---|---|
| $A_{14}$ | Raising the literacy rate | 4.8 |
| $A_{15}$ | Development of desert ecotourism | 5.32 |
| $A_{16}$ | multi- utilization from desert instead of mono utilization | 5.27 |
| $A_{17}$ | Allocation combating - desertification issue to the private sector | 3.79 |
| $A_{18}$ | Prevention of unsuitable land use changes | 7.5 |
| $A_{19}$ | mapping land use planning and determination of desert and salt desert boundaries | 6.44 |
| $A_{20}$ | livestock grazing control | 7.34 |
| $A_{21}$ | Forage Production and increasing economic potential of sustainable husbandry | 6.6 |
| $A_{22}$ | Prevention of plant cutting | 6.46 |
| $A_{23}$ | Vegetation cover Development and reclamation | 7.56 |
| $A_{24}$ | Protection of *Haloxylon spp*. | 6.76 |
| $A_{25}$ | Protection of gravel surfaces (Reg) | 6.45 |
| $A_{26}$ | prevention and reduction in heavy agricultural and industrial machineries traffics | 5.57 |
| $A_{27}$ | Create living and non- living wind break for soil conservation | 6.86 |
| $A_{28}$ | Improvement of soil texture | 4.66 |
| $A_{29}$ | modification of crop rotation and follow methods | 5.42 |
| $A_{30}$ | Modification of ploughing, fertilization, spraying methods | 5.1 |
| $A_{31}$ | Modification of groundwater harvesting | 7.24 |
| $A_{32}$ | Reduction in water consumption (water optimal consumption in farms) | 6.6 |
| $A_{33}$ | Change of irrigation patterns | 7.49 |
| $A_{34}$ | Changing traditional irrigation systems with low to modern systems with high efficiency | 6.53 |
| $A_{35}$ | optimal Collecting and harvesting of water resources (including rivers isolating, Qanat repairing and dredging, utilization of canals and streams and desalination of salty waters) | 6.64 |
| $A_{36}$ | Groundwater feed | 6.08 |
| $A_{37}$ | Construction of flood broadcast networks and the use its alluviums | 5.3 |
| $A_{38}$ | Creation of artificial precipitation to feed aquifers | 3.47 |
| $A_{39}$ | Promotion of greenhouse cultivation | 6.2 |
| $A_{40}$ | Introduction of new plant varieties, resistant to drought and dehydration stress by genetic engineering | 6 |

### 3.2 Calculate relative weight of criteria and alternatives and format group decision matrix (DM)

In order to estimate the relative weight or priority of criteria and alternatives, pairwise comparisons questionnaire was prepared and distributed among the experts. In continuation, the group pairwise comparison matrixes of criteria importance and alternatives priority to each criterion were formed by obtaining expert opinions and combining their ideas by geometric mean. To prevent the prolongation of the word, just matrix of criteria importance (Table 10) and alternative priorities to each criteria calculated by this method are presented.

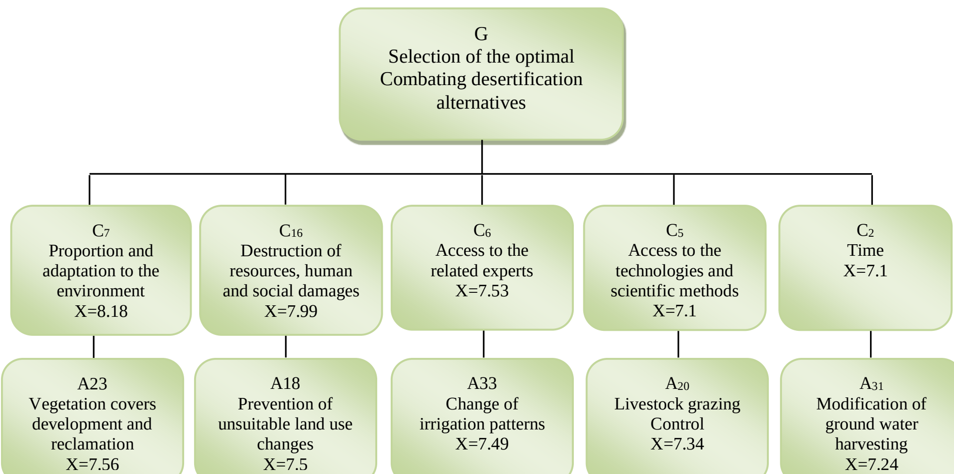



**Figure2.** Hierarchical decision structure to select optimal combating desertification alternatives in study area

**Table10.** Pairwise comparisons matrix of the criteria importance to access the goal of "offering optimal combating desertification alternatives"

| Criterion | $C_{16}$ | $C_6$ | $C_5$ | $C_2$ |
|---|---|---|---|---|
| $C_7$ | 1.2 | 2.5 | 2.5 | 3.4 |
| $C_{16}$ | | 2.3 | 3.1 | 3.1 |
| $C_6$ | | | 1.7 | 2 |
| $C_5$ | | | | 1.3 |

In continuation, matrix values of criteria importance and alternatives priorities (Table10) were entered to EC software based on each criterion importance of combating desertification criteria. Alternatives were obtained in a group format. Besides, graphs prepared based on percentage using normalization and harmonic mean (Table11).

**Table11.** Comparison of proposed criteria importance to access the goal

| Criterion | Preference Degree |
|---|---|
| $C_7$ | 33.3 |
| $C_{16}$ | 31.3 |
| $C_6$ | 15.7 |


Inconsistency Ratio=0.01

Considering these graphs, it is observed that the alternatives are different based on each criterion. Therefore, decision making matrix of optimal combating desertification alternatives according to the group (Table 12) was formed to select final alternatives and classification of their priorities in general framework of MADM (Table 4).

**Table12.** Decision matrix of optimal combating desertification alternatives according to group

| Criteria importance (C) ► | C2 | C5 | C6 | C16 | C7 |
|---|---|---|---|---|---|
| Alternatives priority (A) ▼ | 0.0892 | 0.1095 | 0.1576 | 0.3074 | 0.3365 |
| A23 | 0.2509 | 0.2387 | 0.2488 | 0.1805 | 0.2257 |
| A18 | 0.1960 | 0.1635 | 0.1983 | 0.2383 | 0.2643 |
| A33 | 0.1620 | 0.2565 | 0.2093 | 0.1510 | 0.1599 |
| A20 | 0.2229 | 0.1762 | 0.1608 | 0.2209 | 0.1582 |
| A31 | 0.1682 | 0.1633 | 0.1826 | 0.2092 | 0.1918 |

**3.3 Ranking each option for each index**

After forming the decision making matrix attempted to rank the alternatives (Ai) for each criteria (Ci) in a 5×5 matrix which the rows represent rank and columns represent the index (Table13). Decision matrix of combating desertification alternatives has increasing trend which means the allocate number of each alternative is more than the number of each criterion, so that alternative is more desirable among the others.

**Table13.** Matrix of alternative ranking

| **Criteria (C) ►** / **Rank (A) ▼** | $C_7$ | $C_{16}$ | $C_6$ | $C_5$ | $C_2$ |
|---|---|---|---|---|---|
| First | $A_{18}$ | $A_{18}$ | $A_{23}$ | $A_{33}$ | $A_{23}$ |
| Second | $A_{23}$ | $A_{20}$ | $A_{33}$ | $A_{23}$ | $A_{20}$ |
| Third | $A_{31}$ | $A_{31}$ | $A_{18}$ | $A_{20}$ | $A_{18}$ |
| Forth | $A_{33}$ | $A_{23}$ | $A_{31}$ | $A_{18}$ | $A_{31}$ |
| Fifth | $A_{20}$ | $A_{33}$ | $A_{20}$ | $A_{31}$ | $A_{33}$ |

**3.4 Forming $\gamma_{5\times5}$ matrix according to criteria weights (W)**

At this stage a 5 × 5 gamma matrix is formed, and it was estimated by sum of indexes weights which the alternative of i has rank of k. As mentioned, the weight of each index was calculated by survey of experts and based on Delphi method (Table 14).

Gamma matrix is an assignment matrix, and the optimal answer can be obtained by any of assignment methods. The most common method for solving the linear assignment method is linear programming.

**Table14.** The matrix of number time weight of ranking options

| Rank (C) ► / Alternative Priority (A) ▼ | First | Second | Third | Forth | Fifth |
|---|---|---|---|---|---|
| $A_{23}$ | 0.2468 | 0.446 | 0 | 0.3074 | 0 |
| $A_{18}$ | 0.6439 | 0 | 0.2468 | 0.1095 | 0 |
| $A_{33}$ | 0.1095 | 0.1576 | 0 | 0.3365 | 0.3966 |
| $A_{20}$ | 0 | 0.3966 | 0.1095 | 0 | 0.4941 |
| $A_{31}$ | 0 | 0 | 0.6439 | 0.2468 | 0.1095 |

### 3.5 Ranking alternatives

For final ranking of alternatives linear programming was used (Eq. 1 to 3), and scoring table of options or optimal matrix was formed (Table 11). Since the decision variable contains zero and one value, the output of this program is provided only based on the number 1 in Table 15. The table16 was formed according to table15.

**Table15.** The options scoring

$$*=H \begin{vmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{vmatrix}$$

The optimal objective function = 2.6245

→

**Table16.** The matrix of options optical order

$$A=*\times H \begin{vmatrix} 0 & A_{18} & 0 & 0 & 0 \\ A_{23} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & A_{31} \\ 0 & 0 & 0 & 0 & A_{33} \\ 0 & 0 & A_{33} & 0 & 0 \end{vmatrix}$$

**Table17.** The options ranking

$$\rightarrow \quad \begin{vmatrix} A_{18} & A_{23} & A_{31} & A_{33} & A_{20} \end{vmatrix}$$

Based on Table 17, the preference of alternatives was obtained as $A_{18} > A_{23} > A_{31} > A_{33} > A_{20.}$ After evaluating all alternatives the $A_{18}$ considered as the best one among the others.

## 4 Discussions

In this study a new method was presented to rank combating desertification alternatives priority. The results of final prioritization of alternatives by using LA method was similar to the results of the following methods; AHP (Sadeghiravesh et al, 2010), TOPSIS (Ivani1 and Sofi, 2014), ELECTER (Sadeghiravesh et al., 2014) and WSM (Sadeghiravesh and Zehtabian, 2013). This means alternatives $A_{18}$, $A_{23}$ and $A_{31}$ were ranked respectively first to third. It should be mentioned that LA method has limitation of ignoring decision-makers fuzzy judgment as well as aforementioned methods. Besides, some criteria have qualitative or unknown structure that cannot be accurately measured. In such case, fuzzy numbers can be used in order to achieve evaluation matrix, and prioritization method can be developed using fuzzy method. Another disadvantage of LA method is regarding the amount of data and considering only the data ranks. Therefore, large amounts of data are lost and achieving high accuracy results would not be possible (Mohammadi, 2011). Consequently, it is better to do not use rating models as ELECTER and LA when accurate amounts of data are available. Following results were obtained using pairwise comparisons questionnaires, mean of expert's opinion, group pairwise comparisons matrix of importance, and priority of criteria and alternative. According to decision matrix's table of optimal combating desertification alternatives (Table 12), criteria of proportion and adaptation to environment ($C_7$) and time ($C_2$) have the highest and lowest importance respectively. Criterion proportion and adaptation to the environment ($C_7$) with the importance degree of 33.6% and destruction of resources, human and social damages ($C_{16}$) with 30.7% were placed in first and second order, respectively. This indicates that experts are more concern about environmental issues, and challenges rose in environmental degradation. Also, these tables represent alternatives priority to each criterion. As is taken from the table, selected alternatives will be different according to each criterion. Therefore, selecting final alternatives and rank their priority combinations were conducted on decision matrix by LA model; besides, alternatives priorities were formed base on set of criteria. According to the results of final alternatives' prioritization and by considering all the alternatives, execution of prevention of unsuitable land use changes ($A_{18}$), vegetation cover development and reclamation ($A_{23}$), and modification of ground water harvesting ($A_{31}$), the desertification process can be stopped, and the degraded lands can be rehabilitate. Therefore, it can be expressed in the study area that land use changes are mainly caused by increasing population, unemployment, growth of industry and increasing in urbanization's desires. As an illustration, land use changes are largely happened in recent years because of pressure of drought and industrial growth which lead to conversion of pastures into farms and gardens. As a consequent result, enormous amounts of deep and semi-deep motorized wells have installed in the study area. Rangelands consist of 6 to 15 percent of case area which is strongly influenced by human activities in terms of cutting brush and livestock overgrazing, so that 40 to 50 percent of plant cover are destroyed. Irrigation in agricultural lands is mostly flooding with outdoor pools and outdoor streams with large pores in bed; therefore, more than 50% of water's consumption is wasted and the efficiency of irrigation and transmission is estimated less than 40 percent.

## 5 Conclusions

The obtained results of presented questionnaire (to determine importance and priority of criteria and alternatives to establish decision hierarchical structure) show only criteria and alternatives with group mean more than 7. This considered establishing decision hierarchical chart and providing pairwise comparisons questionnaires.

Desertification is the persistent degradation of dry land ecosystems which is caused mainly by climatic changes and human interferences.  More than 85% of Iran is consist of arid, semi-arid and hyper-arid regions with 34 million ha of desert zones. Therefore, the major part of the country is susceptible to desertification. Although, the government has performed many projects to combat desertification in recent years it seems that they are not adequate due to the country's extensive arid regions. The problem needs more attention and effective national cooperation as well as international one over the long time.

In this research the LA method was used to give optimum alternatives in combating desertification. In accordance with the results, prevention of unsuitable land use changes was estimated as the most important strategy in the study area. Besides, other alternatives such as vegetation cover development and reclamation, balancing charging of groundwater resources respectively were placed in subsequent priorities. Hence, in the framework of macro strategies executive offers are recommended in following:

- Taking serious spatial planning and estimating ecological potential at national, regional and local levels and adapting the applications to the land potential.
- Avoiding land use changes in poor range lands with low fertility.
- Avoid the development of industries in sensitive and fragile regions.
- In terms of development and reclamation of vegetation it is better to use endemic and resistant species and pressurized irrigation systems.
- Prevent degradation of *Haloxylon* habitats and take especial attention to their rehabilitation.
- Balance the number of livestock and pasture's capacity.
- Try to reduce the number of goats in poor pastures because of their high potential in degrading rangelands.
- Avoid grazing off-season in desert rangelands (early and late grazing) due to degradation of poor vegetation.
- According to protect rangelands and support ranchers, forages should be cultivated more or be imported from another countries; in other words, when government supports ranchers in providing forages they may stop cutting brush or overgraze their livestock in rangelands during winter or nights.

The results of this research can be used in future investments aiming to obtain a sustainable development, so that the marginal ecosystems and investments in arid and semi-arid region will be protected. On the other hand, it will help the managers of desert lands to perform restricted facilities in susceptible areas to get better and suitable results and avoid investments wasting Finally, it is recommended that all combating desertification's projects in the study area be done based on all aforementioned alternatives. In this case, less investment would be wasted and the efficiency of such rehabilitation projects may increase. The results of this study will allow desert managers to apply limited investment and facilities in efficient ways which are assigned to control the process of desertification. Hence, we can achieve better results and avoid wasting the national investments.

**References**

Asgharpour, M. J.: Multiple criteria decision making, University of Tehran, Tehran, p. 397, 1999.

Azar, A., Memariani, A.: AHP new technique for group decision, *Knowledge Management* Magazine, 28(4), 22-32, 2003.

Azar, A., Rajabzadeh, A.: Applied decision making (1st ed., p. 185). Tehran: Negahe Danesh, 2002.

Bernardo, J. J., Blin, J. M.: A programming model of consumer choice among multi-attributed brands. J Consum Res, 4, 111-118, DOI: http://dx.doi.org/10.1086/208686, 1977.

Burkard R. E., Qela, E.: Linear assignment problems and extensions, in Handbook of Combinatorial Optimization, Springer, 75–149, 1999.

Celi, R.: Rotorcraft dispatching in large-scale emergencies using sequential linear assignment techniques, Presented at the at the AHS 63rd Annual Forum, Virginia Beach, VA, 2-4 May, 2007.

Forest, Rangeland and Watershed Institute: summary of management program of Iran desert area (2005-2024), 61 p., 2005.

Ghodsipour, S. H.: Analytical Hierarchy Process (AHP), Amirkabir University, Tehran, 220 p, 2002.

Grau, J. B., Anton, J. M., Tarquis, A. M., Colombo, F., Rios, L. and Cisneros, J. M.: Mathematical model to select the optimal alternative for an integral plan to desertification and erosion control for the Chaco Area in Salta Province (Argentine), Biogeosciences Discussion, 7, 2601–2630, DOI: 10.5194/bg-7-3421-2010, 2010.

Hosseinzadeh, S. Y., Khosravibaygi, R., Istageldi, M., Shamsodini, R.: An assessment of environmental assessment of urban area Using the technique of linear allocation Multiple Criteria Decision Makin (Case study: Bandar-e Turkaman city, Iran), Journal of Geographical Landscape, 16(1), 31-51, 2011.

Ivani1, H., Sofi, M.: Assessment of Regional Development Using Taxonomy Model (A Case of Razavi Khorasan, Iran), American Journal of Engineering Research, 3(11), 12-17, 2014.

Ji, Z., Leu, M. C., Wong, H.: Application of Linear Assignment Model for Planning of Robotic Printed Circuit Board Assembly. J Electron Packag, 114 (4), 455-460, doi:10.1115/1.2905480, 1992.

Law Office of Environment and Parliamentary Affairs, International Contract, Laws and regulations the environment protection, Publication of Environment Organization, 847 p., 2004.

Liu, S. C.: A Fuzzy Multiple Attribute Decision Making Approach for Linear Assignment Problems. Fifth Asia Pacific Decision Sciences Institute Conference Waseda University, Tokyo, Japan, July 24-27, 2000.

Meshkat, M. A.: Integrated methods for monitoring and assessing desertification, publication of Forest, Rangeland and Watershed Institute, 145 p., 1998.

Mianabadi, H., Afshar, A.: Multi attribute decision making to rank urban water supply schemes*",* Water & Wastewater Journal, 19(66), 34-45, 2008.

Miao, L., Moore, J.C., Zeng, F., Lei, J., Ding, J., He, B., Cui, X.: Footprint of Research in Desertification Management in China, Land Degrad. Dev., 26 (5), pp. 450-457, 2015. DOI: 10.1002/ldr.2399

Mohammadi, A.: A comparative applied study of linear allocation TOPSIS method and Taxonomy in financial evaluation, Economic Research, 11 (1), 273-302, 2011.

Pomerol, J. C., Romero, S.B.: Multi-Criterion Decision in Management: Principles and practice, (International Series in Operations Research & Management Science) Netherlands: Kluwer Academic, Dordrecht, 2000.

Ramesht, M. H., Arabameri, A. R.: Shahrood-Bastam Basin Zoning for the Purpose of Artificial Underground Aquifer Recharge by Using Linear Assignment Method and GIS Technique, Geographic Space 40(4),134-149, 2012.

Saaty, T. L., Vargas, L. G.: Decision, making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks, New York: Springer, 2006.

Saaty. T. L,: Decision making for leaders: The Analytic Hierarchy Process for Decision in a complex world ,vo1 H,Rws, 1995.

Sadeghiravesh, M. H.: Assessment of Combat Desertification Alternatives Using Permutation method, case study: Khezr Abad region, Yazd province, J. Environ. Plan. Manage. 10, 1-10, 2013.

Sadeghiravesh, M. H.: Evaluation of combat desertification alternatives by using BORDA ranking model, Case study: Khezr Abad region, Yazd province. Journal of environmental management and planning, 1, 13-24, 2014.

Sadeghiravesh, M. H.: the research of desertification effective factors in environmental destroy (case study: Khezr Abad Zone, Environmental Management thesis, Islamic Azad University, 395, 2008.

Sadeghiravesh, M. H., Ahmadi, H., Zehtabian, G.H., Tahmores, M.: Application of analytical hierar- chy process (AHP) in assessment of dedesertification alternatives, case study: Khezrabad region, Yazd province, Iranian journal of Range and Desert Research, 17(1): 35-50, 2010.

Sadeghiravesh, M. H., Khosravi, H., Abolhasani, A., Shekoohi, S., Evaluation of Combating Desertification Alternatives using PROMETHEE Model, Journal of Geography and Geology, 8(1), 28-41, 2016.

Sadeghiravesh, M. H., Khosravi, H., Ghasemian, S.: Application of fuzzy analytical hierarchy process for assessment of combating-desertification alternatives in central Iran, Nat Hazards, 75 (1), 653-667, 2015.

Sadeghiravesh, M. H., Zehtabian, G. R., Ahmadi, H., Khosravi, H.: Using Analytic Hierarchy Process method and Ordering Technique to Assess Combating desertification Alternatives (Case study: Khezrabad, Yazd, Iran), Carpath J of Earth and Env Sci, 7(3), 51-60, DOI: 10.1007/s11069-014-1345-7, 2012.

Sadeghiravesh, M. H., Zehtabian, G. R.: Assessment of Combating Desertification Alternatives Using Analytic Hierarchy Process method and Technique for Order Preference by Similarity to Ideal Solution, Journal of Sciences and Techniques in Natural Resources, 6(3), 17-30, 2012.

Sadeghiravesh, M. H., Zehtabian, G.: Combat desertification alternatives classification with using of Multi Attribute Decision Making (MADM) view point and Weighted Sum Model (WSM), Case study: Khezr Abad region, Yazd province, Journal of Pajouhesh & Sazandeghi, 100, 1-11, 2013.

Sadeghiravesh, M. H., Zehtabian, Gh., Khosravi, H.: Application of AHP and ELECTRE models for assessment of combating desertification alternatives, Desert, 19(2), 141-153, 2014.

Sayyadi, A. R., Hayati M., Azar, A.: Assessment and Ranking of Risks in Tunneling Projects Using Linear Assignment Technique, International Journal of Industrial Engineering and Protection Management, 22 (1), 27-38, 2011.

Sepehr, A., Peroyan. N.: vulnerability Mapping of desertification and combat desertification alternative ranking in Korasan-e-razavi province ecosystems with application PROMETHEE model, Journal of Earth science research, 8, 58-7, (.2011.

Sobhani, A., Khosravi, H.: Assessing Environmental Sensitivity Areas to Desertification in North of Iran, Curr World Environ, 10(3), 890-902, doi.org/10.12944/CWE.10.3.19, 2015.

Symeonakis, E., Karathanasis, N., Koukoulas, S., Panagopoulos, G.: Monitoring sensitivity to land degradation and desertification with the environmentally sensitive area index: The case of lesvos island. Land Degrad. Dev. DOI: 10.1002/ldr.2285, 2014.

Tajoddini, I.: Identification and prioritization of quality standard Prerequisites in industry, Modiriat farda, 2 (1), 82-88, 2003.

Vieira, R.M.S.P., Tomasella, J., Alvalá, R.C.S., Sestini, M.F., Affonso, A.G., Rodriguez, D.A., Barbosa, A.A., Cunha, A.P.M.A., Valles, G.F., Crepani, E., De Oliveira, S.B.P., De Souza, M.S.B., Calil, P.M., De Carvalho, M.A., Valeriano, D.M., Campello, F.C.B., Santana, M.O.: Identifying areas susceptible to desertification in the Brazilian northeast. Solid Earth, 6 (1), 347-360, 2015. DOI: 10.5194/se-6-347-2015

Xie, L.W., Zhong, J., Chen, F.F., Cao, F.X., Li, J.J., Wu, L.C.; Evaluation of soil fertility in the succession of karst rocky desertification using principal component analysis. Solid Earth, 6 (2), 515-524, 2015. DOI: 10.5194/se-6-515-2015

Xu, E.Q., Zhang, H. Q.: Characterization and interaction of driving factors in karst rocky desertification: A case study from Changshun, China. Solid Earth, 5 (2), 1329-1340, 2014. DOI: 10.5194/se-5-1329-2014